Yuhua Luo (Ed.)

Cooperative Design, Visualization, and Engineering

**First International Conference, CDVE 2004
Palma de Mallorca, Spain, September 2004
Proceedings**

Springer

Lecture Notes in Computer Science 3190

This page intentionally left blank

Yuhua Luo (Ed.)

Cooperative Design, Visualization, and Engineering

First International Conference, CDVE 2004
Palma de Mallorca, Spain, September 19-22, 2004
Proceedings

Springer

Visit Springer's eBookstore at: http://ebooks.springerlink.com
and the Springer Global Website Online at: http://www.springeronline.com

Preface

As the complexity of design, visualization and engineering increases rapidly, single-user's effort is no longer enough to accomplish ever-growing requirements. Group effort becomes essential. There are many industrial areas that demand strong CDVE support such as mechanical engineering, aerospace engineering, architecture design, engineering and building construction (AEC), etc. There are numerous other application areas where cooperative and concurrent working is becoming popular, such as entertainment program development, networked gaming, simulation, collaborative learning, etc.

Successful cooperative design, visualization and engineering highly depend on the advances in fundamental research areas such as concurrent processing, middleware, agent-based methods, design patterns, distributed systems, databases, transport protocols in network communication, human machine interaction, group behavior ..., just to name a few. There is a very tight relationship between cooperative design, visualization and engineering. Cooperative design will become impossible without cooperative visualization while cooperative engineering processes would not be complete without cooperative design and visualization.

From my research experience in the field since 1996 in the Spanish National R & D Project CICYT TEL 96-0544, 3D Cooperative Design System (Sistemas Cooperativos de Diseo en 3D), up to the European Esprit (IST) Project No. 26287, Multi-site Cooperative 3D Design System for Architecture, M3D, where I acted as the coordinator and main researcher during 1998–2001, it has been my personal dream to organize an international conference to bring researchers in related areas together. The CDVE 2004 conference is a personal dream that came true. I would like to express my thanks to all the members in the international program committee for their generous support to make the conference possible. The conference provided a unique opportunity to bring multi-disciplinary experts and practitioners together to exchange their experience in cooperative design, visualization and engineering. Over 100 authors from 16 countries and 5 continents contributed to the final program of the conference. We were excited to see contributions from all the aspects of cooperative design, visualization and engineering, as well as cooperative simulation, cooperative learning, cooperative control and many other applications.

We hope that the conference itself was a very first beginning of a continuous cooperative working group effort to promote research and development in this field.

September 2004   Yuhua Luo

Organization

CDVE 2004 was organized by the University of Balearic Islands, Spain, the International Information Visualization Society, and the Special Interest Group on Cooperative Design and Visualization (SigCDV), Information Visualization Society.

International Program Committee

Conference Chair:
Professor Yuhua Luo — Department of Mathematics and Computer Science, University of Balearic Islands, Spain

Chair:
Professor Dieter Roller — Institut für Rechnergestützte Ingenieursysteme, University of Stuttgart, Germany

Members:
Dr. Katy Börner — Information Science & Cognitive Science, Indiana University, USA

Professor Mary Lou Maher — Key Centre of Design Computing and Cognition, University of Sydney, Australia

Dr. Susan Finger — Civil & Environmental Engineering, Carnegie Mellon University, USA

Professor Bjørn Erik Munkvold — Agder University, Norway

Dr. Michael Koch — Department of Informatics, Technische Universität München, Germany

Professor Weiming Shen — Integrated Manufacturing Technologies Institute, National Research Council of Canada, Canada

Dr. Kurt Kosanke — CIMOSA, Germany

Dr. Ram Sriram — National Institute of Standards and Technology, Maryland, USA

Dr. Francis C.M. Lau — Department of Computer Science and Information Systems, University of Hong Kong, Hong Kong

Professor Chengzheng Sun — School of Computing and Information Technology, Griffith University, Australia

Professor Li Bohu — Beijing University of Aeronautics and Astronautics, China Academy of Engineering, P.R. China

Dr. Nobuyoshi Yabuki — Department of Civil Engineering and Architecture, Muroran Institute of Technology, Japan

Professor Mikael Jern — AVS Ltd., Herlev, Denmark

Dr. Zhang Heming — National CIMS Engineering Research Center, System Integration Institute, Tsinghua University, Beijing, P.R. China

Table of Contents

CD2: Cooperative Design 2

CE2: Cooperative Engineering 2

CV2: Cooperative Visualization 2

CD3: Cooperative Design 3

CA: Cooperative Applications

CV3: Cooperative Visualization 3

Author Index   247

This page intentionally left blank

Development of a Cooperative Integration System for AEC Design

Yuhua Luo[1] and José Miguel Dias[2]

[1]Department of Mathematics and Computer Science
University of Balearic Islands, 07122 Palma de Mallorca, Spain
`dmilyu0@uib.es`
[2]ADETTI-ISCTE, Instituto Superior de Ciencias do Trabalho e da Empresa
Lisbon, Potugal,
`miguel.dias@iscte.pt`

Abstract. The paper describes the experience and lessons learned in the development of a cooperative integration system for architecture design in 3D. The developed system is an online cooperative working system to support iterations of composition and decomposition of architecture design with different disciplines such as structural engineering, air conditioning, water and sewage, etc. The system has a 3D design editor which forms the major part of the collaborative 3D distributed virtual environment for online modification and visualization of the design, a project database and a communication tool for synchronous long distance online working meetings. A special geometry error checking module verifies the integrated design in 3D. The system has been evaluated by six life architecture design projects. The evaluation proved that the system is extremely useful and an excellent help for high quality and accuracy control of architecture design projects. The possibility of working in network conference is an advanced feature to facilitate the distance design team work.

1   Motivation, Methodology, and Strategy

The design phase in construction process plays an important role in the final product, the constructed building. However, the design phase is a complex process shared by many specialists, such as architects, structural engineers, air conditioning engineers, energy supply designers, etc. Different specialists usually use different CAD tools that produce their own design results. The whole design process is an iteration of decomposing and integrating designs from different specialist teams at various scales and details. The process involves a high possibility that errors can occur which is extremely costly to correct them when going to site operations. There were no sophisticated ICT tools that could support this iteration process, to aid their cooperative

---

[1] Full Professor, Department of Mathematics and Computer Science, University of Balearic Islands, 07122 Palma de Mallorca, Spain. http://dmi.uib.es/people/yuhua

[2] Associate Professor, Department of Sciences and Information Technology, Instituto Superior de Ciencias do Trabalho e da Empresa, Lisbon, Portugal, www.adetti.pt

design, in order to produce global error free designs. Another factor which makes the difficulty of design integration, amongst many others, is that a considerable amount of the architecture design work is still in 2D, which is neither a convenient format to support this iteration process, nor for error checking and design verification.

Based on this analysis, we have developed an online cooperative working system to support this multiple iteration of composition and decomposition of AEC (Architecture, Engineering and Construction) designs. In addition to this, the system supports many features towards a new way of working in AEC projects.

The basic methodology we have used during the system development, has been a deep investigation on the actual situation in the design phase in Portugal, Spain, Italy and the UK, where we tried to identify the key lacking elements. On the other hand, a close insight into the field of 3D computer graphics, database technology, telecommunication, and computer supported cooperative work was carried out. This allowed us to see the possibility and at what degree the current ICT technology could provide a solution to the AEC practice. A team of computer scientists, architects and engineers have been working closely together, based on the analysis of the current business situation. The strategy is to find a solution to bridge the gap between the current situation and the future way of working. We believed that we could not solve all the problems at once. But we could certainly develop some key elements to solve key scenarios during the design phase.

The paper describes the experience and lessons learned in the development of the system. The system has a 3D design editor which forms the major part of the collaborative 3D distributed virtual environment for online modification and visualization of the design, a project database and a communication tool for synchronous long distance online working meetings. A special module is provided in the editor for users to check geometry errors in 3D and also, to verify automatically the integrated design in 3D, in respect to the occurrence of design clashes and geometric interferences between 3D designs from different disciplines.

The system has been evaluated by six life architecture design projects. The evaluation proved that the system is extremely useful to explain the project ideas to site operators, skilled technicians and clients, because of the availability of 3D models of the building. The system can be an excellent help for high quality and accuracy control of design projects, which can have a very positive impact in the time limits and scheduled construction work deadlines. From the usability point of view, it is an easy to handle and natural to use tool for architecture design team members, as well as for other AEC speciality team members. The possibility of working in network conference is an interesting advantage enabling the distance team design working.

The user evaluation of the advanced features of the system have shown that it is still ahead of the current practice in the architecture design field, as well as in the interface of this area with the different specialties. The ultimate success of the system will depend on many factors including business process reengineering of the whole AEC industry. However, the authors fell that this is the right direction to proceed and that, in time, the industry will accept the trend demonstrated by M3D and will benefit greatly from it.

2   The System

Based on the strategy we decided, a cooperative online integration system has been developed from this initiative, which is named M3D (Multi-site Cooperative 3D Design System for Architecture [5]). See http://www.m3d.org for more details. The current available system is aiming at satisfying the essential needs of a design team with different specialists that may physically located in different sites in Europe or around the world.

From the development point of view, the major M3D system components are:

Module A. The CSCW support platform
Module B. The building design and construction database
Module C. The collaborative 3D Distributed Virtual Environment (DVE)

The following will describe each component in more details.

2.1 Module A, the CSCW Support Platform JESP

The major tool for the users to interact is the 3D Editor within the collaborative 3D distributed virtual environment. The 3D Editor tool is layered on top of an IP compatible collaborative support platform JESP. JESP stands for Joint Editing Service Platform [1] that adopted a distributed architecture and a peer-to-peer network communication model. This module offers group communication (*GC*) and session management (*SM*) to the 3D Editor. See Figure 1 for the location of the JESP platform. It provides a set of communication services, which hides the point-to-multipoint configuration from the applications. It ensures a source ordering delivery of multicast messages over TCP/IP. The session control mechanisms provided by the platform free the applications from specific functions necessary for their inclusion into cooperative environments. These specific functions include communication services multiplexing, support of quality of service, consistency control, admission of new members into a running session, managing early members leave, invocation of new distributed applications, handling of exception events or failures and definition of roles within the group.
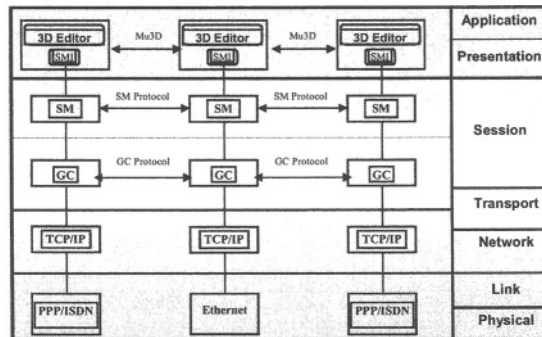
Fig. 1 The layered structure of the M3D system and the corresponding OSI layers

The layers of the M3D system and its correspondence to the OSI layers are shown in Figure 1. The cooperative support layer is application and network independent. All the hosts participating in a session have the same set of resources and application replicas. A related meta-conference module helps users to accomplish general conference management tasks, namely the initiation, management and termination of cooperative working sessions, or obtaining general information about the current collaborative group.

2.2 Module B. The Building Construction Database, M3D Database

The structure of a design in the developed system is a scene graph that understands the concept of AEC objects. One of the achievements made during the development of the M3D system is the adoption and customization of the ISO standard 13567 for all the classification of AEC building object components. The structures with the concept of AEC projects of different design are stored in a WWW-accessible construction database. It supports access control, version control at the AEC file level and interprets and recognizes all individual AEC objects in each design project. It provides the access of any object for the 3D Editor which can also input VRML from local files. A VRML object is uniquely identified by an URL (Uniform Resource Locator) in the database.

2.3 Module C. The Collaborative 3D Distributed Virtual Environment (DVE)

This module is a collaborative DVE (Distributed Virtual Environment) interactive editing system we developed for the AEC sector. The system provides automatic design verification/interference checking, multi-user interactive 3D modification,
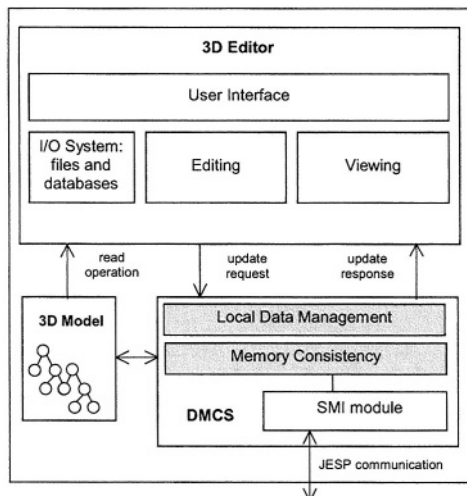
Fig. 2. Local architecture of the collaborative 3D distributed virtual environment.

information visualization, and simulation for large construction spaces. It is divided in several sub-modules at different levels of abstraction (see Figure 2):

The 3D Editor: This module implements the functionality for AEC 3D object editing and visualization, user interface, and input/output operations. It interacts mainly with the OpenInventor 3D toolkit and the operating system.

Aiming at bridging different CAD tools, the system accepts any design with VRML, DXF, or 3DS format. The editor supports multi-user 3D object editing in cooperative working sessions amongst remote teams, on-line group discussion and visualization of the architectural databases. It also supports single user working. There are rich visualization options that the users can use during their cooperative online meetings. A sophisticated set of interactive visualization and AEC object editing operations is available in the system [5], [7], [8]. The important element of the automatic design verification and interference checking [2] is also within this sub-module. Figure 3 shows a snapshot of the user interface of the the collaborative 3D Distributed Virtual Environment (DVE).
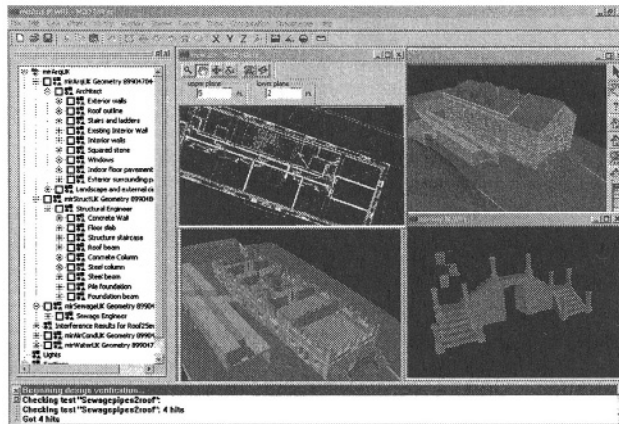
Fig. 3. A snapshot of the user interface of the cooperative 3D DVE

The automatic design verification and interference checking A major motivation of developing the system is to discover the design error and inconsistency in an early stage of the design before it becomes too costly. For this purpose, an important element in the 3D DVE so called Automatic Design Verification (ADV) [2] is developed. This is particularly for the error checking and design verification of the architecture and building construction projects which use 3D as its basic format.

The module integrates the 3D design of all the specialties, such as architectural, structural, water and sewage etc. within the same project to check for possible geometrical and topological inconsistencies. "Inconsistency" here is a loose term to represent an undesired geometric and/or topological condition. For example, a concrete beam blocks the opening of a window can be a serious design error and presents the inconsistency.

As a first step development, our automatic design verification algorithm is implemented using the Constructive Solid Geometry (CSG) framework. Geometric Boo-

lean algebra and regularized set theory [10] are used to express the relationship between the architectural 3D objects and how they may cause interferences. Every interference check can be interactively or analytically expressed as a user defined logic equation to represent a design rule that must hold true.

For easy use, we developed a special language the Interference Detection Language (IDL) for the users to define the checking rules. It features with variables, operators, expressions and scripts. Every set of architectural, structural or other objects that need to be checked against design rules are placed into relevant equations. User defined tolerances can also be enforced. If a false result against a rule is obtained, an undesirable geometric interference or inconsistency will be signaled in the 3D scene. It is subject to the discussion and decision of the multi-user group to deal with the result. A more detailed presentation of the automatic design verification architecture can be found in [2].

In a second step development, the architecture of this sub-module has been completely re-implemented with the OpenCascade toolkit [9]. This is a general toolkit for 3D CAD applications that features Boolean operations and topological checks on the objects shape. We have found OpenCascade to be far more robust than our own proprietary CSG geometry algorithms that we were using in the first step development. With the support of OpenCascade primitives, we are able to perform internal consistency checks on every geometrical object. The consistency test can check for errors such as missing faces or degenerate edges. Any object with incorrect topology, that fails to pass an internal consistency check, will not be supplied to the ADV tests. Since Boolean operators are very sensitive to topology errors and can lead to notoriously wrong results. During the internal consistency check, similar to the ADV, we signal in the 3D scene all the topology errors that are detected in each object. In this way, M3D users can visualize both intra-object errors, from the internal consistency tests, and inter-object errors, from the ADV tests.

Figure 4 shows some examples of the error checking. One degenerate edge is found in interior walls in the top right window while an intersection is found between a sewage pipe run and a pile foundation on the top left and bottom left windows.
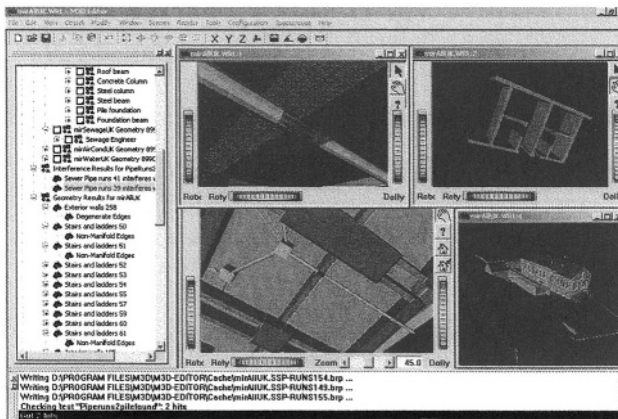
Fig. 4. Design verification for the virtual Mirante project

Distributed Memory Consistency System (DMCS): This component, see Figure 2, hides the 3D application from cooperative and message distribution for maintaining the consistency of the 3D scene graph across the collaborative session. While the 3D Editor module is specialized in managing 3D models, this module deals with general object abstraction and events both local and remote. Local events are generated by the higher level module that are coded in small messages and transmitted via the JESP platform to the other replicas. Remote events (tele-events) are generated by remote replicas. They are recreated in the local 3D data representation. It consists of other three sub-modules [4]:

Local Management Module: this module is in charge of maintaining session information such as list of users, avatars, IP addresses, user's clipboard, selected objects, ordered list of operations, etc.

Memory Consistency Module: this module provides distributed shared object services. All modules on top of this layer see the system as a consistent shared memory system. Therefore synchronization, coordination and mutual exclusion for critical regions are assumed. A special protocol, Mu3D (Multi-user 3D Protocol) [3], was developed to ensure consistency and mutual exclusion of access to the shared 3D scene graph, across all replicas. It uses an innovative technique that ensures total global ordering of exchange messages between distributed peers in cooperation. The Mu3D protocol is implemented inside this module.

Session Manager Interface (SMI) Module: This module is the interface for initializing, sending and receiving messages from the JESP platform.

3   The Evaluation

Along the development period of the system, six real-life architecture design projects are used to test the modules and the whole system. During the final user trial phase, four sites within Europe have been connected by a long distance network (Euro-ISDN based): two sites in Palma de Mallorca, one in Barcelona and one in Lisbon. See Figure 5 for the network connection configuration. Architects, structure engineers, sewage, air-conditioning, electricity engineers, designers are among the end users that have participated in the user trials. They produced the respective 3D models and have tested the M3D modules in isolated work, group work, with their closest collaborators etc. There have been many demonstrations using the M3D system. Many of them are architecture design projects that were shown to clients.

The 3D Editor is the major tool for the user interaction which has been evaluated extensively by all the users. Many functions were designed specially upon user requests. The users have appreciated very much the rich possibilities that the Editor provides for project analysis, visualization and modification. They have found particularly attractive, the real time three-dimensional clipping operation. They claimed that the 3D Editor, both for stand-alone sessions, and co-operative sessions, are "useful and spectacular, knowing no software in the market with these characteristics" [11].
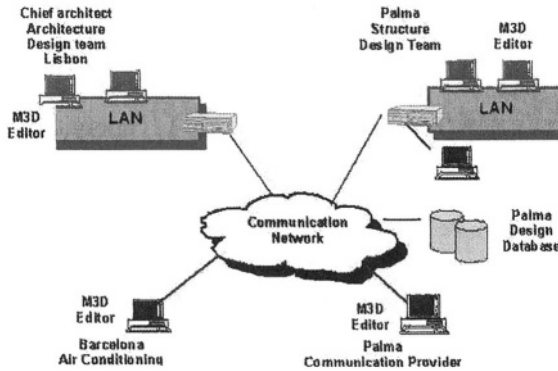
Fig. 5. The user trial connection

According to the user's comments, the automatic design verification was the most innovative functionality among all the modules. The ADV enables clash detection and minimum distance checks between different 3D objects of the same or different specialities. The geometric Boolean set operations of intersection, subtraction, union, as well as in bounding box computation and volumetric growing can be performed. With this module, the users can check if the geometric objects of the same or different specialities fulfil the rules established by the designers or from legislative directions. They feel particularly satisfied by having the possibility of debating and checking in group in real time for validating the integration of their designs in one coherent and clash free design.

The construction database, according to the comments of the end users, is perhaps the key module of the M3D system. It allows the structuring, relating and saving of all the AEC related information concerning the construction project. It was used from the beginning of each user trial project. An obvious advantage is that AEC information is available to all the participants anytime anywhere. All the information concerning the project, from AEC objects, to normative documents, images, materials, version management, records of the meetings, quantities, costs data etc can be saved and retrieved from the database.

Maybe the main difficulty in using M3D system, from the users point of view, was the installation and configuration of the different components of the system, such as hardware and software, routers, ISDN lines, private IP's, as well as the creation of 3D designs with AEC ISO codes, etc, Therefore, in addition to improvement of these, skilled ICT personnel's help seems to be necessary in using the system.

The system has been demonstrated to different kinds of potential clients such as technical service departments in city councils, construction developers, tourist development companies, as well as to famous architects and engineers agencies active in the AEC filed. Many positive comments are received. The potential clients felt that the system is very useful for project understanding particularly because of its availability of 3D appearance of the building. The system can be an excellent help for high quality and accuracy control of design projects which can have a very positive impact in the time limits and construction deadlines. The system was found to be extremely useful to explain the project ideas to site operators, skilled technicians and clients.

From the usability point of view, once installed, the system was perceived to be an easy to handle, intuitive tool for AEC design team members. The possibility of working in network conference was identified as an interesting advantage. Some users mentioned that the system could be very useful for the public administration to create quality requirements and other rules for building construction project requirements.

However, all the potential clients have the fear that the 3D design process itself may still be difficult, given the existing tools in the market and costly. They have felt that it was not probably a system for today, but potentially, for the near future.

4   Lessons Learned

4.1 There Is a Strong Need for the System

The M3D system is a suite of programs addressed specially for AEC projects particularly for project integration iterations. There is a strong need for such system. By using all its components, the system introduces a new way of architectural production for the whole AEC business process.

CAD's role so far in this field is for the computerisation of the architectural design. They have helped the production operations of the project, but they do not change this production process. CAD has been only a little more than an "electronic drawing board". There are 3D display software that can substitute the hand of the architects in the production of perspectives and watercolours. They may also produce 3D rough models for a better review and understanding of what three-dimension means. The spreadsheets help to measure the quantities and the budget.

However, there is still no actual capacity of modelling, integrating and helping the entirely process inherent in the design and building process. There is a strong need to further develop and exploit a system like M3D for the following reasons:

- For using three-dimensional building model as a key geometric element and center to give and organize the information of the whole project;
- For the verification of the accuracy of the designed geometry;
- For the illustration and testing of alternative solutions;
- To explain the relation of the execution of complementary multi-operator tasks;
- For having a unique information source to generate 2D information that allows the necessary integration and disintegration;
- For the effective co-ordination of the skills used in the project;
- For quantification and classification of the building project components;
- For communication at an interregional and international level, through "high level" cooperative work other than sharing common information.

4.2 The Current Practice and User Acceptance of the System

We also observed that the potential users have doubts in using such system into their current practice due to the difficulty and cost of the 3D design process. They feel that

3D design is still a computer intensive based work. In order to the model the building elements to be coherent and for design verification, the process can not be very elementary and the level of detail can become quite high.

The current design practice in Europe for architects is still, to some extent, based in hand drawing and pencil, using telephone and fax as means of communication. Although computerised offices are available, the use of CAD is sometimes "a second step" drawing aid. Additionally, some architects feel that in the conceptual designing stage, the accuracy of 3D may be an obstacle to the creative work. The possibility to overcome this situation and introduce the M3D system is still not clear, although the authors believe that the system could be used after the very first stage of conceptual design. The advantage of networked cooperative work is obvious to avoid frequent travels and meetings. Of course, sometimes nothing can replace a face-to-face meeting. The conclusion is that this system is somewhat ahead of the actual practice. It is designed for a near future in which the 3D software may be generally accepted and used.

4.3 Should Deal with the Whole Design Process

A very important lesson we have learned from the development of the system is that we should work with the whole chain of AEC process. Our user partners have appreciated the 3D integration tool and have used it in their daily practice, during the trials. The tool was able to discover many design errors that usually were not found until the construction work was started. Online cooperative work can also reduce travelling costs. The tool can reduce design errors and, potentially, reduce construction costs. But it requires all the speciality designs to be in 3D. From the current situation, 3D design is still a costly process and it is not clear, which stakeholder in the AEC life cycle, is willing to pay such extra cost, in the design process phase. In countries were design is separated from construction (such as in Southern European countries), the picture is even more difficult. It involves a change in current business process and re-allocation of benefits.

Usually end-clients are still not aware of the advantages of having accurate designs, regarding the integration of all the AEC specialties, in a given building construction project. The authors view the awareness of the end-clients to such issues, as a crucial push towards the full adoption of 3D design in the AEC industry.

5   Conclusions and Acknowledgement

In general, M3D, along with other recent user-driven R&D initiatives in AEC, has begun a big step in a long way in building a new business model to integrate the 3D design into the complete architectural productive process: "Design-Construction-Monitoring-Maintenance". The ultimate success of the system will depend on many factors including business process reengineering of the sector. However, the authors believe that this is the correct direction and, in time, the industry will accept it and will benefit greatly from it.

References

1. A. Almeida and C. A. Belo., "Support for Multimedia Cooperative Sessions over Distributed Environments." Proc. Mediacomm'95, Society for Computer Simulation, Southampton, April, 1995.
2. Dias, J. M. S., Gamito M., "Automatic Design Verification in Building Construction", ASCE Speciality Conference on Fully Integrated and Automated Project Processes, Blacksburg, Virginia, September 26-28, 2001.
3. Ricardo Galli, Yuhua Luo, Mu3D: A Causal Consistency Protocol for a Collaborative VRML Editor, Web3D - VRML'2000, Proceedings of Fifth Symposium on the Virtual Reality Modeling Language, Feb. 2000, Monterey, California, U.S.A. ACM Siggraph, pp. 53 -62.
4. Ricardo Galli. "Data Consistency Methods for Collaborative 3D Editing". PhD Thesis. University of Balearic Islands, November 2000.
5. Luo, Y., Galli, R., Sanchez, D., Bennassar, A., Almeida, A. C., Dias, J. M. S., "A Cooperative Architecture Design System via Communication Network", ICCCBE-VIII, 8th International Conference on Computer Aided Design, Building Construction and Civil Engineering, Stanford University, EUA, August 2000.
6. Y. Luo ET. al., "Beta Release of M3D Application", Esprit Project No. 26287 (M3D) Deliverable 5.2.2, March 2001.
7. Yuhua Luo, Ricardo Galli, Miguel Dias, Manuel Gamito, José Manuel Fonseca, Jorge Silva, "Cooperative Integration of Architectural Design In 3D", Proceedings of the Ninth International Conference on Computing in Civil and Building Engineering, April 3-5, 2002, Taipei, Taiwan, pp. 1093-1099.
8. Yuhua Luo et. al, "Visualization for Cooperative Architecture Design System", Proceedings of IEEE 2002 Conference on Information Visualization, July 2002, London, pp. 497 - 501.
9. www.opencascade.com
10. Requicha, A.A.G., "Representations for Rigid Solids: Theory, Methods and Systems", Computing Surveys, 12(4), December 1980, pp. 437-464.
11. Jorge Silva et. al, "Report on the user trial evaluation", Esprit Project No. 26287 (M3D) Deliverable 5.3, March 2001

Observing Architectural Design: Improving the Development of Collaborative Design Environments

Matthew Simpson & Stephen Viller

School of Information Technology & Electrical Engineering
University of Queensland, Brisbane, Australia
{matts, viller}@itee.uq.edu.au

Abstract. The physical environments in which design collaborations take place provide many affordances, which enable interactions to occur both seamlessly and (in most cases) successfully. Physical collaboration is also facilitated through many aspects of the design process. Virtual design collaboration on the other hand, while successful at achieving the direct representation of activity around the artefacts being manipulated, lacks many of the physical affordances which make collaboration in the physical realm successful. The aim of this paper is to present the physical affordances of design interaction, isolate those which aid the success of physical design and identify which factors are potentially beneficial to improve the affordances of virtual collaborative design environments.

Introduction

An observational study of physical design was undertaken aimed at exploring the nature of collaborative interaction in the design industry. The occurrences of key aspects of design interaction are explored through design process of architectural firms. By viewing the interactions of designers, workplace settings and styles, this study explores the nature of design communication, considering issues of sketching, creativity, gesture, recruitment and movement across mediums. This analysis, we can begin to inform virtual interaction about the driving elements which control the collaborative design process and begin to explore how these key factors can be harnessed to form a framework to guide virtual collaborative design in the future.

Collaboration in Design

The study discussed in this document took place in 2002/2003 in two different architecture offices. The aim of the study was to gain some insight into the physical design collaboration taking place in the two offices, as part of a broader project to inform the development of collaborative virtual design environment. The intention was to use this as an initial scoping study to identify the key research questions to address during

further follow up studies. The longer-term aim is to utilise the detailed analysis techniques of ethnography to inform design decisions based upon our observations.

Observational analysis, and ethnography in particular, has over the past ten years continued to be a very popular method for understanding human activity in context in Human–Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) due to its ability to capture detailed insights into user's requirements and into the interconnection of the activities and social environments [5]. However, the approach also has its limitations as it is not rare to see ethnographical analysis last months or even years. In our case the time allocated didn't allow for the use of such extended periods of fieldwork. We therefore followed a 'quick and dirty' approach to using ethnography in the design process [11].

Collaborative virtual design has long been explored in the context of the architectural [7, 9] and CSCW [4, 6]. Studies in capturing the essence of sketching in conceptual design phases have been conducted, but many stop before exploring situated actions in design firms[8]. Commercial development of collaborative design tools and computer aided design (CAD) while making large advances in visualisation and process, have limited coverage when it comes to exploring social structures and surrounding interactions across everyday practice beyond the computer.

Settings – Work, Practice & Social

This preliminary research was conducted in two Brisbane architectural firms over a six-week period from December 2002 to January 2003. During this period we were able to capture data about the process and practice of those firms as well as their physical work settings. Video-cameras were utilised to enable the review of our observations after the study [12, 15]. Interviews with the office staff were also conducted to establish their view on workplace process, practice and interaction with colleagues. The interviews allowed the fieldworkers to ask questions arising out of the study and to clarify details of observed interactions where necessary.
Each of the firms were of a comparable size and organisational structure, and were observed for a total of two days each. Two fieldworkers were used together, one directing the video camera, and the other recording initial observations and pin pointing interactions for later analysis in the office environment. The scale of this study has allowed for an appropriate scope of initial observation into practices and processes of the two design firms. The aim is to 1.) gain a more accurate understanding of the collaborative themes and issues arising from design workplace environments. 2.) Isolate key aspects of interaction in the design environment for further detailed analysis.

The firms each consist of 15 - 18 people with the organisational break-down between the different roles shown in Figures 1 & 2. The two firms were found to be very similar in structure. The project architects (PA) are in charge of guiding the design and dealing with the client. They are rarely involved with computer drawing as they mainly direct projects and work. The student architects (SA) are required to assist the project architect in their work, providing helpful support in CAD, research and documentation. The two Managers/Project architects have a key role in the organisation, overseeing every important decision made in a project. They organise the

workflow within the company and also ensure that the coherence of the design approach is in line with the firm's ideologies. In Firm A, the landscape architects have a very separate role to the other architects. They are often working on a different project that has no connection to the PA's projects. Interior designers in Firm B have a different role, where they are commonly integrated into projects managed by PA's.

Both firms have a profusion of books, samples, magazines of architecture lying on shelves or desks all throughout the office. The use of such documents was observed throughout the period of observation on numerous occasions. They were typically used to inform the designs or support detailed discussion with colleagues and/or clients. These documents also contain the rules, norms and regulations relative to architecture in order for the designer to refer to them if necessary.
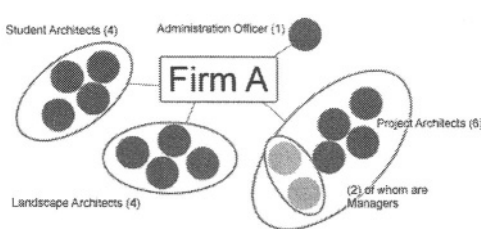
Fig. 1. Firm A Organisation Overview   **Fig. 2.** Firm B Overview
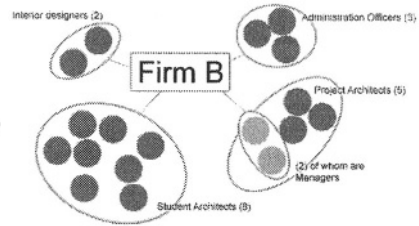
The office layout of the Firm A is open plan, with no high walls blocking the sightlines and the workstations facing the rest of the room as much as possible. The desks are fairly busy with many documents apparently ready for quick consultation. Those documents include plans, printouts, catalogues, samples of material or items, and magazines. Each desk is also equipped with a phone and every computer is connected to the Internet for email etc. On the other hand, Firm B has a more enclosed space with three main zones: the project architects (PA); the "CAD pit" where the student architects (SA) are situated; and the managers-partners who are isolated from the rest of the office by two big shelves. This physical organisation tends to reflect the working processes utilised by the managers, where they play a more formal role in their interactions on projects rather than becoming engaged in chance informal discussions on the development while passing a fellow office worker.

Work Styles

Generally, the work is conducted following a series of actions described in Figure 3. The first idea is sketched on paper in groups from the information gathered by the PA in charge. Those come from the notes and sketches of the PA on site as well as the specifications and preferences given by the client.
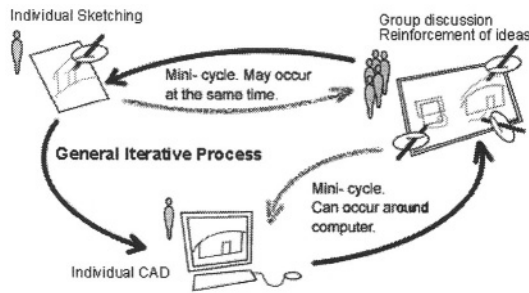
Fig. 3. Iterative tasks for design

This iterative process of design has been well documented in practice [10, 16]. From the initial sketch, a first design is implemented either on computer or as a 3D physical model. The 3D physical model views the building as a volume, for itself or its surroundings, for the purposes of initial volumetric studies. The importance of artefacts such as CAD models for informing design and discussion about the attributes of a project have been explored in other studies of architects. CAD was shown to be effective for both exploring the perception of the problem space in a tangible three-dimensional format, and portraying the interactions between design elements through the artefact to participating group members [13]. The interactions explored throughout this study have been chosen to assist in providing coverage of all stages of the process outlined.

Outcomes and Analysis

The fieldwork revealed several key aspects of interaction inside the constraints of the design process and the architectural office environment. Through the analysis of the video footage in both firms interaction, several key interaction styles have been revealed. While they are not the sum total of all interactions occurring within the various office environments, they do encapsulate the focus of interactions occurring through the environment, for the purposes of informing further detailed interaction analysis. A full analysis has been documented in the project technical report [14] The interactions have been grouped into the following categories to enable classifications of collaboration to occur more freely.
1. Interacting in and through the physical environment,
2. Recruitment/interaction by circumstance (whether proximity or chance contact),
3. Informing interaction with externalised artefacts,

Interacting in and Through the Physical Environment
To assist in understanding what makes physical collaboration important to designers, interviews were conducted, revealing the following. The ability to communicate effectively and efficiently through a common set of values, as in a familiar environment, creates an atmosphere/ambience where people are comfortable with each other.

Solid working relationships are established and from this a mini society is born that manifests itself through shared language, common symbolism and design identity. The use of pre-established and recognisable symbols in design work has been explored by Do and Gross. They examined the types of symbols designers use to display various types of information, exploring how designers identify the types of drawing identifier, relators and modifiers required [9]. The social aspects of the office, together with a saturation of contextual information, provide ambience, which creates common focus and generates inspiration. Communication is of course a key part of collaborative design and the ability to effectively convey ideas through verbal and visual means is essential for all staff: *"Its all about me being next to this person and that person ...It's all about the team."* [Manager of Firm A]

The creation of strong working relationships is reliant on trust and commitment and essential for successful collaboration. In face-to-face situations people instinctively attend to other people around them, assessing body language, attitude, and other visual and verbal cues to determine credibility. Proximity to colleagues provides security, generates atmosphere and fosters collaboration and discussion. By being centrally located, co-workers are immersed in a setting that encourages design and this shared context of work style and influences gives context to communication.

The nature of the open plan office environment and multiple staff working cohesively on various sections of projects, results in numerous collaborative interactions over the course of the project. This key interaction encapsulates a considerable amount of the office activity, especially during the early stages of design when the process tends to be conceptual and paper based. A typical example of this grouping of interaction is outlined in Figure 4 below.

Fig. 4. Conceptual design interaction sequence (physical means)

Figure 4 shows where staff (SA, PA and manager) have come together to discuss the conceptual design of a project, The series of images above reveals the combination of group sketch oriented discussion on a central artefact (a), individual work in own notebooks/drawings (b), and annotation of a staff members drawings (c).

Recruitment/Interaction by Circumstance

Proximity to colleagues also allows for quick access to implicit knowledge and extended personal networks, and promotes an awareness of projects around which allows knowledge sharing despite not being directly involved. It encourages spontaneity and informality in interactions, creating an atmosphere where people feel comfortable about expressing ideas and asking for criticism. This is shown through interactions whereby staff discuss items across the room to those within eye contact, and

those who are engaged in a different task who move within proximity of others, with whom they are working on other jobs and change focus to them. This style of chance or unplanned interaction was frequently observed in both firms.

Backhouse and Drew [2] have explored similar issues, which they refer to as 'recruitment' in interaction. This is where an object (or person) seeks and initiates and engages with another. In the case of the firms analysed, recruitment generally occurred when an individual was conducting an activity away from their personal work environment and moved past another staff member's work space, who 'recruited' them to a current task. While this action is considered a deliberate engagement of the first party, it is seen as a flexible interaction in which the affected parties have engaged in interaction before returning to their initial activities [2].

The impromptu interaction observed in both firms was highly valued, with many believing the teamwork would suffer if they were remotely located. This reflects findings from a study of mobility in a product design firm which had offices in different geographic locations, and the impact this had on design teams [4]. It was found, that while colleagues situated in one office communicated more effectively and had a greater awareness of projects conducted within that office, communication and awareness between geographically separate offices suffered. They suggest that, "Informal and frequent interactions seem to be critical to the way the organisation conducts its work as a whole" [4]. In relation to remote collaboration, the little questions between co-workers would be the hardest to support, requiring the facilitation of real time, synchronous communication of a visual nature. Being able to quickly consult colleagues greatly shortens the design process, and minimises interruptions to the flow of the creative process. If forced to conduct such communication via asynchronous mean such as email, however, waiting for a reply even for a simple question by its very nature wastes time and disrupts the work flow. One participant stated when asked about working remotely and not having face-to-face contact with colleagues: *"...you couldn't share a coffee with them"* (Firm A worker) Proximity also facilitates awareness of body language and non-verbal cues when communicating with colleagues. The following footage (Figure 5) demonstrates an external physical cue resulting in spontaneous interaction between two staff members.

Fig. 5. Recruitment and chance interaction sequence

Here the act of one staff member (A), wandering past one part of the office, results in another staff member in close proximity (B) to look up. This action results in B engaging A in discussion about her current project, drawing her away from her immediate task and temporarily being recruited to the new activity.

Gesture & Externalised Artefacts

Gestures are frequently used to communicate concepts and ideas in conversation, and body language often provides physical clues as to a person's state of mind. Much of the problem with current distributed collaboration is that the lack of non-verbal cues and social context makes it difficult to gauge the mood of the person they are trying to communicate with [3, 4]. Gesture as a communication tool has a number of characteristics and uses as described by Bekker et al., through the outcomes of their study into face-to-face gestures and their use in design situations. Four major categories of gesture were defined, these being: *spatial,* where movement indicates distance, location or size; *kinetic,* describing actions or series of actions; *points,* pointing with a finger usually at an artefact or person; and *other* [3]. All of these types of gestures were observed in the collaborative interactions of the architects, as a tool for explanation and reinforcement of design. Instinctive and sometimes unconsciously made, gestures synchronise with speech and often occur in a spatial context to surrounding artefacts, people and activities. It is this spatial context in relation to physical artefacts with which we are interested in this point. The interaction outlined below (Figure 6) demonstrates one such example of utilising external artefacts. The nature of gesture can relate to these artefacts as shown below.
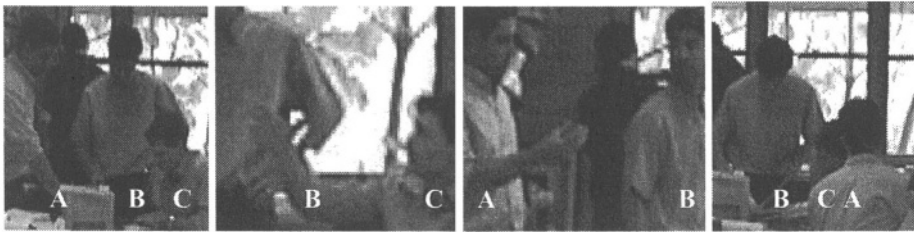
Fig. 6. Sequence of interaction utilising gesture and external artefacts

The sequence begins with three staff - the desk owner, SA (C), the PA (A) and the manager (B). Discussion surrounds a set of plans and involves the sourcing of a material for the project by viewing various catalogues (external artefacts). Once a suitable element is found discussion is shifted from the physical artefact to the computer on the desk. This involves the viewing of the project CAD drawing to identify the details of the artefact integration and confirm the suitably for the project. This results in the manager following up with a new artefact (catalogue) to provide further design options to the SA.

Many gestures can convey complex messages in a single hand movement, such as action, three-dimensional objects and to describe past events [3]. This interaction shows one such example of how a slight of hand can change the focus from project drawings, to catalogue to computer in a faction of a second. You can see the staff's focus change in time with these gestures.

Conclusion

Through the course of this paper we have discussed the observations from key interactions in the design processes in two architectural firms. The complex process of design and individualised interaction is revealed to be as involved as the social and physical context in which it was observed. Exploration of this social structure of design firms has been demonstrated as integral to design interaction.

In undertaking this study, we recognise the great difficulty in replicating the affordances of physical interaction when implementing virtual collaboration and design tools [1]. Rather, this study is part of a process of understanding how we can improve our understanding of those physical affordances so as to develop better tools for virtual or remote interaction in design, whilst also attending to the ease in which designers can switch between the two mediums.

The study reported here has identified recruitment, chance interaction, physical artefacts, and cues and gestures as key interactions. This can now form the starting point for more detailed and focused fieldwork and analysis for the purpose of directly informing the development of collaborative design environments. The context observed through these interactions is an example of where virtual design collaboration as a field can benefit from such studies. While the physical interactions are not necessarily applicable in all design settings, the further detailed observational analyses in key interactions will consider not only the intricacies of physical and virtual interaction, but also the nature of situated actions, which affect the flexibility of day to day design firms process. Ultimately, our improved understanding from conducting studies such as this will inform how they can be applied in the virtual realm.

Following on from this study will be a series of more focused ethnographic observations. These will be targeted towards the generation of a framework that can be used to inform the development of collaborative virtual design environments. The success of this work will ultimately depend on the ability of such environments to support the key interactions identified here. At the same time, it is important to recognise that virtual design environments must support designers in making transitions between physical and virtual representations and interactions. Ultimately sensitivity is required to designers' established work practice so that developed systems are more readily appropriated into the everyday practice of the designers.

References

1. Akin, O. and Z. Anadol, *What's Wrong with CAAD?,* in *4th International Synposium on Systems Research, Informatics and Cybernetics.* 1993: Baden-Baden, Germany.
2. Backhouse, A. and P. Drew, *The design implications of social interaction in a workplace setting.* Environment and Planning B, 1992. **19**: p. 573 - 584.
3. Bekker, M., J. Olson, and G. Olson, *Analysis of gestures in face-to-face design teams provides guidance for how to use groupware in design.,* in *Symposium on Designing Interactive Systems.* 1995: USA. p. 157-166.
4. Bellotti, V. and S. Bly, *Walking Away from the Desktop Computer,* in *CSCW Conference '96.* 1996. p. 209-218.

5. Blomberg, J.L., *Ethnography: Aligning Field Studies of work and system Design,* in *Perspectives on HCI: Diverse Approaches.* 1995, Academic Press. p. pp175-197.
6. Burgoon, J.K., et al., *Designing Interfaces to Maximise the Quality of Collaborative Work,* in *32nd International Conference on System Sciences.* 1999, IEEE: Hawaii.
7. Campbell, D.A. and M. Well, *A Critique of Virtual reality in the Architectural Design Process,* in *HITL Technical Report.* 1994, University of Washington.
8. De Vries, M. and H. Wagter, *A CAAD model for use in early design phases,* in *The Electronic Design Studio,* M. McCullough, Editor. 1990, MIT Press: Mass. p. 215 - 228.
9. Do, E.Y.-L. and M.D. Gross, *Inferring Design Intentions from Designers' Sketches -- an investigation of freehand drawing conventions in design,* in *2nd CAADRIA Conference.* 1997, Hu's Publisher Inc., Taipei: Hsinchu, Taiwan.
10. Heskett, J., *Past, Present & Future in Design for Industry.* Design Issues, 2001.**17**: p. 18-28.
11. Hughes, J., et al., *Moving Out from the Control Room: Ethnography in System Design,* in *CSCW 1994.* 1994, ACM Press: Chapel. p. 429 - 439.
12. Jordan, B. and A. Henderson, *Interaction Analysis: Foundations and Practice.* Journal of Learning Sciences, 1995. **4**(1): p. 39-103.
13. Schmidt, K. and I. Wagner. *Coordinative Artifacts in Architectural Practice.* in *Design of Cooperative Systems.* 2002. Saint-Raphael, France: IOS press.
14. Simpson, M., Y. Riche, and L. Macdonald, *An Observational Analysis of Design in Industry.* 2003, University of Qld: Brisbane. p. 1-15.
15. Suchman, L. and R. Trigg, *Understanding Practice: Video as a Medium for Reflection and Design,* in *Design at Work,* J. Greenbaum, Editor. 1991, L Erlbaum: New Jersey. p. 65-89.
16. Swann, C., *Action Research and the Practice of Design.* Design Issues, 2002. **18**(2): p. 49 - 61.

Visualisation of Semantic Networks and Ontologies Using AutoCAD

Dr.-Ing. Marian Mešina, Prof. Dr. Dieter Roller, M. Sc. Constanza Lampasona

Institute of Computer-aided Product Development Systems, University of Stuttgart
Universitätsstr. 38, D- 70569 Stuttgart
`Dieter.Roller@informatik.uni-stuttgart.de`

Abstract. This paper presents a visualisation of the ASN and ontologies using AutoCAD. The geometric coordinates of nodes are based on the semantic distances. The whole semantic network or some selected parts are visualised on the screen, similar to a cartographic "map". Per mouse click on some node, an application may be opened, which allows reading and modifying the attributes of the corresponding objects.

Keywords. Semantic Networks, Semantic Distances, Ontologies, Visual Data Retrieval, Visualisation, AutoCAD, CAD Systems.

1 Introduction

Rapid Product Development (RPD) is an advanced technology approach that involves techniques for collaboration, data and knowledge representation as well as visualization of engineering information.

The ASN (Active Semantic Networks) has been conceived as a powerful tool for communication and coordination of all activities of developers working on various documents, representing product data. These subjects have been analysed and applied in the frame of research projects SFB 374 [1]. In the semantic network, the nodes correspond to files respectively, database-objects describing all components of RPD-Processes, or real-world objects. The number of used objects and corresponding nodes is usually large. Visual data retrieval is a powerful technique to ease the data selection and data access. The whole semantic network or some selected parts of networks may be visualised on the screen, similar to a cartographic "map". By mouse click on particular nodes, an application may be opened, which allows reading and modifying the corresponding objects [2]. The essential condition for effective use of this technique is the mapping of semantic distances between objects into geometric coordinates of nodes. There are existing products, which support this functionality (e.g. [3]). The distances between nodes in the map should be proportional to semantic distances between objects. In general, this problem can be solved only approximately. In [4] a solution of this task with low cost standard tools, such as MS Excel, is presented.

For modelling of complex knowledge areas ontologies are used. Ontologies are oriented-graphs whose nodes represent different object-types (classes) or also class-instances, and the edges represent the relations between different object categories (classes) and also between class-instances.

There are various publications describing tools for the visualisation of big graphs and semantic hierarchies and networks, for example [5][6] and [7].

The aim of this paper is to present a special capability of AutoCAD and other comparable CAD-Systems for the visualisation of the ASN and ontologies. An important condition is that such tool has a programming interface. The geometric coordinates of nodes can be calculated using e.g., the algorithm presented in [4]; but the use of other algorithms is also possible.

2   Visualising ASN and Ontologies

3D visualisation of graphs offers several advantages. On the one hand, the third dimension provides more available space for the visualisation and consequently the problem of presenting large graphs is alleviated. On the other hand, the user can find a view with none or fewer overlapping edges by rotating the graph within the visualisation space.

The knowledge in an ASN is structured; between the objects in an ASN exist relations and they can be arranged in different categories (classes). The ASN or a section of it can be represented as a graph whose nodes and edges represent concepts and relations respectively.

The RPD information is stored in the ASN knowledge base, which consists of the ASN database, a collection of operating system files (e.g. CAD-models) and middleware, which supports data access, information retrieval and cooperation between all participating persons and teams. The ASN database is a central component of the ASN. This database describes also the relations between the objects and their constraints. The constraints contain the values of attributes of one or more objects, mostly in terms of mathematical equations or restrictions in terms of inequalities. The change of one object or object attribute can cause changes of other attributes of this or other objects. This behaviour of ASN is described through ECA (Event Condition Action) rules.

In the RPD context, the third coordinate could be used to represent the chronological evolution of the RPD-processes.

Within this context a semantic distance can be defined as a measure of similarity among objects, i.e. the weighted distance between attribute values or as weighted distance between nodes in the network.

In [4] a method proposed that allows mapping an ASN into a geometrical view, approximating the values of the semantic distances to the geometrical distances.

An ontology is formally defined in [8] as an oriented graph whose nodes represent concepts (classes or instances) from a domain, and whose edges represent relations. The basic relation is the *is_a* used for the definition of hierarchies. Nevertheless, the type of relations is not restricted to it. The edges may be directed in the case of non-symmetric relations.

2.1 Mapping of Semantic Distances into Geometrical Coordinates

For the approximation of semantic distances into geometrical distances, a criterion of parallelism between vectors consisting of semantic distances and geometric distances is used that indicates how precise the solution is. This criterion is a function of coordinates, whose maximum value can be 1 (that is the ideal case), meaning that the geometrical and the semantic distances are proportional.

The semantic distances between objects can be described by means of a semantic distances matrix $S = (s_{i,j})_{NxN}$. We shall assume that this matrix is symmetric ($s_{i,j} = s_{j,i}$), $s_{i,j} \geq 0$ for $i \neq j$ and the $s_{i,i} = 0$. The proposed algorithm [4] can be used also with a non-symmetric distances matrix. Taking into account these properties, the matrix is mapped into a vector

$$\overline{S} = \{s_{1,2}, s_{1,3}, \ldots, s_{1,N}, s_{2,3}, s_{2,4}, \ldots, s_{2,N}, \ldots, s_{(N-1),N}\} \tag{1}$$

The geometrical distances can be defined through a matrix G where:

$$G_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2} \tag{2}$$

The elements of this matrix can be mapped into a vector

$$\overline{G} = \{g_{1,2}, g_{1,3}, \ldots, g_{1,N}, g_{2,3}, g_{2,4}, \ldots, g_{2,N}, \ldots, g_{(N-1),N}\} \tag{3}$$

A criterion of parallelism P between the vectors $\overline{S}$ and $\overline{G}$ can be defined through the scalar product of these two vectors:

$$P(x_1, y_1, z_1; x_2, y_2, z_2; x_3, y_3, z_3) = \frac{\overline{S} \bullet \overline{G}}{|\overline{S}| \bullet |\overline{G}|} \tag{4}$$

In the ideal case, P carries the maximum value 1 that indicates that the vectors are parallel. If P takes its minimum (P = 0) then the vectors are orthogonal which represents the worst case for mapping (geometric and semantic distances are not correlated).

Our solution proposes a maximisation of P based on the given semantic distances and an optimal reallocation of vertices where geometrical distances mirror semantic ones.

The mapping of the semantic distances into the geometrical coordinates is also possible, if the matrix of the semantic distances is incomplete, e.g. if certain semantic distances were not given at all.

2.2 Advantages of the Visualisation Using AutoCAD

There are several advantages of the use of AutoCAD for the visualisation of ASN and ontologies:

- The main advantage is that the development engineer can see the representation from different perspectives and also perform a zoom operation in order to have a

more convenient view of the objects. It is possible to present at the same time different views of the ASN in several windows with different zoom factor.

- There is the possibility of presenting different user-selected object-types and also various kinds of relations between objects in different layers. In order to have a more ordered view, layers that are superfluous for the user can be hidden.

- In [9] the importance of providing certain aids for the users to improve the visualisation results of complicated 3D objects is shown. In their system there is a tool that allows selecting an object and making it visible or invisible. In our example different types of relations were placed in different layers. Through the use of the layer-technique the relations between objects can be shown or masked.

- The position of the presented objects can be calculated, but there is also the facility of a manual improvement of the presentation. AutoCAD has a comfortable interface (VBA). The positions of the presented objects can be calculated in spreadsheet programs such as Excel or database tables or may be arranged in some other way. The transfer of the data into AutoCAD, the generation and positioning of the geometric elements can be automatically carried out with help of the VBA program.

- Optionally, hyperlinks can be used in nodes and edges linking to more detailed information of the objects and relations. The use of hyperlinks is a necessary condition for feature-based construction with AutoCAD. The use of hyperlinks allows practically unlimited extensions to the semantic assigned to a geometrical element. Clicking at any of the elements in the CAD-model, the hyperlinks deliver a simple text or even direct access to the application and operating system data related to the graphic object. In this way, for example, when a symbol of a CAD-model is clicked the related files can be open and edited.

- The graphic elements in AutoCAD correspond to data in an Excel spreadsheet or records in a database.

- Ontologies can be semantically represented as oriented graphs and consequently can be modelled and visualised in AutoCAD. For the presentation of symmetric or asymmetric relations between objects double-ending or simple arrows may be used.

- For the representation of objects of different kind different geometrical elements can be used. These elements can be designed and configured by the AutoCAD-user if necessary. The geometrical elements can be configured as required with different line-type, colour, line-strength and text attributes. Here e.g. it is possible but not necessary to support the UML conventions.

- Another way of finding additional information to a selected data element is the integration of databases with the CAD-model. Geometrical elements of a CAD-model can be linked with data-records of relational databases. Thus, it is possible to use database functionality in order to look for objects in the CAD-model. Inversely, it is also possible to find in the linked tables the corresponding data records for graphic-interactively selected elements. Since in a complex ASN and also in ontologies an extremely high number of nodes and relations is to be expected, this functionality is very important.

- Algorithms were developed, which allow mapping the semantic distances between the objects into geometrical coordinates. Thus, the search on the basis of the semantic distances can be supported in AutoCAD. Given that a clear definition of

the semantic distance does not exist, different distance definitions must be used for user purposes, which eventually leads to different representations. The representation can be saved in different CAD-models or in several layers of a model.

- The possibility of a 3D presentation is a more obvious advantage. The map of semantic distances into geometrical coordinates can be accomplished better in many cases but not always using the 3D-coordinates. It is also possible e.g. presenting the objects (class-instances) and their relations on the layer with z=0 and the classes and their corresponding relations in other layer with z<>0.

- The program AutoCAD supports numerous plotters and other output devices. Thus, the results of ASN models and ontologies can be documented very well on paper. Saving the model data in DXF, WMF or HPGL format allows passing on the model data to other computing systems. Models of the whole net can be visualised at the same time with detail representations on the screen or on a paper sheet by the use of the AutoCAD windowing. In different windows different scaling factors can be used.

- In active semantic networks different dynamic processes are executed. E.g. the change of an object (node) entails the change of other nodes. The VBA program interface of AutoCAD allows simulating the dynamic procedures in ASN also on the screen.

- The models of the ASN and ontologies could be produced also directly in the AutoCAD. On the VBA basis AutoCAD models can be analysed and exported into external applications (e.g. MS Excel, data bases). The networking information can automatically be recognized and registered in applications

2.3   Experiences and Suggestions for Practical Implementation

Representation of the Nodes

The nodes can be represented in different ways. In the simplest case, the same symbol can be used for all kinds of objects with a different text. In terms of AutoCAD it is convenient defining the symbols as blocks. In our test version we took a 3DFACE (optically represented as a rectangle) element for the presentation of the objects and two attributes to differentiate the elements. The 3DFACE element is on the layer z=1. The attributes in AutoCAD are texts that are requested from the user each time when a block is added. For the first attribute a number is entered as the unambiguous ID for the type of object (e.g. 4 for Persons, or 1 for CAD-models). As value for the second attribute a unique identification of the object (e.g. name + surname) is entered. The attributes have the z-coordinate=2 (superior as the 3DFACE). The insertion point of the block is seen from above in the middle of the rectangle and has the z-coordinate=0. The edges of the network presentation connect the insertion points. This approach can be implemented with minimal software effort. In order not to disturb the readability of the attributes, they may be hidden using the instruction "_hide". Figure 1 shows the advantages of this procedure. A separated layer is created for each kind of object. In this way it is possible choosing to show or hide several kind of objects.
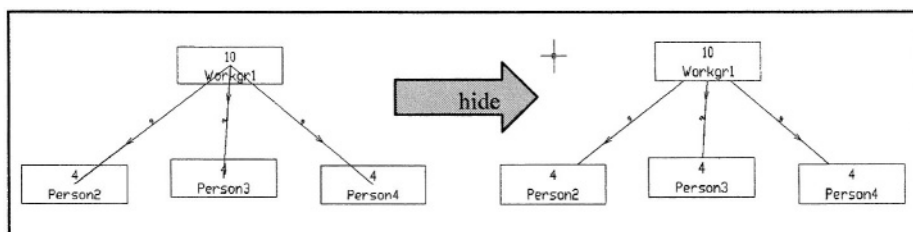
Fig. 1. Use of the instruction "_hide" to mask the edges in the net

Representation of the Edges

For representation of relations simple lines can be used. Also complex objects can be created and used as blocks. In the case of asymmetric relations the direction must be known and should be recognisable. It is advantageous to directly use the associative dimensioning lines of AutoCAD, as manual changes to the graphs can easily be done. With help of the instruction "_stretch" the position of different objects can be changed. The edges belonging to the objects are updated automatically. The edges are on the layer z=0. This way, the readability of the texts of presented objects is not disturbed with the edges. The actual dimensioning text is not interesting and must be replaced by other text representing the semantic of the edges. AutoCAD allows arbitrarily removing the dimensioning arrows or also replacing them by a user-defined symbol. Those symbols used according to the AutoCAD standard are displayed at the end of the dimensioning line and would not be seeing behind the symbol of the 3DFACE objects. Thus, the creation and use of own blocks was necessary for the measure arrow representation. The head of the arrows are sufficiently far away from the end of the measure line (s. Fig. 1).

In the dimensioning text at least the type of relation can be entered as a number. Also for the edges hyperlinks can be used linking them with data sets and data tables. Each edge in AutoCAD as well as in ASN has its own ID. This way it is possible to identify the objects that they connect.

Character and arrow size in the dimensioning easily can be changed later on. For that purpose the AutoCAD system variable "DIMSCALE" may be used.

For each kind of relation (kind of edge) a separate layer is created. So it is possible to show or hide several kinds of relation.

Handling of Layers

Layer 0 is always present by default in AutoCAD. It is recommendable to create a new layer per kind of object and per kind of relation respectively. The levels can be alternatively switched on or switched off. For this purpose AutoCAD has the dialog-box „Layer". When there is a very high number of layers, user tools should be programmed allowing switching on and off determined groups belonging logically together.

Automatic Production of the Net Presentations in the AutoCAD

Basis for the automatic placement of the objects is a data table (s. Table 1) that contains at least the following columns:

☐ ObjectID of the unambiguous name of the object;
☐ The x, y, z coordinates that specify where an object symbol in the CAD model is to be placed.

Because in our example an object symbol is represented through a block with two attributes, for the first attribute a column named KindOfOBj is needed.

KindOfObj	ObjecID	x	y	z	Handle	Hyperlinks
2	CostCalc1	-260	-21	0	97D3	...
2	CostCalc4	211	-77	0	97DF	
2	CostCalc5	416	-69	0	97E3	
2	FEMCalc1	-397	-90	0	97E7	
2	FEMCalc2	-197	86	0	97EB	
2	FEMCalc3	-4	-36	0	97EF	

Table 1. Section of the table containing necessary data for the automatic placement of objects.

Object symbols are inserted as block-references with the following instruction into the CAD Model:

```
Set blockvar = ThisDrawing.ModelSpace.InsertBlock(point,
lockname", sf, sf, sf, winkel)
```

where `point` is the insertion point of the block-reference, `sf` is a block-scale-factor for the three directions x, y, z, and the variable `winkel` defines the rotation of the block around the z-axis.

The insertion points of the block references can be calculated if the semantic distances between the objects are known (s. [4]).

With the variable `blockvar` the attribute values, layer, font size and hyperlink of the inserted block reference can be assigned. After the production of the block references their `handle` is immediately read (AutoCAD object identifier) and registered into the table of objects. In this way it is possible to later access the objects.

For the entry of the relations the following table can be used as basis:

Object1	Relation	Object2	RelNr	x1	y1	z1	x2	y2	z2	Handle
Person1	Conducts	Workgr1	18	-28	323	0	-29	267	0	988F
Person5	Conducts	Workgr2	18	260	326	0	262	274	0	98BE
Workgr1	Contains	Person2	9	-29	267	0	-132	204	0	98ED
Workgr1	Contains	Person3	9	-29	267	0	-33	207	0	991C
Workgr1	Contains	Person4	9	-29	267	0	66	204	0	994B

Table 2. Section of the table „Relations"

The relations are not represented in AutoCAD as blocks, but as dimensioning lines.

```
Set bemvar = ThisDrawing.ModelSpace.AddDimAligned(Point1,
Point2, Point2)
```

Point 1 is defined by the coordinate x1, y1, z1 of the insert point of the block reference for Objekt1. Point2 is defined by the coordinate x2, y2, z2 of the insert

point of the block reference for Objekt2. The dimensioning line connects directly the points Point1 and Point2. Therefore Point2 is also the third argument of the method AddDimAligned.

With the variable `bemvar` the attribute values, layer, font size and hyperlink of the inserted dimensioning line can be assigned. After the production of the dimensioning line their `handle` is immediately read and registered into the table of objects. In this way it is possible to later access the objects.

The tables Objects and Relations were created and saved as an Excel spreadsheet. The data communication between AutoCAD and MS Excel can be very simply implemented on the VBA basis. The positions of the objects in AutoCAD can be graphic-interactively manually improved. It is possible to transfer the new coordinates with the help of the programs back into the Excel tables. Figure 2 shows a section of the representation of the whole example net.
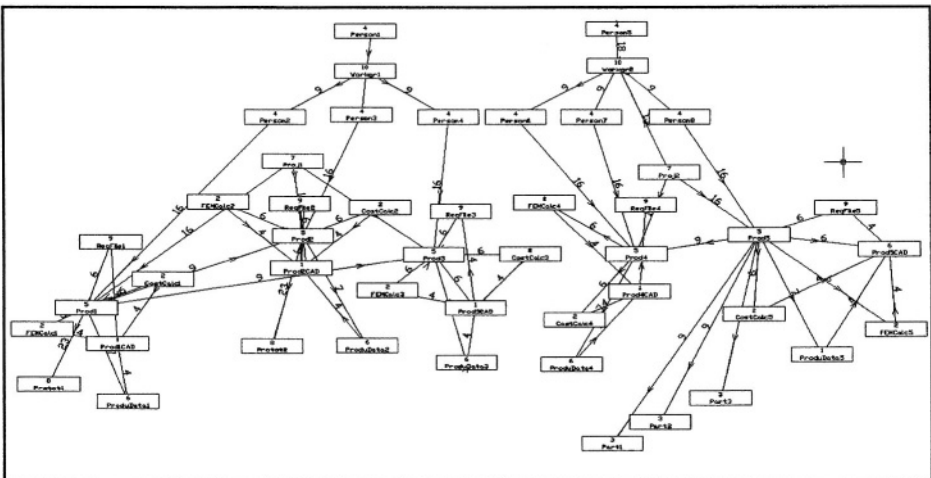
Fig. 2. A section of the representation of the whole example net

Conclusion

The paper has shown that the visualization of ASN and ontologies can be achieved with a low cost tool like AutoCAD or with any CAD tool having a programming interface.

The visualisation presented in this paper is in a sense a method independent of the algorithm used for the calculation of the geometric coordinates based on the semantic distances. Resuming, any algorithm can be used to do this mapping; then the results can be saved in a spreadsheet or in a (relational) database or in an ASCII text-table; and finally AutoCAD is used for the visualisation.

The programming effort needed to implement the transfer of the calculated geometric data from tables into the AutoCAD is small.

The use of a CAD tool having a programming interface allows the user developing his own programs for any further wished manipulation of the visualised data.

Acknowledgments

References

1. SFB374 Entwicklung und Erprobung innovativer Produkte - Rapid Prototyping. www.sfb374.uni-stuttgart.de
2. H. Joosten, M. Mešina, D. Roller, M. Shligerskiy M.
   Visualisierung einer Aktiven Semantischen Wissensbasis für den RPD-Process. Workshop Elektrotechnik-CAD '03, Universität Stuttgart.
3. GRINTEC. WiLa: Projektbezogene Wissensrepräsentation. PDF available on the web, 2001.
4. M. Mešina, D. Roller, C. Lampasona. The Mapping of Semantic Distances into Geometrical Coordinates. Visualisation of Semantic Networks. Attached paper: Workshop "Virtuelle und Erweiterte Realität" der GI-Fachgruppe AR/VR.   Technische Universität Chemnitz. 27. - 28. September 2004
5. B. Le Grand; M. Soto. Navigation in Huge Information Hierarchies: Application to Network Management. In: Workshop on New Paradigms in Information Visualization and Manipulation (NPIVM'99), 1999. Kansas City, USA
6. I. Hermann et al. Graph Visualization and Navigation in Information Visualization: a Survey. In: IEEE transactions on Visualization and Computer Graphics, IEEE Computer Science, 2000, Vol. 6, No. 1.
7. K. Risden; M.P. Czerwinski; T. Munzner et al. An Initial Examination of ease of Use for 2D and 3D Information Visualizations of Web Content. In: International Journal of Human Computer Studies, 2000, Nr. 53(5), pp. 695-714.
8. P. Bednár, S. Hudák. Automatic Linking of Text Documents. In the proceedings of "Informatics and Algorithms 2002", page. 215, Prešov, Slovakia.
9. Luo Y. et. al., Visualization for Cooperative Architecture Design System, Proceedings of IEEE 2002 Conference on Information Visualisation, July 2002, London, pp. 582-588.

Mediating Collaborative Design for Constructing Educational Virtual Reality Environments: A Case Study

Yongjoo Cho[1], Kyoung S. Park[2], Thomas Moher[3], and Andrew E. Johnson[3]

[1] Sangmyung University, 7 Hongji-dong, Jongno-gu, Seoul, Korea
`ycho@smu.ac.kr`
[2] ICU Digital Media Lab, 517-10 Dogok-dong, Gangnam-gu, Seoul, Korea
[3] University of Illinois at Chicago, 851 S. Morgan, Chicago, IL, 60607, USA

Abstract. This paper presents a case study of a multidisciplinary team designing a virtual environment and instrument for young children's science inquiry learning. The designers had the course of meetings to collaboratively develop a learning unit using CLOVES, a virtual world builder. The study showed the potential of CLOVES as a collaborative medium. The designers actively participated in decision-making at every stage of the design process and shared knowledge among one another, which helped the establishment of common ground.

1 Introduction

Traditionally, many world builders support the construction of virtual environments designed primarily to develop applications that highlight the experience of *being* in a virtual environment rather than *learning* in it [7]. The construction of learner-centered virtual environments, in contrast, necessarily begins with an analysis of the pedagogical requirements that in turn act as drivers for the features of those environments. For the past few years, we have developed a series of virtual environments that supports scientific inquiry activities for elementary school students, named virtual ambients [6]. Virtual ambients support instructional designs that allow young learners to conduct observational scientific investigations.

Virtual ambients are not instructional plans; they are spaces within which learning activities may be designed. It is nonetheless essential that educators inform the design of these spaces if they are to use them as components of instructions. From our experience, however, the most difficult problem we encountered was inviting educators into the design process and helping them understand and participate into the construction. Due to the specialized complexity of construction process of virtual environments, the design was largely driven by software developers, which caused the isolation of educators who did not have enough knowledge to understand the distinctive vocabularies and processes of the development.

Collaborative design requires the establishment of "common ground" [3] – mutual ratification of the emergent understanding by team members of the common object of design. The establishment of common ground in multidisciplinary collaboration is

complicated by the fact that participants draw from unique "object worlds" [2], populated by distinctive processes, objects, and vocabularies so specialized that they are nearly opaque to those outside of their disciplines [4]. In this paper, we present a preliminary assessment of a virtual world builder, CLOVES (Construction of Layer Oriented Virtual Environments for Science inquiry learning) which can act as a *medium* for collaborative design among educators, programmers and modelers by providing construction affordances in terms accessible across disciplines, and by making visible the effects of design decisions at every stage of development.

CLOVES supports the development of large and densely populated virtual environments. Populating the objects in a large virtual environment by hand is difficult and time-consuming process. CLOVES provides several ways, both visual and non-visual, to populate a large number of objects quickly. Its visual interface allows easy manipulation and population of objects on a 2D-based workspace. It also allows more sophisticated and automated population through its rule-based scripting tool. CLOVES supports the development of data-rich virtual environments in which objects and the environment itself have embedded properties, which form the grist for student investigations. Designers can bind constant property values to an object template and populate the instances of the object within the virtual world. CLOVES supports the use of virtual instruments. Not all phenomena of interest are visible to human eye; using CLOVES, designers can provide access to invisible phenomena to learners by designing the handheld-based instruments that "sense" the properties of the simulation.

The objects, processes, and vocabulary of CLOVES are squarely within the world of computer science. However, we argue that CLOVES has the potential to support the establishment of "common ground" by literally making visible the incremental products of design, allowing teachers to rapidly bind new concepts to tangible manifestations of design decisions, within the context of supportive feedback from technology domain specialists. As a preliminary test of this conjecture, we undertook a short case study in which a multidisciplinary team was asked to design a learning unit using CLOVES. The study had three objectives. First, since this was the first use of CLOVES by anyone other than its designer, we were interested whether it could be used as a *medium* to effectively produce a design product. Second, we wanted to expose and correct *capability limitations* within CLOVES that constrained the design effort. Most importantly, we attempted to explore the *mutual adaptation* process [8] through which design participants came to establish common ground.

2   Participants

The two primary participants were Betty, a third-grade teacher from a suburban Chicago elementary school, and Armando, a graduate student in Computer Science. Both participants had prior experience with the use of virtual ambient environments in the classroom; Betty's third-grade class had used the *Bee Dance* [5] application, and Armando was responsible for the design of learning assessments associated with that unit. Neither had experience in the design of virtual worlds, and Armando had no

prior experience with the specific underlying tools of CLOVES, such as Ygdrasil [7], CLOVES' scripting language, and virtual instrument scripting toolkits.

Table 1. Design process of constructing virtual ambients

Session	Phase	Brief description of design activities
1-4	Synopsis Design	Introducing to virtual reality systems and CLOVES, checking available resources (3-D models, computers), brainstorming a new world
5-7	High-level Design	Writing rules (Armando), populating rocks with the rules (Armando and Betty), making extensions to the visual interface of CLOVES and its rule-based scripting language
8	Testing	Watching the demonstration of the new world and planning for a new iterative design process

Betty, a teacher with ten years of professional practice at the elementary level, described herself as "interested in science," but "math-phobic" and "not very good with computers." She said that she used computers mostly for e-mail and word processing. Betty described her strongest interests as art and gardening, and felt that she was probably most effective in language arts and social studies rather than mathematics and science. Armando had an especially strong background in the physical sciences; he was an undergraduate chemistry major, and had on several occasions given demonstrations to Betty's students.

3   Method

The designers (Betty and Armando) had eight meetings over the course of two months; each meeting lasted from 60 to 90 minutes. The author of CLOVES was present at each of the meetings, serving a dual role as application specialist and observer of the design process. At the end of each meeting, Betty and Armando completed a brief questionnaire that probed both their use of CLOVES and the nature of their design activity during the session. In addition, Betty (and, to a lesser extent, Armando) took extensive notes during the meetings, which were photocopied and retained.

During the initial session, the designers were given brief introduction of the study objective and familiarized with the questionnaire items that they would be responsible for responding to at the end of each session. They were then charged with the task of developing a set of learning goals, an instructional unit designed to address those goals, and a concomitant virtual environment to support the unit. Next, the designers were introduced to CLOVES. They were given a brief overview of the conceptual framework of the software. Then, they went through the major phases of the design task, demonstrating the CLOVES affordance available to support each phase. They were informed of the graphical models available for their work.

During the remaining sessions, the designers proceeded at their own discretion. The core developer of CLOVES was available to answer questions about CLOVES

functionality, but otherwise adopted a passive observer role. Because Armando was not familiar with the specifics of Ygdrasil, the author also served as the "low-level programmer" for requested extensions to the base system and virtual reality programming (see Table 1).

4 Collaborative Design and Getting Toward "Common Ground"

Over the course of the seven sessions, Betty and Armando were able to develop preliminary versions of all three "design products"—learning goals, instructional unit, and environment design—in an activity intended to complement a third grade curriculum unit on the planets of the Solar system.

4.1 Meteors on Mars

Using the Martian landscape and a palette of available rocks, the designers constructed an activity plan that posed the following problem:

Is there life on Mars? Scientists believe that the presence of water is necessary to sustain life. To find water in Mars, we chose to dig up the softer areas of the planet first. One place where the surface gets "softened up" is where meteors strike on the planet. Unfortunately, most of the meteor impacts happened on Mars a long time ago, and erosion has made it difficult to find the impacted areas.

Fortunately, when an asteroid hits the surface, it breaks down to small rocks that are spread around and creates certain elliptical contours around the impacted area. The rocks form the asteroid also shows higher value of iridium elements than other Martian rocks. Thus, by checking the rocks that have higher iridium values, children can find the contours on the Mars' surface. When they find the elliptical contour, they are supposed to draw a line that crosses the furthest two points in the elliptical shape. When they draw lines from all elliptical shapes they find on the surface, they should be able to see the intersected points of those lines, which is the impact location of asteroid as shown in Fig. 1.
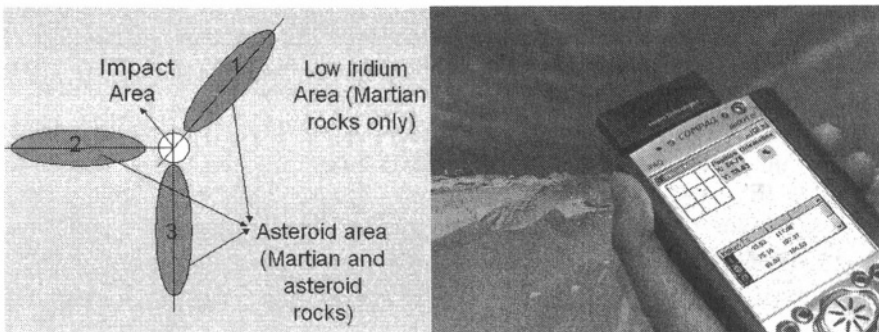

Fig. 1. Finding the impact area of asteroid (*left* image) and the generated virtual world from CLOVES (*right* image)

Table 2. Average use of media across the design sessions

Media	Self-reported distribution (%) of medium usage						
Work medium	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Paper/pencil/whiteboard	50	90	22.5	80	0	0	0
CLOVES	40	10	77.5	0	100	100	100
Other computer usage	10	0	0	20	0	0	0

4.2 CLOVES as Collaborative Medium

Because this was Betty and Armando's first time using CLOVES, the case study cannot reflect the kind of mature usage that would arise from long-term experience with the system. One potential outcome of this study would have been that Betty and Armando would rely on the author of CLOVES to mediate "usage" of CLOVES by serving as its primary user. Instead, after the initial introduction to CLOVES, Betty and Armando used the software with only occasional requests for clarification of program functionality.

In most co-located multidisciplinary learning technology development efforts, designs are elaborated without the use of targeted supporting technologies. In this study, Betty and Armando had access to the usual external representational media, including pencil and paper and a whiteboard, and they used these media extensively during the initial design sessions. During session 4 in particular, in which they worked out the student learning goals and task requirements, Betty and Armando worked exclusively on paper to develop their ideas. During the last three sessions, in contrast, all of Betty and Armando's work took place in CLOVES. Table 2 shows the self-reported distribution of time using various media from the designers.

In response to the questionnaire item probing perceived strengths of CLOVES, Betty initially found it viscerally "appealing," but in later sessions (5-7) consistently cited the ability to see the world as it was being constructed as a principal benefit. She wrote of the ability to "see the world" and "seeing the population of rocks" as turning points in her understanding of the functionality of CLOVES. Armando, with more experience dealing with abstract programming representations, focused instead on the functional affordance of CLOVES, such as the ability to populate regions with random objects, and the "dropping" capability that placed objects at appropriate vertical positions relative to the base terrain.

Most of the usage of CLOVES in sessions 1-3 could properly be characterized as "training" rather than actual design work, and Betty in particular found the complexity of CLOVES—and perhaps even its purpose—opaque at this stage. Following session 3, she wrote, "I need to see the world—Mars—and all of the rocks to better understand our task."

4.3   Exposing CLOVES Limitations

It is not possible to make strong claims regarding CLOVES' usability from this case study, both because Betty and Armando were novice users, and because the author was available to resolve interface issues as they arose over the course of the seven sessions. However, it was encouraging that the frequency of queries to the author reduced substantially over time, and that Betty and Armando operated essentially autonomously during the final three sessions. Not surprisingly, the case study revealed functional limitations in CLOVES that required remediation in order to allow Betty and Armando to build their target environment. One of the limitations is elaborated in this section, both to characterize the nature of the changes effected, but also as a prelude to the discussion of Betty and Armando's moving toward "common ground."

An issue arose when world properties were added to the asteroid regions. Initializing a world property to a constant value for a specific region or layer can be done by using CLOVES' scripting language. For instance, designers can create a simple rule that sets a constant value for a world property – such as iridium value of 0.7 – and then apply the rule to regions in the world. After they populated all objects, the designers used this rule that sets the iridium value with pre-defined threshold—0.7 for the asteroid areas and 0.2 for everywhere else. However, as they started applying the rule to each meteor regions, they were stuck at another important issue.

In CLOVES, world properties could only be set in a region. CLOVES is designed to report the value assigned to a region where the current navigator is located. If no region is specifically bound to the navigator's current position, CLOVES follows the internal hierarchical path of world properties. In virtual ambients, navigators cannot select or grab an object. It only allows the proximity-based user interaction. Due to this fact, no particular value is bound to an object in the original design of CLOVES. In other worlds, probing the property directly from the object is not supported.

However, Betty and Armando felt that the iridium values should have been set as properties of rocks rather than the world. As a simple solution, they proposed creating bounding regions around each object and set the threshold value into the regions. This would work if there were only a few objects. However, more than a thousand rocks were populated at the time. They also proposed creating a low-level function for the scripting language that automatically generates the bounding regions for all objects in the world and possibly set a specific world property in the areas. There were other proposals mentioned during the meeting. For example, what if the teachers who would run this program just say that when there were both Martian and asteroid rocks, the iridium elements of asteroids spread around the air in the area and showed higher iridium value in the area.

While discussing the solutions, Betty proposed the solution that was finally adopted. She asked, "what if we added world properties to an object's template and populated the instances of the object template around the world?" Again serving as low-level programmer, the author of CLOVES implemented the change and the revised version of CLOVES made it possible to add a world property to an object template and populates instances of the object, which would, then, inherit the world property defined in the template; this change took about a day, which was spent mostly on constructing graphics user interfaces.

4.4 Toward "Common Ground"

While Betty and Armando had worked together before, that work had always taken place in the context of the classroom, and the subject of discussion had always been within Betty's domain of expertise: teaching and learning. Thus, Armando approached the design task with a fairly strong contextual grounding; concepts such as learning goals and instructional plans did not require elaboration by Betty during the design process. Betty faced a much more formidable learning task. In addition to her self-reported unease with using computers, she confronted new vocabulary both in programming (e.g., objects, properties) and mathematics (e.g., ellipses, polygons).

Betty's notes and questionnaire responses reflect her process of "seeking common ground." During the first session, Betty began to use the term "object" freely, and (by the last of six pages of hand-written notes) she wrote about "populating the world" with objects, and that "properties or values are put in by us [the designers]." She made reference to a "rules box," but didn't seem to yet have a clear understanding of how rules related to the task at hand. During the next two sessions, Betty expanded her vocabulary markedly. She began to use terms such as "pixel," "properties," "pull-down," and "scale [an object]," and began to be familiar with concepts such as proximity-based sensing and the distinction between local and global properties.

Over the remainder of the design sessions, Betty continued to grow in her understanding of new vocabulary and concepts. While she preferred to let Armando do most of the direct user interaction with CLOVES, she was a full participant in each decision, and demonstrated a strong understanding of all of the sub-tasks (e.g., object placement, attribute binding, rule specification). Betty's suggested solution to the problem of object attribute binding (as shown in section 4.3) was a strong indication of her mastery of new concepts and vocabulary.

5   Discussion

While case studies are inherently limiting in their generality, Betty and Armando's experience was productive on several fronts. The limitations that became visible through their design effort represent both functional and usability improvements to CLOVES that would not have been introduced without undertaking the case study. The robustness of a new system is always on the mind of its developer, so the author was gratified that programming errors did not impede the designers' progress.

The most exciting outcome of the case study, however, was Betty's internalization of the concepts and vocabulary introduced in CLOVES, especially for someone who characterized herself as uncomfortable with technical materials. While Betty was a willing participant, there was relatively little expectation that she would adopt the language used in CLOVES, rather than requiring continuous efforts to "translate these things into her terms," as Armando put it. That she was able to articulate an innovative solution to a technical limitation of CLOVES reflected deep learning, in that she was able to take her new knowledge and apply it productively [1].

6   Conclusion

This paper describes a case study of a multidisciplinary team designing an educational virtual environment. The study showed that the designers got to the point where they could construct the common ground of vocabularies and knowledge. Although it would be difficult to generalize the result of this study for other users or the advantage of CLOVES in collaborative design, CLOVES' visual interface certainly helped educators be involved in the design process and share their knowledge with other designers. In particular, that Betty was able to express her proposal in language akin to that of an advanced undergraduate computer science major was remarkable. Further investigations will be made to evaluate and improve CLOVES and how it can benefit collaborative designers for the development of educational virtual environments.

References

 1. Bransford, J.D., Brown, A.L. & Cocking, R.R.: How People Learn: Brain, Mind, Experience, and School. Washington, DC: National Academy Press (1999)
 2. Bucciarelli, L. L.: Designing Engineers. Cambridge, MA, MIT Press (1994)
 3. Clark, H. H.: Using language. Cambridge: Cambridge University Press (1996)
 4. Geisler, C., and Rogers, E.: Technological mediation for design collaboration. In Proceedings of 18th annual ACM Conference on Computer Documentation (2000) 395-405
 5. Haas, D.: The Honeybee Dance: Classroom-based Science Discovery in a Simulated Environment, M.S. Thesis, University of Illinois at Chicago (2002).
 6. Moher, T., Johnson, A., Cho, Y., Lin, Y.: Observation-based Inquiry in a Virtual Ambient Environment. In Proceedings of International Conference of the Learning Sciences (2000) 238-245
 7. Pape, D.: Composing Networked Virtual Environments, Ph. D. Dissertation, University of Illinois at Chicago (2001)
 8. Reiser, B.J., Spillane, J.P., Steinmuller, F., Sorsa, D., Carney, K., & Kyza, E.: Investigating the Mutual Adaptation Process in Teachers' Design of Technology-infused   Curricula. In Proceedings of the Fourth International Conference on Learning Sciences (2000) 342-349

openVisaar: Enriching Cooperative Visualization by Combining Open Technologies

Frank Goetz and Gitta Domik

University of Paderborn
Computer Graphics, Visualization and Image Processing
Fuerstenallee 11
33102 Paderborn, Germany
{frank.goetz, domik}@uni-paderborn.de

Abstract. In this paper we present a new client-server based visualization framework called openVisaar. For remote visualization encoded video streams are multicast from each cluster client node to the remote application with RTSP (Real Time Streaming Protocol). At the remote site only an ISO-compliant MPEG-4 video player software is needed to decode the video stream. By supporting remote video streams spatially separated working partners have the possibility of synchronous collaboration with our visualization system. For navigation and interaction at the remote site openVisaar offers different client software. Navigation and collaborative interaction can be enhanced with an additional Augmented Reality support. Only components that can be used freely for non commercial purposes are integrated.

1   Introduction

In the last years the rendering and displaying quality of three dimensional computer generated visualizations were enormously improved. Compared to the past their appearance and expressiveness is very good and computer simulated scenarios of reality are more acceptable than ever. As a highly interdisciplinary field, computer generated visualization frequently requires experts and domain specialists with different background knowledge to cooperate closely. Often huge amounts of numerical data are to be explored and understood. Many valuable insights only occur while collaborating and discussing relevant data representations.

The connection of the *CSCW (Computer Supported Cooperative Work)* concept and the *AR (Augmented Reality)* technology delivers new possibilities for intuitive and computer supported cooperative work especially by team work at the same location. Augmented Reality is a technology by which a user's view of the real world is augmented with additional information from a computer model. It constitutes a particularly promising new user interface paradigm by exploiting people's visual and spatial skills to navigate in a three dimensional world. This can be also very helpful for localized collaboration to explore the numerical geospatial data of a climate model that is displayed in computer generated visualization [1].
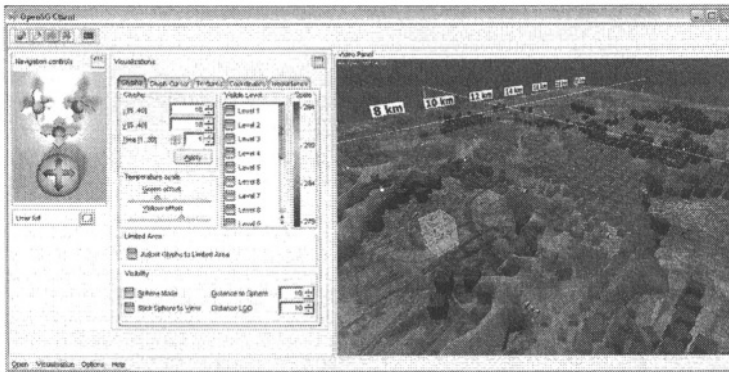
Fig. 1. Exploring geospatial data with Java based remote client of the openVisaar framework

In the past and even today a common method to transport visualizations was the streaming of compressed meshes and textures from a server to a client computer. While visualizing complex scenes with a huge amount of polygons this method often needs too much network capacity and has high demands on the capabilities of the client computer. By using such methods there are big security problems, too. It is very easy for an intruder to steal all original data, because all relevant raw data will be sent directly from the server to a client. In our remote solution we assume that the client computer offers only a fragment of processor power and graphics power of the server. Also a powerful graphics accelerator board is only needed in the cluster-client nodes of our visualization cluster (often called grid). The only demand on our remote client is that it is capable to decode ISO-compliant MPEG-4 video streams. When using Augmented Reality also a minimalist version of the *ARToolkit* has to be executable on the remote computer, even possibly on a PDA (Personal Digital Assistant) [2].

The aim of our work is to develop a platform independent visualization server that takes advantage of the functionality of current graphics accelerator boards and delivers a high performance video stream to the remote client computer (see Fig. 1). In our case high performance video stream means that the picture quality is high, the frame rate is accurate, the needed bandwidth is low and the latency is as short as possible. While using video streams we have a constant and calculable size of network capacity and processor power. The size of the video stream is independent from the size of the visualization and the graphics accelerator board of the client computer does not need special features to display interactive and animated visualizations at an accurate frame rate. It is possible to use the majority of available computers, even laptops and handhelds, as a visualization client [3].

A further point should be that different users are able to access the data that was generated by the visualization server at the same time. Also the coordination between active users should be as easy as possible. It is very important that every user of the cooperative working process gets the same potential for work. There should not be any problems concerning the geographical location or the capabilities of the hardware. The user should not be restricted or excluded from the working process because of using limited hardware or software. The ability to interact, navigate and manipulate at an accurate speed has to be available for all users of a cooperative working process.

2   Related Work

A lot of different projects deal with collaborative visualization, remote visualization and/or collaborative Augmented Reality. Most of them only support one or two of the before mentioned features. Sometimes the lack of important features restricts the user by advanced procedures. A short description of functionality and features of the most interesting solutions in this area will be given next.

2.1   Studierstube

The *Studierstube Workspace* is an application framework for collaborative visualization in Augmented Reality [4]. In this project a concept for a collaborative working environment that simultaneously supports multiple users as well as multiple applications was developed. Studierstube was not designed for distributed rendering and does not support video-based remote collaboration.

2.2   DWARF & SHEEP

The *DWARF* framework is based on the concept of collaborating distributed services [5]. DWARF is a component-based Distributed Wearable Augmented Reality Framework, and facilitates a rapid prototyping and online development process for building, debugging and altering a complex, distributed, highly interactive Augmented Reality system. A description of an integration of Studierstube and DWARF can be found in [6].

The *SHEEP* game [7] is a famous demonstration for a cooperative Augmented Reality consumer application that was designed to test and demonstrate the potential of tangible user interfaces which dynamically visualize, manipulate and control complex operations of many inter-dependent processes. In particular the main focus of the DWARF project is the distributed augmented reality framework. Video streaming or distributed rendering are not supported in the way our system does.

2.3   SharedSpace (ARToolKit & MagicBook)

The *SharedSpace* project [8] has culminated in two related technologies, the *ARToolKit* and the *Magic Book.*

ARToolKit (Augmented Reality Toolkit) is a software library for building Augmented Reality applications. These are applications that involve the overlay of virtual imagery on the real world.

The MagicBook [9] explores seamless transition between reality and virtual reality. When users look at the pages of a real book through a handheld display they can see virtual content superimposed over the real pages. The MagicBook supports collaboration as a physical object, a shared Augmented Reality experience and a multi-user immersive virtual environment. The MagicBook is very restricted to the applications it was designed for, e.g. education or entertainment applications.

2.4   AR Prism & GI2VIZ

AR Prism and its successor *GI2VIZ* are two explorations in the use of hybrid user interfaces for collaborative geographic data visualization [10]. The AR PRISM interface combines three technologies; Augmented Reality, immersive Virtual Reality and computer vision based hand and object tracking. The interface is based on the underlying idea that multiple users gathered around a real map, should be able to see and manipulate three-dimensional virtual geographic information superimposed on the map. This manipulation should be based on physical markers and tangible interaction techniques. In GI2VIZ alternative interface techniques, including a zoom-able user interface, paddle interactions and pen annotations were explored.

3   Design of the openVisaar Visualization Framework

All the described systems lack of one or more key features. In the following chapter we want to present the design of the openVisaar visualization framework. OpenVisaar can be divided into two parts [Fig. 2 shows an overview].
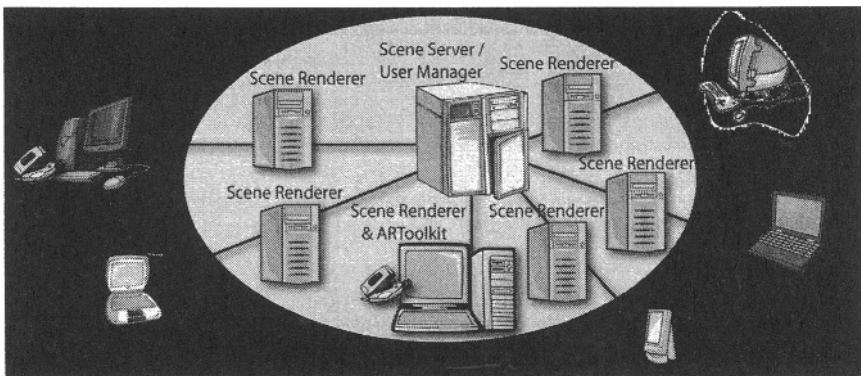
Fig. 2. Components of the openVisaar visualization framework

On one site is the server, normally a cluster composed of a few powerful computers, equipped with modern graphics accelerator boards and appropriate main memory. On the other site there is the client, at most times the computer of the user. This can be a standard pc, laptop or handheld without high demands on the hardware. The only demand is that the client computer is able to decode ISO-compliant MPEG-4 video streams in real-time. Support of Java would be an additional advantage. The server of openVisaar consists of three different services that are executed on a cluster:

- *User Manager:* The actual server that manages the user lists and rights system will be executed on one cluster-server node.
- *Scene Server:* The graphics server controls the replication of the combined scene graph and runs on one cluster-server node, too.

- *Scene Renderer:* A variable amount of graphics clients can be executed on the other cluster-client nodes. Normally the amount of the scene renderers is equal to the amount of available cluster-client nodes.

The *Scene Server, User Manager, Scene Renderer, Java based remote client* and *Augmented Reality featured remote client* use various components and technologies to administrate, render and display the distributed visualization. The three different services of our framework are presented in the next paragraphs. The whole interaction between the different services and remote clients is diagrammed in Fig. 3.
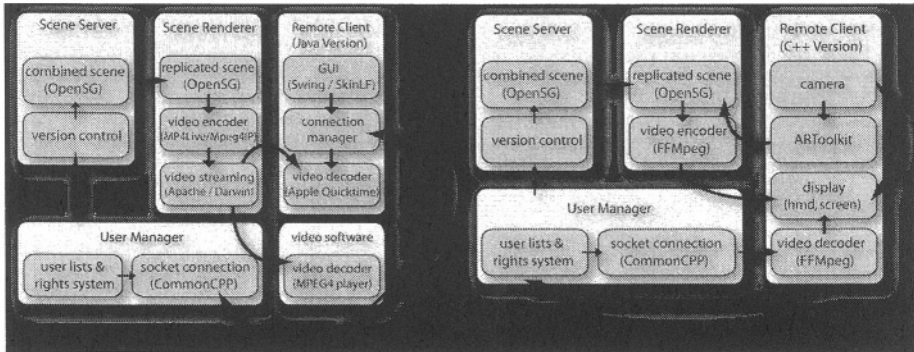

Fig. 3. OpenVisaar architecture with Java based (left) & AR featured remote client (right)

3.1   User Manager

The User Manager provides the elementary coordination functions and a simple right administration. If the remote client provokes an action message, first the User Manager checks the legitimacy of the message with a check up of the actual rights of the user. If the check up was all right, the action message will be forwarded to the user specific Scene Renderer. Additionally, the User Manager receives the changes of the user position, the user orientation and current used tools. This information is collected, too, and will be send to the Scene Server afterwards.

3.2   Scene Server

Both, the Scene Server and Scene Renderer use *OpenSG* for their scene graph management and rendering. OpenSG is a portable scene graph system that provides fundamental functionality to create real-time graphics programs [11]. One central part of the OpenSG design is multithreaded asynchronous scene graph manipulation. The OpenSG data structures are set up in a way that allows multiple independent threads to manipulate the scene graph independently without interfering with each other. This feature allows synchronizing the manipulations of each user with the manipulations of the other users. Finally, every user of the collaborative working community gets the same view on the current dataset.

The centrally stored scene graph is managed by our Scene Server. Changes are executed in agreement with the User Manager. Made modifications are journalized in a simple version controlling system. On every change to the scene, the Scene Server sends synchronized messages to all Scene Renderers to update their replicated scene graph. Furthermore, the Scene Server stores the position, orientation, representation of the user and their visible tools in relation to the common desktop in a second scene graph. Position and orientation are updated regularly by the User Manager and are distributed to the Scene Renderers during the synchronization of the scene graph. At the end of a Scene Server session the scene graph is stored in a file which can be reloaded when restarting the Scene Server.

3.3   Scene Renderer

Every Scene Renderer contains a replicated scene graph that will be regularly harmonized with the scene graph of the Scene Server. Every modification of another user can be seen immediately. There exists exactly one Scene Renderer for every remote client. The Scene Renderer generates an individual view of the shared visualization scene and transports it as video stream to the remote client. All detected marker positions and marker orientations are sent from the remote client to the Scene Renderer. Now, the Scene Renderer has the possibility to calculate the correct positions and orientations for tools, selection-marks and text messages.

All graphics are rendered into a virtual *OpenGL framebuffer* called *pbuffer* (preserved pixel buffer). The pbuffer is used for hardware-accelerated off-screen rendering, followed by the grabbing, encoding and sending of the pictures as video stream. Every frame of the currently rendered picture is sent through the virtual video device *(Video4Linux Loopback Driver)* to the video encoding server *(MP4Live Server)*. Finally, the MP4Live Server generates a real-time video stream by using an ISO-compliant MPEG-4 video codec (e.g. *XviD*).

The *Apple Darwin Streaming Server* (gets the encoded video stream) is a server technology which allows sending streaming video data to clients across the Internet using the industry standard RTP (Realtime Transport Protocol) and RTSP (Real Time Streaming Protocol) protocols. Alternative to the Apple Darwin Streaming Server we support the *Apache* Webserver.

3.4   Client

On the client side one user interface of openVisaar (see Fig. 1) is based on Java and Swing. By using the Java based remote client there are two possibilities to view the video stream at the remote site:
- Download a dynamic link library based on the *MP4Player* (part of *MPEG4IP*).
- View the delivered video stream with an integrated *Apple QuickTime Player*.

The Augmented Reality featured remote client was implemented in C++. For the implementation of the Augmented Reality technology we made use of the ARToolkit and divided it up into two parts, whereby the biggest part was integrated at the client site and only a small part runs at the server site. A combination of ARToolkit and

Open Scene Graph systems was first presented in [12]. For the encoding at the *Scene Renderer* and the decoding at the Augmented Reality featured remote client we use the *FFmpeg* package. We did not find any efficient video codec that supports a transparent video layer, so we are sending the alpha channel as a separate video stream.

4   Cooperative Work with Visualizations

Finally, we want to present what kind of collaboration scenario was already realized and what kind of visualization techniques are supported by our openVisaar systems so far.

Our advanced scenario is the use of visualization with climate modeling. Huge amounts of numerical data have to be explored and understood in the field of meteorology. Meteorologists need information about the evolution process of different physical variables (such as wind speed, temperature, humidity and pressure) depending on time and spatial dimensions. Visualization is one way to monitor this data to ensure that programs are not running far astray of realistic solutions. Thereby visualization may allow early detection of model problems.

OpenVisaar allows every collaboration partner to move viewing position and change viewing angle to gain better comprehension of the displayed data and to look at details. Different visualization techniques can be altered and changed individually, attachments and notes can be made at any three dimensional point and high quality screenshots can be grabbed of a distinguished viewport. All visualization techniques and parameters can be changed by the different collaborators. Techniques and objects that are being changed by one of the users are locked for all other users.

To have a more realistic representation, trees with a Level of Detail more appropriate to illustrate the real landuse of the area can be activated. Clouds, calculated with a particle system, represent the correct atmospheric humidity. Streamlines and stream ribbons can be inserted at arbitrary positions. Differently colored and transparent iso-surfaces with selected threshold values can be inserted in the visualization. The area can be colored with different textures (e.g. street maps, satellite photos) and even the buildings can be represented as simple boxes or complex objects Fig. 4.

Every user has the possibility to share his insights with the cooperation partners. This can be done by marking particular locations or by communicating with the other users (chat, phone or direct talk). In this way many problems can be solved very fast and easy. There are many advantages as compared to an individual solution.

5   Conclusion

We presented a visualization framework that is based on open libraries that can be used freely for non commercial purposes. Further on we tried to combine the aspects of remote visualization, collaborative visualization and embedded functionality for Augmented Reality. At this time, especially the Augmented Reality integration and
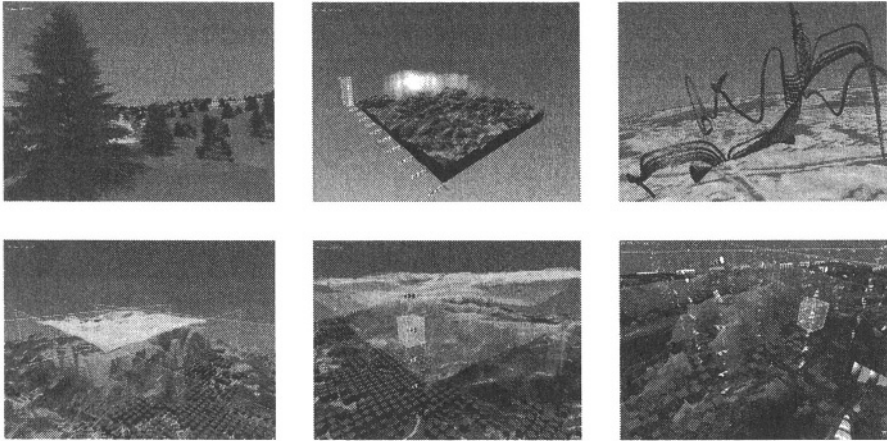
Fig. 4. Screenshots of different visualization techniques provided by the openVisaar system

combination is only in an initial phase. We support two different remote clients. Our Augmented Reality featured remote client works only platform dependent, because it was implemented in C++ and C. By using the Java based remote client, collaboration partners have the possibility to work spatially separated with the same visualization and are able to share their insights directly. This is even possible if they use limited computers, like standard desktop computers, laptops or handhelds.

References

1. Goetz, F., Domik, G.: Remote and Collaborative Visualization with openVisaar. In: Proc. of the Third IASTED International Conference on Visualization, Imaging, and Image Processing, Benalmádena, Spain (2003)
2. Wagner, D.: Porting the Core ARToolKit library onto the PocketPC Platform. In: Second IEEE International Augmented Reality Toolkit Workshop, Tokyo, Japan (2003)
3. Goetz, F., Domik, G.: A Framework for Video-based and Hardware-Accelerated Remote 3D-Visualization. In: Eurographics 2003 Short Presentations, Granada, Spain (2003)
4. Fuhrmann, A., Löffelmann, H., Schmalstieg, D., Gervautz, M.: Collaborative Visualization in Augmented Reality. In.: IEEE Computer Graphics and Applications, 18(4), pages 54-59 (1998)
5. Bauer, M., Bruegge, B., Klinker, G., MacWilliams, A., Reicher, T., Riß, S., Sandor, C., Wagner, M.: Design of a Component-Based Augmented Reality Framework. In: Proceedings of The Second IEEE and ACM International Symposium on Augmented Reality, Columbia University, New York, USA (2001)
6. Bauer, M., Hilinges, O., MacWilliams, A., Sandor, C., Wagner, M., Klinker, G., Newman, J., Reitmayr, G., Fahmy, T., Pintaric, T., Schmalstieg D.: Integrating Studierstube and DWARF. In: Proceedings of the International Workshop on Software Technology for Augmented Reality Systems (STARS 2003), Tokyo, Japan (2003)
7. MacWilliams, A., Sandor, C., Wagner, M., Bauer, M., Klinker, G., Bruegge, B.: Herding Sheep: Live System Development for Distributed Augmented Reality. In: Proceedings of The Second International Symposium on Mixed and Augmented Reality, Tokyo, Japan (2003)

8. Billinghurst, M., Weghorst, S., Furness, T.: SharedSpace: An Augmented Reality Approach for Computer Supported Collaborative Work. In: Virtual Reality, 3, pages 25-36 (1998)
9. Billinghurst, M., Kato, H., Poupyrev, I.: The MagicBook - Moving Seamlessly between Reality and Virtuality. In: Computer Graphics and Applications, 21(3), pages 2-4 (2001)
10. Hedley, N., Billinghurst, M., Postner, L., May, R., Kato, H.: Explorations in the use of Augmented Reality for Geographic Visualization. In: Presence, 11(2), 119-133 (2001)
11. Reiners D., Voß G., Behr J.: OpenSG - Basic Concepts. In: 1. OpenSG Symposium, Darmstadt, Germany (2002)
12. Haller M., Hartmann W., Luckeneder T., and Zauner J.: Combining ARToolKit with Scene Graph Libraries. The First IEEE International Augmented Reality Toolkit Workshop, Darmstadt, Germany (2002)

Multimodal Interaction in a Collaborative Virtual Brainstorming Environment

Fabian Di Fiore, Peter Vandoren, and Frank Van Reeth

Expertise Center for Digital Media
Limburgs Universitair Centrum
Universitaire Campus
B-3590 Diepenbeek, Belgium
{fabian.difiore, peter.vandoren, frank.vanreeth}@luc.ac.be
http://www.edm.luc.ac.be

Abstract. In this paper we present our work in setting up a collaborative virtual environment (CVE) framework which is built to support collaborative creative meetings for geographically dispersed participants. Similar to real life, we rely on the use of quick drawings or sketches as a means of communication to convey new ideas, thoughts or other meta-data to other individuals. Furthermore, we concentrate on facilitating the (collaborative) interaction process through the use of four modalities. The first modality is direct manipulation, which is suitable for direct interaction with the networked environment. Secondly, we look at interaction through gesturing symbols in order not to distract the user's attention from the meeting. As a third modality we consider interaction through menu and widget manipulation. A fourth modality is established by a camera interface. We expect that the combination of the intuitive interface and the real-time visualisation of the virtual environment leads to a better understanding and realisation of one's ideas in an early phase of the cooperation.

1 Introduction and Motivation

People who cooperate in teams often need to meet together to do some brainstorming, or to form, convey, readjust or hit upon (new) ideas. During brainstorming sessions, it is a common practice for participants to use quick drawings or sketches as these convey more than only words can say. However, when the participants are located in geographically dispersed locations, these kinds of brainstorming sessions are impracticable.

'Collaborative Virtual Environments' (CVEs), in general, are applications that provide distributed virtual reality technology to support cooperative work. They consist of virtual spaces that enable participants to collaborate and share objects as if the participants were present in the same place. Currently, CVEs are used for many purposes, some of which include collaborative design [1], manipulation [2], education, simulation, and training. However, on-line games still are the most common form of

on-line virtual environments in use today. Games such as Sony's 'EverQuest' [3] and 'World of Warcraft' [4] are designed to be played by thousands of users worldwide every day.

In this paper we introduce our work in setting up a collaborative virtual environment (CVE) framework which is built to support collaborative creative meetings. Regarding collaborative working, roughly two categories can be identified. In the first, users are located in the same room and, for example, use displays projected on walls or tables as a spatially continuous extension of their own workspace [5]. Our work, however, extends the concept of 'Designer's Outpost' [6] in which participants are *remotely present* while sharing one virtual workbench.

The strength of the proposed environment is in the fact that we, just as in real life, use quick drawings or sketches as a means of communication to convey new ideas, thoughts or other meta-data to other individuals. We expect that by using our system the occurrence of misunderstandings can be minimised or cleared up promptly in an early phase of the cooperation.

This text is organised as follows. In section 2 we elaborate on the collaborative environment that we envisage. Section 3 focusses on facilitating the (collaborative) interaction process through different modalities. Currently, we concentrate on four modalities in particular, which are direct manipulation, interaction through gesturing symbols, menu and widget manipulation, and a camera interface. We end with our conclusions and topics for future research (section 4).

Related work on highlighted aspects will be mentioned in the appropriate sections.

2 Collaborative Virtual Environment Framework

The collaborative environment we envisage consists of a virtual workbench that can be shared by a group of users (who are remotely present) in order to support collaborative creative meetings. In the following subsections we discuss the underlying virtual environment framework and the collaborative setup.

2.1 Virtual Environment Framework

Virtual Environments (VEs) are computer generated, two-dimensional or three-dimensional environments that create the effect of an interactive world in which the user is immersed. In previous research, our research group has developed a code framework for interacting in virtual environments [7,8,9]. In this work, we rely on their framework, of which we'll now give a brief overview.

The framework in its current state can be regarded as a black box that can be used to create VEs that require all sorts of (multimodal) interaction possibilities. Currently, it supports the use of several 3D input devices (e.g. a 3D mouse [10], a MicroScribe [11], 3D trackers), speech input and haptic feedback (e.g. PHANToM [12]).

As different modalities, such as haptic interface, direct manipulation, interaction through widgets, or speech input, present their information in a specific manner, an interface is developed for each of these interaction techniques. These interfaces

should be considered in a sense of a high-level structured syntax of which the designer of the environment can use the supported functionalities.

The data passed into the framework is similar for all created interfaces and is represented by *interaction events.* All events that are generated by the interaction techniques are sent to a central dispatching unit, called a *task conductor.* From there, the interaction events are redirected to the appropriate (application specific) event handling code.

Similar to other interaction techniques, the user interface will also generate and send interaction events to the task conductor in order to perform the necessary tasks.

2.2 Collaborative Setup

Our server-client based CVE system consists of a server application, and for each participating site a client application (GUI). The functions of the server include management of the parties (joining, quitting), sharing of application data (adding, deleting, ...), and floor control to assure mutual exclusion. The main role of each client is to serve as the collaborative interface with the user and to act as the visible part of the collaborative system.

The collaborative environment that we envisage consists of a virtual workbench that can be shared by the users. For each participant, this virtual workbench is projected onto his/her real desk. Equipped with a set of interaction devices and some basic functionalities, this virtual workbench allows participants to brainstorm with other users in an intuitive manner. Figure 1 shows one possible set-up. In this case the projected working area can be enlarged or reduced depending on the available space and need, just by tuning the projector. Other set-ups are supported as well including projecting from underneath the desk or simply using a conventional display.

In order to obtain a one-to-one mapping between the projected workbench and the user's real working area, we provided simple calibration in which the user selects the corners of the projected workbench. As a result, when using for example a 3D pointing device, besides the obvious one-to-one mapping between the real tip of the device and it's projected visual representation, we also can detect whether the tip touches the workbench or not. This will be elucidated in section 3.1.

At this moment, two different network communication protocols are being used simultaneously: TCP/IP and RTP (real-time protocol). The first is used as a reliable means of communication and deals with data that in any case needs to be delivered, whereas the latter is employed to take care of time-critical data.

In the next section we concentrate on the different modalities that are being used.

3 Multimodal Interaction

In a multimodal application, input and output are provided by using different devices. Due to their specific characteristics, each modality has its own needs with regard to the used input device.

Currently, we concentrate on four modalities in particular to facilitate the collaborative interaction process. The first modality is direct manipulation, which is suitable

for direct interaction with the 3D virtual environment. Secondly, we look at interaction through gesturing symbols in order to facilitate a sketching process. As a third modality we consider interaction through menu and widget manipulation. A fourth modality is established by a camera interface as a means to incorporate real-life objects into the virtual workbench.

The functionality of the first three modalities is provided using a MicroScribe [11]. The reasons for using a MicroScribe are threefold. Firstly, we need a *tracking device* in order to be able to intuitively put down sketchy remarks (section 3.1).
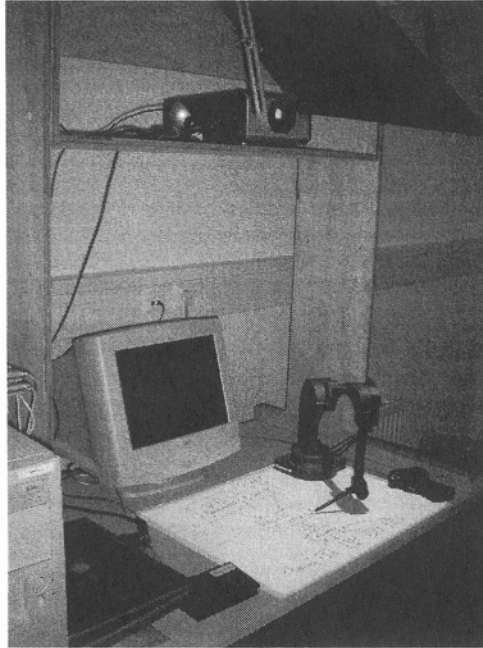

Fig. 1. A possible set-up for displaying the shared virtual workbench.

The MicroScribe is an accurate, affordable 3D digitising system (usually employed to digitise 3D clay models). However, its high accuracy (0.009" or 0.23 mm) and large workspace size (50" or 1.27 m), provide the user also with a natural interaction method for sketching in 2D/3D [13]. The device is depicted in the top-right corner in figure 2. Secondly, the same argument stands up for gesturing understandable symbols (section 3.2). Thirdly, an easy-to-use and comfortable *pointer device* is required for several 'conventional' pointing operations such as menu interaction (see section 3.3) and object selection. Since the user's dominant hand is already holding the MicroScribe, it is not convenient to switch to another input device (e.g. mouse) for menu interaction. Therefore, we chose to use the MicroScribe to interact as well with 3D menus (figure 5(b)).

Since the MicroScribe also comes with two foot pedals, which are very useful for e.g. mode selection, several different interactions (sketching, selecting menu items, selecting objects, ...) can be performed successively in an arbitrary order using the same device. This approach considerably reduces the number of times the user has to release the MicroScribe.

Other conventional (tracking) devices could be used as well [14,15,7], however, from our experiences [13] we discovered they either only work fine in laboratory environments, or are unnatural to use. For example, a conventional (pressure-sensitive) stylus is easy-to-use but depends on a - often small - fixed size working area. Kobayashi et al. [16] and more recently, Oka et al. [17] introduced a fast and robust method for tracking a user's hands and multiple fingertips. Their method is capable of tracking multiple fingertips in a reliable manner even in a complex background under dynamically changing lighting conditions without any markers. Although it feels very natural to the user, a major drawback of this method is that tracking fingers still lacks high accuracy.

Note that the PHANToM [12] is a worthy alternative to the MicroScribe. However, a formal user test carried out by Raymaekers and Coninx pointed out that in a virtual environment the "point-and-click" metaphor should be used rather than a pushing metaphor [8]. As a result, employing a force feedback device only as a tracking or pointing device while ignoring force feedback is quite overkill. In the following subsections we elaborate on the different modalities.

3.1 Direct Manipulation: Collaborative Sketching

In our CVE we rely on the use of sketches as a means of communication to convey certain ideas to other individuals.

Therefore, we must keep an important constraint in mind, which is the ease of use of the sketching tool. The simplicity of the classic pen, which is also available as an input device for the computer, is an important feature that needs to be taken into account in the implementation of our sketching tool. In other words, a sketch-drawing tool needs to work in a natural and intuitive way, which implies that the tool has to work in real-tune and that the movement of the pen has to be closely tied to the resulting curve.

Creating Sketches. In our system, the creation of a stroke is done interactively by sampling the MicroScribe along the trail of the stroke. This only happens when the tip of the MicroScribe touches the workbench (section 2.2). In order to allow for real-time high-level manipulations on the strokes, the individual pixels that make up the stroke are not used. Instead, a high-level internal representation, using cubic Bézier curves, is created. We use the solution of [18]. While sampling the MicroScribe we simultaneously perform an iterative curve fitting technique based on least-squared-error estimation. Existing curve drawing solutions mostly take recourse to a 'batch' curve fitting solution, in which the fitting is done after the stroke drawing is finished, whereas our fitting is done on-the-fly while the curve is being drawn.

The curves themselves are drawn as solid lines. Figure 2 illustrates the use of a MicroScribe as a tracking device in order to intuitively put down sketchy remarks.
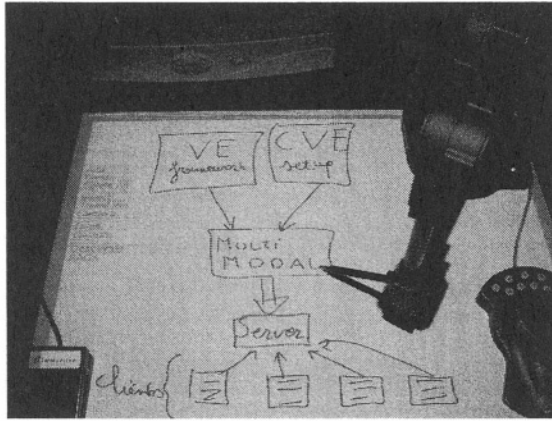
Fig. 2. Employing the MicroScribe as a tracking device in order to intuitively put down sketchy remarks.

Note also there's a one-to-one mapping between the projected workbench and the tip of the MicroScribe (i.e. real working area), through an initial calibration.

We also added support for grouping and performing transformations on (parts of) the sketches. Existing applications transform drawings on a per-pixel basis which results in artifacts because the transformed parts are cut out and then pasted at a new position. In our case the transformation tools (translate, rotate, scale, ...) only affect the underlying geometric description of the selected (parts of the) sketches.

Notice that the user does not have to worry about picking, clicking and dragging control points associated with the underlying curve primitives. That way we preserve the same freedom of sketching a user has when using the "pencil-and-paper" approach.

Furthermore, we provided navigation support by means of a SpaceMouse [10]. This is a 3D optical mouse with 11 programmable buttons which allows us to simultaneously pan, zoom or rotate the virtual camera using only one hand. The SpaceMouse is visible in the lower right corner of figure 2.

Collaborative Sketching. In order to modify existing sketches, they temporarily need to be assigned to the requesting user. The user concerned only has to 'touch' a particular sketch after which an explicit locking request is sent to the server. The server for its part takes care of the request and notifies all other parties in case of acceptance. The requesting client, however, gets informed in any case. All communication involved happens transparently to the user.

By using instantaneous visual feedback (e.g. using different colours or flashing points), users always are aware of which sketches currently (i) are being modified by others, (ii) are attributed to the user himself, or (iii) are unlocked.

Sketches consist of cubic Bézier curves. Consequently, whenever sketches are being drawn or modified, only the affected control points need to be sent to the other participants. In case of transforming sketches or requests for locking/unlocking/..., only specific data is sent over the network.

For these operations, we make use of TCP/IP as a communication protocol. As a result, we are assured that all data arrives in the right order, *and* no data gets lost.

3.2 Direct Manipulation Through Gesturing

When making a sketch, it is sometimes desirable to manipulate the result. Different techniques to manipulate the sketch can be encountered in the literature. For instance, in Teddy [19]. a program which allows the creation of a 3D object out of 2D sketches, a sketch is modified by drawing extra lines onto the sketch. This manipulation then deforms the sketch.

In our case, we have investigated the interface that is needed to perform typical re-occurring operations including transforming sketches (i.e. translating, rotating and scaling), selecting sketches, deleting them, ... without having to turn to menus (and other widgets) which take up a lot of time and distract the user's attention.

We thus need an intuitive user interface for performing these operations. Since the user is already using a sketching interface by means of a MicroScribe, a *gesture interface* comes to mind.

By not using a WIMP interface, but a sketching interface, the user can perform the different operations without having to resort to a button or another interface element that distracts the attention from the sketching process.

Gesture interfaces are used in different applications, such as whiteboard tools [20]. Landay and Myers propose an interactive tool which allows designers to sketch an interface, and transforms it into a complete, operational interface [21]. Traditional gesture interfaces have as disadvantage that they do not offer an accurate means to provide input, while the interface that is generated by the tool of [21] has lost the look and feel of a sketch interface.

In our approach, the purpose of gestures can be regarded as *gesturing the functionality* and not gesturing the widgets themselves. That is, gestures are not turned into widgets since otherwise, the user has to perform twice as much interactions as needed: (i) gesturing the widget, and (ii) interacting with the generated widget. Instead, upon recognising a gesture, the system switches its mode to the corresponding operation. Furthermore, by changing the pointer, the user gets instantaneous feedback about the current mode.

Creating Gestures. The gesturing interface is built upon our intuitive sketching tool (section 3.1). Gestures are created in the same manner as "normal" gestures: the user just draws a gesture, e.g. like an arrow, using the MicroScribe. The difference with a normal gesture is interpretation of the gesture. For each gesture a particular action which performs the manipulation is defined. For instance, drawing an arrow, pointing to the right (figure 3 (a)) indicates that the selected object(s) can be moved to another position. To be more precise, as soon as a horizontal arrow is drawn (and recognised), our system switches to horizontal translation mode (as defined by the direction of the arrow). From now on, the user can precisely position the object by moving the pen of the MicroScribe: the further the user moves the pen away, the further the object is moved.

Several gestures for translating, rotating, scaling and deleting are shown in figure 3.
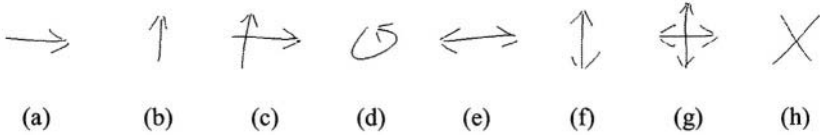
Fig. 3. Several gestures. a) Horizontal translation. b) Depth translation. c) Horizontal and depth translation. d) Rotation. e) Horizontal scale. f) Depth scale. g) Horizontal and depth scale. h) Delete selected object(s).

Recognition of Gestures. Because our gestures are represented by curves, it is easier to exploit the associated curve data instead of using for example a neural network that anyhow has to be trained [22].

Our idea is to induce the intended gesture from (i) the geometrical position of the control points, (ii) the order of appearance of the control points, and (iii) the number of sketches which make up the gesture. That way, we also do not impose any constraints on the user, such as the drawing speed or the size of the gesture.

In order to clarify our approach, we amplify on recognising the 'delete' gesture (figure 3(h)).

Based on the number of strokes drawn by the user, our system will perform some test in order to recognise this gesture. In this case, one possible gesture is the one indicating the 'delete' functionality since it typically consists of two strokes, as shown in figure 4(a). If one of the tests fails, the system proceeds to test the next possible gesture (in this example, also consisting out of two strokes).
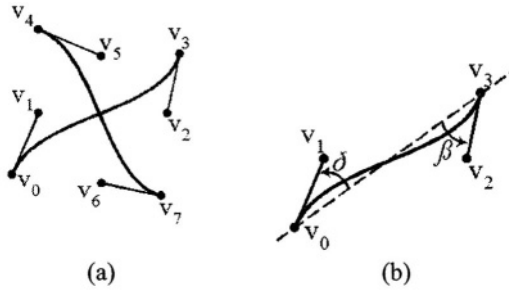

Fig. 4. Recognition process of a 'delete' gesture, a) Gesture made by the user shown with underlying control points. b) Close-up of the first line (indicated in blue in figure (a)).

At first, we test if the two strokes are (nearly) straight lines. We'll show this by means of the first line (figure 4(b)). Since our strokes are represented by cubic Béziers, straight lines occur when all control points are co-linear. That is, ideally, angles ϑ and β should be 0. As users almost never draw real straight lines, angles up to 35 degrees are tolerated. As a result, following equation should be satisfied (the same idea counts for the second line):

$$\vartheta \cong \arccos(\frac{\overrightarrow{v_0v_3}}{\|\overrightarrow{v_0v_3}\|} \cdot \frac{\overrightarrow{v_0v_1}}{\|\overrightarrow{v_0v_1}\|}) \leq 35°$$

Now that we know that the gesture consists of straight lines, we have to check whether the slope of both lines is correct: the slope of $\overrightarrow{v_0v_3}$ should approximately equal 1 whereas the slope of $\overrightarrow{v_4v_7}$ should approximate -1. This is examined by following equations:

$$\frac{v_{3,z} - v_{0,z}}{v_{3,x} - v_{0,x}} \approx 1 \text{ and } \frac{v_{7,z} - v_{4,z}}{v_{7,x} - v_{4,x}} \approx -1$$

As a final test, we need to be sure that the two lines actually cross each other. This is a straightforward operation and comes down to whether or not finding an intersection point. Both t_a and t_b, see following equations, should be in the range 0..1.

$$t_a = \frac{((v_{7,x} - v_{4,x}) * (v_{0,y} - v_{4,y})) - ((v_{7,y} - v_{4,y}) * (v_{0,x} - v_{4,x}))}{((v_{7,y} - v_{4,y}) * (v_{3,x} - v_{0,x})) - ((v_{7,x} - v_{4,x}) * (v_{3,y} - v_{0,y}))}$$

$$t_b = \frac{((v_{3,x} - v_{0,x}) * (v_{0,y} - v_{4,y})) - ((v_{3,y} - v_{0,y}) * (v_{0,x} - v_{4,x}))}{((v_{7,y} - v_{4,y}) * (v_{3,x} - v_{0,x})) - ((v_{7,x} - v_{4,x}) * (v_{3,y} - v_{0,y}))}$$

The recognition process of all other gestures involves similar operations.

We end this section by stating that gesturing the functionality is both easy to create and use and does not distract the user's attention from the brainstorming process. This is particularly due to (i) the use of gestures which are intuitive and easy to remember, (ii) the analytical recognition process which does not involve any training period, and (iii) the user never has to release the MicroScribe for performing typical re-occurring manipulations.

Interpretation of Gestures. A problem that arises in this kind of interfaces is how to specify the mode that the user is working with. The user can either be drawing the sketch, gesturing or using the gesture.

Likewise, the transition between the gesturing mode and the usage of the gesture should be defined. One could stop the gesturing mode when a gesture is recognised but this could introduce a new problem when drawing a gesture which is a subset or a superset of another one. For example in figure 3 one can see clearly that the gesture for making horizontal translations is a part of the gesture for scaling and hence the system has no knowledge whether the gesture is completed.

As a solution, we use the MicroScribe's foot pedals as a means for switching between modes. Moreover, by changing the pointer visual feedback about the current mode is given to the user as well.

3.3 Menu and Widget Interaction

Menu and widget interaction form an essential part of virtual environments. Different approaches to incorporate menus in a virtual environment can be identified in the literature. In JDCAD [23] a "Daisy menu" is used in which a sphere shaped menu is applied to manipulate 3D objects. Others suggested pie or radial menus [24,16,25] in which menu items are represented by slices of the pie. A drawback of the latter is that they still are two-dimensional. Some research into 3D user interfaces has been conducted by Anderson et al. [26] who developed a complete toolkit to create user interfaces for VEs (e.g. the FLIGHT project). A 3D user interface can, for instance, be useful to prevent the need for alternating between using a mouse and using a 3D device when working with a 3D application.

As our main goal is to fully integrate the widget set into the virtual environment, we chose the hybrid approach as presented by [8]. The resulting user interface contains properties based on 2D as well as 3D environments and applications. The UI elements can be arbitrarily positioned and are initially semitransparent, thus not occluding parts of the environment. However, when the pointer approaches the UI element, it fades in to become opaque. This feature is illustrated in figure 5(a) by means of a virtual pointer.

In our system we also provided a MicroScribe interface for the menu interaction in order to let the user carry on with the same input device. This is shown in figure 5(b) in which a menu item is selected by 'touching' its projected version using the MicroScribe's tip.

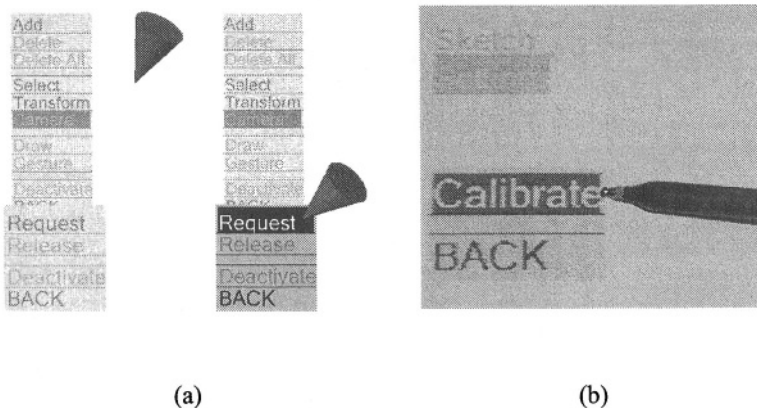(a)   (b)

Fig. 5. a) This illustrates the use of the menus used in our environment. UI elements are initially semitransparent, but, when the pointer approaches them, they fade in to become opaque, b) Employing the MicroScribe as a pointing device in order to intuitively select a menu item.

3.4 Camera Interaction

Video encoding and transmission is traditionally primarily used for video conferencing, video-on-demand, and/or broadcasting applications. Research concerning the use of video streams to represent a user's appearance in a virtual environment has been reported upon in   [27,28,29,30,31,32].   While these applications themselves are a major subject of research, the combination of video communication with (collaborative) virtual environment technology is still relatively unexplored.

We believe that the incorporation of real-time video streams can create a surplus value to collaborative work applications. In this work, we employ the use of a camera as an extra means to incorporate real-life objects into the virtual workbench. For example, similar to situations in real life, while one hand is used for drawing, the other (free hand) can serve for showing objects or pointing. This is depicted in figure 6.

When aiming the camera towards the projected workbench itself, the camera obviously records the projected workbench and consequently retransmits it, causing visual artifacts. This problem could be solved by explicitly extracting only the hand or fingers from the recorded images using computer vision techniques. However, at this moment, we avoid this issue by working in the same way as weathermen do: the user moves his hand in another region with a neutral background while at the same time watching the projected workbench; the camera is aimed towards this neutral background while the recorded images immediately get blended into the virtual environment.

Given the real-time nature of these data streams, an obvious choice for the underlying protocol is the Real-Time Transmission Protocol or RTP, as it handles issues such as synchronisation and packet ordering internally. Our implementation currently employs the JRTP [33] library.

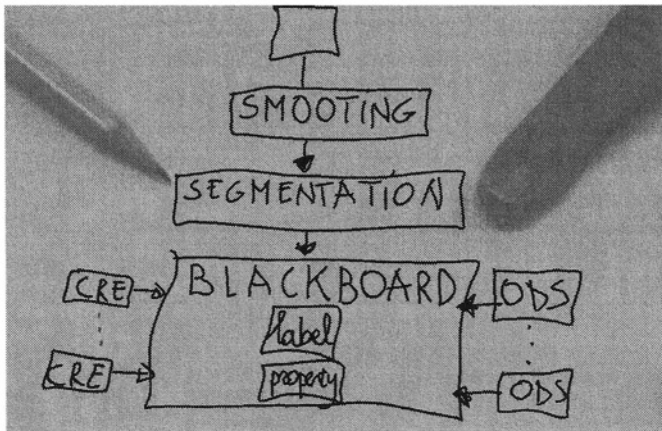

Fig. 6. This snapshot illustrates the use of a camera as a means to incorporate real objects into the virtual workbench. In this particular example, a pencil and a finger are used to emphasise one part of the diagram.

4 Conclusions and Future Research

We presented our work in setting up a collaborative virtual environment (CVE) framework which is built to support collaborative creative meetings. We concentrated on the use of quick drawings or sketches as a means of communication to convey new ideas, thoughts or other meta-data to other individuals.

Four different modalities enable the user's interaction with the virtual environment. Direct manipulation allows a very straightforward interaction with the virtual objects. Next, gesturing permits additional interaction without having to switch to another interface. For more infrequent tasks, widgets and menus are integrated into the environment and manipulated using the same devices. Finally, a camera interface brings the real world of one user into another's virtual world.

Several cooperative working sessions were held among different location. From the user's point of view, our collaborative environment is easy to use, without the need for training sessions. Particularly, the instantaneous visual feedback from both the sketching tool and the camera was appreciated.

In the near future, we would like to incorporate speech into our CVE - this is currently under development; at the moment we use a standard non-integrated tool [34]. Furthermore, we plan to (further) investigate the use of two-handed input, and to incorporate tangible mixed reality interaction.

Acknowledgements

References

1. Luo, Y., Sánchez, D., Bennasar, A., Fornés, J., Serra, J.C., Huéscar, J.M.: Visualization for cooperative architecture design systems. In: Proceedings of Sixth International Conference on Information Visualisation (IV2002), IEEE (2002) 497-501

2. Rekimoto, J.: Pick-and-drop: A direct manipulation technique for multiple computer environments. In: Proceedings of the 10th annual ACM symposium on User interface software and technology, ACM Press (1997) 31-39

3. Sony: Sony Online Entertainment: everquest. World Wide Web,
    http://www.everquest.com/ (2004)

4. Blizzard: Blizzard Entertainment: World of Warcraft. World Wide Web,
    http://www.blizzard.com/wow/ (2004)

5. Rekimoto, J., Saitoh, M.: Augmented surfaces: A spatially continuous workspace for hybrid computing environments. In: In Proceedings of Computer-Human Interaction (CHI1999). (1999) 378-385

6. Everitt, K.M., Klemmer, S.R., Lee, R., Landay, J.A.: Two worlds apart: Bridging the gap between physical and virtual media for distributed design collaboration. In: CHI Letters, Human Factors in Computing Systems (CHI2003). Volume 5. (2003) 553-560

7. Raymaekers, C., De Weyer, T., Coninx, K., Van Reeth, F., Flerackers, E.: ICOME: an Immersive Collaborative 3D Object Modelling Environment. In: Proceedings of Virtual Reality (VR1999). Volume 4. (1999) 129-138

8. Raymaekers, C., Coninx, K.: Menu interactions in a desktop haptic environment. In: Proceedings of Eurohaptics. (2001) 49-53

9. De Boeck, J., Raymaekers, C., Cuppens, E., De Weyer, T., Coninx, K.: Task-based abstraction of haptic and multisensory applications. In: Proceedings of EuroHaptics (to be published). (2004)

10. 3Dconnexion. World Wide Web, http://www.3dconnexion.com/(2004)

11. Immersion. World Wide Web, http://www.immersion.com/digitizer/ (2004)

12. SensAble. World Wide Web, http://www.sensable.com/(2004)

13. De Weyer, T., Coninx, K., Van Reeth, F.: Intuitive modeling and integration of imaginative 3D-scenes in the theatre. In Richir, S., Richard, P., Taravel, B., eds.: Proceedings of Virtual Reality International Conference (VRIC2001). (2001) 167-173

14. Sachs, E., Robert, A., Stoops, D.: 3-Draw: a tool for designing 3D shapes. In: IEEE Computer Graphics and Applications. Volume 11. (1991) 18-26

15. Zachmann: Distortion correction of magnetic fields for position tracking. In: Proceedings of Computer Graphics International (CGI 1997). (1997)213-220

16. Kobayashi, M., Koike, H.: Enhanced desk, integrating paper documents and digital documents. In: In Proceedings of Asian Pacific Computer Human Interaction. (1998) 57-62

17. Oka, K., Sato, Y., Koike, H.: Real-time fingertip tracking and gesture recognition. In: IEEE Computer Graphics and Applications. Volume 22. (2002) 64-71

18. Vansichem, G., Wauters, E., Van Reeth, F.: Real-time modeled drawing and manipulation of stylized cartoon characters. In: Proceedings of the IASTED International Conference on Computer Graphics and Imaging, Honolulu, HI, USA, IASTED (2001) 44-49

19. Igarashi, T., Matsuoka, S., Tanaka, H.: Teddy: A sketching interface for 3D freeform design. In: Proceedings of SIGGRAPH, ACM (1999) 409-416

20. Moran, T.P., van Melle, W.: Tivilo: Integrating structured domain objects into a free-form whiteboard environment. In: Proceedings of Computer-Human Interaction (CHI2000). Volume CHI 2000 Extended Abstracts., The Hague, NL, ACM (2000) 20-21

21. Landay, J.A., Myers, B.A.: Interactive sketching for the early stages of user interface design. In: Proceedings of Computer-Human Interaction (CHI 1995), Vancouver, CA, ACM (1995) 43-50

22. Bimber, O.: Rudiments for a 3D freehand sketch based human-computer interface for immersive virtual environments. In: Proceedings of Virtual Reality Software and Technology (VRST1999), ACM (1999) 182-183

23. Green, M., Halliday, S.: A geometric modelling and animation system for virtual reality. Communications of the ACM **39** (1996) 46-53

24. Deering, M.: The holosketch VR sketching system. Communications of the ACM **39** (1996) 54-61

25. Kurtenbach, G., Fitzmaurice, G., Owens, R., Bauel, T.: The hotbox: Efficient access to a large number of menuitems. In: Proceedings of Computer-Human Interaction (CHI2000). (2000) 231-237

26. Anderson, T., Breckenridge, A., Davidson, G.: FBG: A graphical and haptic user interface for creating graphical, haptic user interfaces. In: Proceedings of the Fourth PHANToM Users Group Workshop (PUG99). (1999)

27. Insley, J., Sandin, D., DeFanti, T.: Using video to create avatars in virtual reality. In: Proceedings of SIGGRAPH, Los Angeles CA (1997) 128-128
28. Yura, S., Usaka, T., Sakamura, K.: Video avatar: Embedded video for collaborative virtual environment. In: Proceedings of the IEEE International Conference on Multimedia Computing and Systems. Volume 2. (1999) 433-438
29. Ogi, T., Yamada, T., Tamagawa, K., Hirose, M.: Video avatar communication in a networked virtual environment. In: Proceedings of INET2000. (2000)
30. Rajan, V., Subramanian, S., Johnson, A., Keenan, D., Sandin, D., DeFanti, T.: A realistic video avatar system for networked virtual environments. In: Proceedings of IPT 2002, Orlando, FL (2002)
31. Quax, P., Jehaes, T., Jorissen, P., Lamotte, W.: A multi-user framework supporting video-based avatars. In: Proceedings of the 2nd workshop on Network and system support for games, ACM Press (2003) 137-147
32. Quax, P., Jehaes, T., Flerackers, C., Lamotte, W.: Scalable transmission of avatar video streams in virtual environments. In: Proceedings of the IEEE International Conference on Multimedia & Expo (ICME2004) (to be published). (2004)
33. Liesenborgs, J., Lamotte, W., Van Reeth, F.: Voice over IP with JVOIPLIB and JRTPLIB. In 26th Annual IEEE Conference on Local Computer Networks (2001)
34. Skype. World Wide Web, http://www.skype.com/ (2004)
35. ANDROME NV. World Wide Web, http://www.androme.com/ (2004)

Cooperative Visualization Framework Based on Video Streaming and Real-Time Vectorial Information

Jesus Bobadilla[1], Luis Mengual[2]

[1] DIA, Computer Science, U.P.M., Crta. de Valencia, Km 7, 28031 Madrid, Spain
`jbobi@eui.upm.es`
[2] DLSIS, Computer Science, U.P.M., Boadilla del Monte 28660 Madrid, Spain
`lmengual@fi.upm.es`

Abstract. The essential purpose of this paper is to describe a framework, in a simple and complete way, which enables the concurrent visualization of audio/video streaming combined with its corresponding synchronous cooperative vectorial information. The architecture presented uses Java JMF API, which offers a simple, robust, extendable, multi-platform solution. It also requires no direct maintenance as regards the incorporation of future video cameras and *codecs* that come out on the market. Instead of the typical separate presentation of videoconferencing and its corresponding preset additional information, we offer the possibility of combining the video image with real-time vectorial information. All the combined bitmap and vectorial information is shared and can be interactively modified by the clients which are using the cooperative visualization framework. The current prototype RTCIM (Real Time Cooperative Information Manager) offers a complete API to implement cooperative applications based on multiple audio/video sessions.

1   Introduction

Collaborative visualization tools can improve the efficiency of the design and engineer processes [1]. Currently there are different real-time applications providing different types of cooperative visualization or cooperative design [2]. A good example of cooperative visualization tool is *Vic* [3], a real-time, multimedia application for video conferencing over the Internet. *Vic* is designed with a flexible and extensible architecture to support heterogeneous environments and configurations. *ISABEL* [4] is another characteristic multiconference application; it uses an innovative service concept, which adapts the collaboration sessions to the user needs.

The cooperative design not only keeps down the original functions of the traditional software engineering but also supports the cooperative work; however, the development of application cooperation tools is a difficult and time-consuming job [5]. Modeling the cooperative product design process is a key challenge in building up cooperative and intelligent product design information systems and environments. Since the cooperative design process is characterized by distributed workflow and complicated interaction [6].

With the improved requirements of agility and design efficiency of product design, more and more attention is paid to the platforms supporting design tasks and using multiple cooperative design tools. In this context, it is important to establish frameworks supporting multimedia and multiple design modes [7, 8]. Actually, *ANTS* [9] provides a useful framework, designed to facilitate computer-supported cooperative work. The concept of a cooperative template is in order to control and manage design tasks on the Net [10]; different designs and implementations [11] use the cooperative template resource.

Most of the real-time cooperative applications supporting videoconferencing have required an enormous development effort in the area of accessing and processing the individual frames and in the communications area. They require continuous maintenance to offer the latest coding standards and to admit the different cameras that come out on the market.

To aid the development of multimedia applications, *Sun Microsystems©* provides *Java Media Framework (JMF) API* [12]. The most evident advantage of its use is the possibility to access the video and audio signal through a wide group of classes and interfaces; a less immediate but very important advantage is that we can rely on *Sun Microsystems* to provide support for new codecs and cameras that come out on the market.

Unfortunately, using the *JMF API* appropriately is not at all simple. The documentation that exists is based on the document *JMF API Guide* [13] and the few books published on the subject in which it does not specify how to access the individual frames, or the detailed way to create effects. The rest is an open search of the Internet, where at most we can find examples of the general use of streams, without reaching the level of pixel processing.

The cooperative visualization framework presented in this paper is implemented using JMF and allows a real-time video image to be integrated with different types of vectorial information, which are then combined inside each video frame by simply modifying the pixel details. The following sections of the paper will explain the main goals of the RTCIM framework, its scope, upper level architecture, communication strategies and semantic representation; finally we provide a graph with the experimental performance results that the framework can reach depending on the different dynamic loads we can apply.

2   Scope of the Framework

The framework presented (Figure 1) can handle several sources of audio and video real-time streams, as well as vectorial stream sources (slides, commentaries, isolated texts and arrows, etc.). All these streams use the real-time protocol (RTP) [14] to communicate via the network system. People involved in the cooperative process (mostly consumers), receive the streams from the network (using RTP) and are able to request the inclusion of vectorial information (text, circles, rectangles, etc.) within the streams. To achieve this type of request, the TCP/IP [15] protocol is used.

To understand the framework, we can imagine a situation where NASA acts as source of live video coming from the Shuttle. This video is sent to a small group of

scientist (consumers) who are trying to solve a difficult problem in real-time. Each scientist can incorporate the necessary vectorial information to the video images to focalise his collaborative idea.
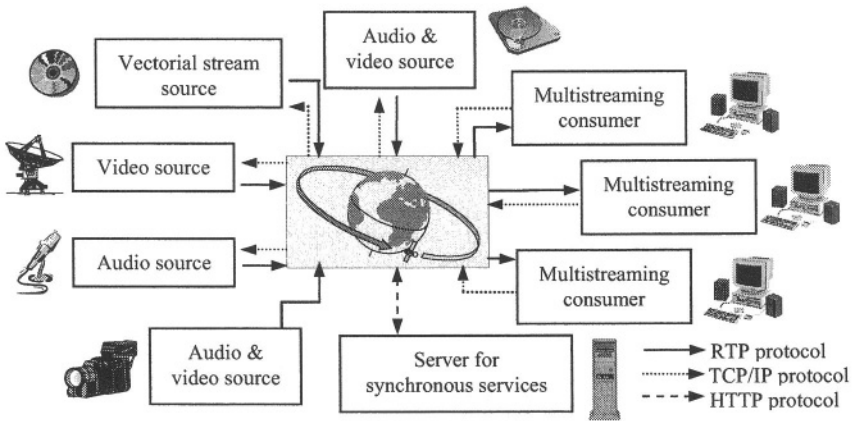

Fig. 1. Framework capabilities

In fact, we are offering a shared blackboard displayed inside the real-time video/s transmitted. This facility is complemented with the typical synchronous services (see Figure 1). At this time, we have finished the software required to use Microsoft Power Point synchronized with the video streams in order to present a more complete scenario to the consumers; this can be a powerful tool, but it is not sufficiently universal as it is platform dependent.

As we can see in Figure 1, source entities act as servers, while consumers act as clients. Sources send the RTP streams (audio, video, vectorial information) combined with the vectorial information provided by the clients' requests. Consumers' requests are received using TCP/IP server diamonds and processed with a JMF *Effect* [13], which is implemented in the framework presented.

3   Communication Strategies

The framework presented is just the upper level diagram of our cooperative information system; the intermediate level comes from the realization of the technical framework: API. Since we are using Java and JMF, our API contains Java packages (sets of classes and interfaces). Finally, using API, we can easily implement different applications or a highly parameterized project.

The success of the final applications greatly depends on the communications performance. To improve the communications performance it is necessary to adapt the application designs to the bandwidth and the network topology we are dealing with. It is not the same to multicast real-time streams via an intranet system than to multicast them via the open Internet.

Figure 2 shows the communications design using a common intranet bus. Each streaming source broadcasts its real-time streams to all the consumers, receiving the vectorial requests via TCP/IP protocol.
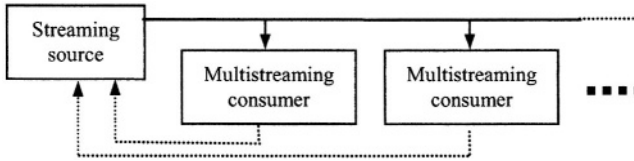
Fig. 2. Common intranet bus communication design
(Dotted line: TCP/IP, continuous line: RTP)

Using the open Internet, the ideal scenario is to have an IP multicast layer available [16]; unfortunately, routers do not support this protocol over the entire Internet. The simplest approach is to open a different session for each consumer, however, this solution is not scalable. The design we have chosen and tested is based on a virtual multicast implemented as a pipeline or chain of consumer transmissions (Figure 3). This solution offers reasonable bandwidth utilization, but is very poor in fault-tolerance and delay aspects.
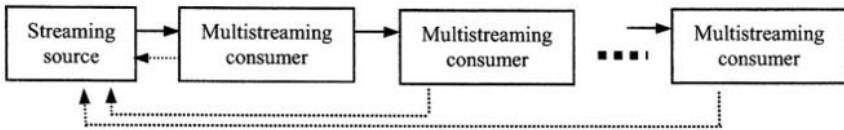
Fig. 3. Internet communication design
(Dotted line: TCP/IP, continuous line: RTP)

It is possible to combine the intranet/Internet approaches, using the Internet to send real-time streams to the different intranets users. In this case, each network would have a computer bridge to receive the streams and act as a streaming source for its own network consumers.

4   Information System Architecture

Figure 4 shows a simplified diagram of the current RTCIM prototype software. At the lowest level, it is supported by Java Development Kit (JDK) and Java Media Framework, using both their presentation/processing classes and the RTP classes. At the upper level, we separate the source side, the consumer side and the synchronous services.

The 'StreamSource' class is responsible for sending both the vectorial streams and the bitmap real-time streams to the network. These streams are merged using the implemented 'Effect', producing a resulting bitmap containing the vectorial informa-

tion. The 'RTPSend' class provides the necessary methods to send the streams using RTP.

The 'VectorialDiamond' class receives the TCP/IP consumers' requests (see Figure 1) and stores them in a suitable data-structure to be used in the dynamic merging process implemented on the stream source side. The 'StreamConsumer' class receives the RTP streams ('RTPReception' class) and, when the Internet communication designs is used, it sends ('RTPSend' class) these streams to other consumers (see Figure 3). Finally, the 'SynchronousServices' class provides the typical text-oriented synchronous services.
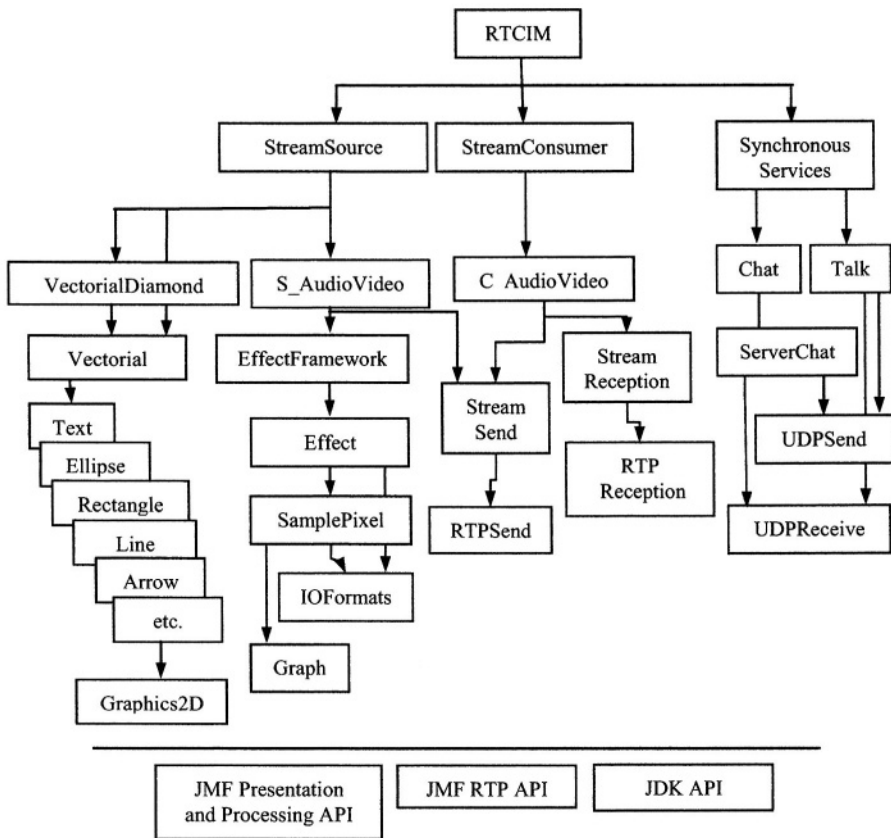

Fig. 4. Architectural design

5   Semantic Representation

Cooperative tools and applications should incorporate a suitable semantic layer in order to facilitate high-level queries, interoperability and cross-organizational share.

Our framework uses a RDF (Resource Description Framework) based on the DARPA Agent Markup Language (DAML) [17]. DAML sprang from a U.S. government-sponsored effort in August 2000, which released DAML-ONT, a simple language for expressing more sophisticated RDF class definitions than permitted by RDFS. The DAML group soon pooled efforts with the Ontology Inference Layer (OIL) [18]; DAML+OIL, a language for expressing far more sophisticated classifications and properties of resources than RDFS. Since achieving a single common ontology is not realistic, we must deal with some degree of semantic interoperability, supported by effective mechanisms to integrate and reconcile overlapping and inconsistent ontology systems [19].

The semantic kernel of our framework is based on a set of DAML+OIL classes which represent time constraints and vectorial information. The framework presented stores the information that the stream sources send and receive with DAML syntax; more specifically, it stores the TCP/IP vectorial request from the consumers. The following code shows the 'Rectangle' and 'Quadrilateral' classes as an example.

```
<rdfs:Class rdf:ID="Rectangle">
<rdfs:subClassOf rdf:resource="#Quadrilateral"/>
<rdfs:comment> RightAngles </rdfs:comment>
</rdfs:Class>

<rdfs:Class rdf:ID="Quadrilateral">
<rdfs:subClassOf rdf:resource="#Polygon"/>
<rdfs:comment>Any four-sided Polygon.</rdfs:comment>
</rdfs:Class>
```

6   Results

Currently, RTCIM offers a framework and an API. We have implemented several application prototypes to test the different functionalities provided by the API classes; we are also implementing a telemedicine application that will serve as a guide experience to provide on-line nose and throat medical diagnoses.

Currently, most of our tests are programmed rather than generated by users working on a graphic user interface. Reliability and efficiency are, at this stage, the most important goals we wish to reach: reliability has been strongly tested by placing the prototypes in extremely long sessions and variable environments (hardware devices, drivers, networks, multiple sessions, etc.); the efficiency study has two major branches: communication strategies impact and system efficiency.

The impact of the communication strategies has been tested by evaluating different data networks: LAN (Local Area Networks) 10-100 Mbps, Frame Relay 2 Mbps and WLAN (Wireless Local Area Networks) 11 Mbps. At JPEG quality 0.2 and RTP packet size of 1024 Bytes, 14 fps (frames per second) are reached in LAN at 10/100 Mbps or FR at 2 Mbps, whilst only 13 are reached in WLAN. With a JPEG quality of 0.7, 11 fps are reached in LAN at 10/100 Mbps or FR at 2 Mbps, whilst only 9 are reached in WLAN.

System efficiency has been tested by evaluating the impact of the computational load applied to the video streaming: technically, the 'Effect' load (see Figure 4). The tests have been performed using different processors. The results are shown in Figure 5. As the computational load of the effects increases (X-axis) the number of frames per second 'fps' that the system is able to produce decreases (Y-axis). The relationship is not lineal due to the different proportions that exist between the computation load of each effect and the actual load imposed by the JMF API and the tested application prototype.
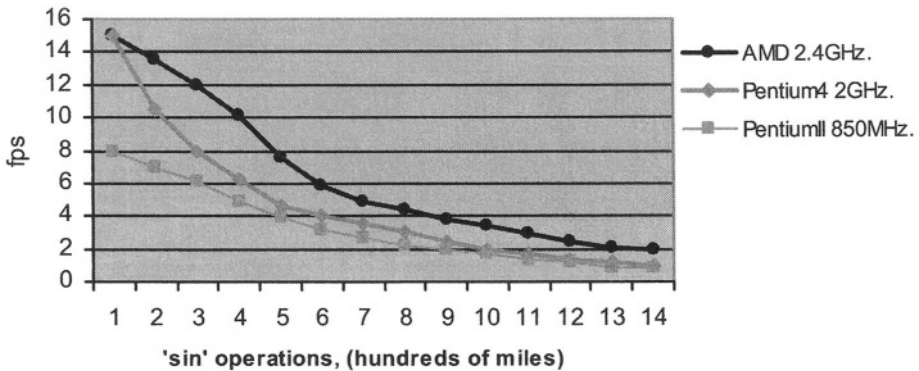

Fig. 5 System performance results

7   Conclusions

Merging video streaming with real-time vectorial information into unique RTP bit-map streaming facilitates concurrent visualization and the implementation of cooperative applications. Our framework will make it possible to implement applications that are suitable for different requirements: cooperative e-learning, security control systems, cooperative medical diagnoses, intelligence sharing, etc.

The framework architecture presented provides a complete, tested API based on JMF. It is reliable, scalable, requires no direct maintenance, can be easily configured to work using different communication strategies and provides a high degree of inter-operability based on its DAML+OIL semantic layer.

Jumping from the prototype scope to commercial applications will require testing the API functionality applied to different environments: networks, computers, devices, users, GUI's, etc. This type of testing involves both technical strategies and psychological focusing in order to provide an efficient, suitable and reliable cooperative interface for specific users. The most important future objectives to be carried out by our framework are the following: specific application implementations, incorporation of well-designed cooperative graphic user interfaces, RTP multicast communication approaches and the improvement of the semantic capabilities by incorporating a specific top-level logic layer

References

1. Fischer, F., Bruhn I, Gräsel, C., Mandl, H.: Fostering collaborative knowledge construction with visualization tools, Learning and Instruction, Vol. 12, Issue 2, (2002) 213-232
2. Bu-Sung, L., Chai Kiat, Y., Ing Yann, S., Keok Kee, L., Wei, S.: Design and Implementation of a Java-based Meeting Space over Internet, Multimedia Tools and Applications, (2003) 179-195
3. http://www-nrg.ee.lbl.gov/vic/
4. http://isabel.dit.upm.es/
5. Zhang, Z., Zongkai, L., Yuchai, G.: The development tool of the application cooperation software, Sixth International Conference on Computer Supported Cooperative Work in Design, (2001) 140–142
6. Gang, Z., Jiati, D.: Cooperative product design process modeling, Sixth International Conference on Computer Supported Cooperative Work in Design, (2001)236–242
7. Yuchu, T., Dongming, L.: A flexible multimedia cooperative product design platform framework, 7th International Conference on Computer Supported Cooperative Work in Design, (2002) 198-204
8. Weiyu, W., Peng, P., Hua, L., Wei, Y., Dongmei, L.: A framework and implementation techniques for cooperative architectural engineering design systems, The Sixth International Conference on Computer Supported Cooperative Work in Design, (2001) 218–222
9. Lopez, P., Skarmeta, A.: ANTS framework for cooperative work environments, Computer, Vol. 36, Issue: 3, (2003) 56–62
10. Xiao-Ping, L., Xiao-Yun, L., Zheng-Feng, H., Xiao-Rong, T.: Research on cooperative template design, The Sixth International Conference on Computer Supported Cooperative Work in Design, (2001) 52–55
11. Pengcheng, Z., Renhou, L.: Computer Supported Cooperative Work in Design, The Sixth International Conference on Design and implementation of an intelligent cooperative design system, (2001) 198–202
12. http://java.sun.com/products/java-media/jmf/2.1.1/
13. http://java.sun.com/products/java- media/jmf/2.1.1/apidocs
14. Schulzrinne, H., Casner, S., Frederick, R., Jacobson, V. (Audio-video Transport working group): RTP: A Transport Protocol for Real-Time Applications, RFC 1889, (1996)
15. Calvert, K.: TCP/IP sockets in Java: Practical guide for programmers, Morgan Kaufmann, 2001, ISBN: 1558606858
16. Lavian, T., Wang, P., Durairaj, R., Hoang, D., Travostino, F.: Edge device multi-unicasting for video streaming, 10th International Conference on Telecommunications (ICT)., Vol. 2 , (2003) 1441-1447
17. http://www.daml.org/
18. http://www.xml.com/pub/a/2002/01/30/DAMLOIL
19. Maedche, A., Staab, S.: Measuring Similarity between Ontologies, Proc. 13th European Conference Knowledge Enginnering and Knowledge Management (EKAW), LNAI 2473, Springer-Verlag, (2002)

Experiences in Product, Process, and Facility Development: A Case of Study

Joaquín Aca[1], Arturo Molina[1], Inés Ferrer[2], Marta Albertí[2]

[1] Centro de Sistemas Integrados de Manufactura
Instituto Tecnológico y de Estudios Superiores de Monterrey
Av. Eugenio Garza Sada 2501, Monterrey, 64849, México
{aca, armolina}@itesm.mx
[2] Escola Politècnica Superior
Universitat de Girona
Campus Montilivi s/n. 17071 Girona, Spain
{ines.iferrer, marta.alberti}@udg.es

Abstract. Competitive advantages in the new global economy will belong to enterprises capable of develop high customized products. In order to compete, companies require adopting structured process to develop and improve their practices in Integrated Product, Process and Facility Development (IPPFD). This research project demonstrates how the methodological use of a Reference Model allows the companies to create a Particular Model to set-up successful IPPFD Processes focusing on specific issues of the company. One case study was implemented to demonstrate how the Reference Model can be used in a company to develop a New Product Development Program to redesign and improve its products.

Keywords: Design product methodology, Product and process modelling, Concurrent design, cooperative engineering, reference model.

1 Introduction

In an era of increased global competition, trends suggest that competitive advantages will belong to enterprises capable of develop high customized products. In order to compete, companies require developing New Product Development Programs with a knowledgeable and skilled work force, and flexible management structures that stimulate co-operative initiatives within and among companies. The incorporation of New Product Development (NPD) concepts will contribute to enterprise growth and their expected impact and benefits will create a more competitive industry as well as higher-value-added jobs.

This research paper proposes the methodological use of a Reference Model that allows the companies to create a Particular Model to set-up successful Integrated Product, Process and Facility Development Processes, independent of the industrial sector of a company, but focusing on specific issues of the company like market opportunities, knowledge, technological constraints and declared goals.

In section two of this paper the Reference Model developed and the Methodology developed to configure Particular Models are presented. In section three, a case study is presented to demonstrate the use of the Reference Model in the implementation of a New Product Development program in a company oriented to design, manufacture and commercialize sanding tools. The goal of this case study was to develop and implement a Product Development Methodology in the company to re-design and improve their products.

2 Reference Model for Integrated Product Process and Facility Development

In this section the Reference Model developed for Integrated Product Process and Facility Development is described. In the first part the scope of the Reference Model is defined; after that a literature review is presented and; finally the Reference Model and the Methodology for Particular Model configuration are described.

2.1 Scope of the Reference Model in the Product Life Cycle

Integrated Product and Process Development (IPPD) is a management technique that simultaneously integrates all essential acquisition activities through the use of multidisciplinary teams to optimize the design, manufacturing, and supportability [1]. In order to develop the Reference Model for Integrated Product Process and Facility Development (IPPFD) it is necessary to define the scope of the Product Life Cycle for engineering activities in this research project. The proposed representation has three elements (Figure 1):

- Processes are cases to be developed during engineering projects: Product Development, Process Development and Facility Development.
- Stages are indicators of evolution level for processes: Conceptualization, Basic Development, Advanced Development and Launching.
- Tollgates are specific results obtained at the end of every stage for a given process, e.g. Product Idea is the tollgate for Product Development process at Conceptualization stage.

Facility Development Process involves three sub-processes: (a) Product Transfer: if the component is a standard part or the component is manufactured by a conventional process and the supplier is found and fulfill requirements in cost, time and quality; (b) Technology Transfer: if the component must be manufactured by a conventional process and the supplier is not found but the technology is available, then it is necessary to design the manufacturing process using the technology available in the company; and (c) Machine Design: if the component to be manufactured is not standard and the technology to manufacture this product is not available, then it is necessary to design a new machine or group of machines to manufacture the component.
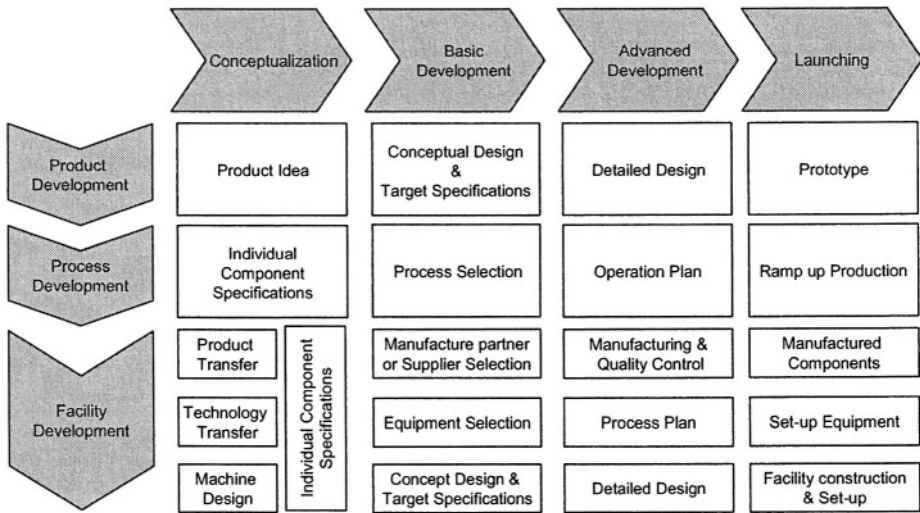
Fig. 1. Representation of the engineering stages of Product Life Cycle (PLC)

2.2 Review of IPPD Concepts

Based on previous definition of Product Life Cycle there are methodologies to support the implementation of IPPD methodologies, among them, [2], [3], [4], [5] and [6]. However, important issues extracted are:

- Methodologies propose methods and tools to support IPPD, however, the integration level of these methods and tools are restricted to exchange information among Stages in one Process or exchange information among Processes for specific Stages;
- Methodologies are designed to support specific disciplines (e.g. Mechanical Engineering); and
- Absence of one methodology able to integrate IPPD methods and tools through all Process and Stages of Product Life Cycle.

Therefore an IPPFD Reference Model has been proposed [7] and it is described in next section.

2.3 Reference Model Definition

The purpose of the Reference Model developed is to allow different companies to implement Product Development Programs using libraries of methods and tools in a "plug-and-play" manner. To achieve this objective the Reference Model must have following properties:

- Reusability / Configurability, it is able to be configured in a Particular Model to get a specific goal in the Product Life Cycle focusing on specific issues of the company like: market, knowledge and technology.

- Robustness, it is based on a tested library of methods and tools to ensure information flow among product development stages and avoid the lack of collaboration between design engineers and manufacturing engineers.
- Integral, due of its structure it is able to adopt new methods and tools from different disciplines (e.g. mechanic, electronic) and integrate them allowing configure Particular Models to different industries.

The Reference Model developed is defined as the complete representation of activities to complete the Product Life Cycle. The proposed Reference Model is described through three axes: (a) Processes: Product, Process and Facility Development; (b) Stages: Conceptualization, Basic Development, Advanced Development and Launching; and (c) Activities: specific tasks that must be executed in order to complete a stage (Figure 2).
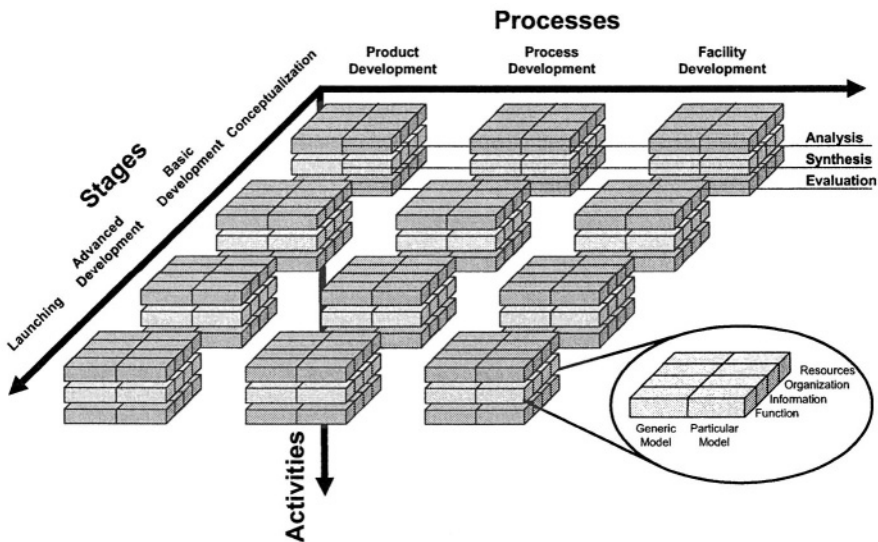

Fig. 2. Reference Model for Integrated Product Process and Facility Development [7]

Activities are classified in three types: (a) *Analyses Activities* are oriented to diagnose, define and prepare information; (b) *Syntheses Activities* are oriented to laying together elements to produce new effects and to demonstrate that these effects create an overall order; and (c) *Evaluation Activities* are oriented to test those solutions against the goals and requirements.

Particular Model is an instantiation of the Reference Model and it is constructed using Activities as basic blocks. Activities are modeled according to four basic but complementary viewpoints [8]: (a) *Function:* represents enterprise functionality and behavior (i.e. events, activities and processes); (b) *Information:* represents enterprise objects and their information elements; (c) *Resources:* represents enterprise means, their capabilities and management; and (d) *Organization:* represents organizational levels, authorities and responsibilities.

2.4 Methodology for Particular Model Configuration

In the era of global competition the tasks of design and manufacturing of products are being executed usually at different geographically locations. On this scenario a typical problem faced in companies is lack of collaboration during stages of life cycle product development. This situation requires the implementation of a collaborative Integrated Product Development process among the different companies participating in the Product Life Cycle activities.

Before the implementation of IPPFD processes in the companies participating in PLC activities, it is necessary to configure the Particular Model from the Reference Model. The Particular Model is the set of activities that represents the company development process for product, process and facility. Benefits from use a Particular Model are: (a) it responds to a specific need of the company; (b) it is designed to be used in the company with human and technological resources from the company; (c) it allows capitalizing previous experience in present projects; and (d) it provides a structured guide of the process in the company avoiding miscommunication problems among team members during project execution.

To configure the Particular Model this research proposes the use of a methodology of three steps must be achieved to fulfill the company requirements
- Phase I – Project Definition: during this phase company requirements are identified and scope of the project is defined in accordance with the Reference Model map.
- Phase II – Activity Sequence Definition, after the project has been defined, throughout this phase the Reference Model is breakdown in Activities in order to evaluate them and select those that are going to be used during the project execution.
- Phase III – Activity Sequence Mapping, once the set of activities has been defined it is necessary to translate each one of the Activity viewpoints (Function, Information, Resources and Organization) from the Reference Model domain to the Company Domain.

3 Case Study: Sanding Tools Development

The case study is divided in two sections. In the first section the Particular Model is configured accordingly to the proposed methodology in previous section. In second section, experiences from project execution are described. This project begins with the join of two companies. First company was oriented to develop sanding tools and second company was dedicated to develop polish machines. The objective of this society was to offer integral service of machines and tools. However, technology used by machines was considered obsolete, besides the manufacturing process for these machines was no efficient. Then the new company decides to implement a program to develop polish machines with new technology and a better design to improve its manufacturing process.

3.1 Particular Model Configuration

Phase I – Project Definition: This case of study was developed in a company oriented to design, manufacture and commercialize sanding tools. The company has a wide catalogue of sanding tools and polish machines, however, these machines were designed long time ago, actually these tools have a good power performance but their appearance and ergonomics must be re-designed to: (a) sustain and increase their market share; and (b) improve their manufacturing practices. The goal of this case study was to develop and implement a Product Development Program in the company in order to re-design and improve their products. Following this methodology the S927-PTD product must be re-designed with a modern appearance, higher quality, fewer components and lower time of manufacture. In Figure 3 is presented the Life Cycle defined to configure the Particular Model in the company.
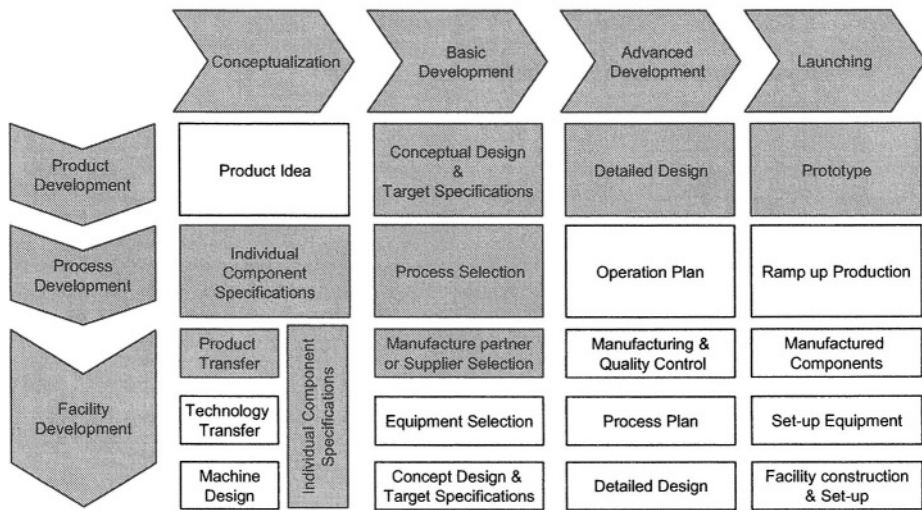

Fig. 3. Life Cycle defined to configure Particular Model for Sanding Tools development.

Phase II – Activity Sequence Definition, after the project has been defined, the Product Life Cycle must be broken-down in activities. These activities are taken from the library for Mechanical Product Development defined in the Reference Model. The complete list of activities is evaluated and those activities that support in best form the project execution are selected to configure the Particular Model. For each one of the Stages must be selected at least one activity for Analysis, Synthesis and Evaluation. In Table 1 are presented the selected activities, methods ant tools to support the Product Development Process of this case study. Similar list of activities is developed for Process Development and Facility Development.

Phase III – Activity Sequence Mapping, once the set of activities has been defined it is necessary adapt each one of the activities to be performed in the company in accordance with the four viewpoints proposed by the methodology.

- Function: the description of the activities was modeled using IDEFØ technique because allow detail the processes in activities for function modeling.
- Information: to ensure the information flow among team members a documentation system based on standard formats was implemented to record results from each activity.
- Organization: for the project execution two project leaders, one in the manufacturing company and another one in the engineering company were named and three sub-leaders were selected to coordinate activities for threes processes to be developed: Product, Process and Facility.
- Resources: technological resources are selected to support each one of the activities. For this case most of the activities were supported by commercial tools, as MS Excel, to develop own tools in the company. Specific tools per activity are specified en Table 1 for Product Development Process.

Table 1. List of Activities, Methods and Tools selected to configure the Product Development process for Sanding Tools.

Stage	Activity	Method	Tool	Type of Activity
Basic Development	Market Requirements	Interviews	Ms Word Ms ACCES	Analysis
	Benchmarking	Parametric Analysis	Ms Exel	Analysis
	Target specifications	QFD	Requirement matrix	Synthesis
	Functional Decomposition	FAST	Flow function chart	Synthesis
	Concept Generation	Morphological Matrix	MsWord Matrix values	Synthesis
	Concept Selection	Group Discussion	MsWord	Evaluation
Advanced Development	Product Modeling	CAD	Pro/E, Boothroyd methodology	Analysis
	Manufacturability Analysis	DFM&A	Boothroyd methodology	Synthesis
	Performance Definition	DOE	DOE	Synthesis
	Engineering Analysis	CAE / FEM	Ansys, Pro/E, AutoCAD	Synthesis
	Product Evaluation	FMEA	Fluent, Ansys Working Model	Evaluation
Launching	BOM Definition	-	MsWord Ms Project	Analysis
	Construction	-		Synthesis
	Testing	-	Test in own designed specimen	Evaluation

3.2 Project Execution

3.2.1 Product Development Process

Basic Development – Conceptual Design and Target Specifications: In order to execute this stage of the project several activities were executed; as the Reference Model proposes these activities were divided in Analysis, Synthesis and Evaluation. At the beginning, *Analysis Activities* were performed; the objective was to prepare a target specifications list of the new product. Two activities support this objective; first activity was to capture customer requirements through interviews with potential users, technicians and engineers from the company; and second activity was a competitive benchmarking to identify the performance products, its advantages and disadvantages, as well as the tendencies of evolution of products. *Synthesis Activities* were executed by means of a functional decomposition and concept generation, in order to separate the design problem in small design problems or modules, easier to administer and solve. The modules derived were: plate, engine, transmission and counterbalance, housing and aspiration system. *Evaluation Activities* were executed by way of group discussion among design and manufacturing engineers about module design, materials and manufacturing process to be used. At the end of this activity a conceptual solution was selected for each module.

Advanced Development – Detailed Design: During this stage of the process the arrangement, form, dimensions and surface properties of all individual parts are finally laid down, the materials specified, the technical and economic feasibility rechecked and all the drawings and other production documents are produced by means of an iterative process of Analysis, Synthesis and Evaluation. For the Plate Module the technique of Finite Element Method (FEM) was used to test the design strength for torsion and flexion stresses, several modifications were made until was reached the requested performance; for the motor selection a Design of Experiments (DOE) was developed, first to know the variables of the motor performance and after that to decide parameters that maximize the motor performance. For the modules of Transmission and Counterbalance a specialized program for counterbalance calculations was used to decide the material to be used and the mass location to control the system. For the modules of Housing and Aspiration System aesthetic and ergonomics have been very important and an iterative process with users was achieved until satisfaction of the requirements. Finally, to evaluate complete design technique of Design for Manufacturing and Assembly (DFMA) was used to reduce the number of components.

Launching – Prototype: In parallel with activities of Detailed Design several prototypes were built for each module to check feasibility and functionality of the concepts developed.

3.2.2   Process Development

Conceptualization: Individual Component Specifications. This stage initiate in parallel with the Detailed Design stage of the Product Development Process. The
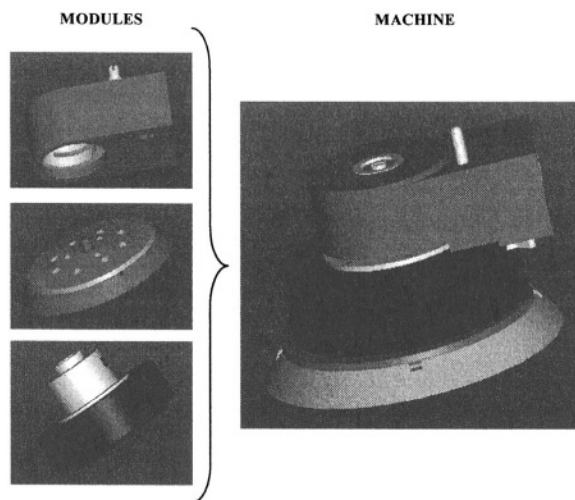
Fig. 4. CAD Model for Sanding Tools

Analysis Activity take results from the Functional Decomposition achieved Product Development Process. For these cases five different processes were developed by separate for each module: plate, engine, transmission and counterbalance, housing and aspiration system. In *Synthesis Activity* manufacturing requirements are identified plainly in three aspects: geometry, material and production rates for individual modules. And during *Evaluation Activity* the boundaries among modules are checked in order to identify potential problems during integration.

Basic Development: Process Selection. This stage is developed in parallel with Detailed Design Stage of the Product Development Process and the collaboration of the company responsible to manufacture the components was very important. For the plate, housing and aspiration system the manufacturing process selected was plastic injection molding. For the Engine and Transmission and Counterbalance modules their components were metallic and the manufacturing process was by chip removal. Since, the complexity of some components the use of CNC and CAM technologies was required. Process Plan for each one of the components was developed by the company responsible to manufacture the components without inspection of engineers from the Product Development Teams.

3.2.3 Facility Development

Conceptualization: Product Transfer. All components from this product were outsourced to external companies responsible to manufacture the components. Complete documentation of the product design (drawings, materials,) was transferred to external companies. Until this stage the project is complete, at this moment the project is in execution and no results are available for next stages.

4 Results and Conclusions

- Configurability of the IPPFD Reference Model allow to develop Programs for New Product Development independent of the product to be developed, however, in order to exploit fully configurability of the IPPFD Reference Model, Case Development is required to generate an Activities Library that allows reuse knowledge in future Process Configuration.
- Particular Model Configuration requires a steep learning curve and the user must have basic knowledge in Product Development theory, but for its systematic structure in long terms the experience of the user results in a reduction of the configuration time.
- Benefits to use IPPFD models in case study of the Sanding Tools Development were: (a) promote the collaboration among design and manufacture engineers, specially in the Plate Module design, participation of the Mold Designer during the Plate Design allow to reduce the time development; and (b) Decomposition of problem design allow to divide the projects in modules with design teams for each one of the modules with individual specifications but able to be integrated in a larger system.

References

1. OUSD, 1998, "DoD Integrated Product and Process Development Handbook", Office of the Under Secretary of Defense (OUSD), Washington, DC - 20301-3000, August 1998.
2. Lee, R. S., Tsaib, J. P., Kaoc, Lind, C. I. and Fane, K. C., 2003, "STEP-based product modeling system for remote collaborative reverse engineering", Robotics and Computer-Integrated Manufacturing, Volume 19, Issue 6, Pages 543-553.
3. Mervyn, F., Senthil Kumar, A., Bok, S. and Nee, A. Y. C, 2003, "Developing distributed applications for integrated product and process design", Computer Aided Design, Article in Press.
4. Yan, P. and Zhou, M, 2003, "A life cycle engineering approach to development of flexible manufacturing systems", IEEE Transactions on Robotics and Automation, Volume 19, Issue 3, June 2003, Pages 465 – 473.
5. Song, P., Tang, M. and Dong J. 2001, "Collaborative model for concurrent product design", IEEE Sixth International Conference on Computer Supported Cooperative Work in Design, 12-14 July 2001, Pages 212 -217.
6. Swink, M., Sandving, J.C. and Mabert, V., 1996, "Customizing Concurrent Engineering Processes: Five Case Studies", Journal of Production and Innovation Management, Volume 13, Pages 229–244.
7. Aca, J., 2004, "Reference Model and Methodology to Configure/Reconfigure Integrated Product, Process and Facility Development Processes", Master Thesis in Manufacturing Systems, ITESM, Campus Monterrey.
8. Vernadat, 1996, "Enterprise Modeling and Integration", Chapman & Hall, London, 1996.
9. Pahl,G., Beitz, W., Wallace,K., Blessing,L. and Bauert, F., 1996. "Engineering design: a systematic approach", Springer, London
10. Ullman,D.G. ,1992, "The mechanical design process". McGraw-Hill, New York, London

Implementing Collaborative Engineering Environments Through Reference Model-Based Assessment

Carlos Vila[1], Fernando Romero[1], and Manuel Contero[2]

[1] School of Technology and Experimental Sciences, Department of Technology
Universitat Jaume I
Avd. Sos Baynat s/n, 12071 Castellón, Spain
`{vila, fromero}@tec.uji.es`
`http://www.cinei.uji.es`
[2] School of Industrial Engineering, Department of Graphics Engineering
Polytechnic University of Valencia
Camino de Vera s/n 46042 Valencia, Spain
`mcontero@degi.upv.es`
`http://www.upv.es`

Abstract. This paper presents an assessment methodology based on enterprise reference models that consider next generation manufacturing principles. Because is becoming ever more frequent for companies to design products and work collaboratively within the framework of the Extended Enterprise, the need arises for a methodology for the successful implementation of collaborative practices. The main contribution of this research work lies in the definition of the reengineering process that allows the transition to a collaborative engineering environment and relies heavily on the use of PLM tools, and the definition of the metrics for change management. The proposal includes a readiness assessment procedure that analyzes the development process from a point of view that considers five levels of maturity with the aim of favoring the management of the collaboration process. The development of this collaborative assessment model is important because, on the one hand, the literature on this particular subject is scarce and, on the other, it can provide us with a deeper understanding of the activities associated to product development by defining the collaboration processes.

Introduction

If collaborative engineering processes are to be efficient the extended enterprise must have a good Supply Chain Management and this requires improvements in the planning and management of complex interrelated systems in order to increase productivity. Information Technologies have allowed integrated systems (MRP, MRPII, ERP, PDMs, PLMs) for decision-making to be used in all its areas. These tools increase the benefits to be gained from the collaborative undertaking and allow instant access to information and coordination of the workflow [1]. One of these solutions, the web-based Product LifeCycle Management tools (PLM), allows management of the life cycle of products and processes by integrating expert

applications that require the exchange of information between Databases, which are the basis on which information models [2] must be built and applied. PLM systems remove barriers between organizations but they cannot be implemented without descriptive models and a collaborative engineering focused implementation process that allow us to understand the functional relationships in the firm itself and among the firms that go to make up the Supply Chain [3].

On the one hand, these descriptive models require a reference architecture for the organization, examples of which include different points of view such as ARIS, CIM-OSA, GERAM, GRAI-GIM, NGM, PERA or SCOR. The problem lies in how to apply the modeling and analysis techniques while integrating the different points of view in order to implement a PLM system within a development framework that attempts to promote the activities of the Extended Enterprise.

On the other hand, we need a readiness assessment model that is oriented by these reference frameworks and can evaluate the current practices in order to achieve a Collaborative Engineering environment. The Next Generation Manufacturing Model [4] is a specific approach that enables the company to be evaluated from four different perspectives and, with the fundamentals of process reengineering, has allowed us to propose an assessment model.

Collaborative Engineering Assessment Models

Implementation of the Concurrent Engineering philosophy, and consequently Collaborative Engineering, implies a great cultural change within the company and should be carried out with caution [5]. The maturity of Collaborative Engineering practices is unlikely to be efficient if they are not preceded by correctly planned implementation, which involves aligning the objectives of the improvements in the product development process with the strategic objectives.

All the above ideas bring us to a newer concept of Collaborative Engineering that that goes beyond those carried out initially and that seeks to highlight the improvement in the innovation of products and of processes that can be achieved with the adoption of this new philosophy:

"Collaborative Engineering supposes the Integration of the Product Development Process through Teamwork with all the areas involved in its Life Cycle. With this aim, product Design Methodologies and Tools are used to allow the regular exchange of the product-related information that is generated and to allow internal and external collaboration to take place. They are also employed to ensure that decision making is carried out in a synchronized way with general agreement, which thus allows firms to achieve the improvement of terms, quality and innovation required by the Client."

It is important to define a series of elements that could constitute Collaborative Engineering basic mainstays. The correct development of these elements, customized for each company, will provide an appropriate Collaborative Engineering environment through which we will ensure the success of this new work philosophy.

In order to achieve this aim, processes and activities modeling is fundamental because it can provide a common working framework with which to begin to implement Concurrent Engineering. Drawing a model of company processes forces

us to reach an agreement about the objectives, facilitates communication and constitutes a tool for the analysis and design of new processes.

However, product development process modeling alone is not enough; we also need to evaluate certain characteristic activities to be able to manage the innovation process and to control and track the new process, thus allowing us to determine the improvements that are obtained. This means that it is necessary to define an entire performance measurement system that will help us to control the new process and to qualify and quantify the improvements in the process.

As teams are the core of Collaborative Engineering, they must be defined and adapted to the new design process, while taking into account all the activities that influence the product life cycle, since they constitute the second basic mainstay. The other mainstays are product design methodologies, computer support for collaborative work tools (CSCW) and Information Technology infrastructures.

The appearance of Concurrent Engineering (CE) was a milestone in the development of this field as it simultaneously lowered product cost, increased product quality and reduced time to market. Several readiness assessment methodologies for Concurrent Engineering implementation were developed over the last two decades. These include RACE from the DARPA Initiative in Concurrent Engineering (DICE) [7], RACE II, Carter and Baker [8], FAST CE and a number of European projects.

Nevertheless, as the concept of Concurrent Engineering has progressed to Collaborative Engineering it seems that implementation processes and methodologies considering the new scenario have not been researched as far as the new methodologies and technologies require.

Research Approach

Our proposal for implementing Collaborative Engineering (CoE) Environments adopts the classic methodology of business process reengineering and has five stages (Fig. 1). Within each of them we distinguish different phases that we are obliged to go through if we want to achieve successful implementation.

It is important to distinguish between two different teams that must participate during the change process. On the one hand, we have the Change Management Committee which has the capacity to make decisions about strategic topics and will participate in the first and last stages. This teamwork will bring about changes by incorporating product and process development experts with an operative level capacity to make decisions. On the other hand, in the redesign stage a Collaborative Engineering Team will be formed in order to complete it and to participate in the pilot project.

The first step to be carried out in the implementing process consists in studying whether the company is suitable for adopting a CoE environment. The business unit must therefore be analyzed to ensure that, in a preliminary approximation, the company can take advantage of CoE because it is aligned with the corporate strategy.
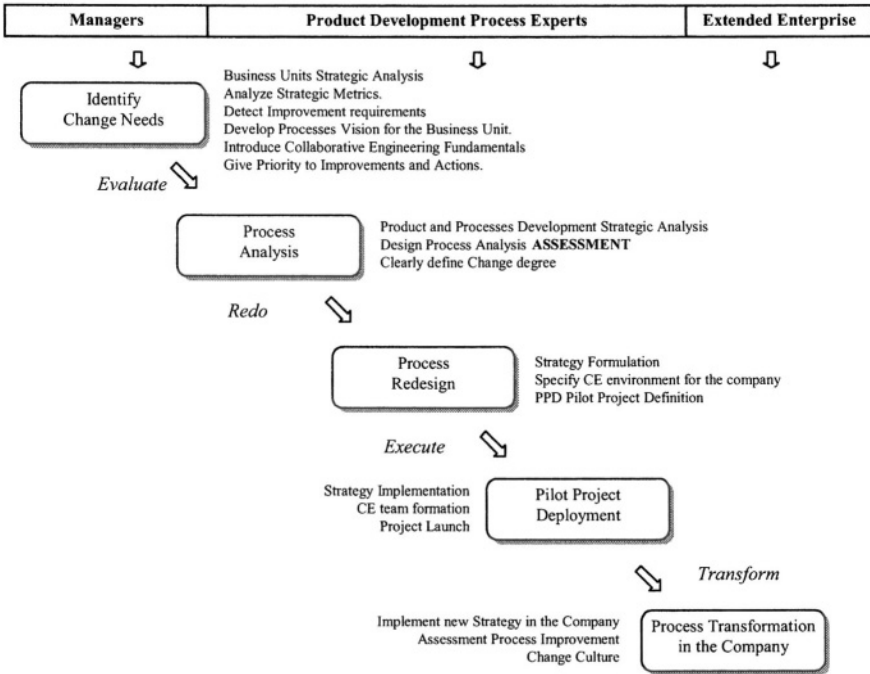
Fig. 1. Reengineering Process for Collaborative Engineering Deployment.

The Company and its products portfolio must be analyzed as well as the product development process (complexity, degree of innovation, markets, etc.) in order to establish the degree of change needed and demanded by the global markets.

Once an improvement in the product development process has been detected, the company has to evaluate the results of performance measurements. In order to understand these performance measurements and their relationships, a Process Vision will have to be adopted and the benefits of CoE must be explained to managers.

The Implementation Management Team must make a decision on whether CoE can be a solution or make a valid contribution. The process we seek to improve by innovation within each business unit must also be identified. To do so, a SWOT analysis can help find out the critical information about the company in order to decide which processes to improve and which operative strategy to develop.

The second stage requires a new Implementation Management Team made up of experts from different areas of the product development process. Here, a modeling methodology is needed and the IDEF family can be used to model each aspect of the Zachman framework for the company.

This analysis is oriented not only toward knowing how the process works but also to gaining a more precise understanding of what mechanisms are involved in producing delays and can be improved, as well as the interrelationships and dependencies between activities. We found that the proposal of Mentor Graphics introduced an excellent metric from the communication point of view and we have

developed an assessment model in accordance with NGM. Once the assessment has been elaborated we will obtain the information of the current state (As-Is) and the desired state (To-Be). This assessment is the main core of our research and the results are presented in this paper.

The third stage involves redesigning the current process and driving the new one to perform parallel activities with CSCW tools, while considering not only the Product LifeCycle but also processes and facilities. Methodologies and techniques for the team must be well defined and the tasks and functions have to be clearly established.

Additionally, some goals must be set and a series of metrics for the product development process need to be considered in order to quantify the improvements of the process, and to know whether the partially achieved objectives really match the strategy of the firm. Another important item is to identify the organizational (cultural) and technical barriers so as to prevent possible failures. To obtain an appropriate atmosphere that facilitates the success of the project, it is also important to develop an entire system of incentives. At the end of this stage the first alternative leads us to define a pilot project and a decision must be made about what product to implement and the extension of the project.

The fourth stage involves carrying out the CoE practices through a team that has been trained in the selected methodologies and design tools as well as in the new communications and procedure environments. Once it has finished, the results must be analyzed in order to make a critical decision that will probably change the culture of the company, that is, the transformation of all the processes into collaborative ones. Therefore, the analysis should include the qualitative achievements (teamwork, technological and communication improvement, knowledge sharing, transparency, etc.) and the quantitative results, which involves adding up both tangible and intangible achievements. The report must clearly show successful and unsuccessful results and achievement of the goals proposed in the objectives that were outlined in the evaluation and in the change plan.

The decision to completely transform the integrated product, process and facilities development procedure is conditioned by the success of the pilot project. The new CoE environment is an improvement and the reengineering process should result in changes that depend on the experience acquired. The CoE team must promote the successful results of the Pilot Project. This stage involves a great deal of work, since a detailed audit of all the activities taking place in the product development processes has to be carried out, and how to transfer the knowledge from the previous experience to each of the departments has to be determined. Finally, it is crucial to adapt the culture of the firm since people are definitely the most valuable mainstay in any collaboration venture.

Findings

Our proposal for CoE assessment, as well as the reengineering framework described, was developed within the Research Project entitled Collaborative Engineering in the Ceramic Tile Supply Chain (CE-Tile). The proposal has four fundamental elements: a *questionnaire* to evaluate the Current Situation, a *matrix* to evaluate the Desired State

(collaborative engineering scenarios), a *Change Diagram* (a graphical representation of shortages) and *Innovation Guidelines* (actions to be carried out in order to improve the process). The evaluation system is based on Carter and Baker's proposal but it has been developed bearing in mind the Next Generation Manufacturing Reference Model. It therefore analyzes its four Dimensions by evaluating a series of Key Factors according to different Maturity Levels.

Dimensions. These allow us to understand each of the broad areas of interest of an extended manufacturing enterprise. *Human Resources* identifies how managers empower people or teams to speed up the IPPD process, team training in use of techniques and tools, and what systems of incentives are used. *Processes* identifies the factors that are directly related to the procedures of product development that satisfy client requirements. *Technology* allows us to evaluate communications among the team member or personal skills. The *Integration* dimension allows us to analyze not only the integration between team members but also with clients and suppliers.

Key Factors. These will allow us to identify the way the company works, the levels of communication that exist and the use of technological resources. These are Key Factors that we consider fundamental in determining the CoE environment and on which we will base our implementing strategy, since they will enable the actions that are specifically involved in improvement to be defined.

Table 1. Key Factors

Human Resources	Processes	Technology	Integration
Team Formation Empowerment Incentives System	Client Requirements Product Development Planing Design Methodologies Engineering Knowledge Standards Validation Design Documentation	Communications Product Development Tools Workflow Management Product Data Information Sharing Feedback Optimization Virtual/Rapid Prototyping	Team Integration Supplier Point of View

Maturity Levels. In order to elaborate the As-Is Questionnaire and the To-Be Matrix we established a series of Maturity Levels for each Key Factor. They do not only reflect the level of effort made by the team to communicate but also consider the level of collaboration performed in order to improve and innovate during product development. We understand that, following the NGM guidelines, there could be five levels of communication effort.

Project. This corresponds to a minimum communication effort: people do not need to exchange the information dynamically and only basic communication takes place.

Program. This involves a communication effort among different engineering disciplines to exchange information and negotiate the IPPD in an interdisciplinary way.

Concurrent. This level corresponds to a multidisciplinary work effort with communication that flows among the different disciplines involved in the process which, besides sharing information, are concerned about innovating and improving the product.

Enterprise. The Product Development Process is so complex that it requires many multidisciplinary teams and the communication environment must be spread throughout the whole company. A process vision is formally adopted and teams constantly seek the innovation and improvement of the product.

Collaborative. This level is attained when the process includes not only many multidisciplinary teams but also suppliers and other companies from the supply chain who are involved in an active way. This development process allows the exchange of information among different companies in order to generate better products, more quickly and in the shortest possible time.

For each Key Factor we have tailored five questions according to each maturity level scenario. During the assessment process, once the questionnaires and the matrix have been completed a qualitative analysis enables us to draw the results in the Change Diagram (Fig 3). Obviously the interview method supposes that lower levels must be satisfied before rising to a higher level.
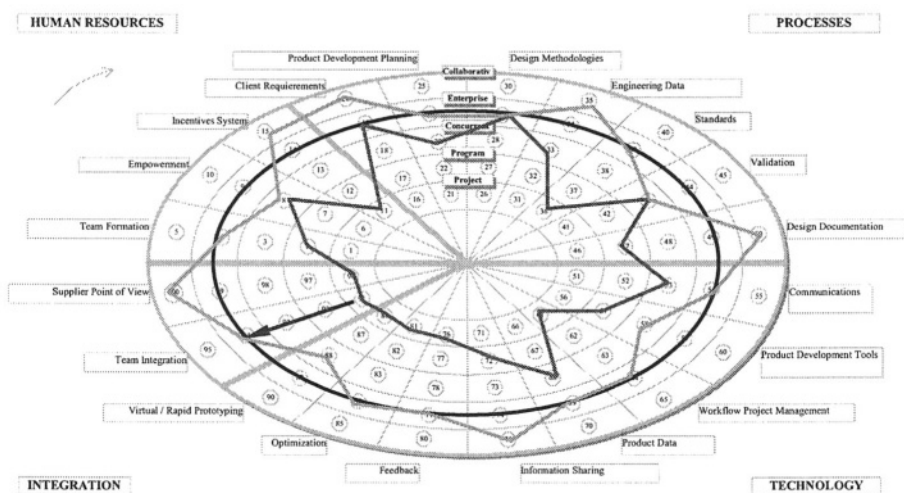

Fig. 2. Change Diagram.

The results will allow us to determine the degree of change for each key factor and for the whole process, at the same time seeking a balanced environment that should include most of the desired states and that should be acquired by progressively prioritizing the most important actions.

Conclusions

The main contribution of this research work lies in the definition of a reengineering process that considers the most important actions involved in the implementation of collaborative engineering. We believe that this assessment solves and updates some

aspects of previous ones which did not consider certain aspects of concurrent engineering from the excellent manufacturing enterprise framework and the opportunity of using collaborative engineering as an approach. The process includes descriptive models following a top-down approach and which are guided by the NGM framework that must be demanded for the implementation of PLMs with the aim of favoring the management of the collaboration process.

The development of an assessment model for collaboration is important to researchers because, on the one hand, the literature on this subject is scarce and, on the other, it provides us with a deeper understanding of the activities associated to product development by defining the collaboration processes that take place, above all, when the organization is undergoing a process of delocalization and distribution of production. Thus, our model seeks to be more complete by adapting NGM and filling some gaps left by the previous system. In addition, the factors are guided toward analyzing the different mainstays of Collaborative Engineering.

Acknowledgement

References

1. Chandra, C. & Kumar, S. (2000). Supply chain management in theory and practice: a passing fad or a fundamental change? Industrial Management&Data Systems, 100,100-113.
2. Boddy, D., Macbeth, D., & Wagner, B. (2000). Implementing collaboration between organizations: An empirical study of supply chain partnering. Journal of Management Studies, 37, 1003-1017.
3. Shapiro, J. F. (2001). Modeling the Supply Chain. (1 ed.). Duxbury, Thomson Learning.
4. Jordan, J. A., Michel, F. J. (2000). Next Generation Manufacturing. Methods and Techniques. John Wiley & Sons, Inc.
5. Sriram, Ram D (2002). Distributed and integrated collaborative engineering design / Ram D. Glenwood, MD Sarven Publishers cop.
7. Winner, R.J., Pennell, J.P. et al. (1988) "The role of concurrent engineering in weapons system acquisition', IDA R-338, Institute for Defense Analyses.
8. Carter, Donald E., Baker, Barbara S. (1992) "Concurrent Engineering. The Product Development Environment for the 1990s". Addison-Wesley corp.

A Modularity Framework for Concurrent Design of Reconfigurable Machine Tools

Roberto Pérez R.[1], Joaquín Aca S.[2], Andrés Valverde T.[2], Horacio Ahuett G.[3], Arturo Molina G.[2], Carles Riba R.[4]

[1] CSIM – ITESM. Campus Monterrey, México - University of Holguín
roberto.perez-rodriguez@upc.es
[2] CSIM – ITESM. Campus Monterrey, México
{aca,valverde,armolina}@itesm.mx
[3] CDIP - ITESM. Campus Monterrey, México
horacio.ahuett@itesm.mx
[4] Industrial Equipments Design Center. Mechanical Engineering Departament
Politechnic University of Catalonia. Diagonal 647, 08028, Barcelona, Spain
carles.riba@upc.es

Abstract. In response to the need for cost-effective systems than can be quickly adapted to changes in product design and manufacturing processes, the next generation of machine tools should be reconfigurable and intelligent. Reconfigurability allows for the reduction of machine design lead time, machine set-up and ramp-up time. The principal characteristics of the Reconfigurable and Intelligent Machines are modularity, convertibility, flexibility and cost-effectiveness. This paper applies a concurrent design reference model to Reconfigurable Machine Tool development. A methodology for this purpose is introduced, and the bottlenecks in the process are identified, namely, the procedure to design modules. In response, a technique for the development of modules that are consistent with the product portfolio of the machine tool builder is outlined.

Keywords: Modularity, Reconfigurability, Concurrent Design, Machine Tool

1 Introduction

Trends in the new global economy suggest that competitive advantages will belong to enterprises that are capable of developing highly customized products. In this new environment of high competition, it is necessary to develop manufacturing systems that can be rapidly adapted to the dynamics of the market.

Over the last few years, considerable efforts have been made to develop and implement Reconfigurable Manufacturing Systems (RMS) that provide a cost effective answer to such market demands [1]. In principle, RMS are designed to adapt rapidly to changes in product mix and volume. The key is to rapidly update the structural design of the equipment; both in terms of hardware and software. The art and science of RMT development are still at their developmental stage.

A goal of the work presented in this paper is to provide a methodology for the design of RMT. In particular, this paper proposes a design process for RMT, and outlines a methodology for the designs of modules for RMT. On section 2 a literature review of research in Reconfigurable Machine Tools (RMT) is presented. A Reference Model used to configure a first approach of the methodology to design RMT is described in Section 3. Section 4 presents experiences obtained from implementation of this methodology, and describes the bottlenecks that are particular to RMT design. Finally, Section 5 introduces techniques and tools that need to be integrated in the library of the Reference Model to make it applicable to RMT design.

2   Review

The characteristics that determine the ease of reconfigurability are the following: modularity, integrability, customization, convertibility and diagnosability [2]. Modularity allows for a fast and reliable integration during the change of structure of the RMT from given production capacity to a different production capacity for a desired amount of products from a given family. The modularity has been studied widely from the functional and constructive point of view [3], [4]. The studies of the modularity in the RMT are sparse, and for the most part dedicated to the modular selection [5], [6].

Garro and Martin [7] have identified a modular design of a machine tool related with the environment and the determination of control modules. Kate and Chung [8] provide a new type of RMT, denominated arch–type RMT, whose spindle location is a function of the angle of the part face changes. Koren and Kota [2] patented an RMT where the type, location, and number of spindles could be adjusted in response to changing product requirements. Lander [9] discusses the impact of production requirements on the design of RMT.

Systematic design tools have been developed for RMT. Zatarain et al. [10] propose a method to analyze the dynamic stiffness of a machine tool using pre–calculated component information. Yigit and Ulsoy [11] introduced a methodology to evaluate the dynamic characteristics of RMT. Moon and Kota [12] developed a systematic methodology for the kinematic synthesis of machine tools starting from a mathematical description of the machining tasks. Yigit and Ulsoy [13] analyzed the vibration isolation of RMT and proposed different isolation strategies depending on the RMT requirements. Moon et al. [14] introduced a systematic methodology to evaluate machine tool errors using module information. All of these studies address specific topics related to RMT design and construction. However, they do not address the design process as a whole.

3   Reference Model

To develop a methodology for RMT design, this research project proposes the use of a Reference Model that allows the companies to create a Particular Model to set-up successful Integrated Product, Process and Facility Development Processes (IPPFD).

   The model is independent of the industrial sector of a company, but focuses on specific issues of the company like market opportunities, technological constraints and declared goals. This model has been tested for different product development scenarios [15].

   The Reference Model developed is defined as the complete representation of activities to complete the Product Life Cycle. The proposed Reference Model is described through three axes: Processes, Stages and Activities (see Figure 1).

— Processes to be developed during engineering projects: Product Development, Process Development and Facility Development. Facility Development involves three sub-processes: (a) Product Transfer: If the component is a standard part or it is manufactured by a conventional process and a supplier is found and fulfill requirements in cost, time and quality; (b) Technology Transfer: if the component must be manufactured by a conventional process, the supplier is not found and the technology is available, then it is necessary to design the manufacturing process using the technology available in the company; and (c) Machine Design: if the component to be manufactured is not standard and the technology to manufacture this product is not available, then it is necessary to design a new machine or product to get the component.

— Stages are indicators of evolution level for processes: Conceptualization, Basic Development, Advanced Development and Launching.

— Activities are specific tasks that must be executed in order to complete a stage. These are classified in three types: (a) Analyses Activities are oriented to diagnose, define and prepare information; (b) Syntheses Activities are oriented to laying together elements to produce new effects and to demonstrate that these effects create an overall order; and (c) Evaluation Activities are oriented to test those solutions against the goals and requirements.
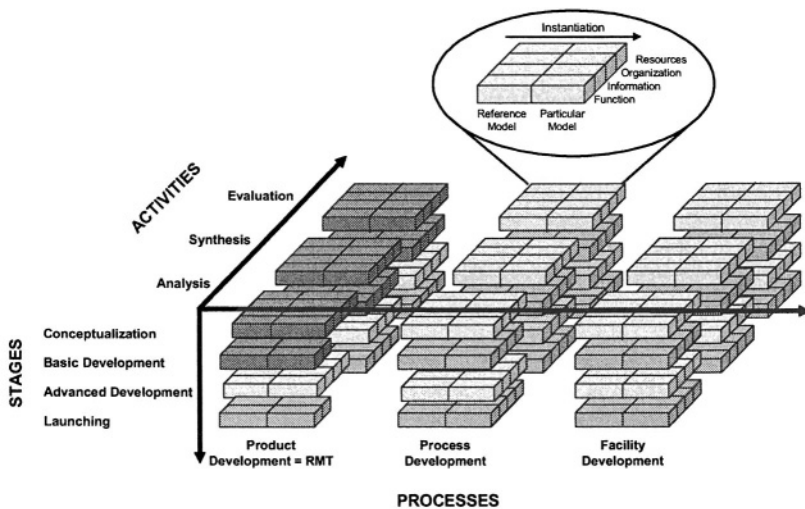

Fig. 1. Reference Model for IPPFD that was applied to RMT design to obtain a formal methodology

The properties of this Reference Model are:

—Reusability / Configurability: ability to be configured in a Particular Model to get a specific goal in the Product Life Cycle focusing on specific issues of the company like: market, knowledge and technology.

—Robustness: based on a proven library of methods and tools to ensure information flow among product development stages and avoid the lack of collaboration between design engineers and manufacturing engineers.

—Integral: due of its structure, the model is able to adopt new methods and tools from different disciplines (e.g. mechanics, electronics) and integrate them allowing for the development of particular models to different industries.

Based on this Reference Model a Particular Model for RMT development was prepared. The details of the methodology for the Conceptualization and Basic Development stages to develop a RMT and the experiences obtained from this process are presented in the following sections.

4   Methodology for Reconfigurable Machine Development

The methodology for the development of RMT was prepared and tested around a specific design case. The Chamber of Metal Making Companies of the State of Guanajuato, Mexico, stated the need for a machine that could be adapted to two different processes: cutting of flat glass, and flame cutting of steel plate. A team of four undergraduate students, working under the supervision of a Master's Student and a Professor was responsible for applying the reference model and deploy the design methodology using this case. The scope of the process was limited to the stages of Conceptualization, Basic Development and Advanced Development. Some details of this process are presented in the following paragraphs.

Conceptualization: during this stage of the methodology the objective is to define the project to be developed and delegate responsibilities for project execution. For this case study the customer request a reconfigurable machine able to cut different materials: glass and steel plates. Four students from the Research Center for Manufacturing Systems at ITESM were responsible to follow the methodology to develop the machine in a period of five months.

Basic Development: during this stage the objective is to capture customer requirements, establish target specifications and generate and select a feasible concept to be developed in next stage. To capture customer requirements and translate them to technical specifications, Competitive Benchmarking, Patent Analysis and QFD techniques were used. The requirements and specifications for this machine were: High speed (1 m/s); High Precision (+/- 0.01 mm); Quick change and set up time (1 hr maximum); work envelope of 1.2m x 2.4 m; maximum glass thickness of 0.01 m; and maximum steel plate thickness of 0.0254 m.

After the specifications were defined, the Functional Analysis System Technique (FAST) was used to define and classify functions of the RMT. A morphological matrix was prepared to generate solutions (see Table 1).

Table 1. A morphological matrix prepared to generate solutions

Finally, Pugh Charts were used to evaluate different configurations of the RMT and select one concept to be developed further. The different natures of the two processes had a clear impact on the characteristics of the RMT. For example, in glass cutting operations, the cutter must stay tangential to the cutting path. Consequently, the tool head must provide an extra degree of freedom when compared to the flame cutting process. On the other hand, the flame cutting process generates high temperatures that might have an effect upon the structure, a factor that is negligible in glass cutting.

Advanced Development: Mathematic models were implemented in Excel for the selection of components such actuators, linear guides and sensors. Selected components were modeled using a commercial CAD system (Pro/Engineer).

Figure 2 shows the design of the structure of the RMT machine that was designed for glass / steel plate cutting. The important features in this design are the modular construction of the tool holder and the table. Both of them can be rapidly changed when changing from one process to the other.
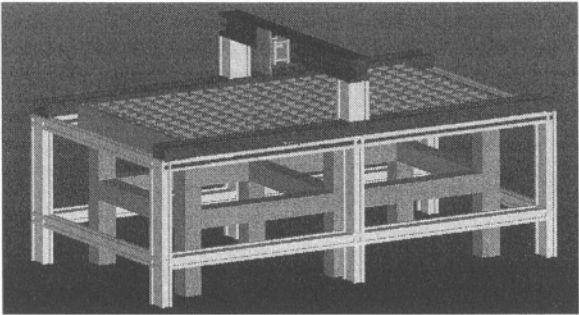

Fig. 2. Conceptual design of the reconfigurable machine prototype

The methodology was analyzed to identify the strengths as well as the bottlenecks that were exposed during the solution of the test case. In principle, the methodology did provide a roadmap that could be used to streamline the design process. Information was presented and stored in formats that were clear to the members of the design team. On the other hand, some of the tools proved to be redundant, in particular those who were associated with the correlation of functions and components.

Perhaps the most important bottleneck was found when trying to take the results of the morphological matrix to the synthesis of the different substructures of the machine. In essence, there was neither a basis to determine in detail the composition of the different modules, nor a defined criteria for grouping the different components into packages that could somehow facilitate the machine tool construction. Ease of construction, assembly, set up, and service were included in sequential order, after functionality had been addressed. The test case exposed the need for a tool to bridge this gap, that is, between functions to be performed and modular components to facilitate the concurrent design of a RMT.

5 Modularity and Reconfigurability Approach in Machine Design

The general characteristics of a methodology based on modularity are proposed now to fill the gaps that were found in the test case. In general, modular design methodologies are based on two perspectives: functional oriented design and constructive oriented design. In their original conception, neither one of them is complete for the purpose of RMT design because they are not integrated. In the functional approach, modules are designed in terms of the functions that each module is to perform, and satisfies the customer's objectives by the simple addition or subtraction of modules. On the other hand, the constructive approach produces a modular decomposition that facilitates fabrication, assembly and transportation during the product life cycle.

The fundamental characteristic of RMT's is their modular construction, which is neither completely functional, nor completely constructive, but rather possesses reconfigurability oriented modularity. *Reconfigurable modularity* refers to a set of principles and rules that define a family of machines or products, to the manner and shape in which modules are standardized and their respective interfaces. These modules allow modifications to the structural and functional configuration of the machine, in such a way that significant changes to product form and demand can be accommodated.

The proposed methodology for the modular development of RMT's establishes four domains (see Figure 3) which go from the requirements of the machine tool builder to the definition of the reconfigurable modularity. Each layer established by the methodology and shown in Figure 3 constitutes a formalization of the knowledge that is obtained in any given step.

The first domain allows the identification of the machine tool builder's requirements that affect not only the development of the machine but also its ability to be reconfigured. This domain is developed in the general framework (see Figure 3). Each functional requirement contains a set of variables that facilitate their analysis in later stages of the model. This step helps to establish the requirements layer, which is simply a representation of the intentions of the machine tools builder about the reconfigurability, as well as basic information of the machine's builders, useful in the second step.
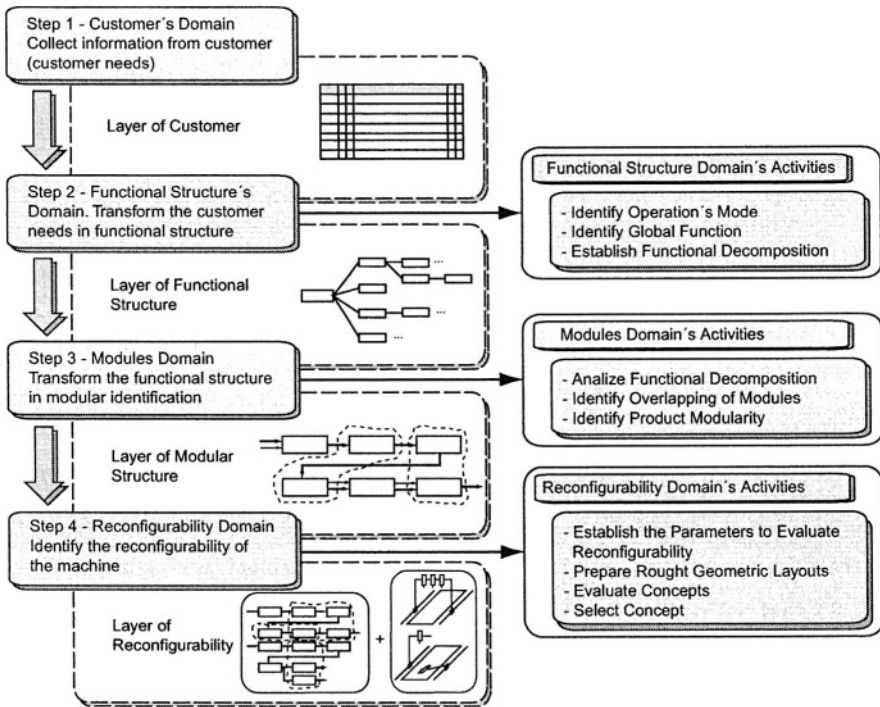
Fig. 3. Overview of the modular reconfigurability design methodology

The methodologies developed about the functional structures present two basic problems [3], [4], [16]. First, there is no clear methodological procedure for the definition of the ideal sub-functions for a given set of requirements. Second, there is no method that guarantees a coherent decomposition of the functions into sub-functions. The step of Functional Structure's Domain, is a way to solve the previous problem, using a combination of a hierarchical functional decomposition, heuristic rules and knowledge about the machine. This domain also it belongs to the general framework (see Figure 3).

Once all functions have been decomposed to a given level, the last layer will represent the sub-functions that are more related to the final structure of the machine. This process facilities the decision making process about the reconfigurability of the machine. Once this step is concluded, the layer of the modular structure is obtained, which is only a transformation of the information that is contained in the layer of functional requirements into more concrete information with the modularity of the product.

Four activities are recommended within this step (see Figure 3). The first one consists of identifying which are the parameters that characterize the reconfigurability of the machine, or family of machines. The second activity consists of generating preliminary geometric schematics that allow one to determine configurations for the machine from the modular structure layer. To determine possible variants for the concepts, heuristics criteria are used. Table 2 presents the selection of three basic concepts for the case presented here.

Table 2. Reconfigurability Concept Matrix that evaluate the Reconfigurability Parameters vs Concepts Design for the development of a RMT

⚫ = Strong relation   ⊖ = Medium relation   ◯ = Weak relation

Once the different machine concepts have been defined, it is necessary to evaluate them, taking into consideration the preceding information. To evaluate these concepts in terms of their reconfigurability, a tool is used. The evaluation tool is the Reconfigurability Concept Matrix (RCM) that evaluates the Reconfigurability Parameters vs Concepts Design of the machine tool prototype. Through this matrix, the interaction among the selected concepts and the reconfigurability parameters established in step four (see Table 2) can be visualized. It can be seen on this matrix that the first concept for the reconfigurable machine tool for plates is most adequate, considering the reconfigurability parameters.

In the RCM matrix, the columns represent the different concepts for the construction of the machine tool and the rows represent the reconfigurability characteristics that are desired in the machine. The cells of the matrix represent the relation that exists between each concept of machine and each one of the reconfigurability characteristics that wish the machine's builder, of this form, can be appreciated the proximity of each concept with each characteristic of reconfigurability (see Table 2).

This approach allows the validation of the geometric configurations of the selected reconfigurability concepts, and constitutes the parameters that complete the layer of reconfigurability for the proposed methodology, for selection of the best concept.

6   Conclusions

This article has presented a Modularity Framework for Concurrent Design of Reconfigurable Machine Tools. The developed methodology provides an aid in the generic identification of the reconfigurable modules starting from the knowledge of the requirements of the machine tool builder. This methodology was integrated to the library of techniques and tools of the references model.

To improve the methodology, a future work is needed. It's necessary to develop a Reconfigurability Index that allows the numerical comparison of reconfigurability parameters of a machine tool.

Acknowledgement

References

1. Koren, Y., et al., Reconfigurable Manufacturing Systems, Annals of the CIRP, Vol. 48/2 (1999) 527–540
2. Koren, Y. and Kota, S., Reconfigurable Machine Tools, U.S. Patent 5,943,750 (1999)
3. Stone, Robert B., Towards a Theory of Modular Design, Doctoral Thesis, University of Texas at Austin, United States of America (1997)
4. Fixon, S.K., Three Perspectives on Modularity – A Literature Review of a Product Concept for Assembled Hardware Products, Massachusetts Institute of Technology, ESD-WP-2001-06 (2001)
5. Moon, Y-M., Kota, S., Design of Reconfigurable Machine Tools, Journal of Manufacturing Science and Engineering, Vol. 124, May, (2002) 480-483
6. Blackenfelt, M., Managing Complexity by Product Modularization, Doctoral Thesis, Royal Institute of Technology, Stockholm, Sweden (2001)
7. Garro, O. and Martin, P., Towards New Architectures of Machine Tools, International Journal of Production Research, Vol. 31, No. 10 (1993) 2403–2414
8. Katz, R. and Chung, H., Design of an Experimental Reconfigurable Machine Tool, Japan–USA Symposium on Flexible Automation, Ann Arbor, Michigan, (2000)
9. Landers, R.G., A New Paradigm in Machine Tools: Reconfigurable Machine Tools, Japan–USA Symposium on Flexible Automation, Ann Arbor, Michigan, (2000)
10. Zatarain, M., Lejardi, E., and Egana, F., Modular Synthesis of Machine Tools, Annals of the CIRP, Vol. 47/1 (1998) 333–336
11. Yigit, A.S. and Ulsoy, A.G., Application of Nonlinear Receptance coupling to Dynamic Stiffness Evaluation for Reconfigurable Machine Tools, Proceeding IME, Part B: Journal of Engineering Manufacture, Vol. 216, No. Bl (2002) 87-101
12. Moon, Y-M., Kota, S., Generalized Kinematic Modeling of Reconfigurable Machine Tools, Journal of Mechanical Design, Vol. 124, March, (2002) 47-51
13. Yigit, A.S. and Ulsoy, A.G., Design of Vibration Isolation Systems for Reconfigurable Precision Equipment, Japan–USA Symposium on Flexible Automation, Ann Arbor, Michigan, (2000)
14. Moon, Y–M. and Kota, S., A Methodology for Automated Design of Reconfigurable Machine Tools, Proceedings of the 32nd CIRP International Seminar on Manufacturing Systems, Leuven, Belgium, May, (1999) 297–303
15. Aca, J., Reference Model and Methodology to Configure/Reconfigure Integrated Product, Process and Facility Development Processes, Master Thesis in Manufacturing Systems, ITESM, Campus Monterrey, (2004)
16. Erixon, G., Modular Function Deployment (MFD), Support for a Good Product Structure Creation, 2nd WDK Workshop on Product Structuring, Delf, Holland (1996)

A Cooperative Design Environment
Using Multi-Agents and Virtual Reality

Nobuyoshi Yabuki[1], Jum Kotani[2], and Tomoaki Shitani[3]

[1] Associate Professor, Department of Civil Engineering and Architecture
Muroran Institute of Technology, Muroran, Hokkaido, Japan
yabuki@news3.ce.muroran-it.ac.jp
http://yb3.ce.muroran-it.ac.jp
[2] Civil Engineer, Hokkaido Railway Company, Hokkaido, Japan
[3] Doctoral Student, Division of Civil and Environmental Engineering, Graduate School
Muroran Institute of Technology, Muroran, Hokkaido, Japan
shitani@news3.ce.muroran-it.ac.jp

Abstract. This paper presents a new design environment using Multi-Agents and Virtual Reality (VR). In this research, a design system with a virtual reality function was developed. The virtual world was realized by using GL4Java, liquid crystal shutter glasses, sensor systems, etc. And the Multi-Agent CAD system with product models, which had been developed before, was integrated with the VR design system. A prototype system was developed for highway steel plate girder bridges, and was applied to a design problem. The application verified the effectiveness of the developed system.

1 Introduction

In structural detailed design, engineers determine the section dimensions of each member and check all the members for compliance with applicable design codes. If a member is found to violate any code, engineers have to re-design the member and perform code checking repeatedly until the member satisfies the code. If the design change is significant, they have to analyze the total structural system again and repeat the code checking process. The whole process tends to be time-consuming and error-prone.

A number of research efforts have been made in order to develop efficient design environments by using 3D CAD systems and product models. These design environments can provide capability of fairly smooth data transfer among 3D CAD systems and non-CAD application systems by the interoperability of the product model. Although they improve the efficiency of the design process, engineers have to spend time and consciousness for data transfer among systems yet. This problem may be solved by putting all related systems together and by making a single package. However, this solution would lose a number of other advantages such as free competition among software developers and vendors, and it would let users abandon their legacy systems.

We believe that intelligent agents, which can support engineers and designers autonomously in various ways, operating in the background and without users' consciousness, play a significant role in solving the problem. Thus, we previously developed multiple agents, and developed Multi-Agent CAD [1] by integrating them with a 3D CAD system while using an IFC-based product model for sustaining the interoperability. In this system, one agent autonomously checks the compliance of the user's design with a design code when the engineer designs steel members in the 3D CAD system. The other agent checks external constraints such as constructability and economy, and gives the user comments and advices while the engineer is designing. Although the developed Multi-Agent CAD worked well, the user interface of 3D CAD of the Multi-Agent CAD environment has many aspects to be improved. One of the main deficiencies is that the 3D CAD shows the three-dimensional objects and space on a two-dimensional display so that the user often wonders which member is close to the user and which is far. This is particularly seen in the situation of three-dimensionally complicated structures such as steel girder bridges.

Therefore, we incorporated a virtual reality function into the Multi-Agent CAD environment in this research. Unlike the pseudo virtual reality, where only 3D CAD images are displayed on a computer monitor, the virtual reality we utilized is based on the two different images shown alternately with a great speed; one is to be seen by the right eye and the other by left. We used high-speed shutter glasses to view the 3D virtual world.

In this system, the user not only can view the 3D CAD models more three dimensionally but also can edit the members in the 3D CAD. For example, the user can change the dimension of a member by selecting it appropriately, which was an irritating task in the conventional 3D CAD system. Once the user modifies the dimension, the agent autonomously converts the data into a product model data, and the modified dimension is checked for compliance with applicable design codes by the agents. If the design violates a design code, the agent tells the user so by popping up a small window on the computer display.

This paper presents the architecture of the system, describes its prototype system, and shows an illustrative example of application of the system to a steel girder bridge.

2   The Previously Developed Multi-Agent CAD Environment

The previously developed Multi-Agent CAD environment [1] is shown in Fig. 1. In this model, the result data of structural analysis is transferred to the 3D CAD system via the product model and converters. Although load and basic dimensional data of each member are contained in the data, the detailed section dimensions are not included yet. Thus, the user determines section dimensions by using 3D CAD system. In this process, the Multi-Agents support the user's design.

The Multi-Agent CAD system consists of a 3D CAD system, a system interface, a user interface, and Multi-Agents. Three agents were developed: (1) a simple code checking agent, (2) a design situation checking system, and (3) a database agent. These agents can check the user's design autonomously and inform any violation and improper design to the users while they are using the Multi-Agent CAD system.

All the data designed in the Multi-Agent CAD system is transferred to the Code Checking System via the product model and converters. However, almost all members should already conform to the design codes because the simple code checking agent has already checks the design in the detailed design process.
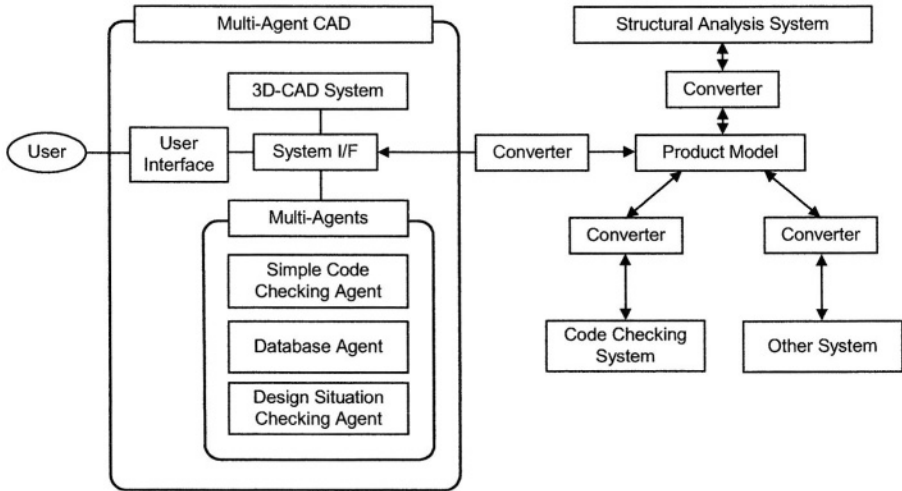

Fig. 1. The previously developed Multi-Agent CAD environment

3   A Product Model for Steel Girder Bridges

In this research, we used Industry Foundation Classes (IFC) Release 2x, i.e., IFC2x, [2] of International Alliance for Interoperability (IAI) as a base of the product model for steel girder bridges. IFC is an object-oriented data model for representing buildings and other construction related information. IFC contains not only physical properties of structures such as its parts and members, their dimensions, materials, shapes, locations, etc., but also spatial concepts such as floors, rooms, and abstract concepts including projects, organizations, etc. IFC has been developed to enable the interoperability among CAD and non-CAD application systems by IAI.

In IFC2x, there are four main classes, i.e., IfcObject, IfcPropertyDefinition, IfcRelationship, and IfcRepresentationItem. IfcObject class and its sub classes define physically existing objects such as beams and columns. IfcPropertyDefinition class and its sub classes can contain supplementary information, which is not included in IfcObject classes. IfcRelationship class and its sub classes define the relationship among objects and property sets. IfcRepresentationItem class does not share the root with other three groups of the classes and is defined separately. This class provides resources on geometric information of members.

Although IFC2x provides the IfcBeam class for representing beams, it is not possible to divide IfcBeam into flanges and webs. Thus, we defined a new class for plate

girders, which is a sub class of a newly defined CivilStructureElement class, a sub class of IfcElement class. Since IFC2x has no classes for representing loads, we defined a new class "load" and attached it to IfcObject class as its sub class. The "load" class can contain the load data of objects such as beams and columns. A part of the product model is shown in Fig. 2. To implement the product model schema and instances, ifcXML (Extensible Markup Language) [3] was used.

Fig. 2. Outline of the developed product model for steel girder bridges

4 Multi-Agents for Supporting Steel Girder Bridge Design

The multi-agents developed in this research consist of a strength checking agent and a design situation checking agent.

The strength checking agent checks whether the section designed by the user is appropriate or not for the given loads by checking the conformance with the design code. As a design code, Japanese Highway Bridge Specification [4] is used.

The design situation checking agent checks whether the design satisfies situational constraints such as: whether the selected section of the girder has the same height as the adjacent girder and whether the designed section is economical or not. This agent retrieves the location and section data of the related given by the product model data and checks the situation based on the knowledge given by design engineers.

Those agents work in the background and check the design autonomously when the user determines the section dimensions or modifies them. Multi-agents may make conflicts at some occasions, where some mediator agents may be necessary. However, the user plays as a mediator in this system at the moment. This may increase the opportunity for the user to consult with other designers and engineers about conflicts. We intend to develop agents for mediating such conflicts in the future.

5   A Design System Using Virtual Reality

Virtual reality is a realistic simulation by a computer system using interactive software and hardware. The requirements for virtual reality include (1) virtual world, (2) immersion, (3) sensory feedback, and (4) interactivity. The virtual world can be realized as a three-dimensional space by using computer graphics. The user can feel immersed in the virtual world by using a special display system. Feedback and interaction can be realized by using a sensor system connected with the virtual world and the user.

3D computer graphics is a computing technique for rendering images of objects in the three-dimensional space. Most typical 3D computer graphics include OpenGL [5] and DirectX [6]. DirectX is an application program interface (API) for Windows, and was developed by Microsoft. On the other hand, OpenGL does not depend on particular hardware or operating systems. Thus, we considered choosing OpenGL for implementation. However, OpenGL is a library of the C language. Since we used Java as a system development language, we decided to use GL4Java [7], one of the OpenGL Java bindings, with which Java programs can call OpenGL libraries.

Although a perspective view image on a 2D display, generated from a 3D model, can be viewed as a three-dimensional image, most viewers cannot feel immersed in the virtual world because the image lacks true cubic effect. It is necessary to generate two different images: one is for the right eye and the other for the left one in order to enable true three-dimensional viewing. Such images can be generated by using GL4Java. Further, liquid crystal shutter glasses can allow the user to see the images for right eyes by his right eye and the ones for the left eyes by the left eye. We used CrystalEYES3 of StereoGraphics as liquid crystal shutter glasses. The shutters of these glasses synchronize with the computer display showing right and left images alternately at more than 120 Hz by using the infrared emitter unit. More than one viewer can see the images three dimensionally if they wear the glasses.

Sensor systems such as transmitters and receivers can realize sensory feedback and interactivity. Within the boundary of such sensor system, the user can change the viewing direction and location by just moving his or her head or fingers without typing commands from a keyboard. We used FASTRAK of Polhemus as a sensor system. Since the radius of the boundary of FASTRAK is about 1 m, viewing location is limited to 2 m, which is too small considering the size of typical bridges. Thus, we magnified the distance in the sensor area with some factor so that the user can view bridges from any point in the virtual world.

We developed a detailed design system using virtual reality. The system architecture is shown in Fig. 3 and Fig. 4. Fig. 5 shows computer graphics images of a steel girder bridge for right and left eyes respectively.
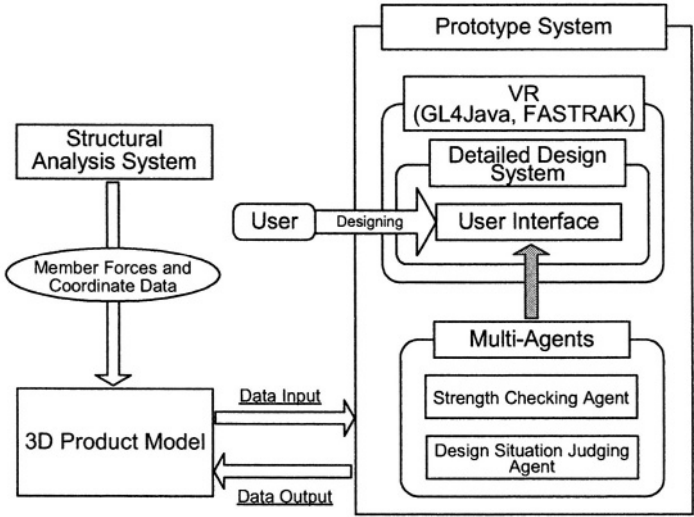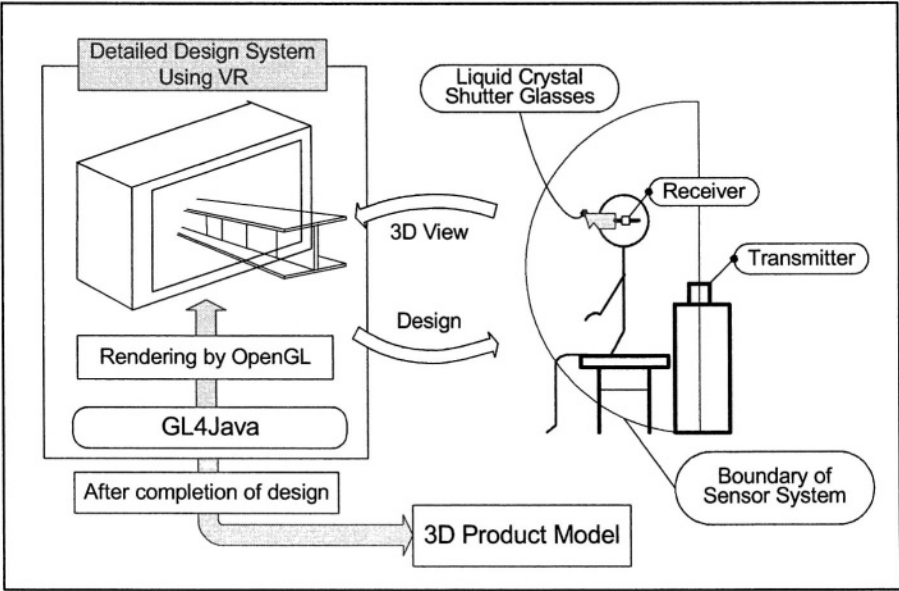

Fig. 3. The developed design environment
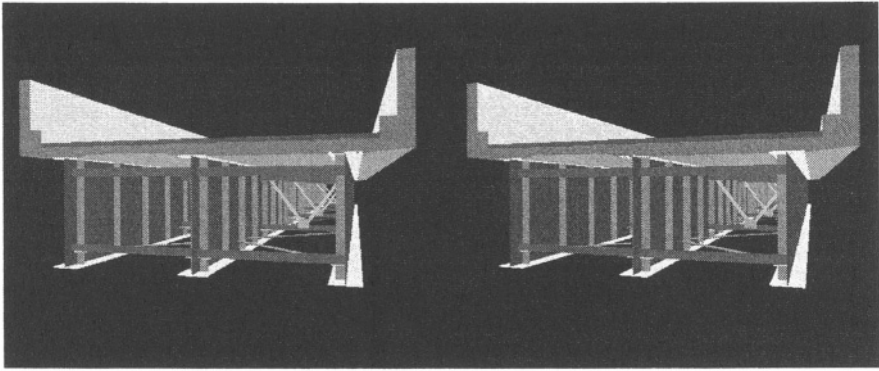

Fig. 4. Detailed design system using virtual reality

Fig. 5. Computer graphics images representing a steel girder bridge for right and left eyes

6   Application of the Prototype System

In this section, an example of application of the developed prototype system to highway bridge design is described. The bridge is a highway simple supported non-composite steel plate girder bridge. The design follows the Specifications for Highway Bridges [4].

First, the preliminary structural analysis of the given bridge has already been performed, and the output data of member forces (bending moments, shear forces, etc.) of plate girders and coordinate data are converted to product model data. The data has been input to the developed detailed design system.

Next, the user designs the plate girders, viewing the images for right and left eyes by the liquid crystal shutter glasses, so that the user can feel immersed in the virtual world as shown in Fig. 6. While the user is in the process of determining the dimensions of the plate girders, Multi-Agents check the design and warn the user, e.g., "The thickness of the upper flange must be larger under the given load condition," if the design needs modification. And the violating element of the design member is highlighted by changing its color from yellow to orange in the display. The user can modify the dimensions by using the window under the 3D virtual world. Another agent, which checks the situation and warns the user, works like this way.

Several students and engineers used this system for designing a steel bridge and they gave good comments on the system performance.

7   Conclusion

In this research, a design system using virtual reality was developed, and the previously developed MultizAgent CAD system connected with product models was integrated with the new VR design system. The design environment using VR and Multi-Agents found to be effective by applying the prototype system to a design problem.

Future issues include the improvement of the VR system and application of the system to other bridge design.

Fig. 6. A selected element of the design member is highlighted by changing its color from yellow to orange

References

1. Yabuki, N., Kotani, J.: A 3D CAD Environment Using Multi-Agents and a product Model. (in Japanese). Journal of Civil Engineering Information Processing Systems, Vol. 11. Japan Society of Civil Engineers, Tokyo (2002) 1-8
2. International Alliance for Interoperability: Technical Guide for Industry Foundation Classes -- Release 2x. http://iai-international.org. (2000)
3. ifcXML: http://iai-international.org.
4. Japan Highway Association: Specifications for Highway Bridges, Part 1, Part 2. (in Japanese). (2002)
5. OpenGL: http://www.sgi.com/software/opengl/
6. DirectX: http://www.microsoft.com/windows/directx/default.aspx/
7. GL4Java: http://www.jausoft.com/gl4java.html

Using Specifications to Build Domain-Independent Collaborative Design Environments

Crescencio Bravo, Jesús Gallardo, Beatriz García-Minguillán, Miguel Á. Redondo

Computer Science Department University of Castilla - La Mancha
Paseo de la Universidad, 4-13071 Chidad Real (Spain)
{Crescencio.Bravo,Miguel.Redondo}@uclm.es, {Jesus.Gallardo,
Beatriz.Garcia23}@alu.uclm.es

Abstract. Nowadays, Collaborative Technologies is an area of growing interest with a great number of developments being carried out. However, most of them deal with specific applications, and building a complete collaborative environment implies a great effort. We have experienced this in the development of DomoSim-TPC, a collaborative environment for the learning of domotical design. To overcome these limitations and difficulties, we outline the application of specification techniques to describe some characteristic elements of CSCW/CSCL systems, such as the approached domain, the problems to solve or the communication mechanisms. Thus, in this paper we first analyze the domain-dependent DomoSim-TPC system to generalize its positions in order to obtain a specification which models a domain of design and the textual communication forms between the users. Then, we present a domain-independent tool that processes this specification to dynamically generate a collaborative system allowing the approach of the specified design domain.

1 Introduction

Collaborative Technologies are emergent technologies that are being applied to support and to improve group work (CSCW) and the learning processes (CSCL). In the past decade, many CSCW and CSCL systems have been built. However, most of them approach specific applications and are not flexible nor adaptable to different situations and purposes, especially in the field of CSCL and of real time collaboration systems. Moreover, these systems are complex to build and do not easily accommodate changes [1]. But at the moment, there are not suitable tools that make this development less expensive and less error-prone. According to Verdejo et al [2], the production of a customized collaborative learning environment is very time-consuming since the complete coverage of a domain requires a large amount of effort.

   Our aim is to facilitate this production task by means of the use of specification techniques to model some components of Collaborative Systems (CS) and the construction of tools that process these specifications and allow generating some modules of the systems in an automatic, fast and easy way. In other works we have explored the possibilities of defining specifications for the modelling of design domains in CS of design learning [3]. These works are in consonance with the proposals of Chang et al [4], who indicates that one of the directions for the future

work in CSCW is to build generic models for collaborative work, as architectures or formal languages, which allows developers –or users– to describe properties and conditions of the systems. The next step consists in developing tools that generate software systems starting from these models.

Our focus of interest is the CSCL systems for the learning of design tasks. These systems usually follow the instructional method of Problem Based Learning (PBL) [5] with the aim of reinforcing the commitment among the learner and the activity he/she carries out. The design problems are usually complex and require that the designer builds an artefact or carries out a process under certain conditions.

In this work a domain-independent CSCL system for the learning of design is described. This independence or flexibility is materialized by means of the specification of the domain, of the problems to solve and of the communication among the users during the domain task (to design). This allows the users to create their own domains and problems, as well as to select the way to communicate.

To define these specification languages we take the XML standard as a basis. This allows building computable models that can be process efficiently and in an easy way by the software tools. Some authors use XML-based languages for the specification of CS components or, even, of the work or learning process these systems incorporate. For instance, Amor et al [6] use descriptions based on XML to describe the specification of the application architecture and its components and aspects. Verdejo et al [2] use this notation to describe learning activities (the users, the tasks they carry out, the tools they use, etc.). Martínez et al [7] use XML specifications to represent interactions in CSCL systems. However, these systems are centred in describing the processes but not the models or artefacts the users manage in their activity.

This work is organized as follows: in the next section the DomoSim-TPC system is presented; in section 3 the information processed by this system for the management of problem solving activities is analyzed, and this process is described relating its phases with the elements of a problem; in section 4 a specification technique based on XML to describe domains, problems and the communication is proposed; in section 5 we will describe an architecture to support these domain-independent systems; and finally, we will conclude with a synthesis and outline the future work.

2 DomoSim-TPC: The Design and Simulation Subsystem

From the perspective of the conceptual framework that the CSCL paradigm [8] provides, we have developed the DomoSim-TPC system, a collaborative system for the distance learning of domotical design, which includes support for setup, realization, monitoring, analysis and storage of learning activities. This system can be considered a CSCW system of domotical design as well as a CSCL environment for Domotics learning [9].

The Domotics discipline (Home Automation) deals with the automation of housing for the optimization and control on comfort, energetic consumption, security and communications. We represent the Domotics domain by means of a set of object types, called operators, and of relationships among them. The operators are classified in management areas, e.g. thermal comfort, energetic control, etc.

The functional architecture identifies a set of levels (Organization, Experience and Analysis), subsystems and tools. The levels organize in a general way the system. The subsystems arrange software tools that offer specific functionalities. We have identified the following subsystems: Activity Management subsystem, Communication and Coordination subsystem, Design and Simulation subsystem, and Monitoring and Activities subsystem.

3 Collaborative Solving of Design Problems

The users of the DomoSim-TPC system are classified in two profiles: teacher and student. The students are arranged in groups coordinated by one or more teachers. The access to the tools is regulated according to the user's profile. The students use the system to solve problems. An additional support for communication and coordination is available for them. The teachers define learning experiences, help the students and monitor the system use.

A problem collection is fundamental in a learning application based on the instructional method of PBL [5]. In PBL the students work actively in groups on problems extracted from the real practice. Each problem describes the requirements of the model that the students have to build. In this situation the student plays the role of a professional designer. These domotical problems are well structured, and they are defined with the following elements (that can be applied to other design domains): (a) identification and description, (b) complexity level, (c) plan of the house on which to carry out the design, (d) internal and external environmental aspects, (e) technical characteristics of the house, (f) requirements or necessities, (g) constraints, and (h) simulation cases and hypotheses.

The *activity* abstraction allows teachers to propose a specific problem to a specific group of students. From the organizational point of view, a problem is a learning object that can be reused thanks to the activity. Synchronous collaboration makes it necessary to coordinate the users in work sessions. A session is the period of time in which the members of the work group can cany out a task in a shared workspace.

The process of detailed problem solving is framed in the Design and Simulation subsystem. This subsystem is based on a semi-structured interaction model that proposes Collaboration Protocols [10], Flexible Structuring techniques [11] and the use of the Language as Action [12] to structure the student work. The Collaboration Protocol synchronizes the joint access of the students belonging to the group by means of five shared workspaces in where carry out the tasks and of a structure for the navigation along them. All these workspaces integrate different mechanisms of direct manipulation, support for communication, coordination and decision-making, and awareness techniques [9]. The workspaces, the collaboration protocol and the information produced and interchanged among the workspaces are shown in fig. 1.

In these workspaces the diverse components of the problem are used. The **Design** workspace is the first one accessed when the group starts the resolution of a problem. In this workspace the students have to collaborate to build a model. They use actions of edition, relationship and parameterization of operators. The design is made on the plan of the house (c), which is obtained from the plan identification contained in the problem definition. The students can access a textual formulation of the problem at

any moment. This formulation, which includes the problem description text (a), is built automatically starting from the problem definition. The complexity level (b) determines the quantity of work to carry out. The characteristics of the house (e) and the constraints of the problem (g) condition the model design, since they limit the number of elements that can be used or the value of certain parameters. The requirements (f) indicate to the students the elements that should include in the model and the characteristics it should have. From this workspace, the Work Distribution, Parameterization, and Cases and Hypotheses workspaces can be accessed.
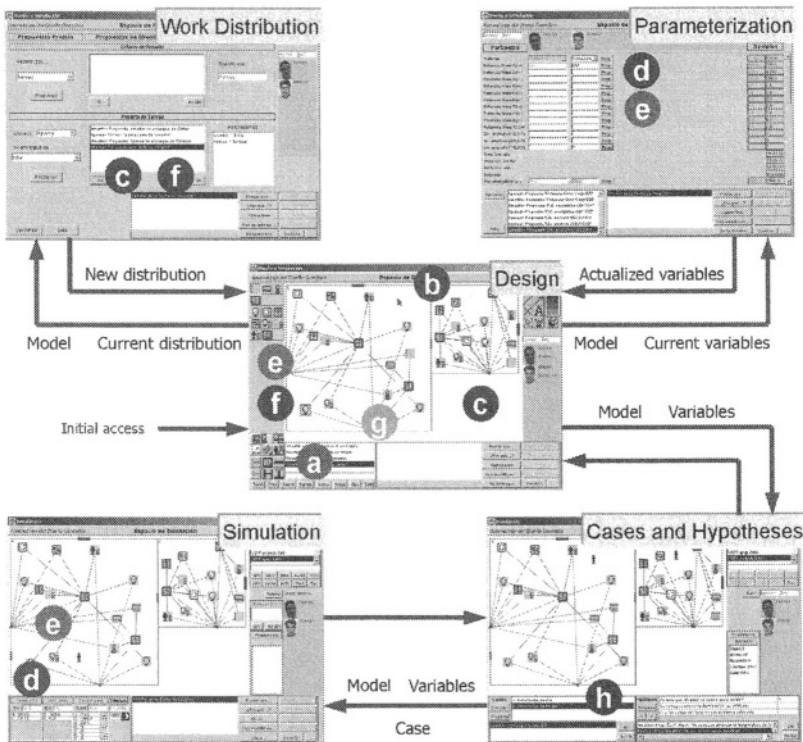
Fig. 1. The resolution process in the Design and Simulation subsystem.

In the **Work Distribution** workspace the students define a list of assignments of actions to organize their work. A first criterion allows assigning each room to a student so that only he/she works in it. The rooms are determined by the plan (c). A second type of criterion consists in assigning each management area (f) to one user, so that he/she can work using only the operators of the defined area, but being able to make it in any part of the plan. This work *distribution,* expressed as a data structure, is passed from this workspace to the design one.

In the **Parameterization** task the students define the values of the problem parameters by means of a discussion process based on proposals. The list of parameters contains the data relative to the environmental aspects (d) and to the house characteristics (e). The initial value of these data is specified in the problem. A data structure representing the *variables* is shared between the Parameterization and

Design tasks. The *model* is passed from the Design to the Parameterization (as well as to the Work Distribution) so that the needed model information is available in these tasks.

In the **Cases and Hypotheses** workspace the students select the case to simulate and check the verification of the hypotheses. To do this, they discuss following a process based on proposals [9]. These cases and hypotheses are those that the problem incorporates (h), although the students can propose other new ones. The selected *case,* the *model* and the *variables* are passed to the Simulation. In the **Simulation** the students experiment with the designed model following a collaborative discrete event simulation. The evolution in the time of the variables that make up the environmental aspects (d) and the house (e) is maintained, starting from the initial value of the parameters defined in the Parameterization.

4 Component Specification

Although DomoSim-TPC approaches a particular case study, as it is Domotics, there are parts that are useful outside of this system. Their tools of users' administration, of communication, coordination and decision-making, and of analysis are directly reusable in other domains. The Collaboration Protocol and the interaction model based on the structuring suppose a framework for the realization of learning environments by means of design and simulation. The tasks of Work Distribution, Parameterization, and Cases and Hypotheses are domain-independent, while the Design, the Simulation and the problem definition tool are domain-dependent. Our purpose is to generalize the system to approach other design domains, reusing the generic components and turning the specific ones into generic ones making them domain-independent. This new system is called SPACE-DOMAIN. In a first stage, the aim is to define a specification technique that allows describing the domain and the problem collection. In addition, we will allow the specification of the communication messages to make the communication support more flexible.

We propose the use of XML to define these specification languages. The choice of this notation is because of its feature of standard language and its interoperability. An advantage of XML is that it would allow, by means of XSLT (eXtensible Stylesheet Language Transformations), the generation of XHTML (eXtensible HTML) pages visualizable on a browser with a representation of the domain or the problem or any other document that includes their elements. We do not consider specific proposals for expressing components of design, like MOF[1] and XMI[2] of the OMG[3], because of their complexity.

In the following sections these languages (DDL, PDL and CDL) are presented and some examples are shown. It is necessary to take into account that the aspects of behaviour with respect to simulation have not been approached.

---

[1] Meta Object Facility: http://www.omg.org/technology/documents/formal/mof.htm
[2] XML Metadata Interchange: http://www.omg.org/technology/documents/formal/xmi.htm
[3] Object Management Group: http://www.omg.org

4.1 Domain Definition Language (DDL)

We take advantage of the modelling of the Domotics domain to define a generic
design domain as a set of operators and relationships among them. The operators have
properties, and the own domain also has properties or general variables. The
relationships will be expressed by means of associations to which a graphic
representation based on lines is assigned. Also, graphic objects based on predefined
figures such as circles, rectangles, lines, arrows, crossings and text can be included.
The general structure of the specification can be extracted of the example in table 1,
which shows the Digital Circuits domain. This specification allows describing not
only graphical aspects but semantics aspects (properties, relationships...).

Table 1. An XML file describing the Digital Circuits domain.

```
<?xml version="1.0"?>                          toolbaricon="imag/icono_or.jpg"
<!DOCTYPE domain SYSTEM "domain_spec.dtd">     link_points="3,8,10">
<domain name="Circuitos digitales"              <properties></properties>
  operator_areas="Circuitos digitales"        </operator>
  operator_types="puerta">                     ...
<graphics>                                      <operator id="entrada_salida"
  <link id="conexion"                             area="Circuitos digitales" type="puerta"
    toolbaricon="imag/linea.jpg"/>               icon="imag/ent_sal.jpg"
</graphics>                                       toolbaricon="imag/ent_sal.jpg"
<operators>                                       link_points="1,2,3,4,5,6,7,8,9,10,11,12">
  <operator id="puerta_and"                       <properties></properties>
    area="Circuitos          digitales"         </operator>
type="puerta"                                  </operators>
    icon="imag/and.jpg"                         <relationships>
    toolbaricon="imag/icono_and.jpg"             <relationship id="conexion" operator1="puerta"
    link_points="3,8,10">                          operator2="puerta" link="conexion"
    <properties></properties>                      directed="no"/>
  </operator>                                    </relationships>
  <operator id="puerta_or"                      </domain>
    area="Circuitos          digitales"
type="puerta"
    icon="imag/or.jpg"
```

The elements that compose the specification and their attributes are the following
ones:

- *domain:* It is the root node. It includes two attributes *(operator_areas* and
  *operator_types)*that correspond to the areas and types in which the operators can
  be classified.
- *graphics:* This node contains the definition of the graphic aspects of the domain. It
  contains two types of nodes:
  - *line:* It defines the graphic line types that will be used in the links. It contains the
    attributes *stroke* (broken...), and *start* and *end* of the line (arrow, triangle...).
  - *link:* It defines a link graphic object. It has as attributes the line type *(graphic),*
    which is a *line* node; *label,* which refers to the text label associated to this link;
    and *toolbaricon,* which is the icon that will be shown in the button associated to
    the relationships using this link.
- *operators:* In this section the domain objects are described. Each *operator* node has
  the following attributes: identifier *(id);* the *area* to which the object belongs; the
  object *type;* the drawing with which the object is represented in the whiteboard
  (icon), a primitive object (rectangle, circle...) or an image file; the icon that appear
  in the operator toolbar *(toolbaricon);* and the coordinates in which links on that

object can be carried out *(link_points),* which are numbered from 1 to 12 according to the clock hours.

- • *properties:* Each object has a set of properties reflected in *property* subnodes. Their attributes are: *name, type* and *initial* (the initial value). If the property is of list type, it also will have a *values* attribute with the possible values of the attribute separated by comas.
- – *relationships:* This node points out what relationships can be established among the operators previously described. Each *relationship* has as attributes: *id,* which is the name; *operator 1* and *operator2,* which are the types of the linked or related objects; *link,* which refers to the link (defined in *graphics*) that represent this relationship; and *directed,* which indicates if the relationship is directed or not.

4.2 Problem Definition Language (PDL)

In the PBL a collection of problems is required. We base on the modelling of a domotical design problem to derive the specification of a generic problem of design. We consider different labels to represent the identification and description data of the problem, the variables or parameters, the requirements and design constraints, and the cases and simulation hypotheses.

Table 2. A DTD XML file describing the collection of problems.

```
<?xml version="1.0"?>
<!ELEMENT problems ( problem* ) >
<!ELEMENT problem ( description?, comments?,
  variables?, requirements?, constraints?,
  cases?, hypotheses? )>
  <!ATTLIST problem id CDATA #REQUIRED>
  <!ATTLIST problem name CDATA #REQUIRED>
  <!ATTLIST problem domain CDATA #REQUIRED>
  <!ATTLIST problem complexity_level
    (LOW | MEDIUM | HIGH) #REQUIRED>
  <!ATTLIST problem background CDATA #IMPLIED>
<!ELEMENT description (#PCDATA)>
<!ELEMENT comments (#PCDATA)>
<!ELEMENT variables ( variable+ )>
<!ELEMENT variable EMPTY>
  <!ATTLIST variable name CDATA #REQUIRED>
  <!ATTLIST variable type CDATA #REQUIRED>
  <!ATTLIST variable values CDATA #IMPLIED>
  <!ATTLIST variable initial_value CDATA
    #IMPLIED>
  <!ATTLIST variable to_define (TRUE | FALSE)
    #IMPLIED>
  <!ATTLIST variable modifiable (TRUE | FALSE)
    #IMPLIED>

<!ELEMENT requirements ( requirement+ )>
<!ELEMENT requirement EMPTY>
  <!ATTLIST requirement condition CDATA
    #REQUIRED>
<!ELEMENT constraints ( constraint+ )>
<!ELEMENT constraint EMPTY>
  <!ATTLIST constraint condition CDATA
    #REQUIRED>
<!ELEMENT cases ( case+ )>
<!ELEMENT case ( initialization* )>
  <!ATTLIST case id CDATA #REQUIRED>
  <!ATTLIST case name CDATA #REQUIRED>
  <!ELEMENT initialization EMPTY>
    <!ATTLIST initialization variable CDATA
      #REQUIRED>
    <!ATTLIST initialization value CDATA
      #REQUIRED>
<!ELEMENT hypotheses ( hypothesis+ )>
<!ELEMENT hypothesis ( variable* )>
  <!ATTLIST hypothesis id CDATA #REQUIRED>
  <!ATTLIST hypothesis name CDATA
    #REQUIRED>
  <!ELEMENT variable EMPTY>
    <!ATTLIST variable name CDATA #REQUIRED>
```

The DTD (Document Type Definition) is shown in table 2, which describes the format of the XML files that specify the problem collection. A problem has as attributes an identification (*id*), a *name,* the *domain* to which the problem belongs and a *complexity* level (LOW, MEDIUM and HIGH), and is defined on a *background,* which can be a graphic image. The textual formulation of the problem is located in the *description* and *comments* labels. A problem can contain *variables.* Each *variable* has a *name,* a *type,* a list of *values* if it is of enumerated type, an optional *initial value,* and two attributes indicating if it should be defined as part of the solution to the problem (*to_define*) and if it can be modified by the students during the design (*modifiable*). The *requirements* allow indicating the activity objectives in a more

formal way than the description and the comments. The *constraints* indicate limitations in the model, which condition the solution. Both elements are expressed by means of logical conditions with a specific syntax. These conditions allow the system to evaluate the solutions to the problem, since their verification can be checked. Finally, the DTD includes the *cases* and simulation *hypotheses.* Each *case* is described with an identifier and a *name,* and it contains a list of assignments *(variable, value).* Each *hypothesis* includes an identifier, a text (*name*) and a list of the involved variables.

4.3 Communication Definition Language (CDL)

For the communication support we have decided to incorporate a Structured Chat in a similar way as C-CHENE [11] and DomoSim-TPC. This chat is defined as structured because it offers a pre-established set of communication acts and a structure for the conversation. These acts, called *structured messages,* have a semantic meaning understandable by the users. Some of these messages are unfinished sentences that have to be completed with text by the user. As an alternative to these structured messages, this chat also includes other two communication possibilities: *open messages,* which represent the possibility of introducing any text like in a traditional chat, and *repeated messages,* which allow reusing any of the last five sent messages (open or structured). The idea is to offer varied and fast alternatives to communicate. The repeated messages are an innovation with regard to C-CHENE and DomoSim-TPC. Their aim is to reduce to the maximum the time needed to write a message by means of the complete or partial reuse of previously typed text.

The Structured Chat is a generic tool that extracts the instances of the messages from an XML file. This allows reusing it in other contexts and domains. Table 3 shows a message set that has been successfully used in some projects.

Table 3. An XML file describing a specific set of communication messages.

```
<?xml version="1.0"?>                          <message id="m5" repliesTo="m1">
<communication>                                    <text>I think so</text>
  <message id="m1" requiresText="true">        </message>
    <text>I think that... </text>              ...
  </message>                                    <message id="m8" repliesTo="m2"
  <message id="m2" requiresText="true">            requiresText="true">
    <text>Why...?</text>                            <text>Because...</text>
  </message>                                    </message>
  ...                                        </communication>
```

The messages represent frequent expressions in the design domain. There are messages that must be completed with an additional text *(requiresText)* and others that are reactive messages *(repliesTo).* A classification criterion for structured messages is according to their purpose. Thus, there are usually messages relative to the domain task, for the interaction control and to express intentions or general opinions. Although some messages can be in more than a category.

Following the proposal of the Coordinator [12] system, the communication acts that can be selected in a specific moment depend on the conversation state. Concretely, in the example (see table 3) there are two messages *(m5 and m8)* that reply to other two *(m1 and m2).* To indicate the message to which the user replies, he/she has to select it from the list of received messages.

5 System Architecture and Implementation

The generic design system we have developed to validate the specifications and to experiment with this approach is called SPACE-DOMAIN (Specification and Automatic generation of Collaborative Environments of design). This system has been implemented using the Java Technology.

Its architecture is shown in fig. 2. This is based on a client/server approach. We identify two servers: one of applications and data (ADS) and another of synchronization (SS). The ADS carries out two tasks. Firstly, this contains a DBMS (Database Management System) that manages the relational tables which store the users' data, activities, sessions, users' work (models and interactions) and the messages exchanged among the users. This service is accessed by means of JDBC. Secondly, this stores and serves the XML documents representing the specifications, the DTDs indicating the format of these specifications, and the HTML pages and applets of the system. The protocols used in this service are HTTP and FTP.
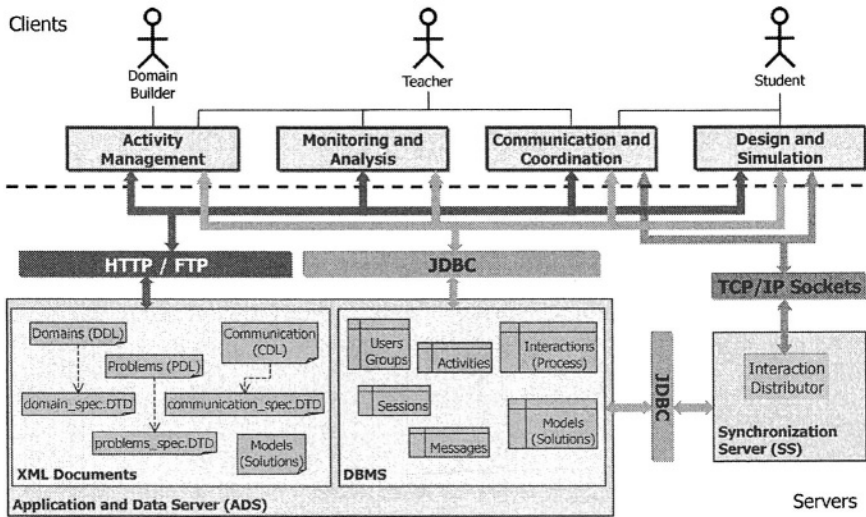
Fig. 2. Technological Architecture of SPACE-DOMAIN.

The SS provides the synchronous collaboration among the users. The distribution of the users' actions is carried out capturing the users' interactions, representing them with a *message* abstraction and sending this data package to the rest of users in the same session. The JSDT [13] is used to implement this distribution process.

The system users are organized in tree roles. The *domain builder* takes charge of describing new domains, creating specifications with the DDL; this task includes the definition of the problems and the communication with the PDL and CDL respectively. He/she uses XML editors of the Management Activities subsystem. The *teacher* uses the Activity Management subsystem to organize the participants and to define design activities. He/she can use the tools of the Monitoring and Analysis subsystem to observe and study the experiences, and can communicate and coordinate with the students with the Communication and Coordination subsystem. The *students*

can also use the tools of this subsystem to communicate and coordinate with the members of their group or with the teachers. The Design and Simulation subsystem allows students to solve the problems proposed by the teacher. The model built by the students is stored in the database in the form of relational tables, although it can be stored and read in XML notation optionally. This facilitates the manipulation of models and their exchange with other software tools.

SPACE-DOMAIN is a software system that does not translate the specification in source code, but it operates on a generic design domain that is instantiated in execution time starting from the given specification (DDL, PDL and CDL). In fig. 3 two examples of design sessions can be seen: the first (left) corresponds with the specification shown in table 1; the second (right) shows an example of the Data Flow Diagrams domain. In both cases the different components of the system can be seen: the Session Panel with two users collaborating (right), the Structured Chat (bottom-right), the operators (top-left), relationships (left) and graphic figures toolbars (right), and the collaborative whiteboard (centre) in which the user's tele-pointer can be seen.
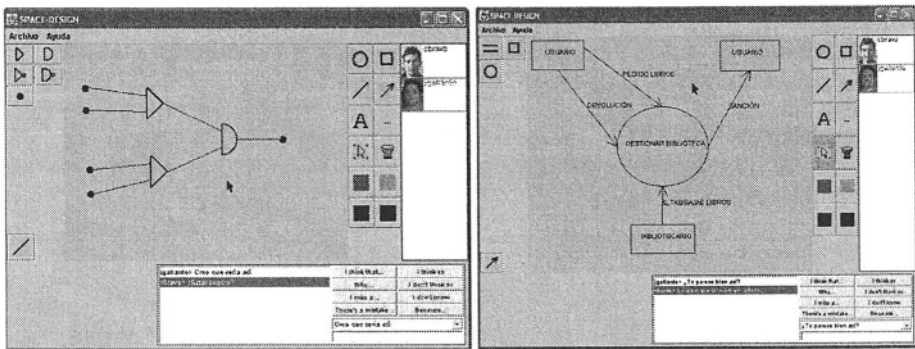
Fig. 3. Two design sessions: the Digital Circuits and Data Flow Diagrams domains.

6 Concluding Remarks and Future Work

In this work we have described how to put together Collaborative Technologies and specification techniques to reduce the development effort of CSCL systems for design learning. The main contribution of this work consists in the definition of three specification techniques (DDL, PDL and CDL) that allow users to define the domain on which the system operates, the problem collection and the communication messages. This allows generating a collaborative application starting from the processing of these specifications. These specifications express a computational model which is reusable by different tools due to the underlying XML-based representation. We have developed a system using this approach and we have carried out experimental tests with it that have allowed us to check that it is useful and valid for the following domains: Data Flow Diagrams, State Diagrams, Digital Circuits, Use Cases Diagrams and Class Diagrams. The system is going to be used in the teaching and learning of Software Engineering, what will allow us to extract conclusions about the modelling task in this discipline.

The following objective is to approach the specification of other components of CS, such as the collaboration protocols –general or detailed–, the tasks to carry out and their relationship with the user interface elements, which will allow system builders to describe the instrumentation of the tasks. On the other hand, it is necessary to complete this work with the specification of the behaviour of the models during the simulation task, when these are susceptible of being simulated, and also to build author's advanced tools that allow non-experts users to build specifications.

References

1. Li, D. & Muntz, R.R.: A Collaboration Specification Language. Proceedings of the 2nd Conference on Domain-Specific Languages (DSL'99). Austin, Texas, USA (1999)
2. Verdejo, M.F., Barros, B., Read, T. & Rodríguez-Artacho, M.: A System for the Specification and Development of an Environment for Distributed CSCL Scenarios. In: Cerri, S.A., Gourdères, G. & Paraguaçu, F. (eds.): Intelligent Tutoring Systems. Lecture Notes in Computer Science, Vol. 2363. Springer-Verlag (2002) 139-148
3. Bravo, C., Redondo, M.A., Ortega, M., Bravo, J.: Organizing Problem Solving Activities for Synchronous Collaborative Learning of Design Domains. In: Cueva, J.M, Martín, B., Joyanes, L., Labra, J.E. & del Puerto, M. (eds.): Web Engineering. Lecture Notes in Computer Science, Vol. 2722. Springer-Verlag (2003) 108-111
4. Chang, C.K., Zhang, J. & Jiang, T.M.: Formalization of Computer Supported Cooperative Work Applications. Proceedings of the 8th IEEE Workshop on Future Trends of Distributed Computing Systems (FTDCS'01) (2001)
5. Barrows, H.S. & Tamblyn, R.: Problem-based learning: An approach to medical education. New York: Springer (1980)
6. Amor, M., Fuentes, L., Jiménez, D. & Pinto, M.: Adaptabilidad en Entornos Virtuales Colaborativos: Una Aproximación basada en Componentes y Aspectos. In: Barros, B. & Dimitriadis, Y. (eds.): Proceedings of Workshop de Trabajo en Grupo y Aprendizaje Colaborativo. San Sebastián (Spain) (2003) 21-30
7. Martínez, A., Dimitriadis, Y. & de la Fuente, P.: Aportaciones al análisis de interacciones para la evaluación formativa en CSCL. Llamas, M., Fernández, M.J., Anido, L.E. (eds.) Proceedings of 4th International Symposium of Computers and Education, 41 (2002)
8. Koschmann, T. (ed.): CSCL: Theory and practice of an emerging paradigm. Lawrence Erlbaum Associates (1996)
9. Bravo, C., Redondo, M.A., Ortega, M. & Verdejo, M.F.: Collaborative Discovery Learning of Model Design. In: Cerri, S.A., Gourdères, G. & Paraguaçu, F. (eds.) Intelligent Tutoring Systems. Lecture Notes in Computer Science, Vol. 2363. Springer-Verlag (2002) 671-680
10. Miao, Y. & Haake, J.M.: Supporting Concurrent Design by Integrating Information Sharing and Activity Synchronization. Proceedings of the 5th ISPE International Conference on Concurrent Engineering Research and Applications (CE'98). Tokyo (1998) 165-174
11. Lund, K., Baker, M.J. & Baron, M.: Modelling dialogue and beliefs as a basis for generating guidance in a CSCL environment. Proceedings of the International Conference on Intelligent Tutoring Systems, Montreal (1996) 206-214
12. Winograd, T.: A Language/Action Perspective on the Design of Cooperative Work. In: Greif, E. (ed.) CSCW: A Book of Readings. Morgan-Kaufmann (1988)
13. Sun Microsystems: Java Shared Data Toolkit. http://java.sun.com/products/java-media/jsdt/ (2004)

Fostering Creativity in Cooperative Design

Adriana S. Vivacqua[1] and Jano M. de Souza[1,2]

[1] Computer Science Department, Graduate School of Engineering (COPPE)
{avivacqua, jano}@cos.ufrj.br
[2] Computer Science Department, Institute of Mathematics (DCC/IM)
UFRJ - Federal University of Rio de Janeiro
Rio de Janeiro, BRAZIL

Abstract. Creativity has become a valuable asset, given the fast paced changes most companies must nowadays deal with. Companies now look for creative, highly adaptive individuals who can explore new solutions and quickly adapt to changes in the environment. Studies of creativity have shown that it has a social aspect and that interdisciplinary groups seem to lead to more innovative ideas being generated. More often than not, complex problems can only be handled by groups of individuals who bring their individual knowledge, experiences and skills to the table. However, this generates difficulties in communication and information exchange, since individuals have different views and understandings of the problem and possible solutions. Design is a field especially well suited for creativity studies, since it is an inherently creative activity, one in which problems are often open and poorly defined. These problems often can only be solved through an iterative, continuous process of learning about the problem through exploration of solutions. In this paper, we present a framework to handle wicked problems, supporting problem evolution and idea exploration by an interdisciplinary group of designers. Using problem modeling, and agent technologies, we mean to facilitate information exchange, knowledge management and exploration of ideas during problem solving.

1 Introduction

Design is an inherently creative activity. Designers often develop unique solutions to problems they encounter. When working on a project, designers must deal with unknown variables and open and changing specifications. In many ways, design problems resemble wicked problems, which are open-ended, poorly specified and volatile. These problems are usually solved by an iterative and explorative process, through which designers learn about the problem as they experiment with possible solutions. Many creativity theorists believe that much of the creativity in problem solving comes from handling the problem and framing it in different ways, experimenting with the problem and solution spaces. Seeing something in a different light often sparks new ideas and insights that may help find a solution.

In addition, many problems (design and other types) have now become too large for a single person to deal with well. Problems are no longer resolved by a lone individual, but by a team of designers, working together to reach a common goal. These

groups are often interdisciplinary in nature, which frequently results in disagreements or confusion establishing shared concepts. Cooperation has become an important factor in problem solving, and it should be supported by appropriate tools.

Our research concerns group creativity, and we are particularly interested in studying and supporting cooperative creative processes. There are several theories on individual creativity and some systems have been constructed for individual and group settings, but we feel research in this area is still lacking. Given today's fast changing environments, many companies in different domain areas have come to need creative thought: they need to be able to quickly adapt to changes in the environment and respond to opportunities. Thus, creative group work becomes more important.

This paper is organized as follows: in the next section, we present some background work and theories that underlie this work. In section 3, we present our models and approach. In section 4, we finish with a discussion.

2   Background Work: Creativity and Problem Solving

2.1   Creativity Research

Several researchers consider creativity to the process that leads to the production of something innovative (novel) and useful [1,2]. Thus, there is an association of the product and its usefulness with the definition of the word. Hence, creative work can only be assessed by its outcome.

Csikszentmihalyi [3] presents creativity as the product of a system of three elements: the domain, the individual and the field. According to him, the domain establishes shared symbols and rules, individuals work within a domain to create something new and the field judges these contributions to determine whether or not they are creative and deserve to be incorporated in the domain (effectively changing it). Thus, the system is cyclic, and knowledge continually built on previous knowledge, with the best ideas being absorbed into the domain and the bad ones being discarded, in a process similar to the evolutionary. He emphasizes the importance of consultations with members of the domain and of dissemination of the work after it is done, so others can build upon it.

Researchers have also pointed out that a fair amount of domain knowledge is needed to generate creative solutions. An individual needs to be immersed in the problem before he can generate a solution. Furthermore, with complex problems, a great part of the problem is understanding it: designers spend a large amount of time trying to grasp the problem.

Shneiderman [4] proposed a four-stage framework for the creative process, which he believes can and should be supported by appropriate computer tools: collect (gathering information from diverse sources, such as the web or libraries); relate (consulting with individuals who may be able to furnish useful insights); create (experimenting with possibilities, trying to generate new solutions); donate (where the results of the process are disseminated in the community). These four stages are cyclic and a person can go from one to the other as needed. This framework is based on the following assumptions: (1) new knowledge is built on previous knowledge; (2) tools can

support creativity; (3) refinement is a social process; and (4) creative work is not complete until it is disseminated.

Kao [5] highlights the interaction between individuals and the existence of an appropriate environment to creative solutions. According to him, creativity is the art of transforming one form of knowledge into another. He points out that, in jazz, there is a balance between cooperation and competition, as musicians try to outdo each other without losing the agreed-upon theme. These interactions, where individuals have the freedom to create and add to the group creation, are at the heart of improvisational jazz music and are a source of some great cooperative endeavors.

2.2 Problem Solving

Problem complexity has increased: problems are no longer easily defined and tractable: they now have several dimensions and change with time. Wicked problems are ill-defined, open problems. They have no clear stopping point and have several possible solutions [6]. The problem solving process is an exploratory one, through which designers try different solutions and learn about the problem as they do so. It is often necessary to form interdisciplinary teams of experts to handle these complex problems. The number and diversity of players involved in a project becomes an additional complication [7], for it can make communication harder, and create fragmentation in a group, as solutions become fragments of group member's perspectives, understandings and intentions.

However, Fischer [8] points to the differences between individuals as a potential creativity source. The fact that individuals come from different backgrounds and have to externalize their ideas and explain their assumptions and domains to each other increases the potential for creative sparks. Along similar lines, Nissani [9] argues that forming interdisciplinary groups to handle complex problems will potentially lead to more creative solutions. He sustains that outsiders bring fresh insight and methodology to the problem at hand, and that many complex problems can only be tackled by pooling together resources from a number of different disciplines.

By introducing a person of a different field, communication problems, already frequent in cooperative work, may become more serious, given that this person does not "speak the same language" as the others. Hence, the introduction of this external individual needs to be supported by appropriate tools, so that he or she may understand the problem at hand and make a contribution. These external individuals could provide many new insights and help generate more creative solutions.

2.3 Systems

Some systems have been built that bring external knowledge to problem solving: one such system is presented in [10]: as designers work, the system searches an image base for images related to the current design topic, hoping to produce creative sparks. These images have been previously catalogues by other designers, thus leveraging on the knowledge of the community. Another system, IdeaMagnager [11] is a knowledge management system on a PDA that allows individuals to record their ideas whenever

they have one. The system retrieves and displays related information from the user's agenda, to help with idea development. In a similar vein to ours, these two systems present the idea of retrieving information to help with idea generation and exploration, but they work on the individual level (one designers working alone on a problem), while we are interested in the interactions between individuals.

The Brainstorm system [12] permits users to anonymously send emails to an idea server. These will then get posted and can be criticized by other users. The idea of anonymity is interesting, since it enables a person to contribute without having to worry about what others will think, alleviating "peer pressure". Nevertheless, too much (or harsh) criticism may discourage an individual from generating ideas or suggesting them. Ficher's EDC [8] is an enhanced physical environment that allows group members to discuss problem solutions with the aid of tabletop and wall displays, physical objects to help design solutions and computers to record rationale.

3   The Approach

Schön holds that design is a reflective practice, and that a designer frames a problematic situation by setting its boundaries, selecting items to focus attention and imposing a coherence to guide subsequent moves [14]. According to Restrepo [13], design problems require a lot of structuring, that is, drawing upon external knowledge to compensate for missing information and using it to construct the problem space. Problem structuring occurs during the initial phases of design, but reoccurs periodically as the activity progresses.

Given the definitions of creativity and these strategies for problem solving, we have been working on creating a framework for creative problem solving. It is important to note that we focus on problem solving and not creativity in the arts, as we are more interested in problems where there is a goal, but it is poorly defined and open to interpretation. Domain knowledge is particularly important in problem solving, as is external and personal knowledge that individuals bring in to apply to the problem. It will influence the way each person looks at and approaches a problem. In cooperative work, the solution to a problem is the result of a series of interactions between members of a group involved in solving it. We are interested in the interactions within a group of individuals generating creative solutions to problems, and focus our research on group problem solving and creativity stemming from these interactions.

3.1   Underlying Models

As discussed above, mapping the problem is an important aspect of creative problem solving. We believe it is crucial to have a means through which the group can represent the current state of the problem, to keep in mind what goals they're trying to reach. Additionally, the experimentation process, with its various idea threads and discussions should also be captured and supported, so that designers can go back and review what they have done and progress they have made towards a solution. It is often the case where a group will get lost in a discussion, taking many directions and

straying farther from the original problem. Every once in a while, the group must be steered back to the original problem.

We have envisioned an environment to support problem solving that bases itself on the problem and its exploration. Designers start their exploration by defining the problem, or the goal they want to accomplish (this may be a high level definition). Designers should have a representation of the problem always at hand, to remind them of what they are working towards and what the current state of affairs is. This should be graphically represented, so as to facilitate viewing and discussion. Our problem model contains the following elements:

- Problem: initial problem description, this will serve as root for the graphs that represent the problem space. This should include a description of the problem and its goals.
- Sub-problems: breakdowns of the bigger problem, these are also problems and include goals, characteristics, etc.
- Characteristics: features the solution should have. These may be determined by the client (a requirement), group (a feature), individual (a suggestion) or domain (a constraint inherent to the domain). These may be mandatory or optional.
- Assumptions: assumptions individuals base their work on when designing a solution. These may lead to certain characteristics or constraints that will have to be addressed.
- Questions: questions may be raised by an individual when working alone or by the group, and they may be resolved with the client or by the group. These sometimes lead to decisions or the establishment of new characteristics or constraints.
- Decisions: decisions made regarding the solution, which may be generated by the group, an individual or the client, usually after an evaluation process (formal or informal). These are defining elements of the solution statement, and may have implications that translate into new characteristics the solution will need to have.

Additional Resources may be linked to the graph, to enrich the problem description and solving process. These include: explanation nodes, files or contacts that may be useful during the process. Designers should be able to manipulate and collectively build this problem representation.

The process of exploring the problem should lead to an eventual solution and should also be captured. Dialog mapping [7] is an interesting approach, for it allows the individuals to visualize their discussions and decisions. We have been considering, at an initial stage, the use of the IBIS model [15] for argumentation mapping and capturing rationale during discussions. It is important that these be linked to the problem model, to reflect what discussions led to what decisions or characteristics of the solution. These discussions contain the justification for each decision made.

3.2   Supporting Systems

An environment for creative problem solving should supports idea generation, exploration, discussion and evaluation. We have envisioned a system that enables group

members to discuss their ideas while working on the problem definition and solution. Work on the solution can be done in private or as a group. It is important to allow the individual to work on his or her own, as it is often the case that a person will have some good ideas experimenting on the problem alone, without having to address questions that may arise in a group setting. Thus, each individual should be able to bring the current problem definition to a private space and work on it, and then bring it back for the group to look at. The point is not to have one person take off and solve the problem, but to generate ideas the group can work on.

In addition to that, the introduction of external knowledge should be facilitated. Each person has certain knowledge that falls outside the problem domain and that should be tapped for analogies and innovative ideas. One possibility is to map each user's knowledge through text processing; extracting areas of interest the user is interested in. Clustering users' documents, emails, contacts lists and webpage visits, an information extraction agent could produce a simple model of the user's different interests and knowledge fairly quickly. In an attempt to provide a "creative spark", one could present the user with information or keywords from these other domains. This involves perhaps using words that span more that one domain to link them, or using dictionary or thesaurus such as WordNet to find links between words and bridge different contexts. Agents are particularly useful in this case, as they can work proactively on the background, bringing necessary items to the user's attention.

As this involves bringing in personal information to the shared space, agents should not cross the borders between personal and shared spaces. The agents can work only within the personal space or within the shared space, and it is up to the user to decide which bits of information should be shared and how to do it.

4 Discussion

Cooperative work has become an important factor as companies realize that there are many problems that can only be solved by teams of experts working together. Many of these problems are unique and poorly defined, and creativity has become an asset as changes in the environment happen fast, redefining the problem even as it is being handled. The ability to adapt and handle changes in the problem definition thus becomes crucial to problem solving.

In interdisciplinary groups, establishing shared understanding is also an important problem, as individuals will have different views of the problem and possible solutions. It is also important to track changes and decisions made and how close the team is to actually finding an acceptable solution. When exploring possible solutions, it is easy to get lost in the exploration, straying far from the original problem and goals. We believe it is important to have a shared representation not only to help group members understand what they're working on, but also to help them focus on the problem-solving task itself. We have presented a problem model to be shared and collectively built by designers working on a problem, and we intend, initially, to use IBIS as a design rationale capture model. We have also briefly outlined a system to support creative problem solving.

This framework is a work in progress. There are many questions that still remain open, such as issues of motivation: researchers seem to agree that intrinsic motivation is crucial for creative work, but there is some controversy on whether extrinsic motivation is beneficial or detrimental [16]. The issue here is how to get individuals sufficiently involved with the problem that they will produce useful, innovative solutions. Another issue is that of decision-making itself, especially when deadlines come close: if the group can't reach a consensus, perhaps voting is in order or, if there is a hierarchy, a decision might have to be made by the lead designer or the client.

Additionally, there is a timing in the creative process that we intend to incorporate into this framework. An individual may become engrossed with the problem and not think about the big picture. At some moments, one must look at the full picture, be critical and evaluate the situation. However, criticism can't happen too early, as one of the serious problems in creative work is that some ideas get discarded too rapidly. Early criticism may lead to ideas not getting explored or even suggested, as individuals might choose not to say something for fear of criticism. Thus, it is important to create an open environment, where every contribution is important and will be considered before being discarded. We have been working on "modes of work", procedures that the group can adopt to help guide the exploration of the problem and solution space. These are currently under definition.

We believe this is an important problem, which deserves more attention that it's been getting. Creativity is important for many disciplines but more so for design, which involves novel thinking with each problem. Techniques such as the reuse of design objects and stock solutions for simple problems could free designers to think of solutions to more complex parts of the problem. The introduction of external knowledge should enrich the problem solving process, even as it forces externalization of ideas, discussion and interaction between group members. We believe this is an important aspect of problem solving that hasn't been widely explored so far.

Acknowledgements

References

1. Bonnardel, N.; Creativity in Design Activities: the Role of Analogies in a Constrained Cognitive Environment; Proceedings of Creativity & Cognition, 1999
2. Burleson, W. & Selker, T.; Creativity and Interface; Communications of the ACM, vol 45, n. 10; October 2002
3. Csikszentmihalyi, M. Creativity: Flow and the Psychology of Discovery and Invention. Harper Collins Publishers, New York, 1996
4. Shneiderman, B. Leonardo's Laptop: Human Needs and the New Computing Technologies. MIT Press, Cambridge, MA, 2003
5. Kao, J. Jamming: the Art and Discipline of Business Creativity. Harper Collins Publishers, New York, 1997

6. Buckingham Shum, S., MacLean, A., Bellotti, V. and Hammond, N. Graphical Argumentation and Design Cognition. Technical Report KMI-TR-25, Knowledge Media Institute, Milton Keynes, UK, 1997.
7. Conklin, J. Wicked Problems and Social Complexity. In Dialogue Mapping: Defragmenting Projects through Shared Understanding. Forthcoming. CogNexus Institute, 2003. http://cognexus.org
8. Fischer, G. Symmetry of Ignorance, Social Creativity, and Meta-Design. In Proceedings of Creativity and Cognition, 1999
9. Nissani, M. Ten Cheers for Interdisciplinarity: A Case for Interdisciplinary Knowledge and Research. Social Science Journal 34 (2), pg. 201-216, 1997
10. Nakakoji, K., Yamamoto, Y. & Ohira, M. A Framework that Supports Collective Creativity in Design using Visual Images. In Proceedings of the 3rd Conference on Creativity and Cognition (C&C'99), Loughborough, UK 1999
11. Shibata, H. & Hori, K. A System to Support Long-term Creative Thinking in Daily Life and its Evaluation; In Proceedings of the 4th Conference on Creativity and Cognition (C&C'02), Loughborough, UK, 2002
12. Stenmark, D. Klang, M. & Olsson, S. A Critical Look at Knowledge Creation. In Proceedings of IRIS22, Jyvaskyla, Finaland, 1999.
13. Restrepo J. and Christiaans, H. Problem Structuring and Information in Design. In Expertise in Design: Design Thinking Research Symposium 6, Australia, 2003
14. Schön, D. Educating the Reflective Practitioner Basic Books, New York, 1987.
15. Kunz, W. & Rittel, H. Issues as Elements of Information Systems. Working Paper WP-131, Institute of Urban and Regional Development, Univ. Calif. Berkeley, 1972.
16. Collins, M. A. & Amabile, T.M. Motivation and Creativity. In Sternberg, R.J. (ed.) Handbook of Creativity, Cambridge University Press, Cambridge, USA, 1999

Design and Manufacturing Assistance Tool for Drawing Sheet Metal Parts

Maria Luisa G.-Romeu, Quim de Ciurana

Escola Politècnica Superior
Universitat de Girona
Campus Montilivi s/n. 17071 Girona, Spain
{mluisa.gromeu, quim.ciurana}@udg.es

Abstract. Sheet metal parts are frequently designed without the systematic consideration of product development requirements like manufacturability, process planning, manufacturing optimization and production planning. Concurrent Product Design and Manufacturing means that the designer has to consider all the requirements of the product development process and incorporate these considerations into the product design. Decisions made at this point, concerning parameters, greatly affect the final cost, utility, and production time. Currently, there are many different systems and methods to assist the designer, ranging from simple design rule packages to very sophisticated expert systems. This paper shows how the developed system can assist the engineers in order to take into consideration important factors and facilitate the execution of some calculations during the early stages of drawing parts design. The tool output is a report which contains checked drawing process rules and recommendations and initial approximation reckonings to be added to the part plan.

Keywords: Concurrent Engineering Tools, Manufacturing Design, sheet metal processes, computer manufacturing, DSS.

1 Introduction

Process planning is the act of preparing detailed operating instructions for turning an engineering design into an end product, i.e. the part. This implies the need to translate the design specifications of a part into the required manufacturing operating instructions (Steudel, 1984).

There is a great deal of manufacturing data involved in process planning, such as the identification of machines, tools, flanging, parameter selection for the process, operations, etc. (Granville, 1989). All of these data has to be evaluated in order to select the sequence. Process planning requires many kinds of human abilities, which should be present in the process planner (Steudel, 1984).

The traditional approach to solving the process planning task is the one commonly used in a manufacturing company: the plans are handed over to the manufacturing process experts who then specify the procedures to make the product. The process

planners, using their experience and knowledge, generate instructions for manufacturing the products based on the design specifications and the available installations and operators.

The area most developed so far has focused on machining applications. Research and development in manufacturing applications such as heat treatment, forging, injection molding, and sheet metal manufacturing is still premature, and the reported systems for sheet metal manufacturing rely on a high level of interaction from the expert who provides decision making at different stages of planning (Gao et al. 2000).

Sheet metal components are widely used in industries like aerospace, electronics, machine tools, refrigeration and air conditioning, etc., and they form a significant part of manufacturing activity. Sheet metal components are important not only from a functional point of view, but also from an aesthetic one, since they are used as enclosures to cover products and are visible to the outside world.

The manufacturing processes required for sheet metal components are identified by analyzing the component layout, and then manually translating design information into manufacturing information (Sing and Rao, 1997). To overcome inherent difficulties and limitations associated with human beings, research work is making progress in the area of automatic transformation of design information into manufacturing information through feature recognition (Jagirdar et al. 2001).

Currently, there are many different systems and methods to assist the designer, ranging from simple design rule packages to very sophisticated expert systems, but they must be less complex and more user-friendly. The main aim of this research is to develop a computer-aided system or tool for sheet metal manufacturing. The purpose of the system we have developed is to assist engineers to consider important factors and facilitate some calculations during the early stages of drawing parts design.

During this process it is important to consider several factors such as material properties, lubrication between die and work piece, press stiffness, punch and die geometry, die material and process methods used. Of course, the quality of the drawing product depends on the experience, skills, knowledge and opinion of the die designer, the manufacturer and the press operator.

The tool has been developed with the aid of technical literature and expertise in product design, die design and drawing process elicited from users in companies. The tool output is a report which contains checked drawing process rules and recommendations and initial approximation reckonings to be added to the part plan.

2 Research Design and Methodology

In this section the different stages used to develop the tool are described. The stages are briefly defined below.

- The initial stage was a review of theory on sheet metal processes, focused on drawing processes. This study has been done with different books (mainly handbooks), Internet sites and journals.
- The second stage of the research was conducted on-site at the company, in order to understand the manufacturing processes and process planning tasks, and to find out users' requirements for computer-aided tool functions.
- The third stage was to develop the first iteration of the computer-aided system. The underlying methodology can also be tailored to general sheet metal fabrication.
- The fourth stage was to develop the design of the tool. The tool is basically made up of two components. The main component was first created as an interactive platform, which contains all the rules and recommendations and from where the second component is executed. The second component was created as database software. This component allows the user to calculate a required parameter based on the database of materials and dies.
- The last stage was to validate the tool, with different empirical cases.

3 Tool Descriptions

The tool consists of two inter-connected computer applications, the first of which contains the rules and recommendations, while the second one contains the database of different materials and allows results to be obtained.

Each of the applications will produce output documents that identify one single product. In this way, any company using this set of computer applications will be able to save copies of all the documents created to produce any specific part.

In order to better classify the parameters of the process, it is considered appropriate to use the PowerPoint program to break it down into three large groups, as is recommended in sheet metal drawing theory: the geometric and/or design parameters, the properties and dimensions of the sheet metal, and the characteristics of the process.

In order to present the rules in the three groups in an orderly and visual way, the user can choose to move through the program entering and exiting each of the three groups:
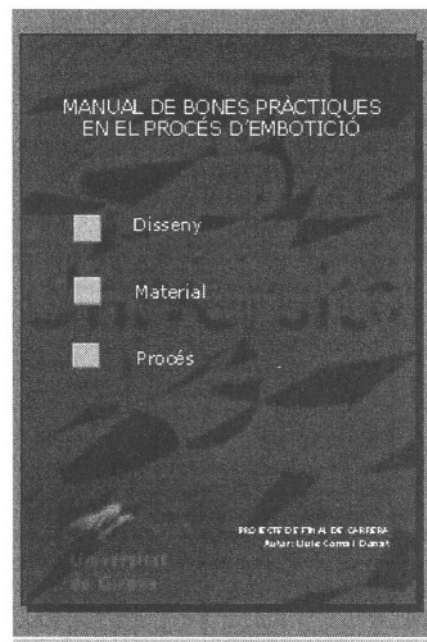
Figure 1: Initial screen of the rules

1. Design: In this group the user will find rules covering the design and development of the diameter of part, as well as advice about diameters and radii of the punch and the die.

2. Material: This next group lists the qualities with which the metals must comply, the parameters that must be known, and the materials which are more adequate as well as those which are less so. The thickness of the sheet metal also influences the process to a large extent.

3. Process: In the final group the pressures required to carry out the different types of drawing, specifically shallow drawing, deep drawing, ironing and embossing of sheets to make them stiffer.

Entering the design screen another classification is found, which allows the user to get closer and closer to the file to open in order to check if the specific rules of the ubject the user is searching for are being followed or not.
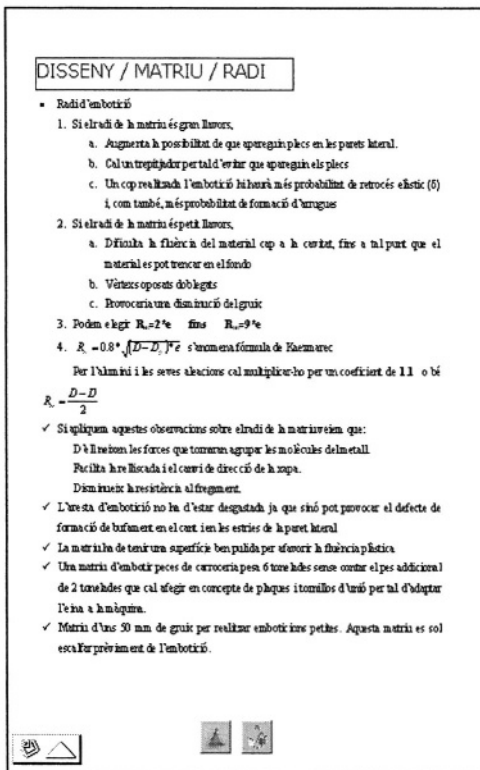
Moving progressively through the program, the user will arrive at the file which contains the rules and the suggestions necessary to produce a good drawing, according to the radius rules as shown in Figure 2.

Other parameters not previously mentioned but which can easily be found moving through the program are also dealt with, as for example: velocities, lubrication, choosing the type of press adequate for each type of operation, recommendations for health and safety in the workplace, storage, maintenance, annealing, etc.

The program opens with a screen from the Projecte.mdb file of Access where the user is able to choose which type of drawing to perform. Next, the respective screens open so that calculations appropriate to the type of drawing chosen can be made.

Figure 2: Die radius rules screen

The main screen of another computer program can be seen below. From this screen the user can move from one window to another (Figure 3).
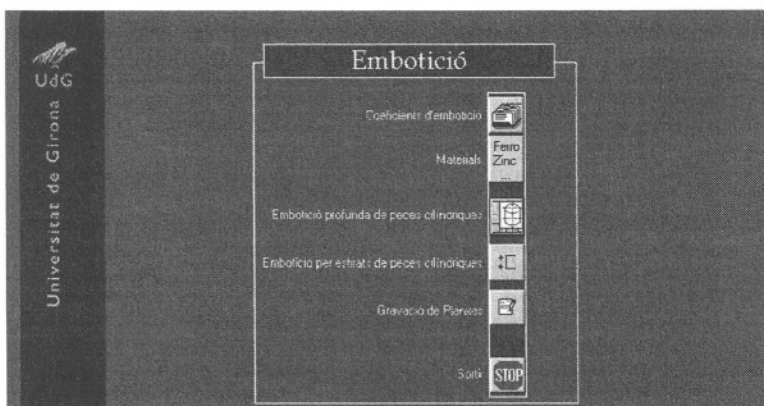
Figure 3: Main screen of the ACCESS computer program

In order to simplify the information search and to create a program which is interactive between the user and the tool, a computer application is most efficient because it allows a large amount of information to be stored and a large number of operations to be carried out in a short period of time. If these operations have been introduced correctly by the programmer, the computer will not make a mistake.

3.1 Rules

Making use of the theoretical knowledge acquired in the information search phase (Radhakrishnan et al., 1996), and taking into consideration all the specifications of the project, we have chosen a visual presentation which is as easily understandable, as fast and as direct as possible in order to present the rules and recommendations to bear in mind when drawing a part.

Some rules, which are collected in the PowerPoint program and are based on knowledge taken from the literature, have been elaborated and classified in the different groups referred to so that the user can find them in an easy and understandable way.

The rules or suggestions referred to are important in order not to commit unnecessary errors which would cause a loss of time and materials when drawing, resulting in higher costs without producing any profits. Situations experienced by groups of people involved in the drawing process have been summed up and from them a set of rules, neither too short (so that the reason behind each rule is understood) nor too long (so that the user can quickly find what he/she is looking for), has been created.

The rules can be found and in PowerPoint and can be accessed directly from certain points of the program with the help of VisualBasic.

3.2 Calculations

The second computer program calculates the specific dimensions and materials of the parts (Choi et al. 1998) to be made. It also determines the dimensions of the necessary tools and machines (Singh and Sekhon, 2002).

Access has been used to respond to the design problems associated with different elements involved in the process. Through a series of calculations and iterations the program has been able to solve problems related to the design of these tools (die and punch) as well to the machinery necessary for such an operation, starting from the necessary force (minimum power of the machine) and from the height of the final part (minimum stroke of the machine).

3.3 Databases

Using Access, a database storing information concerning all the necessary parameters related to the material used and the drawing process employed has been developed.

The characteristic parameters of the materials in the database are: the parameters of foreseeable reductions in the first operation and in other operations (m1, m2); maximum velocity, specific pressure, traction rupture load (drawing), resistance to sheering (when cutting the sheet metal), resistance to compression (when drawing in order to increase the stiffness of the sheets or even for aesthetic reasons); deep drawing sets and the most adequate type of lubricant.

The database is never definitive because materials can be added, if desired, with their respective characteristic values. The screen with the form for the material is the following (Figure 4):

Figure 4: Material maintenance form

Once the form for the material has been seen, it is necessary to observe and analyze how the three different types of drawing implemented in the program are calculated:

1. Deep drawing of cylindrical parts. This part has been chosen because it is a typical shape in the drawing process. We know the necessary formulas to determine the number of iterations that must be carried out to obtain the final part, calculating for each intermediate step the diameter and height of the part obtained, the diameter of the punch, the diameter of the die, the radius of the punch, the radius of the die, the drawing force, the treading force and the total force. The initial diameter of the part, the minimum surface of the sheet metal, the type of lubrication and the maximum recommended velocity have been calculated before the iteration (Figure 5).
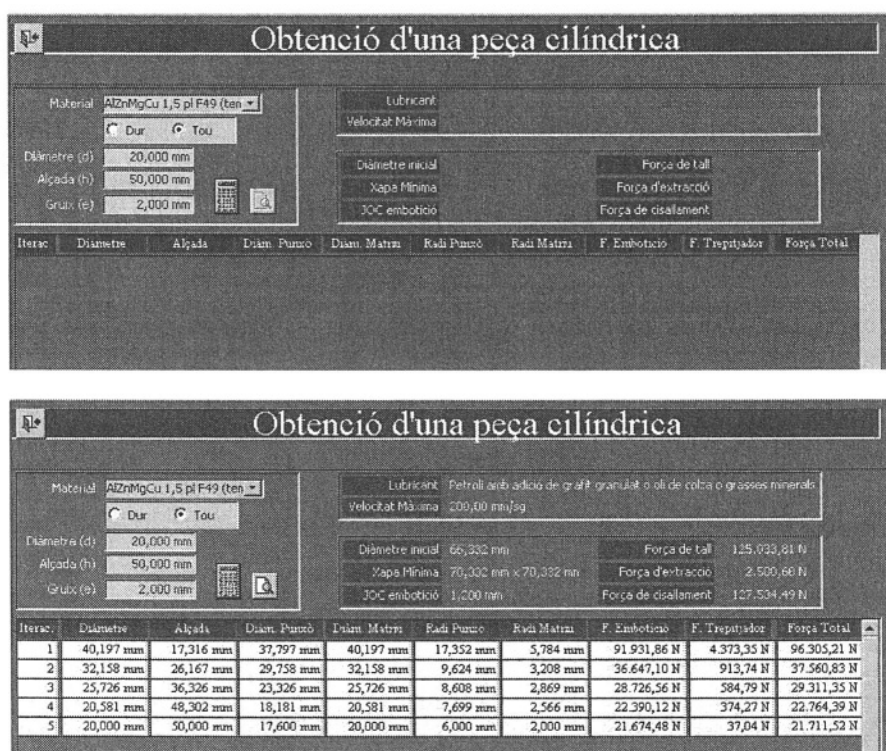
Figure 5: (a) Input screen for Deep drawing of cylindrical parts (up) **(b)** Output screen report (down)

2. Drawing cylindrical parts through ironing. In this type of drawing the side walls of the part are made thinner while the thickness of the base is maintained. Because the interior diameter remains constant, after the procedure this thinning results in the part having a height much greater than initially calculated. In this type of drawing we want to know, at each intermediate step, the thickness, the

outside diameter and the height of the part, as well as the diameter of the die and of the punch and the force necessary to carry out the procedure.

3. Drawing sheets by embossing. This type of drawing has been chosen because for some time it has been very commonly used to increase the stiffness of the sheets or to obtain a more aesthetically personalized sheet. It consists in provoking a physical deformation, simple form drawings repeated along the edge of the sheet and no more than 1 cm deep. In this type of drawing one is expected to know the pressure necessary to create one figure and, at the same time, to know the total force necessary to carry out the entire embossing procedure.

4 Results

The tool can be tested with the next example and it will be used to elaborate the report of the part that it is supposed to be manufactured (Figure 6). It is about a cylinder which final geometry has 20mm of outer diameter and 50mm of height. The sheet thickness is 2mm. The material characteristics of the sheet are the following AlZnMgCu 1,5 pl F49 (cool hardened), DIN code 3437571. And it is decided to be manufactured using a deep drawing operation.

Figure 6: Deep drawn part

   Once starting data are known, the steps that must be followed are:

1. Revise the rules which were grouped round: Design, Material and Process. (Figure 1).
2. If the material of the cylinder, AlZnMgCu 1,5 pl F49 (cool hardened), has not been introduced in the database of the application, the application allows you to jump to materials database by the means of a link from Material rules group (second button in Figure 3). The material will be introduced then through the material maintenance form (Figure 4) filling the required fields as recommended lubrication or yield strength e.g.
3. Finally, the selected part has to be manufactured by a deep drawing operation. So, it is from Process rules group where the operation will be chosen and it will be able to access to the calculations screen. Deep drawing of a cylindrical part corresponds to the third button in Figure 3. A calculation screen for that operation will be opened by clicking on that button (Figure 5a). In that point, the material field must be chosen if there already exists in the database; if there does not, the previous step 2 must be carried out. Following geometrical features of the part have to be defined; these features depend on the operation chosen and for the part in Figure 6 they will be: diameter, height and thickness. If all this information is accessed to calculation application it will fit enough to click on calculator icon. An output screen report (Figure 5b) will
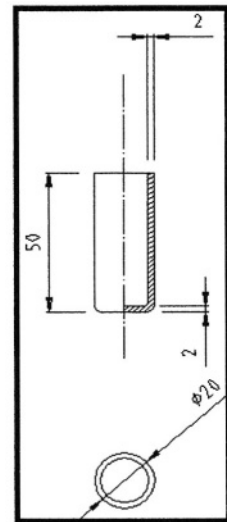
be obtained. On the header it will provide data related to material (lubrication and maximum speed) and data related to the operation (blank diameter, minimum thickness, clearance, cutting and shearing force and extraction force). For a deep drawing operation it also provides the number of needed iterations to manufacture the part. The values of the next parameters are given for each intermediate iterance: part height and diameter, punch and die radius, deep drawing force, blank holder force and final force. Clicking on button next calculator icon will be enough for turning the screen report in a paper report or printing format (Figure 7).

Resultats Cilíndric

Material :	AlZnMgCu 1,5 pl F49 (templat en	Lubricant :	Petroli amb adició de grafit granulat o oli de c
Tipus :	TOU	Velocitat màx. :	200,00 mm/sg
Diàmetre :	20,000 mm	Diàmetre inicial:	66,332 mm
Alçada :	50,000 mm	Joc Embotició:	1,200 mm
Gruix :	2,000 mm	Xapa mínima :	70,332 mm x 70,332 mm

Força Tall:	125.033,81 N
Força Extracció :	2.500,68 N
Força Cisallament:	127.534,49 N

Iter	Diàmetre	Alçada	Diàm.Punxó	Diàm.Matriu	Radi Punxó	Radi Matriu	F.Embotició	? Trepitjador	F.Total
1	40,197 mm	17,316 mm	37,797 mm	40,197 mm	17,352 mm	5,784 mm	91.931,86 N	4.373,35 N	96.305,21 N
2	32,158 mm	26,167 mm	29,758 mm	32,158 mm	9,624 mm	3,208 mm	36.647,10 N	913,74 N	37.560,83 N
3	25,726 mm	36,326 mm	23,326 mm	25,726 mm	8,608 mm	2,869 mm	28.726,56 N	584,79 N	29.311,35 N
4	20,581 mm	48,302 mm	18,181 mm	20,581 mm	7,699 mm	2,566 mm	22.390,12 N	374,27 N	22.764,39 N
5	20,000 mm	50,000 mm	17,600 mm	20,000 mm	6,000 mm	2,000 mm	21.674,48 N	37,04 N	21.711,52 N

Figure 7: Output paper report

The application of calculations together with the database connects important parameters from Design, Material and Process. The tool has integrated the most usual relationships among these rules that have been classified in the three groups and that govern the deep drawing process. The reports can be quickly prepared by the tool. And the application allows you to estimate material changes easily and the suitabitility of a press machine of the layout because the drawing force needed is provided.

5 Conclusions

The tool offers two important advantages. First, it offers skilled or unskilled/inexperienced designers guidance by not forgetting the most important details for matching the desired part features with the best or preferred manufacturing process features from the beginning of the product life cycle. Secondly, the ease of using the format allows it to be part of a platform (Internet, for instance) where it can be consulted by designers from any discipline (research, industry or education).

The system developed is user-friendly and implemented in a common format. For this reason it was developed in an Access database, on a PowerPoint platform and it incorporates VisualBasic applications.

It is interesting to consider Concurrent Engineering as having two sides: one soft and the other hard. The soft side deals with cultural and attitudinal changes while the hard side is concerned with the tools and the hardware required to implement the concept. Traditionally, the research concentrating on the hard side has been the Computer Integration Manufacturing concept.

The goal of this work was the development of a computer tool to help process planning for sheet metal processing (focused on the drawing process). It can help engineers decide on manufacturing parameters such as blank dimension and the forces needed for the process of drawing sheet metal. It is based on knowledge obtained from collaboration with enterprises.

References

1. ASM Handbook Volume 14 "Forging and Forming"
2. Choi, J.C., Kim, B.M., Cho, H.Y, Kim, C., Kim, J.H. (1998) An integrated CAD system for the blanking of irregular-shape sheet metal products. Journal of Materials Processing Technology: 83 (2) 84-97.
3. De Vries, J. (1996) "Integrated Process Planning for small batch manufacturing of sheet metal components" Ed. University of Twente
4. Gao, J.X., Tang, Y.S., Sharma, K. (2000) A feature model editor and process planning system for sheet metal products. Journal of Materials Processing Technology, 107 (1) 88-95
5. Granville C., Computer-Aided Process Planning (1995) Computer-Aided Engineering: 8 (8) 46-48.
6. Jagirdar, R., Jain, V.K., Batra, J.L. (2001) Characterization and identification of forming features 3-D for sheet metal components. International Journal of Machine Tools and Manufacture, 41 (9) 1295-1322.
7. Radhakrishnan, R., Amsalu., A., Kamran, M., Nnaji, B.O. (1996) Design rule checker for sheet metal components using medial axis transformation and geometric reasoning. Journal of Manufacturing Systems 15 (3) 179-189.
8. Sing, W.M., Rao, K. P., (1997) Knowledge based process lay-out system for axisymmetrical deep drawing using decision tables. Computers Industrial Engineering, 32 (2)299-319.
9. Singh, R., Sekhon, G.S. (2002) An intelligent system for optimal selection of dies and tool for sheet metal operations. Journal of Engineering Manufacture., 217 821-828.
10. Steudel H. (1984). Past, present and future the CAPP systems. International Journal of Production Research, 22 (2) 253-266.
11. Wick, C., Veilleux R.F. (1990) Tool and Manufacturing Engineers' Handbook. Volume 2: Forming. SME. New York.

The Method of Unified Internet-Based Communication for Manufacturing Companies

Martin Ota, Ivan Jelínek

Czech Technical University in Prague, Department of Computer Science and Engineering,
Praha 2, 131 25 Karlovo nám. 13, Czech Republic
{otam, jelinek}@fel.cvut.cz

Abstract. In manufacturing companies there is a wide spectrum of software systems that operate with product data. It seems obvious that the interoperability and ability of data exchange, based on native formats of each system, is not possible. Fortunately there are a lot of data formats, such as STEP, VRML, XML-based and many others that help to solve the problem. However the communication and the utilization of communication channels are not so much unified and systematically used. We assume that the problem could be solved by the simple and unified communication method, based on the modern internet-based approach. Its development is the aim of our research. This method should enrich the existing methods of communication, not replace them. Our method is based on TCP/IP protocols and XML web services.

1 Introduction

As everybody knows, there is a strong trend toward software integration, under the umbrella of EAI (Enterprise Application Integration) activity [1]. It means that all software subsystems of an organization can be used as one interconnected system that uses one global shared database. Also the integration of manufacturing enterprises would have to be realized in accordance with EAI principles. However the manufacturing field is special due to the existence of a product. Both virtual and physical products differ especially: data gathering from the traditionally designed previous versions; product designing, dimensioning and debugging; the manufacturing of prototypes/products; measurement and data gathering; lifecycle support; and th0e process of innovation. Thus a wide spectrum of software systems is used that operate with CAD (Computer Aided Design) data, which means systems operating with data that centre round the manufactured products. CAD systems are the well-known representatives, however the design process encompasses more than CAD tools, which are used only for drawing and/or modeling. There are other CAx systems, such as CAE (Computer Aided Engineering) tools, CAM (Computer Aided Manufacturing) tools and many others. There is an activity, called CIM (Computer Integrated Manufacturing), which tries to roof the utilization of the aforementioned systems. The integration of design and manufacturing processes by computer systems is the goal of CIM. This idea is nothing new – the first concepts of CIM were published in 1973 and first used in 1984 [2]. Since the field of manufacturing enterprises was not mature enough to

migrate towards CIM, this approach was almost forgotten. Nevertheless nowadays the climate in the manufacturing sphere is much more open for information technologies, resulting in a mature climate for the deployment of CIM ideas, and the CIM term is being restored.

Due to the expansion of the utilization of CAx technologies in the 1990's, the need for some CAD data management has arisen. It caused the development of PDM (Product Data Management) systems that tries to systematize and manage the product oriented data [3]. PDM stores the data and manage the relationships between them – usually through a relational database subsystem. CAD data are not being directly changed by these systems. The classification of data helps to make them accessible for other processes. The idea of the utilization of the technical data of a product in other enterprise spheres (such as a managerial one) is only logical consequence. It is obvious that each enterprise is equipped by some complex information system. The frequent goal of present enterprise information systems is to integrate whole software subsystems (including Internet portals) and computer aided business processes. The portals are used as a gateway for information obtaining and/or application using.

The following list summarizes more frequent software systems that are processing the product oriented data: CAx – Computer Aided processes (CAD, CAM, CAE, ...), PDM – Product Data Management systems, PLM – Product Lifecycle Management systems, ERP/SCM – Enterprise Resource Planning / Supply Chain Management systems, CRM – Customer Relationship Management systems, DW – Data Warehouses and Data Warehouse Pumps, IS – Enterprise Information Systems, EIP – Enterprise Information Portals, and EAP – Enterprise Application Portals.

The crucial problems, which have not been satisfactorily solved till now, are how to interconnect these software systems and how to make data produced by one system accessible to each other.

2   The Problem of Heterogeneity

Each CAx system usually uses its own internal file format with an unknown representation of data. A typical example is the DWG file format of AutoCAD. This format is incompatible even across the AutoCAD releases. So, each enterprise system is based on different data representation and native file format. In accordance with the demand of software interoperability in CIM-type enterprises the systems have to be able to export data in some intermediary format (such as DXF, IGES, and many others) that other systems are able to import, as it is shown in Fig 1. There is a big drawback to this scenario: the user of system B, who requests data, either must be a user of system A as well (he/she must be able to open correct file and export it to intermediary format) or the other user of system A must be present. The figure 2 depicts a typical scenario of product design process.

If the data are managed by the PDM system, the native formats of each system will usually be stored and managed. Since native formats differ from intermediary formats used for export-import, the drawback of export-import scenario is not eliminated. If other systems, such as PLM or ERP, are implemented, the problem will be similar. The export-import is not the sole problem of PDM – there are the others: almost

every CAD user has to become PDM user; it is not only data management and meta-database – overall information is extracted (redundancy); inaccessibility of information outside extracted selection; and the problem of the synchronization of changes (weak synchronization + redundancy = inconsistency). Previous text is focused on generalized problems and on the ideas of presently used integration. The following list tries to generalize the problems of real integrated solutions: the developed ways of integration are not universal; the development of interfaces and software bridges repeats; imperfect integration (it is loss-making); poor work efficiency; and badly scalable enterprise infrastructure.
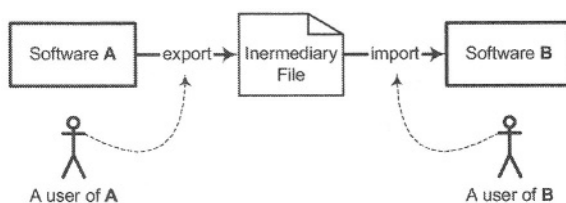
Fig. 1. Export-import Scenario
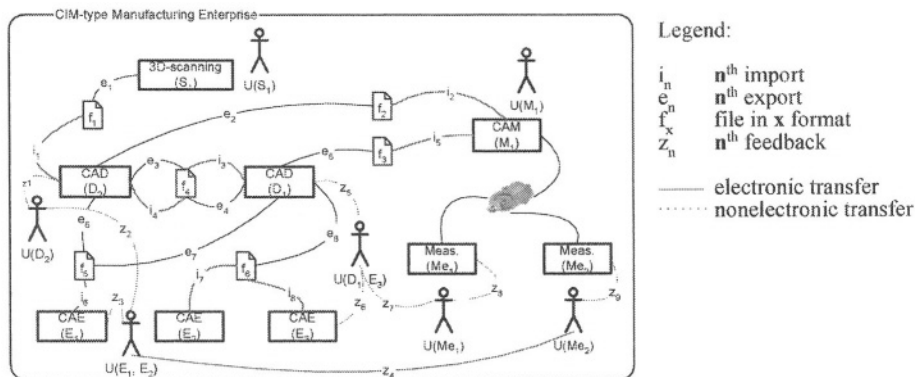
Fig. 2. The scenario of the CIM type design process

3   Integration Trends

The problems discussed previously initiated a lot of activities that deal with them. There are some concepts how to implement the integration mechanisms in a time when software systems are designed. The trends of EAI head towards the utilization of integration brokers and application servers. However these ways are not so suitable for the integration of existing CAx systems and moreover those are tightly coupled with a used platform (for example with used integration broker, such as MS BizTalk Server).

A considerable integration way calls STEP (Standard for the Exchange of Product Model Data) and is standardized by ISO 10303 [4]. The standard enables to define entities by the EXPRESS language. The real objects can be described by this definitions and the description can be serialized to the platform independent STEP physical file, which is based on text format. Those files can be used as intermediary file in export-import scenario. STEP defines the methods of implementation based on active file exchange, shared databases and intelligent knowledge based systems. There is a new draft of ISO 10303 Part 27 that defines Java Language Binding to the SDAI (STEP Data Access Interface). We believe that STEP is perspective standard, however even the STEP is not without problems. This set of standards is too massive, so the implementations of STEP are problematic. There is a lot of material that must be studied, and there are a lot of rules that must be kept. The full implementation of this standard is neither easy nor cheap. This problem is connected to the evolution of STEP – Part 27 illustrates it. Java is a very popular language, especially in the field of software integration. This language has been widely used for several years. However STEP has not been able to respond correctly till now. For example there is C# language, which is the current competitor of Java, without any STEP support. Thus we suppose that a lot of STEP parts are dependent on particular technologies, thus STEP can not keep abreast.

There are some more problems with STEP than complexity and dependency. A considerable one concerns efficiency. The STEP based integration is often realized by text file format that is not effective. We suppose that this way of data transferring is suitable for so-called chunky communication, but not for so-called chatty communication. If some product of enterprise is designed and the export-import between two CAD systems occurs for example several times per hour, it will have to be supported by the most effective way possible. Vice versa, if the data are stored for long time, it will be possible that the software equipment of enterprise will be changed. In this case the STEP seems to be the best solution – thanks to the independency of standardized STEP physical files.

4   A Unified Communication Model

We believe that for so-called chatty communication a very simple mechanism could be developed that would be independent enough. We suppose that Internet and its mechanisms are really omnipresent, thus the main goal of our research is to develop unified communication model that will be dependent only on Internet [5].

Our proposed model of communication is based on the TCP/IP suite of protocols. The communication is stateless, simple Request – Reply. Transferred data can be represented as a primitive (basic) format, such as text string, real number and etc., or as a known complex format, such as STEP, IGES, VRML, etc. It means our method is above all the channel of communication. The basic scenario of communication is peer-to-peer and is similar to the chat of two collaborating people. It means there is neither master nor slave and any software system can be in the same role as another one. There is an example of that communication in Fig. 3.
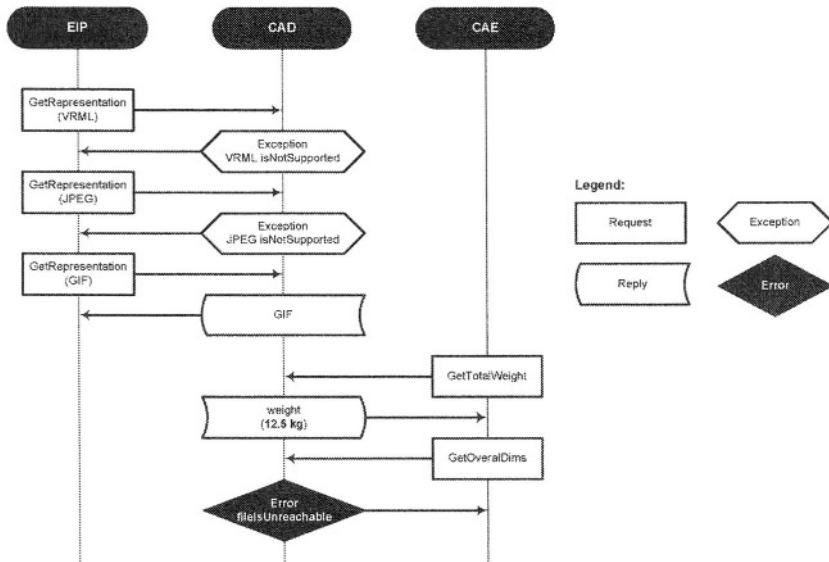
Fig. 3. The scenario of proposed communication

If software systems want to communicate with the other ones through the proposed mechanism, the interface that the model defines will have to be implemented. The main benefit of the model is that there is just one interface that can be used for communication with each system. It would seem that some changes in each system are necessary. And it could be a problem, especially for CAx systems. However these systems are designed as quite open, so there are mechanisms how to implement an interface by third-party programmers. Any other enterprise subsystem can implement this interface too. So, the examples of utilization are really various. It can be used by two different CAD systems for exchanging the models of virtual product. The product data can be transferred to the PDM system by this mechanism. When EIP needs to render picture of some product, it can apply CAD module for visualized data.

The mechanism allows software systems to chat without human control. This chat consists of *requests* and *replies*. In the case of any problem the *exception* or *error* is returned instead of expected reply. The exception means that the requested system is not able to make the correct reply (for example, requested data format is not supported). The error signalizes the problem in communication (for example, the data file is damaged during the communication). The requests and replies can be classified into three groups, as shown in Fig. 4. The simple requests/replies use primitive date types, such as numeric and text fields. The compound ones transfer lists, such as a list of supported formats. The wrapping requests/replies use some complex formats, such as STEP physical file.

Our system consists of two levels. As it was noted above, the basic one is based on the TCP/IP suite of protocols. In the case of the use of this layer the each system,
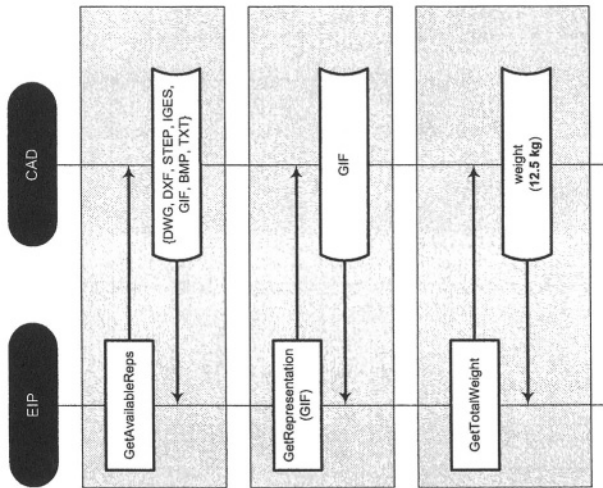
Fig. 4. The types of requests/replies

which is connected to the communication strategy, must be equipped by an interface. The interface must be able to respond to an event on specific port, even in the moment when the system does not operate. A whole strategy of communication between these interfaces is similar to HTTP 1.0. It is application protocol, as well, that uses TCP and IP protocols for data transmission and addressing. The communication is stateless however a structure of transmitted data, which is not based on text but on binary format, is different. The final form of data in TCP datagrams is not finished yet – it will be published later.

The second level is based on XML web services. It means, XML, SOAP, WSDL and UDDI technologies [6]. It can simplify the utilization of the communication mechanism in Java and/or .Net based systems, which are more frequent distributed platforms of modern enterprise IS. The principle is the same as a utilization of TCP/IP based layer. Ever communication system must be equipped by an interface, which however does not directly listen in on specific port, but is based on some web service protocol (usually HTTP). Besides, this way demands that each computer with systems that support this service to be equipped by a web-server, which carries out the web service working. The next difference is the factual communication is realized by invoking of XML web service functions. The set of functions is also not definitive, however it is evident that will be based on basic data types, in order to platform independency (such as Microsoft .Net).

These levels are optional – the whole integration of enterprise can be based either on TCP/IP or on XML web services. It is possible to implement a mixed model that uses both TCP/IP and XML web services levels. This solution must be enriched by a software bridge. This bridge translates requests and/or replies between TCP/IP and XML web services levels, and will be defined by proposed model.

The purpose of the proposed model is to solve the problem of data exchange and its automation. A typical scenario of how to use this model would be for example the enrichment of the PDM system by *Open With* functionality, which allows the selection of alternative software for processing of selected file. In this case PDM calls the

interface of destination system that provides a list of supported formats and its priorities of use. After that the interface of the system where the file was created is called, again with the query for supported formats. When a suitable format is found the interface of source system is invoked for converting. It launches a specific system or its proper component that performs the conversion and passes the file to PDM which is consequently able to pass the data to the destination system. A similar scenario could be a direct communication between two CAD systems with extended user interface for this activity.

At the moment we perform testing with the following software: AutoCAD, Inventor, MicroStation, own PDM system, IS and web portal. The extensions of software by specific interfaces were successfully realized and data exchange was automated. As a serious problem with these systems appears the quality of conversions to an intermediary format. The information gets lost and distortions occur.

5   Relation to STEP

STEP was mentioned as a powerful standard for the integration of enterprise software based on chunky communication. The proposed unified communication model is designed for chatty communication. It is necessary to define the relation between these two approaches. The unified communication model is the method of the communication mechanism. It can use STEP and it can be used by STEP.

The first possibility how to use these two approaches together is the utilization of STEP wrapped by the described wrapping requests/replies. It means that any systems are allowed to communicate through STEP, probably through STEP physical file, and this communication can be facilitated and especially automated by unified communication model. For example, a short case study where a user would like to import some part of assembly to the Pro/ENGINEER follows. The part is created by Autodesk Mechanical Desktop. The project files are managed by some PDM system. The user selects DWG file, which represents specified part, in the PDM and opens it with Pro/ENGINEER. At this moment the Autodesk Mechanical Desktop is requested (through unified communication model) for the STEP representation of the part. As a replay the wrapped STEP physical file is transferred and imported by Pro/ENGINEER, so the part can be added into the assembly.

The other possibilities are based on SDAI. The unified communication model can be used on the both sides of SDAI interface. It means that the subset of integrated enterprise software systems that are interconnected by the proposed model can behave as enterprise database, and it can be accessible to another subset of systems that utilize the STEP. The inverted topology, where a real database with SDAI is present, is possible. The systems that are integrated by the unified communication model can access this database through SDAI interface. It can be helpful in the situation, where some systems are integrated by STEP and SDAI and the other systems are not suitable for STEP based integration.

The described model integrates enterprise software systems by interconnection. However the model does not define any integrating software component with user interface. What component is selected as the integrated gateway for users depends on

the particular integration strategy. We presume that it usually should be PDM system or some portal solution that should be tightly coupled with the unified communication model.

6 The Support of Lifecycle of the Unified Communication Model

As the practice of the majority of data formats and communication protocols shows, it is necessary to take their evolution into account. Due to the evolution a proposal how to support and control the life cycle of the model is its part (the model should be a "self-maintenance"). We propose the Internet portal centered on the lifecycle of the model. Evolution demands will be collected here and the model will be possibly updated – by some authority – in accordance to these users' requirements. Thus, at the portal, there should be the actual documentation of the model with exact description. This portal solution supposes the authority that will be focused on the support of lifecycle of unified communication model and its maintenance. It could be, for example, a subject at a technical university.

7 Conclusion

We have reviewed the methods of communication among software systems that produce and consume product oriented data. Our investigation has found out that there are a lot of data formats suitable for data exchange, but the communication channels are lacking. We believe the unified communication method, based on the simple and independent mechanisms of Internet, helps to solve the problem of software communication in enterprises. The basic parts and ides of the described model are designed. At the moment time we are refining the final form of TCP/IP and XML web services data transfer. Also we are designing the definition of the draft of the software bridges between TCP/IP and XML web services based layers and between unified communication model and SDAI.

References

1. Linthicum, S., D.: Enterprise Application Integration. Addison-Wesley. 1999.
2. Cheng, W. – Yushun, F. – Deyun, X.: Handbook of Industrial Engineering. 3rd Edition. John Wiley & Sons. 2003.
3. The PDM Information Centre. http://www.pdmic.com/ in January 2004.
4. ISO 10303, Publicly available parts. http://www.nist.gov/sc4/step/parts/ in January 2004.
5. Ota, M. – Jelínek, I.: Information Flow Between CAD and the Rest of an Enterprise. Proceedings of the 17th International Conference on Systems for Automation of Engineering and Research (SAER 2003). Sofia, 2003.
6. Champion, M. – Ferris, C. – Newcomer, E. – Orchard, D.: Web Services Architecture. W3C Working Draft 14 November 2002.

Constructing a Global and Integral Model of Business Management Using a CBR System

Emilio Corchado[1], Juan M. Corchado[2], Lourdes Sáiz[1] and Ana Lara[1]

[1] Department of Civil Engineering,
University of Burgos, Spain.
escorchardo@ubu.es, lsaiz@ubu.es, amlara@ubu.es
[2]Departamento de Informática y Automática,
University of Salamanca, Spain.
corchado@usal.es

Abstract. Knowledge has become the most strategic resource in the new business environment. A case-based reasoning system, which incorporates a novel clustering and retrieval method, has been developed for identifying critical situations in business processes. The proposed method is based on a Cooperative Maximum Likelihood Hebbian Learning model, which can be used to categorize the necessities for the Acquisition, Transfer and Updating of Knowledge of the different departments of a firm. This technique is used as a tool to develop a part of a Global and Integral Model of business Management, which brings about a global improvement in the firm, adding value, flexibility and competitiveness. From this perspective, the model tries to generalise the hypothesis of organizational survival and competitiveness, so that the organisation that is able to identify, strengthen, and use key knowledge will reach a pole position.

1 Introduction

This paper presents the results obtained with a case-based reasoning system (CBR) developed to identify critical situations that allow firms to take decisions about acquisition, transfer and updating processes in knowledge management. In this study, we centre our attention on the problem of knowledge management, from a pragmatic and managerial approach that contemplates, the possibility that knowledge can be classified and organised in order to achieve a better understanding. This issue is based, above all, on understanding the distinctions between transformations in forms of knowledge, starting from an inferior level (data and information) and advancing towards other higher levels, such as knowledge itself and its management, individual, and even organizational responsibilities.

Case-based reasoning (CBR) systems have been successfully used in several domains such as diagnosis, monitoring, prediction, control and planning [9, 10, 11]. CBR systems require adequate retrieval and reuse mechanisms to provide successful results. Such mechanisms need to be consistent with the problem that has to be solved and with the data used to represent the problem domain. A CBR system is a method-

ology used to construct software tools to assist experts in the resolution of problems. The CBR system presented in this paper incorporates a Cooperative Maximum Likelihood Hebbian Learning model (CMLHL) that facilitates the data clustering and indexation and automates the retrieval and adaptation stages of the CBR system. This method is closely related to factor analysis (FA) and exploratory projection pursuit (EPP). It is a neural model based on the Negative Feedback artificial neural network, which has been extended by the combination of two different techniques. Initially by the selection of a proper cost function from a family of them, to identify the right distribution related to the data problem. This method is called Maximum-Likelihood Hebbian learning (MLHL) [3]. Then, lateral connections derived from the Rectified Gaussian Distribution [7] are added to the MLHL architecture [3]. These enforce a greater sparsity in the weight vectors.

This paper reviews the concept of CBR system and outlines the CMLHL model used in its construction. The first prototype of the system has been tested on a multinational group, specialised in the design and production of components for the automotive industry. This initial system is presented and the results obtained are shown.

2 The Problem Solving Model

Case-based reasoning is used to solve problems by adapting solutions that were used to solve similar previous problems [11]. A case is normally composed of a number of attributes that represents a problem and of a solution for that problem. Fig 1. shows the reasoning cycle of a typical CBR system that includes four steps that are cyclically carried out in a sequenced way: retrieve, reuse, revise, and retain [11]. During the retrieval phase, those cases that are most similar to the problem case are recovered from the case-base.
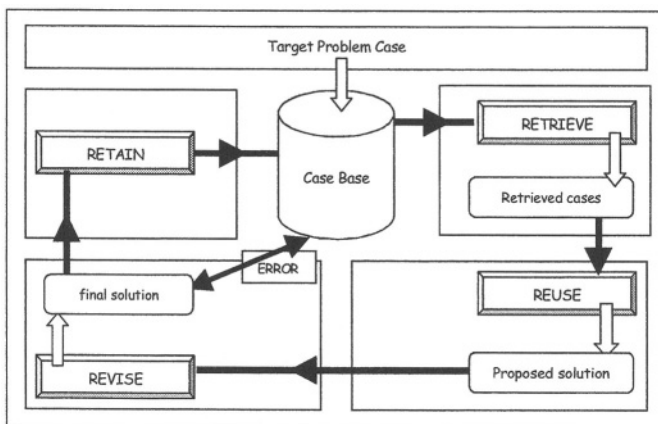
Fig. 1. CBR system reasoning cycle.

The operation of a CBR system involves the adaptation of old solutions to match new experiences, using past cases to explain new situations, using previous experi-

ence to formulate new solutions, or reasoning from precedents to interpret a similar situation. The recovered cases are adapted to generate a possible solution during the reuse stage. The solution is then reviewed and, if appropriate, a new case is created and stored during the retention stage, within the memory. CBR systems update their case-bases and consequently evolve with their environment. Although the CBR systems are tools to assist the decision taken process and they have not been developed to be autonomous, some of their reasoning stages may be automated [8, 9, 10].

The CBR system developed in the framework of this experiment incorporates a CMLHL model that clusters the cases, facilitates the case indexation and automates the retrieval and adaptation stages. Now the CMLHL model is presented and then the proposed CBR system is outlined and evaluated.

3 The Cooperative Architecture

We use the standard Maximum-Likelihood Network [1, 3, 5] but now with a lateral connection (which acts after the feed forward but before the feedback) derived from the Rectified Gaussian Distribution [2, 6, 7] and using the cooperative distribution. Thus we have:

Feedforward: (1)

$$y_i = \sum_{j=1}^{N} W_{ij} x_j, \forall i$$

Lateral Activation Passing: (2)

$$y_i(t+1) = [y_i(t) + \tau(b - Ay)]^+$$

Feedback: (3)

$$e_j = x_j - \sum_{i=1}^{M} W_{ij} y_i,$$

Weight change: (4)

$$\Delta W_{ij} = \eta . y_i . sign(e_j)| e_j |^{p-1}$$

Where:
the parameter τ represents the strength of the lateral connections.
The cooperative distribution in the case of N variables is defined by:

$$A_{ij} = \delta_{ij} + \frac{1}{N} - \frac{4}{N} \cos\left(\frac{2\pi}{N}(i-j)\right) \quad \text{and} \quad (5)$$

$$b_i = 1 \quad (6)$$

where δ_{ij} is the Kronecker delta and i and j represent the identifiers of output neuron.

4 Case Study

The developed system has been tested in a multinational group, leader in the design and production of a great variety of components for the automotive industry. The justification of this choice lies in the fact that the characteristics of its management represent a favourable environment and opportune moment for the introduction of Knowledge Management. There is an undergoing organizational change and the firm faces great growth and expansion, which requires a rapid adaptation to the demands of the sector, with greater resources, imminent transfers and accurate forecasting of knowledge, together with the immediate demand to capitalise on them, to share and to use them within the firm.

The design of the preliminary theoretical model of Knowledge Management shown if Fig. 2 is based on three components: the Organisation -Strategy and People-, Processes -Acquisition, Transfer and Updating of Knowledge- and Technology –Technological Aids-, from which the propositions of the model are defined.

The population sample used came to 277 registries (individuals) that correspond with the "necessities of knowledge" showed by the head of eleven departments of the company studied. This knowledge gathers different stages (knowledge levels) that depict the current situation of each department for the tasks or activities assigned to each department to be successfully accomplished. Also, it has been possible to obtain valuable data on the degree of importance for the company of the gathered knowledge.

This way, it is possible to identify the lack of the knowledge that it is necessary to perform the activity, so as to make the right decision on its acquisition in terms of how it is acquired, or what is the cost or time needed. In the same way, it is possible to specify the knowledge possessed which is not comprehensively employed, either because the person does not use it in its entirely or because it has additional value and potential use, for other departments. Furthermore, it is possible to include the analysis corresponding to the necessary evolution of the present knowledge to detect new knowledge, to eliminate the obsolete one and to validate new necessities, among others.

Then in this particular problem, the cases are composed of several attributes, representing the state of the enterprise, and the solution is an attribute that represents the situation of the firm and the degree of information required to improve its management process. The data was register by observations, questionnaires and personal interviews to the employees of the studied company. Figure 3 shows the results obtained in this study. The case-base stores 277 cases representing previous states of the firm together with their associated risk levels. Cases are clustered and indexed using the CMLHL model, as can be seen in Figure 3.a. The retrieval and reuse stage are carried out applying equations 1 to 4. As a result of the application of these equations to a given problem case (a new situation of the firm), we obtain information about its risk level, which may be one of the stages presented in Figure 3.b. Figure 3.b is obtained by an analysis of the results obtained and shown in Fig. 3a. To see the relation between Fig3.a and Fig3.b, we have kept the same nomenclature. The CBR system is comparing a new situation with previously evaluated ones and letting us know at which group the present situation belongs. The revision is carries out manually in this

first prototype and ones a new case is evaluated, it is incorporated to the case-base of the CBR system during the retain stage (learning step).

Acquisition process
* To identify the Lacking Knowledge and their characteristics of Creation value What?
* To analyze the way of getting it Where?
* To quantify Cost Acquisition How much?
* To analyze Temporary Restrictions When?

· To Acquire
· To Transfer / to Prepare
· To Upgrade

Proposal for the Creation, Generation and Captures of the Knowledge

Transfer process
* To identify Experts Who?
*To determine other uses of the Knowledge Which their value is?
*To document the knowledge (normalized format and simple) How?
*To consent to the knowledge Who needs it?
* To identify Experts Who?
*To determine other uses of the Knowledge Which their value is?
*To document the knowledge (normalized format and simple) How?
To consent to the knowledge Who needs it?

· To Transfer / to Prepare
· To Upgrade

Proposal for the Organization, Sharing, Formalization and Use of the Knowledge

Upgrade process
* To analyze the evolution of the knowledge for the creation of value
* To validate the necessity of Knowledge
* To eliminate Obsolete Knowledge
* To detect new Knowledge

·To Upgrade

Proposal for the Detection, Advanced, Elimination and Refinement of the Knowledge

Fig. 2. Shows the theoretical model of Knowledge Management.

Fig.3.a shows the result of CMLHL clustering and indexing process on the case-base. The projection identifies separated clusters (clouds), each of then has been labeled. We have identified mainly 9 clusters or clouds. Fig.3b is a graphical representation of Fig.3a.
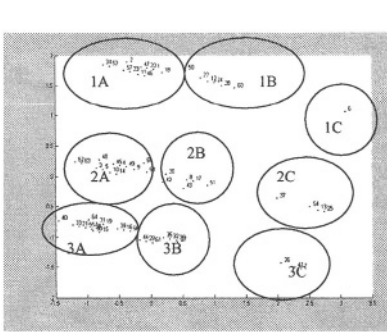
Fig. 3.a: CMLHL on the real data.   Fig. 3.b: Results Representation.
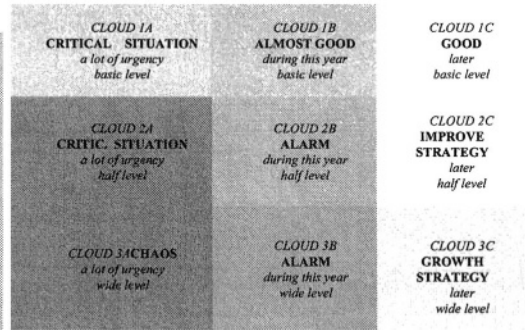
5 Results and Conclusions

The system presented above is an assistant tool. It has helped us to identify, in an automated way, the risk states at which a firm may be and to understand more about this business management process. In terms of firm type, the points of cloud 1C are related to a GOOD SITUATION. The firm is in this place because the level of knowledge required is low and therefore the acquisition of knowledge is not a priority. Also the fact that only one point (point 6 in Fig. 3a.) appears underlines the fact that the company only has to acquire knowledge in one specific area.

In a contrasting case, in the area occupied by the clouds labelled as 3A, there is a lot of urgency to acquire knowledge at a wide level. This area is called "CHAOS". In a similar way, in the area occupied by clouds 1A and 2A there is a need to acquire knowledge urgently at a half or basic level. It could be that in these cases there is a holding of knowledge that can put the company in a CRITICAL SITUATION, since it may depend on the concession of new projects, the incorporation of new clients and all those parameters that somehow help to generate activity within in the firm.

The area occupied by the points of the cloud 2C outlines the possibility to acquire knowledge at a later stage but in one period but at a half level. This could mean an IMPROVE STRATEGY in the firm, where it needs to improve in what it already possesses. However, cloud 3C represents the situation that the firm has to acquire the knowledge later but at a wide level. This means that the company should think about the idea of enlarging and growing, both in terms of new processes, and new products. This is: GROWTH STRATEGY. The points corresponding to area 1B are related to an ALMOST GOOD area, because the knowledge is needed urgently at a basic level. Cloud 2B and 3B identifies an ALARM area, because there is not urgency and the level needed is half.

The initial results show that the presented system is a reliable tool to identify critical situations that allow firms to take decisions about acquisition, transfer and updating processes about knowledge management. Other methods, such as Self Organizing Maps have been applied and have provided less accurate results, from the point of view of the firm management experts. CMLHL provides more sparse projections than

the others methods [6, 12] and captures some type of global ordering in the data set. A second prototype of this system is under construction. It will be integrated with in the distributed management system of the enterprise and it will deal with more information about the firm.

Acknowledgements

References

1. E. Corchado and C. Fyfe, Orientation Selection Using Maximum Likelihood Hebbian Learning, International Journal of Knowledge-Based Intelligent Engineering Systems Volume 7 Number 2, ISSN: 1327-2314. Brighton, United Kingdom. April (2003).
2. E. Corchado, Y. Han, C. Fyfe. Structuring global responses of local filters using lateral connections. J. Exp. Theor. Artif. Intell. 15(4): 473-487 (2003)
3. E. Corchado, D. MacDonald, and C. Fyfe, Maximum and Minimum Likelihood Hebbian Learning for Exploratory Projection Pursuit, Data mining and Knowledge Discovery, Kluwer Academic Publishing, (In press)
4. J. Friedman and J. Tukey. A Projection Pursuit Algorithm for Exploratory Data Analysis. IEEE Transaction on Computers, (23): 881-890. (1974).
5. C. Fyfe, and E. Corchado, Maximum Likelihood Hebbian Rules. European Symposium on Artificial Neural Networks. (2002)
6. E. Corchado, C. Fyfe: Connectionist Techniques for the Identification and Suppression of Interfering Underlying Factors. International Journal of Pattern Recognition and Artificial Intelligence. Vol. 17, No 8 (2003) 1447-1466.
7. H.S. Seung, N.D. Socci, and D. Lee, The Rectified Gaussian Distribution, Advances in Neural Information Processing Systems, 10. 350 (1998).
8. J. M. Corchado and J. Aiken (2002) Hybrid Artificial Intelligence Methods in Oceanographic Forecasting Models. IEEE SMC Transactions Part C. Vol. 32, No.4. pp. 307-313.
9. J. M. Corchado and B.Lees (2001) A hybrid case-based model for forecasting. Applied Artificial Intelligence: An International Journal Vol 15, no. 2, pp 105-127.
10. S. K.Pal, T. S. Dillon and D. S. Yeung (2000) Soft Computing in Case-based Reasoning. (eds.). Springer Verlag, London, U.K.
11. I. Watson and F. Marir (1994) Case-Based Reasoning: A Review. Cambridge University Press, 1994. The knowledge Engineering Review. Vol. 9. N°3.
12. T. Peña, L. Joyanes, M. A Manzanedo, L. Sáiz, Knowledge Management and measuring intellectual capital in business organisations, Soft Computing (SOCO'2001). UK

'Under Construction': The Potential of a Web Based Application in Managing and Maintaining Large Area Urban Modelling

John Counsell

Faculty of the Built Environment, University of the West of England, Bristol, BS16 1QY,
United Kingdom
John.Counsell@uwe.ac.uk

Abstract. Staff in the Faculty of the Built Environment at the University of the West of England (UWE) have been engaged in 3D modelling urban areas since 1984. In the UK it will be mandatory that all local planning authorities make much of their data available on-line within the next two or three years. A broader 'VR across the Web' based involvement in this activity has been advocated. Recent exploration of a web based application for collaborative work has enabled analysis of some of the necessary functions of a collaborative on-line repository for managing and maintaining large area urban modelling. Using this as a basis a prototype repository for such urban modelling tasks has been tested with on-line remote access. Interestingly the same web application framework is also proving effective in a broad range of web based collaborative activities from education and learning through to distributed research projects.

1 Introduction

Staff in the Faculty of the Built Environment at the University of the West of England (UWE) have been engaged in 3D modelling of buildings and urban areas since 1984. These models have been used for applications ranging from the automatic co-generation of visualisation, drawings and schedules to Virtual Reality (VR) and the Web. Since 1984 a number of different Computer Aided Architectural Design (CAAD) systems have been used to create these models, some in succession to others, some in parallel with translation from one to another because each is easier to use in one sphere of the whole task than another. Such heterogeneous models may be created independently, even to different scales and standards, however this is sufficiently difficult to manage in practice to justify a common underlying co-ordinating geometric structure or primary model to which all relate or from which all are initially generated. UWE have since explored the use of an underlying geographic information system to support this primary model. The visible and interactively explorable aspects of the model are output in Virtual Reality Modelling Language (VRML), which is browsable using plugins on the Web. While fully 3D spatial analytical tools in GIS would be desirable, and currently available commercial GIS packages are still presented as two-dimensional and map-based, 3D data can be usefully stored and searched within them.

One means of reducing the total cost of use of such models is to broaden their appeal and thus spread the cost of initial creation and subsequent amendment and use across a wider range of applications and participants. Designing a building or development has been described as fundamentally a collaborative, interdisciplinary, geographically distributed multimedia activity.[1] If this collaborative digital multimedia activity is integrated and disseminated on-line, and encompasses a large enough urban area, it may provide the context and constraints for future development and serve to inform and engage the public. In the UK it will be mandatory that all local planning authorities make much of this data available on-line within the next two or three years. A broader 'VR across the Web' based involvement in this activity has been advocated. Recent exploration of a web based application for collaborative work has enabled analysis of some of the necessary functions of a collaborative on-line repository for managing and maintaining large area urban modelling. Using this as a basis a prototype repository for such urban modelling tasks has been tested with on-line remote access. Interestingly the same web application framework is also proving effective in a broad range of web based collaborative activities from education and learning through to distributed research projects.

FBE/UWE modelled part of Bristol for a Virtual Reality (VR) experience to demonstrate millennium landmark proposals. FBE/UWE later modelled the environs of the Tower of London to support bids for funding and to provide the context for judging the visual impact of iterative design development. Data conversion and amalgamation from all the diverse sources was the major impediment to effective group working to create the models. Initial work focused on using a Geographic Information System, (GIS) to assist retrieving all the appropriate data that described the part of the model under creation. It was possible to predict that management of many historic part models stepping back through time, allowing for different expert interpretations to co-exist, would be in itself a major task requiring a spatial database (GIS). Current work is now focused on enabling this approach via the Web. This is beginning to realise the potential for use of this process for asynchronous group modelling or updating along the lines of a collaborative virtual design studio and planning information system.

2   CAAD Context Models, and the Bristol Model

In 1995 FBE/UWE received a commission to model part of Bristol to create a VR experience to demonstrate the millennium proposals to the Commissioners, in conjunction with Bristol 2000, Bristol City, Division Ltd. and Aardman Animations.[2] Keeping the models up to date since, as an accurate reflection of changes on the ground, is a major data management problem. Piecing in new CAAD models received from Architectural Practices to visualise them in context as part of the planning negotiation process has often taken staff at Bristol City several days of work for each instance. Because the model is so complex and so proprietary the Bristol City staff still operate as a specialist visualisation bureau service. This paper argues that this process could be better handled by devolving the responsibility and the tools to the practices concerned via the Web.

2.1   The Tower of London Models

Historic Royal Palaces (HRP) commissioned FBE/UWE in 1996 to model the environs of the Tower of London to create illustrative material to support bids for funding to the Heritage Lottery Commission.[3] The model was then intended to provide the context for judging the visual impact of each stage of the increasingly detailed development and refinement of the designs. Two models were created, an as proposed and an as existing model. Both were modelled in 3D down to street furniture, railings and kerbs. The two shared many common elements and were in effect two different part models with a common core. A wide range of archeological data was examined to later model the various historic developments of the site. This included borehole data to enable reconstruction of the successive ground levels, with archaeological records from digs from which the existence and form of demolished or altered buildings could be projected. Management of many more historic part models stepping back through time, while allowing also for models of different expert interpretations to co-exist, derived from and referenced to the same archaeological data, was predicted to be a major task requiring an underlying spatial data management system. In addition to the issues caused by data from disparate sources and by fast track collaborative working, it proved very time-consuming, lacking spatial database tools, to sift through all the possible sources of data to discover those relevant to a specific part of the project. There was a real cost in the retrieval and marriage of data from diverse sources, and a further issue as to how such models might be used in practice as the visual expression of a management system. Collaborative assembly, modification and management of two such linked models and their associated elements using the file and data management tools in Autocad and 3DS Max alone proved difficult. Collaborative working on the model also highlighted the difficulties of managing the long transaction times during which parts of the model were being amended or enhanced.

2.2   Issues in Optimising CAAD Modelling to Operate in VR

Subsequent work at FBE/UWE focused on the translation and simplification of the previous 3DS Max format Models into VRML for interactive use via web browsers. However the triangular mesh based models that resulted from the translation process created file sizes in VRML that were far too large for effective interactive exploration in a browser and proved very difficult to optimise or simplify to a lower level of detail. This is still an issue with models that emanate from architectural practices and another argument for devolving responsibility for insertion to the practices themselves. Since then work at FBE/UWE has concentrated on generating optimised VRML models from GIS (providing embryonic spatial management tools) and on interrelating the VR and GIS 'views'. A recent project that was carried out using the Internet (a commercial consultancy project for three dimensional virtual yellow pages urban web sites) would have benefited from a web based management system for the groupwork process, and to manage the 'checked out' sets of data. This has now become the focus of study.
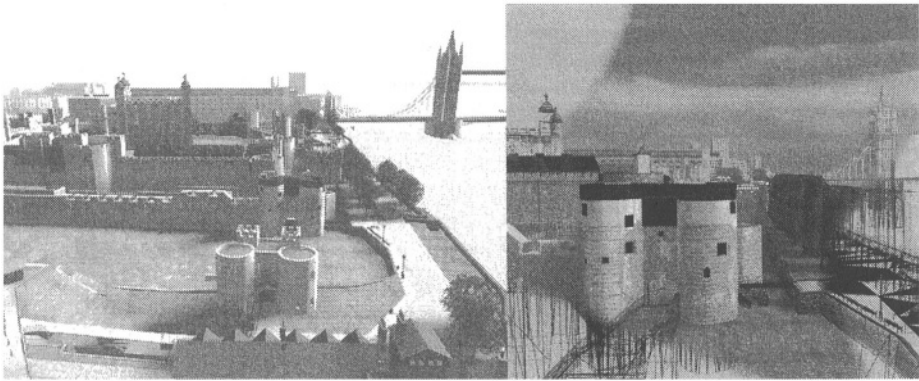
Fig. 1. The Tower of London CAAD Model

2.3   Groupwork Distributed in Time and Place

The cost of keeping CAAD based large area urban models up to date and in continued use justifies every effort to broaden applications and access. A bureau service such as that operated by Bristol City is an expensive resource, which yet at peak demand becomes a bottleneck. Broader access requires lower access costs for interaction and updating combined with the ease of distribution offered by the Web. Several subsequent GIS based VR projects at FBE/UWE and elsewhere have shown that it is practicable for a group working asynchronously to collaborate in creating and maintaining a large area urban model and that significant CAAD expertise is not required. In the UK it will be mandatory that all local planning authorities make much of their planning information available online within the next two or three years. Smith argued for a broader VR across the Web based involvement in this activity so that it 'should be both usable and attractive to the public, the planner, the private sector and the political representatives involved in the planning process. A system should offer collaborative group interaction, with groups deciding and acting together to plan an environment for the good of the whole'.[4] Similar recent arguments for community engaged planning are put forward by Hamilton et al,[5] who have consequently developed an interlinked GIS and VR environment, where changes in either update the other.[6]

2.4   A Lack of Standards for Integrating Modelling in Existing Urban Contexts

Bourdakis argued that coordination of different models or part models is sufficiently difficult to manage in practice to justify a common unifying geometric structure or primary model, to which all relate or from which all are initially generated.[7] CASA started by defining a consistent high level of detail for the whole of their Bath City model and now generate reduced level of detail part models or 'views' from it. However an alternative, more 'lazy and evolutionary', approach may be to model the

whole at a lower level of detail and then to introduce pockets of higher detail as these become available from CAAD modelling or as debate and interactive use define a demand for more detail at that location. This would accord with the view that modelling and updating take place over a long period and that software, bandwidth, standards and detail will change over that time, rendering any fixed level of detail potentially obsolete. There is still not sufficient control of the level of detail nor ease of reconciliation of different group-worked parts during shared assembly of a 'jigsaw'. There has been found to be an increasing need for standards for scalability (levels of detail) and structure, and tools for integrating different forms of representation or media.

3   The Valhalla Project and Remote Sensing

This project was funded under the information society technologies (IST) programme of the European Union, and ended a year ago. Valhalla stands for Virtual Access to Landscapes and Historic Gardens at Linked Locations. [8] It included a spatial database to manage the capture and storage of video captured automatically by real-time cameras overlooking selected historic gardens, which were also visible on the web. The VRML models of the gardens were coordinated in the same way to present the same field of view and focus as the video camera view, and act as a dynamic key providing hyperlinked explanations of plants and content in the view as active server pages from the database, together with a 3D spatial search for digital images, including archived video clips, old prints and paintings following spatial referencing. This has highlighted a need to record more metadata with raw data and images than is the norm. 3D models in general, and VR and particularly VRML models (due to download times), lack the dynamic behaviour of crowd scenes, traffic and plant movement which convey life and credibility, and that real-time or archived film captures so readily. While this project addressed the intermingling of video and appropriate 3D modelling, current investigation at FBE/UWE is focused on the intermingling and common registration of modelling into highly accurate aerial and side-scanned Lidar data, since the Environment Agency have now flown a significant proportion of sensitive areas of England and Wales, sampled from enormous datasets at resolutions of 50cm, 25cm and even 2cm. This is a similar move towards the synthesis of those features best modelled in 3D and those best captured by remote sensing, and a move away from modelling all aspects of the context to modelling just those aspects that remote sensing (in this case video) cannot capture, such as future proposed changes or recreations of historic settings.

4   Web 'Applications' to Manage Collaborative Modelling

There are a number of initiatives now to manage web based collaborative modelling. For example the FAPS Institute, University of Erlangen-Nuremberg, 'is now developing a Web-based collaborative environment to facilitate the planning and design of production systems. Each production system can be defined by such para-
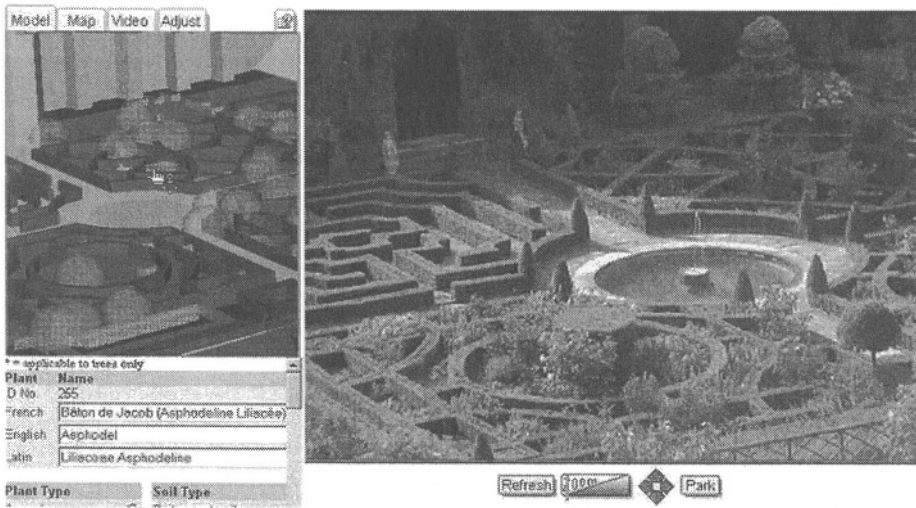
Fig. 2. Shows Model slaved to Video & ASP

meters as products, processes, resources and their relationships connected to a central repository of 3D/VRML objects'.[9]   Domos/D-studio use VRML to facilitate the management of complex design processes such as urban development and infrastructure planning, tested in a 'series of large-scale urban development projects in the Netherlands including the Station Island project involving the complete reorganization of the Amsterdam central station quarter'.[10] FBE/UWE have recently been developing a template collaborative web system, managed through the browser interface and based on active server pages and a database managed repository. This has been used recently across a range of applications, including: student peer group appraisal of work; a case study with live data of the construction and use of an innovative building as a repository for teaching and learning; a collaborative research study; a collaboration between planning authorities in a region; and an exposition of a heritage site over time for a project to restore the estate. The repository approach works well with check-out and in of the spatial sectors into which the VRML modelling is sub-divided, however more work is required to set out parameters within which alternative proposals can be developed, and for integration into existing contexts such as Lidar or SARS data. This could be handled either by over-riding the existing Lidar at the location, or by superimposing the proposal in a manner similar to that necessary for Augmentation of Reality viewing. It is suggested that these parameters, including minimum and maximum boundaries, accord quite closely with the logical extents used in early design stage planning briefs and 3d master plans. While there has been much work in optimising the zoning of large area urban models for download, it is suggested that increases in bandwidth may make political, building line, 'line regulataire' and other early design stage planning constraints more useful for such models in the future, and that development of parameters expressing the relationship of a 'plot' for development proposals within a

collaborative web based modelling environment should express these logical guidelines that relate to real-world activities.

5   Conclusion

It is argued that there is still a need for standards that support the construction and maintenance over long periods of wide area contextual models by enabling:

- Diverse contributions to central shared repositories by users distributed in time and place, enabled by inexpensive broadly accessible tools and open standards;
- Two way links for interactive exchange between a selected view and the source data; multiple media, sources of data and appropriate metadata;
- Scalability or multiple levels of detail;
- Facilities for accommodating change over time;
- Retention of multiple different interpretations or proposals for comparison.

It is argued that Spatial Information Systems offer a most promising route to implementing these. The projects have shown the potential of a GIS based process for asynchronous group modelling or updating along the lines of a collaborative virtual design studio. It has been found that CAAD systems that focus strongly on modelling new buildings often risk being unable to effectively incorporate the context, landscape and existing buildings, or ease assessment of the wider impact of new development. Yet the growing prioritisation of sustainable urban development makes the development of inclusive modelling, analysis and information systems increasingly important. It is argued that in this respect GIS development is significantly in advance of CAAD systems development. However now that group work is increasingly likely over the web for the creation of these models there is now a need for wide area model repositories that are accessible across the web, together with appropriate tools to manage the shared task of modelling over long periods of time.

References

1   Mitchell, W.J.: in Wojtowicz, J.(ed): Virtual Design Studio. Hong Kong University Press, (1995).
2   Counsell, J., Phillips, R.: A Procedural Approach to Simplification of Detailed 3D Cityscape Models for Virtual Reality Use. In JEC-GI'96 Proceedings, Second Joint European Conference & Exhibition on Geographic Information, IOS Press Amsterdam (1996).
3   Counsell, J,. Phillips, R.: The Tower of London Computer Models. Proceedings of IV'97, the International Conference on Information Visualisation, IEEE Computer Society, California (1997) 186-191.
4   Smith, A.: Metaworlds and Virtual Space - Towards the Collaborative Virtual Design Studio. in Proceedings of the International Journal of Design Computing DCNET'98, (1998) on-line at htpp://www.arch.usyd.edu.au/kcdc/journal/vol1/dcnet/
5   Hamilton, A., Trodd, N., Fernando, T., Watson, K.: Learning through visual systems to enhance the urban planning process. Vol 28. Environment and Planning B: Planning and Design (2001) 833-845.

6 Song, Y., Hamilton, A., Trodd, N.: Developing an Internet based Geographic Visual Information System. In Wood, J. (ed): Proc of GIS Research in the UK 2003 Conf. City University, London (2003) 197-200.
7 Bourdakis, V. From CAAD to VR, Building a VRML model of London's West End. Proceedings of 3rd UK VR-SIG conference, DeMonfort University, Leicester, (1996) on line at http://www.cms.dmu.ac.uk/VRSIG
8 http://environment.uwe.ac.uk/valhalla/
9 Institute of Manufacturing Automation and Production Systems (FAPS), Department of Mechanics and Manufacturing at the University of Erlangen-Nuremberg (Germany)
10 Domos/D-studio, a Belgian software company http://www.d-studio.be

Interest Management for Collaborative Environments Through Dividing Their Shared State

Michal Masa, Jiri Zara

Czech Technical University in Prague, Karlovo nam. 13
121 35 Praha 2, Czech Republic
michal.masa@ciant.cz, zara@fel.cvut.cz

Abstract. Not all participants in a collaborative virtual environment (CVE) need to be informed of every other participant's activities. The technique used for filtering irrelevant messages is known as interest management, which has to minimize network traffic and to reduce the burden of clients. However, considering the CVE shared state maintenance, interest management is nothing else than a disruption of the perfect case where every CVE participant maintains the identical copy of the state. In this paper we present an interest management technique that organizes the shared state into domains and sub-domains and enables clients to express their interest in particular sub-domains only. This approach specifies an interest management in a general way and it can be used for a wide range of CVE applications. Key ideas are being implemented as part of General Variables (GV) library and verified in our testbed CVE system for social interaction called e-Agora.
Keywords. 3D graphics, collaborative virtual environments, interest management

1 Introduction

Collaborative virtual environments (CVE) in general are aimed at interaction among users connected by network and spread physically. In a typical CVE, users do not need to know about every other user's activities. Filtering irrelevant messages is usually referred to as interest management. Its main goal is to minimize network traffic and to reduce the burden on clients (notion client stands for combination of software and hardware in this text).

The shared state of CVE describes the current state shared among CVE participants [12]. It can be divided into two parts: fixed and dynamic. The fixed part remains unaffected for the whole life of the CVE. It usually describes the geometry of landscapes, buildings, rooms and other virtual objects. In contrary, the dynamic part varies during the system runtime. It can describe positions of users in VE, state of light switches etc. When a client connects to the system, it has to collect both, the fixed and the dynamic part. By composing them together it can produce the actual VE representation. From the point of communication view, the dynamic state is delivered to the client in two forms: initial state and state updates. The former is delivered only once after the client has connected to the system and it contains the actual state at the

time of connection. The letter is being delivered to the client until it disconnects from the system and it represents particular changes of the dynamic state.

The optimal situation would be if every CVE participant maintained the identical shared state. From this view, the interest management is a disruption of this ideal. When interest management is employed, participants maintain and synchronize only those portions of the shared state that are of particular interest for them.

In this paper we present an interest management technique that organizes the shared state into domains and sub-domains. The technique is content independent since it filters the data extrinsically [10]. For specifying clients' needs we partially adopt the general aura-nimbus interest management model [5, 12] and extend it by including security issues as well.

In section 2, we divide CVEs into two main directions and characterize them from the view of shared state and interest management. In section 3, we briefly review GV concept and e-Agora CVE. Section 4 contains the description of our approach to interest management and we clarify the notions of domain and sub-domain. In section 5 we demonstrate the usability of our method in e-Agora CVE. Section 6 highlights the consequences of the approach. The experimental implementation is discussed in section 7 and section 8 concludes the work.

2   Previous Work

The research in the field of CVE can be divided into two main directions. The first direction represents large-scale distributed simulations (LSDS) where thousands of entities move and interact in a large and open area [10]. Battlefield simulations are the typical case. The entities should be aware of other entities in their proximity so the visibility is the most important factor for interest management here. The technique used to approximate visibility computations in these simulations is to break up the world spatially into a number of regions of various shapes – grid cells. Every client that wants to receive information subscribes into regions, which intersect with its area of interest. The client can also subscribe directly to an entity of interest to receive high fidelity information about the entity [1,11].

In LSDS, the environment is usually considered static. The shared state consists of entities' state mostly and no centralized repository is used to store the shared state. The entities are forced to transmit their state periodically (heart-beat) so the late joins can obtain the actual state.

The second research direction is aimed at CVE systems for social interaction and multi-user cooperation [4,9]. Although interest management techniques used in LSDS apply here as well, the interaction among users is based on a much more subtle basis. In social and cooperative environments, the scene is usually composed of enclosed logical spaces (rooms in a building). The partitioning of the scene into regions for interest management purposes is more intuitive and regions typically correspond to logical spaces. Outdoor spaces can be partitioned in a similar manner as in LSDSs. However, interest management cannot consider only visibility information or entity type information (as usual in LSDS). The scope of information exchange among users is much broader and should not be restricted only to geographic regions. Users can form logical workgroups and interaction within a workgroup can be shared

only by workgroup members – either for efficiency or security reasons. For example, while workgroup members who are located in separate regions do not need positional information about other members they cannot see, they should still be able to communicate with them. Alternatively, users who are located in the same region at the same time, but belonging to different workgroups, might be limited in the way they can interact. This technique is called functional filtering [3].

In contrast to LSDSs, social and cooperative systems enable users to modify the virtual environment in a number of ways. The users can introduce new objects in the scene, remove them or change their properties. To be more specific, in our testbed application e-Agora the users could play desk games, install exhibitions or paint graffiti on walls. The state is usually stored in some form of centralized repository (can be virtual in non client-server architectures), which is used to update late joins.

However in many systems, the partitioning of the shared state for interest management purposes is strongly explicit and suited for a particular purpose. For example MASSIVE-3 divides the virtual environment into Locales containing several Aspects [6]. While Locales are used for spatial subdivision, Aspects define functional and organizational scope. In contrast to hard coded approaches we tried to define an interest management abstraction to provide a common base for a wide range of collaborative applications.

3   Overview of General Variables (GV) and e-Agora

The GV concept [8] was designed to formalize storing and distributing updates in a typical net-VE system. If a user performs an interaction in the world the client sets a particular GV to some value (byte stream). This value is then sent to a server, which updates its GVs database and forwards the value to other connected clients. They parse the value and perform the original action locally. If a new client (late join) connects to the system, the server sends it the content of the GVs database so that the client can update its state promptly.

e-Agora [2] is our testbed net-VE system aimed at social interaction and culture content dissemination. Visitors connected via the Internet can see each other by the help of avatars and communicate by chat and gestures. The virtual environment is a model of an existing culture centre in the city of Prague. The system has been built on the top of the GV concept and VRML technology.

4   Partitioning the Dynamic Shared State:
Domains and Sub-domains

To allow users to express their interest in only some part of the shared state only, we propose to partition the shared state into domains and sub-domains (Figure 1a). The domains represent categories of areas of interest (logical groups, regions, navigation, chat or game playing). The sub-domains represent concrete areas (particular group, room, chat theme or specific game). Any state variable can belong to any number of

domains – its domain set is specified upon its creation and it defines the scope of the variable.

When the state variable update is being sent (a user performs some action in the VE), the actual sub-domain values (sub-domain set) have to be associated with the update, one sub-domain value for every domain in the variable domain set. To construct the sub-domain set, we utilize aura (Figure 1b). The aura represents an individual set of areas of interest, which are impacted by the client. The aura is specified as a set of sub-domains. These sub-domains, which domains match with the variable domains are put in the variable update sub-domain set (Figure 1c).
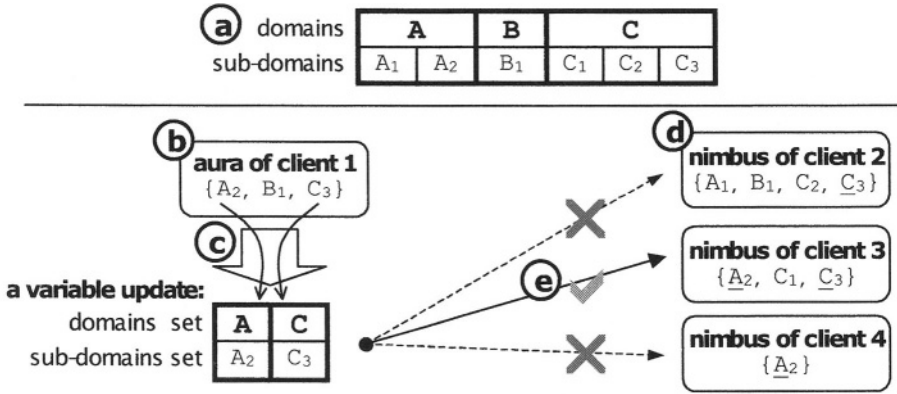
Fig. 1. Process of creating, filtering and receiving the variable update: a) sample domains and sub-domains, b) source client's aura, c) filling the variable sub-domain set according to aura, d) nimbi of potential receiving clients, e) update propagation to a final recipient client 2. The other clients' nimbi do not contain all sub-domains from the update's sub-domain set. Common sub-domains are underlined in clients' nimbi

To express the client's interest in a set of areas, we utilize nimbus (Figure 1d). Nimbus is a counterpart of the aura and is also specified as a set of sub-domains. To determine whether a client is interested in a particular update, we check if every sub-domain in the variable update sub-domain set is contained in the nimbus. If so, the update is propagated to the client (Figure 1e). In other words, we perform restricted intersection of the aura and the nimbus for domains contained in the variable domain set. If the intersection contains a sub-domain for every domain, the update propagation occurs.

5   Application of Domains to e-Agora

While we have specified how to organize the shared state and how to express the interest, the semantics of domains is arbitrary and application specific. To explain our approach, we will illustrate how it can be applied to a future version of e-Agora CVE, which is currently being developed.

Table 1. Domains and sub-domains identified in e-Agora CVE

Domain		Sub-domain	
Chat	C	Different chat themes	$C_1, C_2, C_3, \ldots$
Navigation	N	General navigation	N_1
Scene Editing	E	General editing	E_1
Desk games	D	Desk games within a world	$D_1, D_2, D_3, \ldots$
Spaces	S	Spaces within a world	$S_1, S_2, S_3, \ldots$
Worlds	W	Worlds making up the VE	$W_1, W_2, W_3, \ldots$
Logical groups	G	Logical groups within the VE	$G_1, G_2, G_3, \ldots$

Table 2. Types of state variable domain sets used in e-Agora

Domain set of the variable	Semantics of the variable
{ C, G }	Chat within a group.
{ N, G, W, S }	Navigation in VE. The scope is limited to combination of the group, the world and the space.
{ E, G, W, S }	Independent editing of the scene. The scope is limited to combination of the group, the world and the space.
{ E, W, S }	Joint editing of the scene. The scope is limited to combination of the world and the space. However, it is not limited to the group, so changes are visible to every user.
{ P, G, W }	Playing desk games within the group and the world.

First, we have to define domains by finding possible categories of area of interest. In e-Agora, users can chat, navigate in VE, play desk games or edit objects in the environment (install exhibitions, move chairs and tables, etc.). The VE is made up of several worlds (culture centres) connected together. Every world is composed of spaces (rooms). Users are divided into logical groups that operate independently. According to this classification, we have formed domains and sub-domains as listed in Table 1. Now we can partition the shared state by assigning state variables to one or more domains – construct the variables' domain sets. Table 2 contains five types of domain set used in e-Agora along with their semantics description.

The combination of domains restricts the scope of the variable. Since the chat variables in Table 2 do not contain S or W domain, the communication among users is limited only to participants of the same group and it is not limited in space. Navigation variables describing positions and orientations of the users are a different case. A user has to express interest in a particular combination of the group, world and space to receive updates. The e-Agora also enables two types of editing in the VE. First we have independent editing for every group, where each modification occurs only in the group it has originated from. It can be used for group related projects. Secondly, cross-group editing occurs in every group. An example is installation of an exhibition that should be visible to all users. Playing desk games is also not related to particular space, so users can iconize the desk game, move to another space and continue playing the game.

When a user enters the VE, her client expresses the interest with the help of the nimbus. If she is interested only in chat, her nimbus will contain only particular chat theme or themes and the group to which she belongs: e.g. { C1, G2 }. If she wants to

see the other users too, her client extends the nimbus and specifies a particular world and space along with the navigation interest itself: { C1, G1, N1, W2, S3 }. If she wants to see the users in adjacent spaces too, her client extends the nimbus again by adding these spaces: {C1, G1, N1, W2, S3, S2, S1}. And finally, if she wants to join or watch some desk game, her client extends the nimbus by the particular desk game: { C1, G1, N1, W2, S3, S2, S1, D2 }. The aura is being composed in the same manner. However, the aura usually contains only one sub-domain for each domain; for example the user is usually presented in one space only.

6   Consequences of the Proposed Approach

6.1   Generalized Late Joins

As we have illustrated, users may be interested only in particular updates of the shared state. If two users play chess in a pub, most of other users in the pub do not need to be informed about their turns. However, the same findings apply to late joins - only a fraction of the global shared state is of particular importance for them. In our concept, we generalize the notion of late join to include already connected clients that has changed their nimbus. Once the client changes its nimbus (or sets it up for the first time), it becomes a late join for specific part of the shared state. Like if another user in the pub from example above wants to watch the chess game, the client changes the nimbus accordingly and receives the current state of the game. Subsequent game updates can follow until the client reverts the nimbus. The client can provide a timestamp of the last update it has received to obtain only recent changes of the state.

6.2   Security Management

Interest management techniques have to minimize network traffic and reduce burden of clients. However, messages can be filtered for security reasons too. This is applicable in cases when users should be restricted to perform some activities or to observe activities of other users. These security requirements can be seamlessly integrated with our interest management concept. Every nimbus and aura change performed by a client can be a subject to a security checking. If the client tries to add a sub-domain to its nimbus, the security checking compares the client's access rights with the rights required to receive updates from the sub-domain. The nimbus modification has no effect if the comparison fails. Similarly, if the clients try to add a sub-domain to its aura, client's access rights are compared with the rights required to send updates to the sub-domain. Again, if the comparison fails, the aura modification has no effect.

7   Implementation

To verify the proposed approach, we extended our existing GV library by aura/nimbus manipulation methods. The GV library is implemented as a JavaBean [7] to ensure platform independence and reusability.

To eliminate any dependencies on particular networking schemes (client/server, peer-to-peer, multicast), we integrated an abstract class Channel to the concept. Implementations of this abstraction are responsible for dissemination of the updates to all nodes, which nimbi intersect with the source node's aura. The appropriate Channel for the update propagation is selected based on flags associated with the update. Several channels were implemented, each providing different QoS: TCPChannel for reliable ordered connection, UDPChannel for unreliable unordered transmission, MChannel for unreliable multicast and LRMPChannel for reliable multicast. Channels are registered by addChannel method of the class Concept, which inserts them into an ordered list by supplied priority level. Whenever an update is being sent, sorted list of registered channels is traversed and the first channel that accepts the particular flags settings of the update is delegated to broadcast the update. Channels are also responsible for receiving the update and notifying the Concept class that in turn invokes variableUpdated callback method.

7.1   Future Work

We have already implemented a straightforward client-server solution for aura/nimbus manipulation and for storing and sending updates to late joins. Currently we are working on pure peer-to-peer architecture, which involves appropriate mapping of domains and sub-domains to a given set of available multicast addresses.

8   Conclusion

In this paper, we have identified the problem of interest management in the context of the maintaining complex CVE shared state. We argue that interest management technique actually limit or restrict the CVE participants to maintain and receive only specific parts of the global CVE shared state. We have proposed a general interest management method, which is based on partitioning the shared state into domains and sub-domains. The aura-nimbus model has been adopted for expressing clients' impacts and interests in the VE. We demonstrated an application of our approach on e-Agora, a CVE system aimed at social interaction.

9   Acknowledgments

References

1. Abrams, H., Watsen, K., and Zyda, M. Three tiered interest management for large-scale virtual environments. In Proceedings of Virtual Reality Systems and Technology, 1998.
2. Adamec, J., Cizek J., Masa M., Sidoni P., Smetana P., and Zara J. Virtual House of European Culture: e-AGORA. In Proceedings of the 1st International Conference on Virtual Storytelling, 2001.
3. Capps, M., and Teller, S. Communications Visibility in Shared Virtual Worlds. In Proceedings of the Sixth IEEE Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, 1997.
4. Dive Web site: http://www.sics.se/dive/
5. Greenhalgh, C., and Benford, S. Boundaries, awareness, and interaction in collaborative virtual environments. In Proceedings of the Sixth IEEE Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, 1997.
6. Greenhalgh, C., and Snowdon, D. Inside MASSIVE-3: Flexible Support for Data Consistency and World Structuring. In Proceedings of the Third International Conference on Collaborative Virtual Environments, 2000.
7. JavaBeans specification: http://java.sun.com/products/javabeans/docs/spec.html
8. Masa, M., and Zara, J. The General Variables Concept: A Simple Step from Single- to Multi-user Environment. In Proceedings of 2001 IEEE International Conference on Information Visualisation, 2001.
9. MASSIVE-3 Web site: http://www.crg.cs.nott.ac.uk/research/systems/MASSIVE-3/
10. Morse, K. L. Interest management in large-scale distributed simulation. 1996.
11. Morse, K.L., Bic, L., and Tsai, K. Multicast Grouping for Dynamic Data Distribution management. In Proceedings of the 31st Society for Computer Simulation Conference, 1999.
12. Singhal, S., and Zyda, M. Networked Virtual Environments. Design and Implementation. ACM Press, 1999.

Using Simulation, Collaboration, and 3D Visualization for Design Learning: A Case Study in Domotics

A.I. Molina, M.A. Redondo, C. Bravo, M. Ortega

Dpto. de Informática. Universidad de Castilla – La Mancha
Paseo de la Universidad, 4. 13071 – Ciudad Real. Spain
aimolina@inf-cr.uclm.es
{Miguel.Redondo, Crescencio.Bravo, Manuel.Ortega}@uclm.es

Abstract. Computer-assisted educational environments are an excellent complement to the learning process. However, when domains are complex, the expected learning support objectives may not be achieved. We are interested in the exploration, study and application of new interactive technologies suitable for their use in the classroom. We propose the use of Computer Supported Collaborative Learning combined with Simulation and 3D representation for assisting in learning processes. We believe in the potential of this synergy to support learning in a case study: the teaching of Domotics, i.e., the design of automated control facilities in buildings and housings.

1 Introduction

Computer-assisted educational environments are an excellent complement to learning processes. Especially, design and simulation environments are tools offering contrasted benefits for discovery learning in multiple domains. However, when these domains are complex, the expected learning support objectives could not be achieved. This complexity justify the necessity to carry out the design activity itself in groups. From this the perspective of modelling and simulation in collaboration, we developed DomoSim-TPC [1], a system supporting collaborative learning in Domotics. This domain studies the integral automation of housings and buildings. The system provides shared workspaces integrating tools for domain problem solving with communication and coordination tools.

This system was improved with support for 3D simulation, allowing the learners to achieve additional cognitive benefits. Using Virtual Reality for learning should articulate mechanisms that enhance effective learning. These techniques will allow users greater interaction possibilities. Using this new tool the students can interact with the generated virtual scenario. This scenario, which is built under a variety of constraints, represents a solution to a proposed problem. This way, this 3D simulation tool allows the students to test their proposal of solution in a more realistic way.

Currently, most of the systems treats Virtual Reality and Computer Supported Cooperative Work separately. This occurs in Domosim-TPC, when the 3D simulation is

a single user tool. Now, our objective is combining them in a collaborative virtual simulation workspace.

But this 3D approach makes the interaction between users and shared objects more difficult, so that the complexity of multiple users sharing the same workspace has to be studied [2]. This work will show the way in which CSCL combined with simulation and 3D representation can help in the discovery learning process, in which the students are responsible for what they learn.

The paper is organized in this way: in the following section, the problem and the application domain is introduced; next, we explain the way followed by our research group in the development of educational applications in Domotics; we have developed a tool called Domo3D for 3D representation of domotical building projects, which is briefly described in the following section; next, we describe our objective of combining CSCL, Simulation and 3D representation for learning processes. Finally, we will draw some conclusions and outline the future work we plan to develop.

2   The Problem: Teaching Design in Domotics

The domain where the necessity appeared and where our investigation is being applied is the learning of Domotics, i.e., the design of automated control facilities in buildings and housings.

In Spain the new Formacion Profesional (Technical Training) defined in the LOGSE (Spanish Law for Primary and Secondary Education) takes professional profiles into account where training in Domotics is considered as a necessity. Some learning stages in electricity and electronic courses are centered on the study of the design and maintenance of singular installations and automation of buildings dedicated to housing. In this area the design of domotical installations have a fundamental role.

In this kind of training, the realization of practical experiments is specially important. However, the necessary material to carry out these works is usually expensive and in many cases its readiness is low. This problem is increased by the difficulty to bring the student to real situations, to reproduce accidents and to outline chaotic situations which can happen in the real world and whose designs should be prepared.

This situation creates an ideal framework for learning an incipient discipline like Domotics. A 3D representation allows a better understanding of spatial and visual aspects of a project of domotical building.

2.1   The Application Domain: Domotics

The term Domotics is associated to the set of elements that, when installed, interconnected and automatically controlled at home, release the user from the routine of intervening in everyday actions and, at the same time, they provide optimized control over comfort, energetic consumption, security and communications.

There are three types of domotical elements [3]: sensors, actuators and systems or controllers. *Sensors,* also called receivers, are elements that receive the information

from the atmosphere, for example, atmospheric or luminosity variables. They can also obtain information on the actions humans carry out in their daily interaction at home, such as pressing a switch or coming into a room. These include sensors of temperature, luminosity, gas, smoke, intrusion, etc. *Actuators* are elements that receive the order to be activated or deactivated. They consist of actions such as switching a light on/off or opening/closing a shutter. As in the case of sensors, there are a great variety of actuators. Among these actuators we can include, for example, the heating system, air conditioning, the alarm, etc. Finally, the *systems* or *controllers* are in charge of processing the information coming from the sensors and, by means of the appropriate control programming, they activate or deactivate the actuators.

The domotical elements are grouped by means of links into different *management areas.* Four such areas could be Thermal Comfort, Control over Luminosity, Security and Energy Control. Basically these four areas include most of the domotical elements although their number and functionality is constantly increasing.

2.2   Teaching Design Procedures in Domotics

When creating educational applications for teaching Domotics, we take in account Direct Manipulation [4-7] as interaction style. To create a visual system for the installation of domotical elements in buildings, we developed a domotical simulation environment [8]. In this environment, and by means of Direct Manipulation, the student use a set of domotical elements contained in a toolbar. This elements can be located, connected and parameterized using actions such as "drag and drop". The great variety of elements and the actions on them makes this type of design a complex problem in which the student can easily get lost and be unable to complete it satisfactorily. To tackle this complex problem we follow the ideas of Soloway [9], and Bonar and Cunningham [10], who proposed the development of intermediate solutions in their programming environments. We have developed a tool called PlanEdit [1]. With this editor, the student carries out a first approach to solving the problem by making a plan with abstract actions of design. Thus, by working abstractly, they should be able to manage the first approach to the solution without any great difficulty.

In pursuit of the traditional model of the classroom where students work collaboratively to perform practical tasks, we decided to develop our system in order to support group work.

Tools based on asynchronous communication are used in order to specify, discuss and organize the general approaches to the solution to the design problem [11]. An editor is available for the individual drawing up of design strategies by means of a specification language with a high level of abstraction. The elements of this language have a visual representation associated which facilitates their use by means of the typical procedures of direct manipulation. Once built, the models are presented to the other members of the group. The group, by using a method of argumentative discussion, comment and request explanations about the decisions taken. The author is forced to react to these comments by arguing, justifying and refining their decisions. All this is carry out in a constructive and collaborative process that leads to learning.

The results generated from this process are organized in a table of contents which can be accessed and visualized.

These results are a good starting point for the second phase. But it is necessary to list and to organize attributes associated with the elements comprising the model. This is carried out by means of a collaborative tool based on the direct manipulation of the domain objects. With this tool you can select, insert, eliminate, move operators, etc [12]. The tasks associated with this design process can be distributed among the participants following various criteria. As the objective of the design is to obtain a model fulfilling certain requirements, this is verified by means of the hypotheses approach matched against the simulation of the model. This simulation, in which all the members can interact in real time by direct manipulation and synchronous communication, will contribute to error detection, the result of reflection and the discovery of inconsistencies in the approach. These processes should lead the group to a self-directed learning [13].
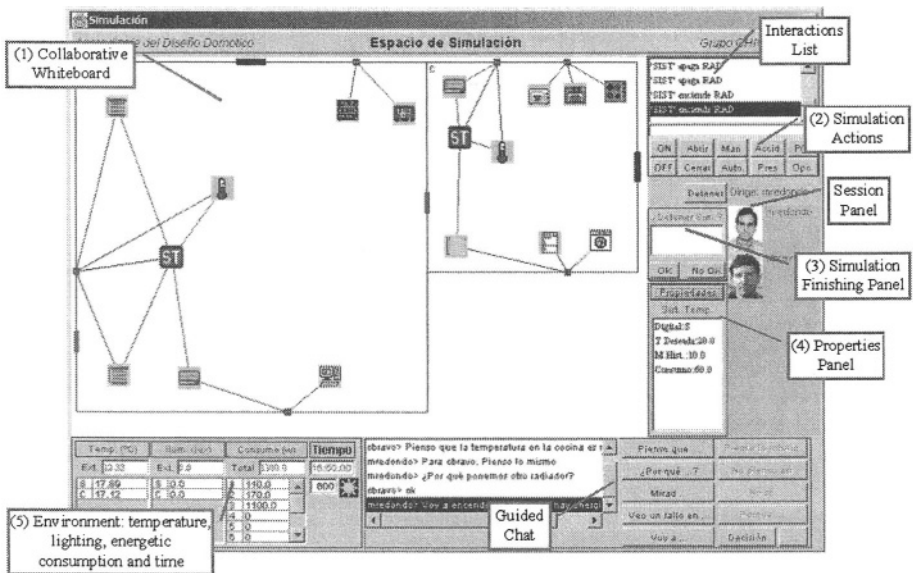
Fig. 1. Space for bi-dimensional simulation in Domosim-TPC.

Figure 1 shows the user interface of the collaborative simulation tool. The different elements of the simulation tool are: the whiteboard with the designed model (1), buttons to carry out simulation actions (2), a panel to propose the finishing of the simulation (3), a panel of operator properties (4), and simulation information (temperature, illumination, consumptions and clock) (5). It also contains the awareness and discussion elements: the Session Panel, the interactions list and the Guided Chat. This figure shows a simulation session of a designed model by the students. This model contains, in the lounge (left room), 2 radiators, 1 air conditioner, 1 temperature sensor

and the regulator system, as well as some appliances (computer, television, and stereo). In the kitchen (right room), the students have inserted another thermal comfort subsystem and the appliances that the problem demands (microwave, oven, cooker, refrigerator and washing machine). The operators are connected to the plugs to obtain electricity and to facilitate the regulation control, according to the domotical system of Power-Line Carrier. With a different color link to the electrical connection, the receivers and activators are linked to the systems that regulate them. The students have defined parameters of each operator such as the energy consumption, the calories...

3   Support for 3D Simulation: The Workspace Domo3d

The aforementioned system, Domosim-TPC, was improved with an additional workspace, called Domo3D, to make a 3D interaction possible during simulation. Inmersion and direct interaction with a 3D representation of the problem allows a better internalization of the user's acquired knowledge. Using this new workspace adds some advantages: better perception of areas and a greater emotional and semantic communication.
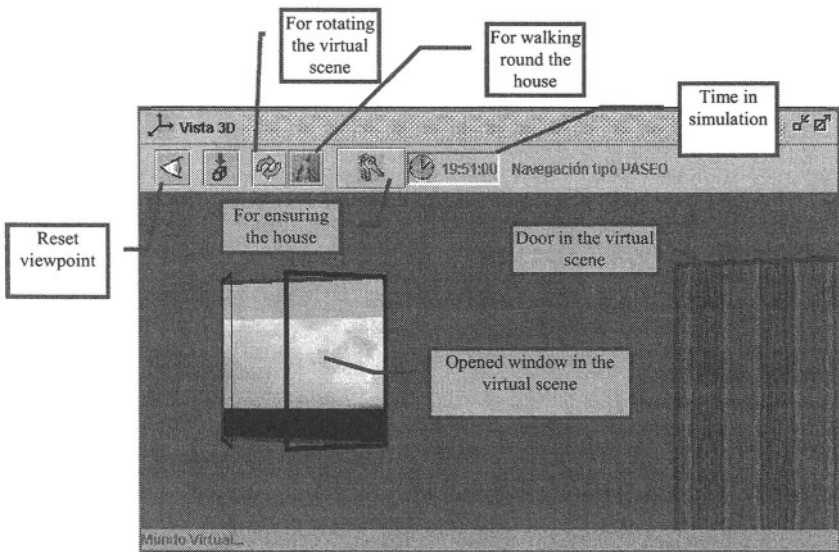
Fig. 2. Three-dimensional view of the domotical building.

Figure 2 shows the appearance of the interface of the tool Domo3D. For its implementation Java technology has been used; including the Java3D API for creating the three-dimensional housing model.

There are several factors that add a degree of interest to the user that uses the new workspace Domo3D; these are *events, realism, animation* and *power to answering.*

But this feature has been, up to now, individual: this 3D experimentation space is not available to all the participants in the same view. Now, our objective is to incorporate a collaborative virtual simulation tool like an additional workspace in Domosim-TPC. For this, we propose a participative 3D simulation, in which the participants are agents in a simulation such as players in computer-supported games.

4 Towards a 3D Collaborative Simulation Workspace in Domosim-TPC

The next step is to develop a 3D collaborative simulation wokspace. Using this new tool for supporting Domotics learning adds some advantages:

-   The additional dimension (height) introduces new possibilities, and enriches the simulation. Using a 3D model enhances realism during the simulation.
-   New interaction possibilities. Users, immersed in 3D simulations, improve their spatial and navigations abilities thanks to practising real tasks in the virtual scene. Operating in this kind of environments is more simple and natural for the users. However, interaction with other users immersed in the shared virtual workspace also improve their social and negotiating skills.
-   A most realistic perception is provided. The purpose of this kind of interfaces is to obtain immersion systems that emulate a real environment and produce a most effective learning. A shared workspace provides a natural and intuitive way to interact with other students.
-   Also, new kind of information is accessible (visual attention and physical movements, position and orientation, ...). It will allow us to characterize users. Also, information related with interaction between the virtual human inside the virtual scene, and with the shared objects, is available.

This new tool in Domosim-TPC raises several aspects to be considered:

-   Controlling the concurrency problems when several users interact with the same object in the 3D representation.
-   Solving the distribution of events between several users in the virtual scene. All the interactions must be distributed immediately to the group members to be to shown in the shared space. Being able to ascertain order between events is very important for understanding the sequence of actions in distributed systems. We propose the use of the Schiper-Eggli-Sandoz protocol [14] with the aim of eliminating the problems related to maintain the consistency during the simulation and ensure the same view to all participants.
-   Including awareness mechanisms during the simulation that allows the users to know what the other students are doing. The essence of a collaborative virtual environment is that users are explicitly represented to each other within a shared space.
-   The system must inform of the interactions in a textual way. This information allows following the trace of actions that are activated whereas the user interact

with the domotical elements in the house. In this way, not only changes are shown in visual mode, but also additional information in supplied (for example, numerical data), which makes a deeper knowledge possible.

During the simulation users can play different roles (owner of the home or intruder) and interact on the model to provoke reactions. Simulation actions (to switch on/off, to open/close, to break a link, to simulate human presence in a room...) are used to modify the behavior of the objects in the model and to check if the model behavior is what was expected. This behavior is reflected in real time in the 3D visualization.

5   Conclusions and Future Works

The way followed by our research group in the development of educational environments began with Direct Manipulation. The need for collaboration between students showed the need to use Collaborative Teaching/Learning Systems when the problems to be solved are of a certain complexity. In this paper, we have described our motivation and design principles to add a 3D representation during simulation in a collaborative e-learning environment of domotical design, which is taken as starting point in our research. In order to include a Collaborative Virtual Simulation Workspace we propose the combined use of collaborative capacities, 3D representation and simulation. This approach can offers new possibilities of interaction and benefits in many activities of learning related to engineering, architecture and other areas. It improves the understanding of the mechanisms that govern the simulated reality or simulated process and enhances visualization aspects.

From a technological point of view, this tool is achieved. Our proposal for the future includes the experimental evaluation of the system using obtained results in the use of Domosim-TPC(not including the 3D simulation space) as a reference point. Also, usability studies must be elaborated and applied.

Acknowledgements

References

1. Redondo M.A., et al. PlanEdit: An adaptative tool for design problem solving learning. in 2nd Conference on Adaptative Hypermedia Systems (AH2002). 2002. Málaga (Spain): Lectures Notes Computer Sciences.
2. Molina A.I., Redondo M.A., and Ortega M. Virtual Reality for Teaching Domotics. in IADIS International Conference Applied Computing 2004. 2004. Lisboa (Portugal).

3. Molina, L., Ruiz J. M., Instalaciones automatizadas en viviendas y edificios. 1999: McGrawHill.

4. Sedighian, K.K., M. An Interface Strategy for Promoting Reflective Cognition in Children. in CHI'97. 1997. Bristol, UK.

5. Sedighian, K.W., M. Direct Object Manipulation vs. Direct Concept Manipulation: Effect of Interface Style of Reflection and Domain Learning. in HCI'97. 1997. Bristol, UK.

6. Shneiderman, B., Direct Manipulation. Sparks of Innovation in Human-Computer Interaction, ed. B. Shneiderman. 1993: Ablex Publ., NJ.

7. Shneiderman, B., Designing the User Interface. 1997: Addison Wesley Publishing Company.

8. Bravo J., et al. Un entorno de simulación para la automatización integral de viviendas. in Congreso Universitario sobre innovación educativa en las enseñanzas técnicas. 1996. Zaragoza.

9. Soloway, E., Learning to Program =Learning to Construct Mechanisms and Explanations. Communications of the ACM, 1986.

10. Bonar, J., Cunningham. R. Intelligent Tutoring with Intermediate Representations. in ITS--88. 1988. Montreal.

11. Redondo, M.A., Bravo, C., Bravo, J., Ortega. M. Colaboración en entornos de aprendizaje basados en casos reales. Aplicación en ambientes de diseño y simulación. in INTERACCIÓN 2000. I Jornadas de Interacción Persona-Ordenador. 2000. Granada (Spain).

12. Bravo, C., Redondo, M.A., Bravo, J., Ortega., M, DOMOSIM-COL: A Simulation Collaborative Environment for the Learning of Domotic Design. SIGCSE Bulletin (ACM) - Inroads, 2000. 32, no.2(June 2000): p. 65 -67.

13. Bravo, C., Redondo, M.A., Ortega, M., Verdejo, M.F. Collaborative Discovery Learning of Model Design. in Proceedings of 6th International Conference on Intelligent Tutoring Systems Conference (ITS'2002). 2002. San Sebastián (España).

14. Schiper A., Eggli K., and Sandoz A. A new algorithm to implement causal ordering. in Intertional Workshop on Distributed Algorithms. 1989. New York: Lecture Notes Computer Science.

A Virtual Reality Framework for RC Building Design and Construction Cooperation

J. Wang[1], S.A. Chou[2], C.C. Chen[3] and C.S. Wang[2]

[1] Department of Civil Engineerng, Tamkang University,
TamShui, Taiwan 251
wang@mail.ce.tku.edu.tw

[2] Information Technology Department, Sinotech Engineering Consultants, Ltd.
Taipei, Taiwan 10572
inf-ctr@sinotech.com.tw

[3] Civil, Hydraulic and Information Technology Research Center,
Sinotech Engineering Consultants, Inc.,
Taipei, Taiwan 10572
ccchen@sinotech.org.tw

Abstract. With the advance in computer technology, virtual reality (VR), which allows users to explore and interact within three-dimensional (3D) virtual environment, becomes affordable and begins to play a vital role in various engineering practices. By establishing 3D VR models, engineers are able to sense, examine, simulate and evaluate their design works and identify inconsistency between design and construction to ensure work quality. Building a 3D VR model is time-consuming and labor-intensive. Hence, it is important to develop an effective approach to relax the aforementioned limitation for rapid prototyping VR models. In this paper, we propose a framework that correlates engineering design process and World Wide Web technology to generate Virtual Reality Modeling Language (VRML) models. An information system for the design and construction of reinforced concrete (RC) building structures has been developed to demonstrate the versatility and robustness of the proposed framework.

1   Introduction

Reinforced concrete (RC) building design visualization is a subject that depends on geometric and physical perception. However traditional methods for design collaboration sometimes fall short of conveying the complicated design concept when the designers need to exchange their ideas with others. In particular, the number of engineering drawings and documents grow exponentially along with the complexity of the project. With the use of Virtual Reality (VR), better understanding and communication is achieved because designers' concept is exemplified with multimedia, animation and interaction in a pseudo environment. The interactive nature of VR makes it a natural extension to the 3D graphics that enable designers, project managers, site workers and clients to visualize and sense real world structures before actually building them.

VR is a three-dimensional visualization technique using computers to simulate real world environment through 3D-navigation mode for better immersion and analysis. Yet most developments were limited to certain hardware and software platforms. Whereas, the development of the World Wide Web (WWW) over the last decade has led to many Internet-based VR applications using Virtual Reality Modeling Language (VRML) [1]. These VRML models offer many advantages including ease of use, quick access, low cost and cross platform compatibility. Moreover, VRML-formatted websites can be accessed at any time from any location without the need of sophisticated software to allow users to examine the details of the models. The important advantages of virtual reality environment over other computer-based design tools are that it enables users to interact with the simulation to conceptualize relations that are not apparent from a less realistic representation, and to visualize models that are difficult to understand in other ways.

In the field of civil engineering, virtual reality has been adopted for more than one decade. For example, construction visualization for steel structures [2], simulation of construction equipment [3] and bridge inspection [4] are just a few from recent years. Hobbs [5] reported that up to 30 percent gains of efficiency can be achieved by using VR and other techniques to improve communications in the construction process. Whyte [6] described three different practical modeling approaches for VR applications in the context of house building, i.e. library-based, computer-aided design (CAD) translation and database approaches.

In this paper, a design collaboration model is proposed and an architecture which correlates engineering design process and WWW technology to generate VRML models is implemented. An information system based on this architecture for the design and construction of RC building structures has been developed to demonstrate the versatility and robustness. VRML models are produced directly from the output of structural analysis and design programs. All components within the VRML models are linked automatically to relevant information sources such as drawings, reports, and other documents. Three-dimensional structural frames, and individual member, including beams, columns and connections, can be observed with web browsers. Element geometries, bar placements, formworks and their arrangements can be examined in arbitrary directions controlled by users. More design details such as structural analysis results and design drawings can be queried through browsers. The objective is to provide a unified visualization interface using VRML models to enable design information sharing and to improve collaboration among clients, designers, constructing workers and site engineers.

2   VRML-based Design Collaboration Model

A construction plan usually consists of several stages including feasibility study, planning, preliminary design, detailed design and construction, according to its task contents. In different stages, engineers need to prepare engineering drawings, documents and budgets to describe the functions, settings, geometry, dimensions, construction methods and costs of the infrastructure. These design drawings and documents are very important communication means for all project participants including

clients, designers, site engineers, contractors, construction workers and government agencies. The amount of documents and drawings grows along with the complexity of the project. This situation is even worse for large-scale turnkey projects, which are very popular today. Collaboration between design and construction teams becomes a frequent and important issue. Project managers have to cope with the challenge to ensure the built infrastructure is conformed to the original design. The quest of foreseeing construction difficulties and sequences is a demanding goal to reach.

VRML models provide a convenient way for design information search and exchange during design and construction stages. The fact that VRML models are described by objects rather than geometrical data makes it possible for simulating real conditions such as collision detection, collision response, gravity etc. Herewith, we propose an idea of using VRML models, the so-called VRML-based Design Collaboration Model (VRMLDCM), to enhance the communication among the design and construction groups as illustrated in Fig. 1. In Fig. 1, the visualization models that are described by VRML are served as universal external communication interfaces for construction work groups to understand the design intents marked within the center of circles. The products of design activities, e.g. drawings, guidelines, design documents, estimation reports, analysis data and other related data are located beyond those universal interfaces. Further, with the use of 3D VR models, engineers are able to feel, examine, simulate and evaluate their design works and identify inconsistent problems between design and construction stages to ensure high quality construction. Users navigate the
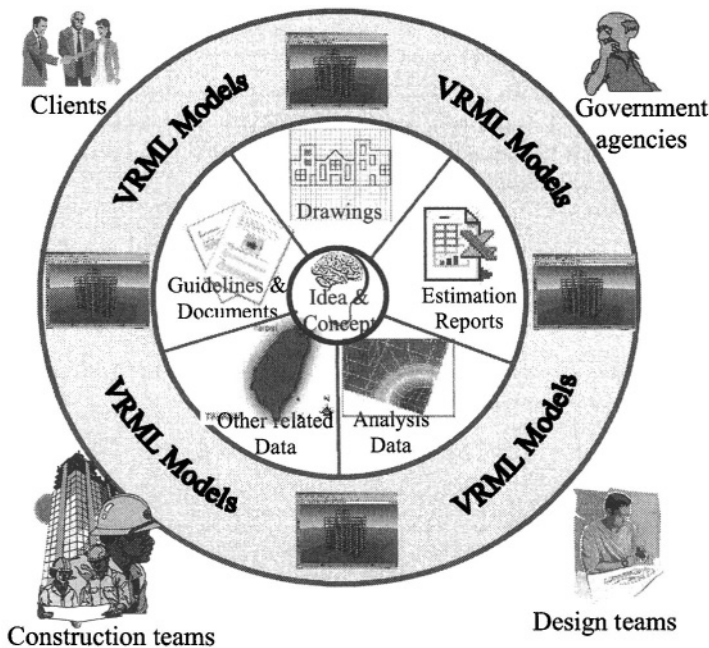
Fig. 1. VRML-based Design Collaboration Model diagram

VRML models through standard web browser and access all related design information by selecting arbitrary elements intuitively. As building 3D VR models is usually time consuming and labor intensive, it is key to the success of VRMLDCM. Hence, it is important to develop an effective architecture to relax the aforementioned limitation for rapid prototyping VR models.

3   The VRML Implementation Architecture

The success of VRMLDCM depends on the tight integration of VRML models into daily design activities. Yet most designers are only capable of using high level programming tools to do analysis and produce design data, but not familiar with building VRML models. Hence, we propose a VRML Implementation Architecture (VRMLIA) to link together generic analysis and design programs, post processors, VRML graphic kernel, WWW and users. In the proposed VRMLIA, several VRML models can be generated on demand upon the completion of programs and post processors as shown in Fig. 2.

The VRMLIA consists of four distinct layers. Starting from the designer side, the first layer is the "Design Layer" where commercial software, programs and post processors for constructing output data, documents, reports and drawings for specific engineering applications are located. The post processors are developed by the engineers familiar with the application and enterprise based graphic libraries. The enterprise based graphic libraries provide graphic functions to display, import, export, convert and print CAD, bitmap images and VRML models for all enterprise users. In the graphic libraries, calling functions to generate VRML models are very similar to those for CAD drawing output.

The second layer is the "Data Layer" which includes a collection of output data from the "Design Layer" e.g. documents, drawings, reports and analysis data. A standard PROTO/EXTERNPROTO library is also included in this layer. PROTO and EXTERNPROTO are two constructs in VRML to allow new nodes to be created by prototyping, which is a more powerful mechanism than instancing. A PROTO gives both the definition of the node and its implementation, whilst an EXTERNPROTO gives a node definition and a reference to a PROTO in another file. This mechanism allows libraries to be created and reused.

"Visualization Layer" is the third layer that consists of VRML graphic kernel, ASP/CGI/JSP server side scripts, VRML models and design information requested by the last layer, "Collaboration Layer". With users' requests collected by sever-side scripts, the VRML model for the entire frame of a RC structure and those for the structural components are created dynamically by VRML graphic kernel using the data in "Data Layer". Related design information is also generated and correlated with relevant objects in VRML models automatically. The visualization layer is located at designated web site where information is published to all network users. Finally, in the collaboration layer, design and construction teams are able to watch, examine and walk into the VRML models through VRML viewer. These VRML models are also served as universal interfaces for the retrieval of related design information.
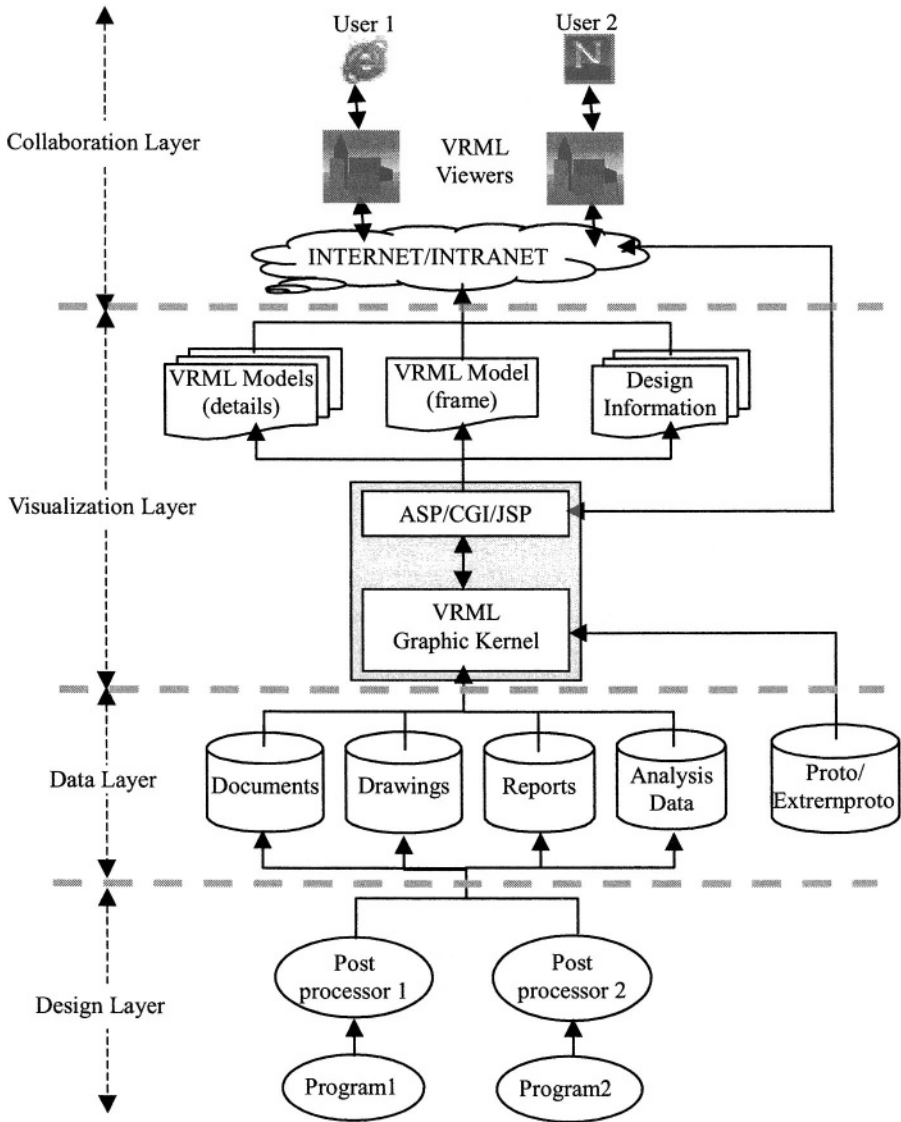
Fig. 2. The VRML Implementation Architecture

4   Examples and Discussions

The design of a 12-story RC building is given as an example. In the design layer, a commercial software ETABS [7] is used for the structural analysis of the sample

structure while a post processor called ETABSD [8], developed by Sinotech Engineering is applied for the ductility design of high-rise RC structures. The data layer consists of four types of data that are the outputs of ETABS and ETABSD. The prototyping schemes provide 48 types of bar hooks listed on American Concrete Institute (ACI) [9] and local design code and guidelines [10].

The VRML graphic kernel in the visualization layer is a component object extension of Sinotech's existing graphic libraries. There are two types of VRML models exporting from VRML graphic kernel in visualization layer. The first is a frame model for the whole frame of the RC building and is created based on the outputs of ETABS program. All related documents, drawings, calculation reports, analysis data and other related data are automatically linked to relevant VRML objects within the frame model. The second type VRML models reveal the reinforcement details of structural components in the frame model, for example the placement of bars and stirrups in the beams, columns and joints.

A screen shot of frame model is given in Fig. 3 with a user control panel on the upper right corner of the screen. Design information linked to the frame model includes beam reinforcement calculation reports, column reinforcement calculation reports, bar drawings, a summary report of beam and column quantities and other details of structural components.

With VRML models, engineers are able to conduct cursory layout examination on the design since both viewpoints and directions are controllable. Users can click on any structural component to view the reinforcement details (see Fig. 4). When navigating, further design information such as the moments and axial loading of a column can be verified with 3D diagram as shown in the pop-up window of Fig. 4. These models can be set up for self-rotating to help the practitioners conduct design check as shown in Fig. 5.
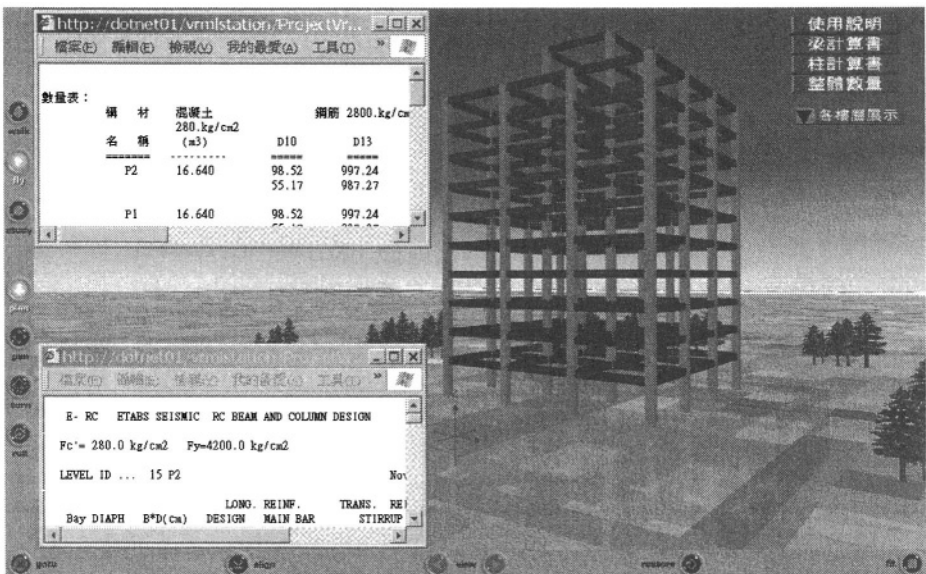
Fig. 3. The frame model of an example structure and its design calculation and quantity reports
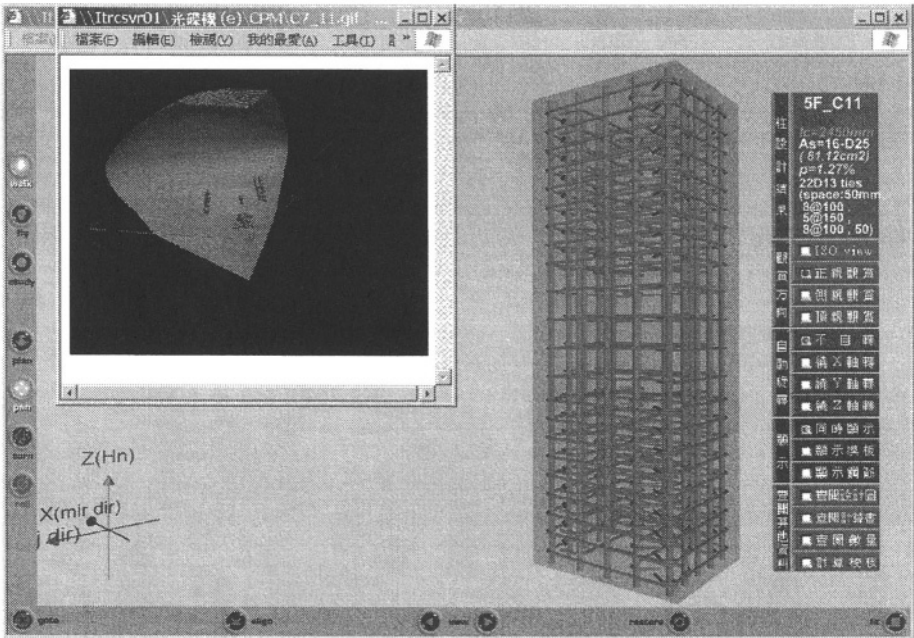
Fig. 4. The reinforcement details of Column 5F_C11 and its design check diagram
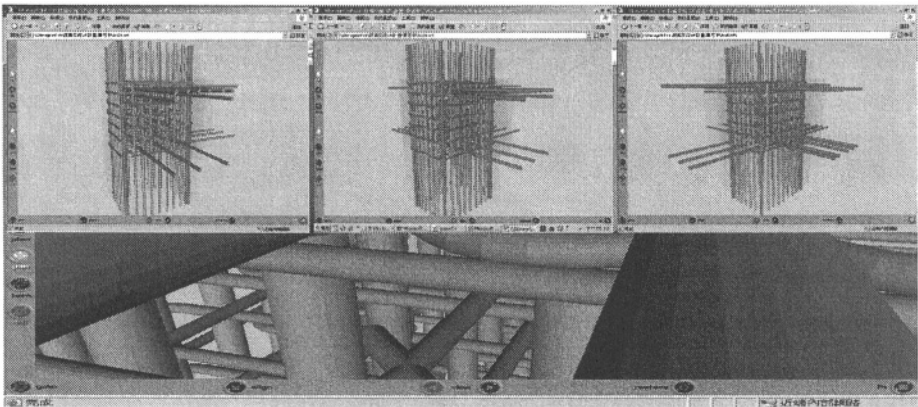
Fig. 5. Column and beam joint reinforcement details with automatic rotation

The placement of bars, stirrups and bar hooks and the continuation of bars are important concerns to construction teams. The VRML models of reinforcement details of beams, columns and joints provide a vivid demonstration for site workers before actually placing bars into forms. Constructibility issues such as the placing sequences of bars, stirrups and formworks can be demonstrated by VRML models. These are very important to the construction groups. The sequence and location of stirrup and bar placement on the column can be demonstrated by animation.

5   Conclusions

With the increase in complexity of modern construction projects, the need of information exchange is also increasing because a variety of tools are adopted in different stages, e.g. analysis, design, construction and maintenance of the projects. The technology of VRML provides robust means to improve communications among members of construction projects. In this paper, we propose a collaboration model called VRMLDCM to address the aforementioned issues. The model is further implemented as VRML implementation architecture (VRMLIA) to correlate engineering design process and WWW technology to dynamically generate VRML models of the design objects and the details of their components. This architecture also helps engineers in associating design information with VRML objects. The practicability and robustness of VRMLIA have been demonstrated by applying it to the design of a RC building. This versatile architecture is also possible to extend to other engineering applications such as plumbing and piping design or others if proper programs are adopted in the architecture. Possible directions for future studies include the extension to X3D (Extensible 3D) for VRML graphic kernel and its integration with assorted XML-based technology and the IFC (Industry Foundation Classes) /STEP (Standard for the Exchange of Product model data) information exchange models.

References

1. Hartman, J., Wernecke, J.: The VRML 2.0 Handbook, Addison-Wesley, New York (1996)
2. Lipman, R., Reed, K.: Using VRML In Construction Industry Applications. In Proceedings of Web3D - VRML 2000 Symposium, Monterey, CA (2000) 21-24
3. National Institute of Standards and Technology: User-Controlled VRML Simulation of an Excavator, Tower Crane, and Dumptruck. http://cic.nist.gov/vrml/equip.html (1999)
4. Jáuregui, D., White, K.: Implementation of virtual reality in routine bridge inspection. In Proceedings of Transportation Research Board 82nd Annual Meeting, USA (2003) 12-16
5. Hobbs, B., Dawood, N.: Harnessing the power of Virtual Reality— The potential for VR as a Virtual Integrated Environment for Project Development in Construction. In Proceedings of the Berkeley-Stanford CE&M Workshop: Defining a Research Agenda for AEC Process/Product Development in 2000 and Beyond, Stanford University (1999) 26-28
6. Whyte, J., Bouchlaghem, N., Thorpe, A., McCaffer, R.: From CAD to virtual reality: modeling approaches, data exchange and interactive 3D building design tools. Automation in Construction (2000) 43-55
7. Computers and Structures: ETABS—Integrated Building Design Software, Berkeley (2003)
8. Chen, K.C., Lin, T.W., Wang, F.W., Chiang, G.C., Chin, C.C.: Ductility Design and Graphic Programs for High Rise RC Structures. Research Report SEC/R-CS-98-01, Sinotech Engineering Consultants, Inc., Taipei (1998) (In Chinese)
9. ACI Committee 318: ACI 318-95 & Commentary (ACI 318R-95). Building Code Requirements for Structural Concrete, USA (1995)
10. Chinese Institute of Civil and Hydraulic Engineering: Reinforced Concrete Engineering Research Report 14-Reinforced Concrete Design Guidelines and Explanations (Civil 401-86), Taipei (1997)

Cooperative Design for Artistic Performances

Michal Masa[1], Jiri Zara[1], Bohus Ziskal[2], Pavel Smetana[2]

[1] Czech Technical University in Prague,
Karlovo nam. 13, 121 35 Praha 2, Czech Republic
`michal.masa@ciant.cz, zara@fel.cvut.cz`
[2] International Centre for Art and New Technologies,
Kubelikova 27, 130 00 Praha 3, Czech Republic
`ziskal@ciant.cz, ps@ciant.cz`

Abstract. ALTERNE (Alternative Realities in Networked Environments) platform aims at providing a high level of integration between various techniques supporting mixed reality, graphics, interaction and behavioral models. This paper focuses on two collaborative aspects the platform provides. First, it contains a virtual object repository, which allows artists to share their ideas and support collaboration on projects based on ALTERNE platform. Second, it enables direct and remote access for public visitors to the artistic installations so that all concurrent visitors can cooperate on the exploration of the installation.

1 Introduction

ALTERNE (Alternative Realities in Networked Environments) aims to construct a *collaborative alternative reality* platform to support the development of digital, interactive and participatory artistic activities. We define alternative reality as a generalization of virtual and mixed reality beyond the common "space-based" simulation. While traditional virtual reality essentially addresses the construction of visually realistic synthetic worlds, ALTERNE supports additional layers that will make it possible to explore other concepts such as: causality, relations between time and space, alternative laws of physics, alternative life forms, etc., in a more radical fashion [1, 2].

ALTERNE platform supports artistic VR installations that will be accessed either directly or remotely. The availability of the remote access is import since the physical size of the installation will always limit the number of direct spectators and we want the installations to be open for the widest possible public [3].

In general, ALTERNE platform provides two collaboration stages, one for the artists and second for the visitors. In the first stage several artists can cooperate together on the creation of an installation. In the second stage several direct and remote visitors can interact together and explore the installations mutually influencing each other.

Section 2 describes architecture of the ALTERNE platform, its building blocks and connections between them. Section 3 discusses both collaboration aspects of the platform and Section 4 concludes the work.

2   ALTERNE Architecture

At the heart of the ALTERNE system is a *Visualization Server* (VS), which is connected to some display device (i.e. SAS Cube) as well as to *Lightweight Clients* (LC) via *General Variables* (GV) server. Lightweight Clients influence the content displayed in SAS Cube through the visualization server. The content which is displayed by the server originates in the *Virtual Object Management Server* (VOMS), where all past exhibitions as well as 3D models, animations, etc. and related material (conversion tools, HOWTO documents, FAQs) are stored. Artists take an advantage of this service during the design stage of their artwork. The basic block scheme of the ALTERNE system is shown in the Figure 1.
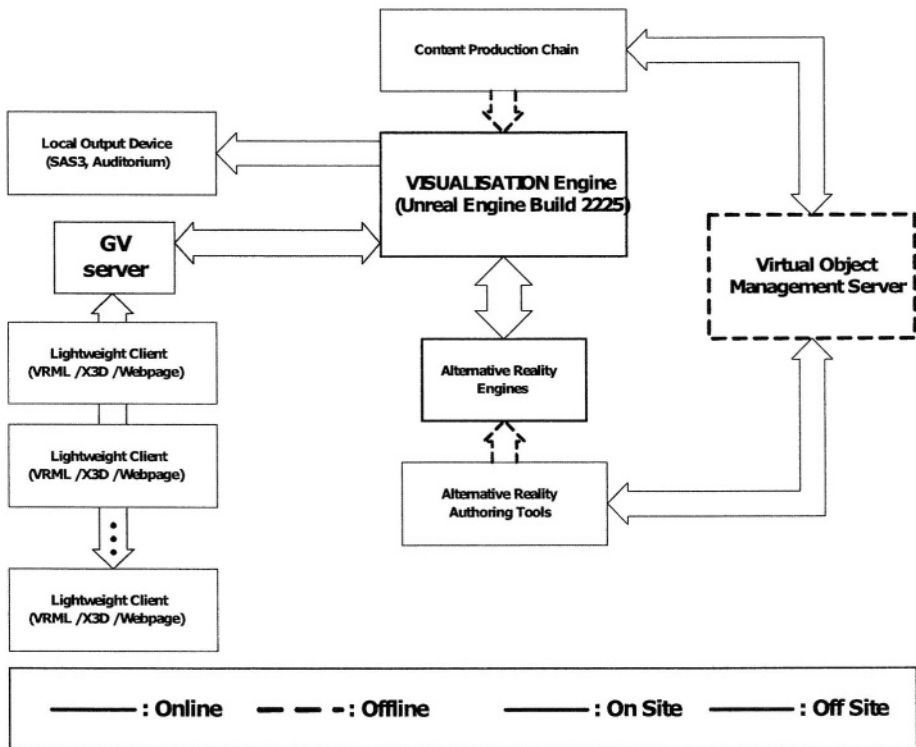
Fig. 1. Schematic view of the ALTERNE architecture
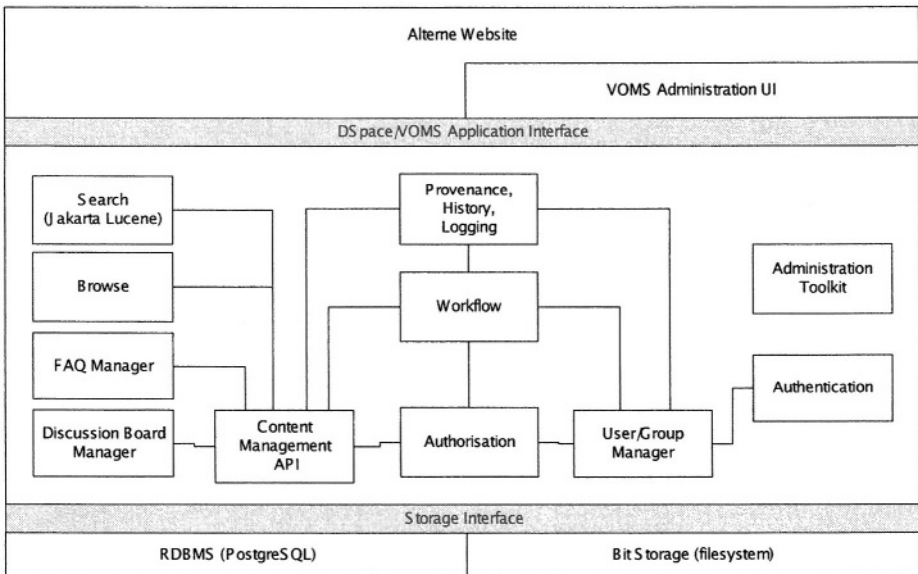
Fig. 2. Architecture of the Virtual Object Management Server

VOMS has been built on the top of DSpace, an open-source digital asset management system created at MIT [4]. Figure 2 displays the VOMS architecture that has been derived from DSpace. The server is separated into three distinct layers: The lower level is the storage layer. It consists of a relational database for storing metadata and a "bit stream" storage module for storing the digital assets. The central layer of the system contains modules that implement the business logic of the system. This part of the repository server implements the behavior of the repository itself. The top layer is the services layer, which consists solely of web user interface.

Content of the VOMS is organized into a two-level hierarchy. The highest level, called a community level in the DSpace notation, will cover particular ALTERNE-based projects. Every community is then organized into one or more collections which contain logically-related material used in a specific project.

The indexing and search abilities are based on metadata associated with every asset stored in the system. VOMS internally uses the Dublin Core metadata format to describe the stored assets. Dublin Core belongs to rather simple structured generic metadata format. Its elements are intended to be optional, repeatable and extensible [5]. This way it can be easily tailored to the needs of describing different digital asset types.
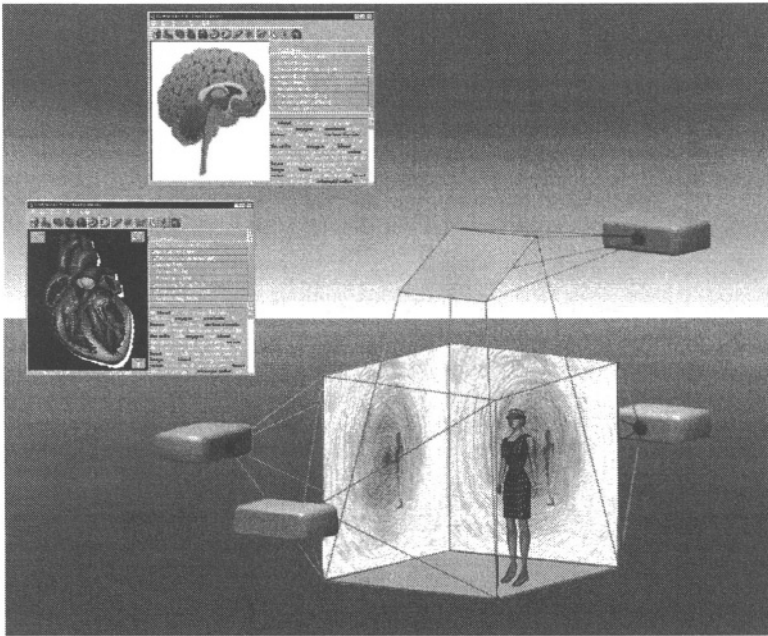
Fig. 3. Lightweight Client in 3D mode displaying 2D projections from CAVE (the projectors are shown for illustrative purpose only). Two GUI windows contain controls to change properties of the installation.

2.1 Lightweight Clients

The primary aim of the Lightweight Clients (LCs) is to enable remote exploration and control of artistic installations. LCs are connected to the installation(s) via the Internet and they mediate the experience of an immersed visitor to virtual visitors. The virtual visitors can perceive the installation in three modes:

1. 2D environment with video and audio streaming from the installation
2. 3D environment with 2D video produced by CAVE projectors and audio from the installation
3. 3D environment with 3D model of the installation

In addition to perceiving the installation, the virtual visitors are given means to change properties of the installation(s). The properties, their types and semantic actions are specified by the artists during the authoring process and proper GUIs are generated automatically. Depending on the LC's mode, the GUI can be 3D or 2D. However, we suggest using 3D GUI only for simple and intuitive properties since the manipulation of 3D controls is still very cumbersome.

Figure 3 shows a LC in 3D mode that uses video stream from CAVE projectors to display the installation venue with the immersed user (the second mode from the list above).

2.1.1   Integration of Lightweight Clients to the System

As the Figure 1 illustrates, LCs communicate with the visualization engine(s) through an intermediating element – General Variables (GV) server [6]. The server's role is to maintain consistency of installation properties at all clients. That means that all clients connected to an installation will see the same most recent properties. Since there is no response from the visualization engine (except the video and audio streaming), without the GV server the clients would not have any other means to synchronize values of the installation properties.

Another purpose of the GV server is to provide awareness among users by the help of avatars and communication channels (chat).

2.1.2   Overview of General Variables

The GV concept (Figure 4) was designed to formalize storing and distributing dynamic state in a client-server model. The fixed part of the VE state and its management is not covered by the concept since its implementation is closely tied with concrete application.
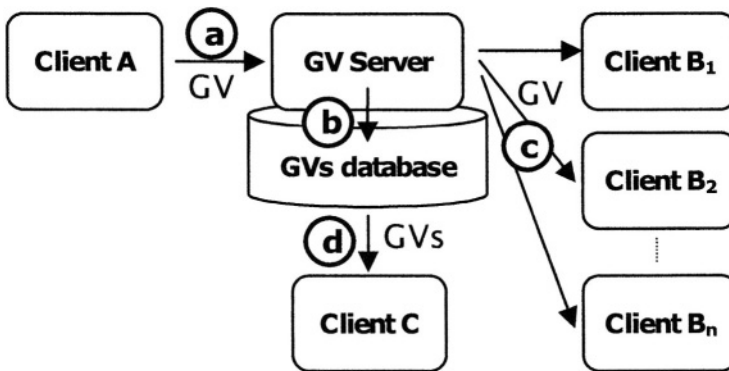
Fig. 4. General variables concept. Storage and distribution of general variables. a) sending a GV to a server, b) storing the GV in the GVs database, c) forwarding the GV to connected clients, d) sending the GVs database to a late join

If a user performs an interaction in the world (i.e. changes a property of the installation or his/her own position) the client sets a particular GV to some value. The value can be of arbitrary type (single value, array or heterogeneous structure). Then this new value is sent to a server (Figure 4a), which updates its GVs database (Figure 4b) and forwards the value to other connected clients (Figure 4c). They parse the value and perform the original action locally (i.e. update and display the new value of the property). If a new client (late join) connects to the system, the server sends it the content of the GVs database so that the client can update its state promptly (Figure 4d). In this scenario, the GVs database represents the dynamic state; GV values exchanged between the server and the clients correspond to dynamic state updates; and the content of GVs database sent to the late join represents the initial state.

3   Conclusion

ALTERNE project aims at construction of a novel kind of platform for the development of high-end digital arts productions and the teaching in domain of mixed reality installations. In this paper we described two collaborative aspects of the ALTERNE platform. Although the development of the platform began only recently, we have already produced several working prototype components that are now undergoing the debugging process.

4   Acknowledgements

References

1. Cavazza, M, Hartley, S., Lugrin, J.L., Bras, M.L.: Alternative Reality: a New Platform for Virtual Reality Art. In Proceedings of the 10th ACM Symposium on Virtual Reality Software and Technology, 2003.
2. Manovich, L.: The Language of New Media. Cambridge/London: The MIT Press, 2002.
3. Legrady, G.: Intersecting the Virtual and the Real: Space in Interactive Media Installations. In New Screen Media: Cinema, Art, Narrative. London: British Film Institute, 2002.
4. Smith, M., Barton, M., Branschofsky, M., McClellan, G., Walker, J.H., Bass, M., Stuve, D., Tansley, R.: DSpace: An Open Source Dynamic Digital Repository. D-Lib Magazine 9:(1), January 2003.
5. Day, M.: Metadata for Images: Emerging Practice and Standards. In Proceedings of Challenge of Image Retrieval, Newcastle, 1999.
6. Masa, M., and Zara, J. The General Variables Concept: A Simple Step from Single- to Multi-user Environment. In Proceedings of 2001 IEEE International Conference on Information Visualisation, 2001.

GEMMA: A Cooperative Control System to Collect Environmental Marine Waste[1]

B. Estrany, M. Mascaró, A. Bibiloni, G. Serra, E. Sideaner, J. Laredo,
B. Capo, B. Alcover

Universitat de les Illes Balears, Departament de Matemàtiques I Informàtica,
07122 Palma de Mallorca, Spain, Europe
http://80.39.95.27/gemmaweb/
tomeu.estrany@uib.es
mascport@uib.es

Abstract. GEMMA is a Cooperative Control System designed with free software tools. The system was developed through an agreement between the UIB[2] and "Conselleria de Medi Ambient de les Illes Balears". The system was developed to manage and coordinate several mobile resources (boats, planes) dedicated to maintain clean coastal and beach waters in the Balearic Islands. The implemented system, based on a client server architecture, is flexible and accepts several configurations depending on the information magnitude or the localization and dimension servers. The features that cause the flexibility of the system are: modularity (each functionality is independent to the others), cross platform (each module can run independently on Linux, Windows, Mac Os X, ...) and distributed (depending on the requirements it is possible to install modules in different network points).

1 Introduction

In the last years the Balearic Islands (Spain) have become a reference point in the Mediterranean Sea area. Balearic Islands are one of the most important places in Europe for tour operators and one of the main maritime routes.

As a result of this and other causes, as the population increases, the degradation of the natural environment has taken place. We do not forget that the sea is a fundamental component of our natural environment, and does not free of the pollution impact caused by all the situations that generate waste in our coasts. In addition this waste stains in more cases are directly observed by the tourist and in the habitants getting worse the prestige of our islands.

For all these reasons is necessary to start up a coordinated action to eradicate the problem of waste and ash dumping in our coasts.

---

[1] This project was support by the Government of the Balearic Islands.
[2] Universitat de les Illes Balears. Spain. Europe.

The main goal of the GEMMA[3] project is to develop a cooperative and interactive real time system that supply several tools to manage and send orders to some mobile resources (ships and humans), and makes an automatic and real time data flow generation with the information provided by the mobiles and the control center. This project tries to take part in the maritime waste collection plan of the local Government[4].

GEMMA project offers an integral solution to implement a control and management ship system. GEMMA is basically a set of elements (hardware, software and communication tools) that lets a Control Center to locate, in any time, mobile resources and waste coast. At the same time provides supplies the communications between mobile resources and the Control Center. Once the information generated by the Control Center in analyzed and processed, GEMMA will facilitate the take decision process to the maritime waste collection plan staff. GEMMA will also produce useful historical data base information to improve and prevent future actions.

1.1 Overview

The main intention is to design a waste collection system integrated by the following elements:

1. Waist stains localization system.
   - ☐ Air fleet.
2. Waste collection system.
   - ☐ Marine fleet.
3. Control and management system.
   - ☐ Communication module, Control Center.

GEMMA project tries to solve the third part of the waste collection system. In other words GEMMA project is ordered to: receive the location data of the mobile elements (boats and planes); receive information about the possibly incidence warnings produced by mobile resources, police, and external people; process them and render them in the GEMMA GUI[5] application system; introduce all the information in a data base system for their later analysis. GEMMA System must support too a communication between mobile resources and Control Center by GPRS, GSM and SMS.

GEMMA System Support. GEMMA System (fig 1) provides support to the main points of the waste collection plan:

- ☐ Make a daily control of the Islands Coast.
- ☐ Supervise the cleaning-boats action.

---

[3] In Spanish and Catalan languages GEMMA has a double meaning: "gem" and "Ship and Environment Management".

[4] Autonomic Government: Govern de les Illes Balears

[5] GUI: Graphical User Interface.

☐ Mobilize resources to manage any possible incidences.
☐ Make a historical activity data base.

Once the information data is stored in the system, users can consult and manipulate it. The GUI interface to consult the information must be friendly and useful.
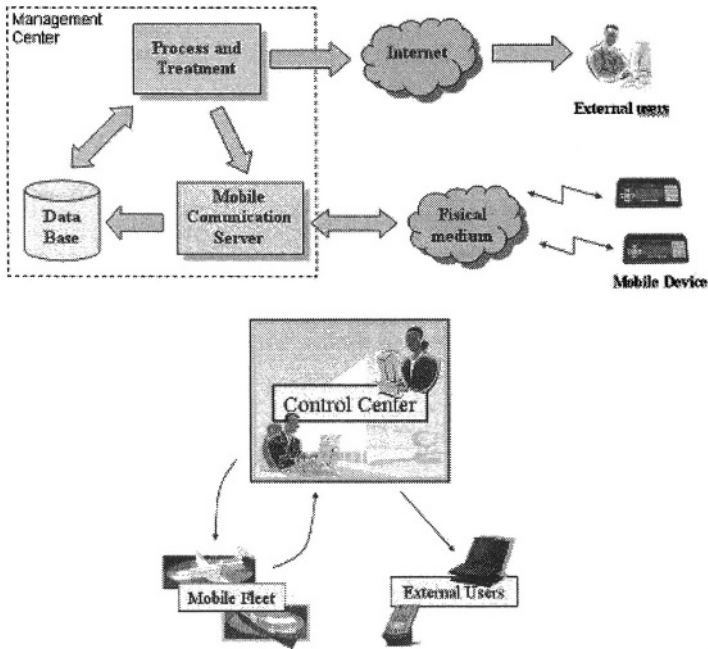
Fig. 1. GEMMA system scheme and data management process.

2   Architecture

This section describe the hardware and software GEMMA System architecture.

2.1   Hardware Architecture

Hardware architecture is integrated by two independent groups. By hand mobile communication devices and for the other hand the GEMMA System LAN (fig 2).

   Mobile Devices. The device used to develop the GEMMA System is Movilcom[6]. Each ship (boats and planes) has one of this integrated. This device has inside a GPS

---

[6] Movilcom is distribuited by Datatronics.

module to locate the ship, and support modem connections by GPRS/GSM to maintain duplex connections between the Control Center and mobile resources.

Local Area Network. In figure (fig 2) we can see a scheme of the LAN and the hardware platform necessary to implement our solution. This scheme shows every connected component by a Router and a Switch. The network presents a star topology.
Hardware components:

- Wiring: UTP 6, 1000Mbps.
- Router: Offers to the LAN an external connection and makes a routing and firewall tasks. CISCO 837.
- Switch: Interconnect all the components in the LAN. 3COM, 1Gb.
- Main Server: Contains the web server, the data base server and the web map server. Linux (SUSE 9), Dual Xeon 2800 Mhz, 2 GB RAM.
- Mobile Communication Server (SCDT): Mange connections between mobile resources and Control Center. Windows XP, Pentium IV 2800 Mhz, 1GB RAM.
- Work stations: Are used by the controllers to supervise and execute the GEMMA system work. Linux (Mandrake 10), Pentium IV 2800 Mhz, 1 GB.
- Terminals: Are use by the administrator users to introduce external data information in the GEMMA System. Linux (Mandrake), Pentium IV 1800 Mhz, 512 MB RAM.
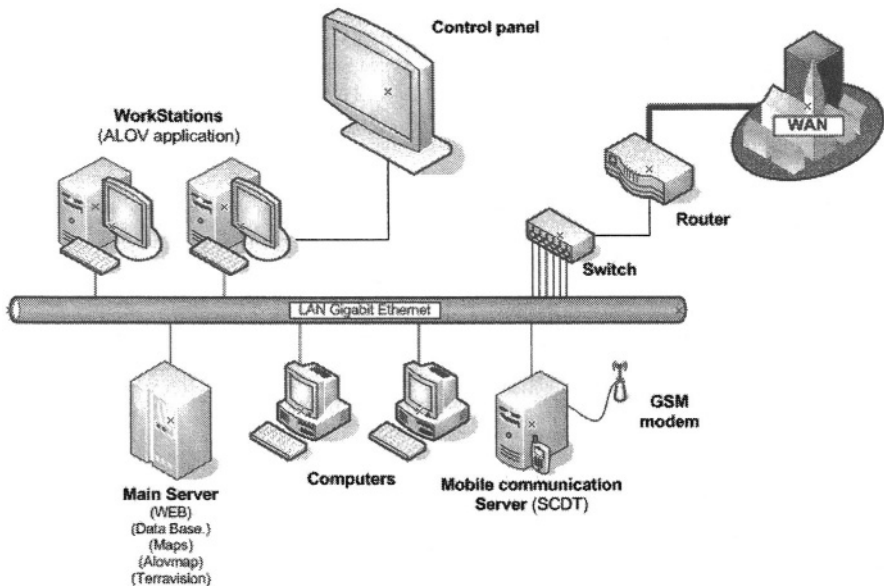
Fig. 2. GEMMA System network scheme.

2.2 Software Architecture

Our system is multiplatform, distributed, and it is developed 90% using free software tools. Graphic User Interface is developed in Java, the most suitable language to develop applications in Internet, and uses geographical data in Open GIS format [3], [4]. This feature let to possible users view the system information around the world with hardware and software independence (Personal computer, handled PC, cellular phones,).

GEMMA system is composed by 5 modules: communication manager, data base server, JSP web server, Web Map Server (WMS), and the main control application (fig 3).

Communication Manager. It manages all the communications between the Control Center and the rest of entities which can interact with the system information (cleaning boats, police, observer planes, coast guard, city councils, etc). The communication system is the unique module that was not developed using free software tools in order to satisfy the requirements of the communication supplier company (Telefónica). Communication Manager (SCDT) was developed in Delphi under a windows platform. It offers several concurrent tools to manage the communication between the controllers, boats and the rest of entities. Communication takes place using GPRS/GSM technology to manage text messages and data files, and phones calls to implement direct communication between the several entities what take place in the process. All the communication process is completely integrated in the graphical user interface, automatic and transparent to the final users.

Data Base Server. It was developed using a MySQL server. This module is the part of the GEMMA System where geographical information is stored. It also contains all the information about the present state of the boats and planes (position, velocity, and actual incidences). Data Base Server provides support of agenda and historical data too, and is the nexus of union between the five modules in the GEMMA System.

JSP Web Server. It was implemented using a Jakarta-Tomcat server. The system has an apache Web Server with a JSP module to serve geographical information to the Internet. Using several java servlets the information can be visualized and manipulated by authorized users around the world, and offers to the controller real time interaction with the system in any part they want. In other words controller terminals can be situated in a foreign control center place.

Web Map Server. This module provides satellite photographs to make the controller vision more realistic. The most significant problem in internet applications which use a high definition images is the large cost in bytes of the images to fetch through the web. To solve that, the GEMMA System has integrated a MitOrthoServer [2]. This module can takes a large TIFF images storage in the server machine and offers to the WWW clients little JPG images via apache server, which can be

downloaded without any problems in any part of the world. Using this tool, the GEMMA System can render little region photographs from high definition images.

Graphical User Interface. The main Control Center application was developed entirely in Java. This feature makes possible the use of GEMMA in any platform with J2SDK installed. From a free Java application to render static GIS information application, the "Alov Map" [1], a new interactive render system GEMMA GUI, was developed. GEMMA GUI is able to render GIS information and refresh some contents when the system requires it. In this way, the system can show the real positions of the entities, boats, planes and incidences, and can offer to the controller extra information about them. In addition, the system is capable of establishing a phone call or sending a message selecting any item on the screen.

The Communication Manager controls all the process in a cooperative mode. In this way, several controllers can interact with all the entities (boats, plane and other controllers) in GEMMA System in the real time (fig 4).

GUI module also offers the users statistical and historical results of the cleaning process. This information is visible entirely by the controllers and with restrictions by a WWW browser for other users.

Is also has been developed a little version of the GEMMA GUI to enable a pocket to PC access to the information of the GEMMA System.
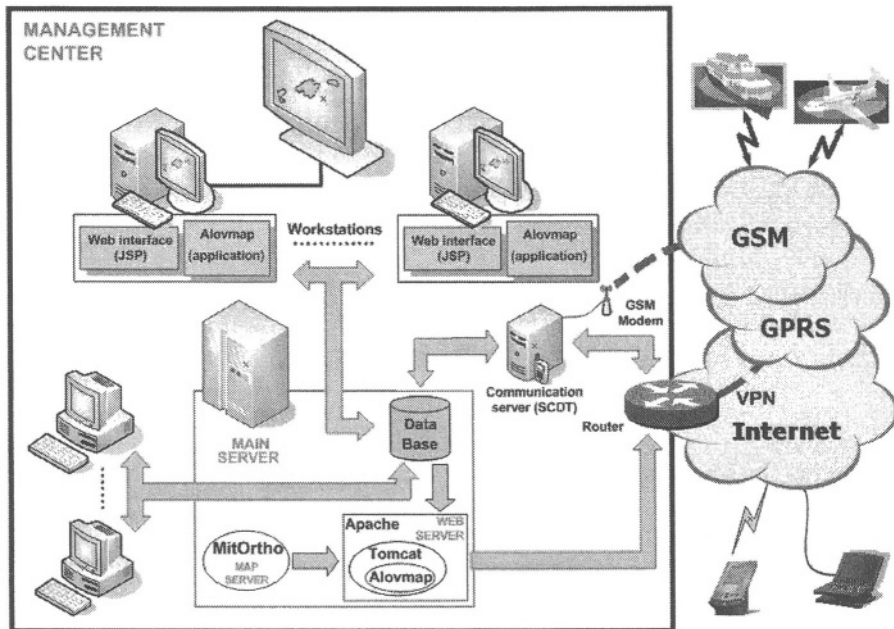
Fig. 3. The five GEMMA system modules and its relationship.
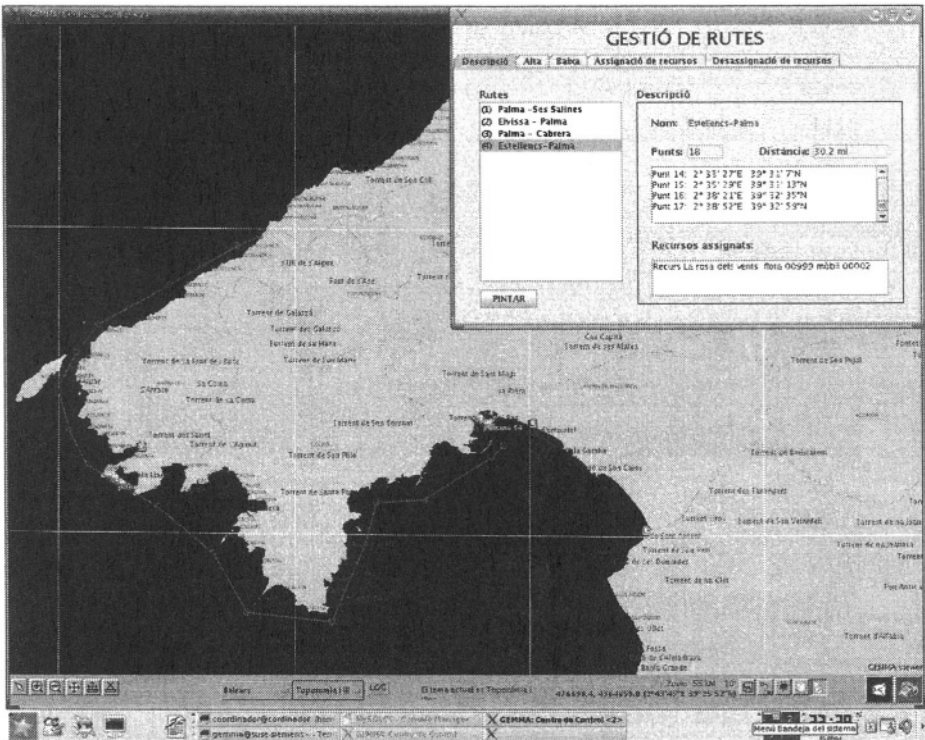
Fig. 4. Sending a message to a boat located in the south Mallorca Island. You can see too the daily route of the boat (pink line).

3   Operability

GEMMA System can manage all the process by the Control Center room. Using the GEMMA GUI controllers can observe the position of any mobile entity, obtain their day work path, send or receive messages, establish phone calls, assign routes to the boats and planes, observe current incidences and obtain historical results.

Routing and positioning. Controllers can view the current position of any mobile or incidence using the mapping tool. Boats, planes and incidences appear, on the screen with some information. The information is in text or color image format. In this way controllers can see the present state of any mobile or incidence on the screen map (no position, GPS open, organic incidence, chemical incidence, ...) , and can navigate through this map (moving, zoom in, zoom out see figure 5).

Fig. 5. Working path and positioning information of one boat in the Formentera Island (Spain).

Sending and receiving messages. Controllers can send messages to the mobile entities simply by clicking on one mobile symbol on the screen. It's also possible to send messages to a group of mobile entities at the same time. The message is send to the mobile by GPRS or GSM.

When mobiles send messages to the Control Center GEMMA GUI notifies this to all the controllers. At this time, any of them can attend to the message and make the right action, put an incidence in the system, reply the message, etc.

Managing incidences in GEMMA. When the reconnaissance airplane locates an incidence, it sends a photograph and its location to the Control Center. Then the incidence is show on the screen. Also when controllers receive a message or a phone call from any mobile or external entity, then can select the incidence tool in order to introduce manually the new incidence in GEMMA.. Once the incidence is in the system all the controllers or external users (www, pocket PC) can view the new incidence on the screen.

Controllers can also delete incidences in GEMMA in real time when the mobiles assigned to an incidence notify to the Control Center the end of the work.

Other functions. GEMMA System also supports actions to: manage the data base, create statistics, importing new mobiles and GIS shapes, configure the information that appears on the screens, reset the mobiles (modem com), import photographs from the planes, etc. All tasks are implemented to function in a cooperative real time environment.

4   Results

Actually the GEMMA System is full operability since 06/01/2004. The response and results of the Cooperative GEMMA Control System are satisfactory.

System allows a cooperative work of 3 controllers, 12 coastal boats, 27 beach boats and 1 plane. Controllers can manage the efforts of all this mobile resources using GPRS and call phone connections. In all time controllers can verify the sate and locations of all mobile resources. Simultaneously mobile resources are connected to each controller to inform them of the possible actual incidences and their response.

In the first week GEMMA System gets collected a great amount of waste. As anecdotal in the 13th day one death cetacean (8.5 tones) and half tone of waste was collected.

To see the actual state of the GEMMA project and a real time information about the system functionality visit http://80.39.95.27/gemmaweb/index.html.

References

1. Alov Map. http://www.alov.org/. University of Sydney, 1999-2004.
2. MITOrthoServer. http://ortho.mit.edu/mitorthoserver. Massachusetts Institute of Technology, 2001.
3. OpenGIS Consortium. http://www.opengis.org/. 2004.
4. Fernández P., Bejar R., et alt. Web mapping interoperatibility in practice, a Java approach guided by the OpenGIS Web Map Server Interface Specification. University of Zaragoza. European Project TIC98-0587, 2000.

Appendix: GEMMA System Extra Pictures
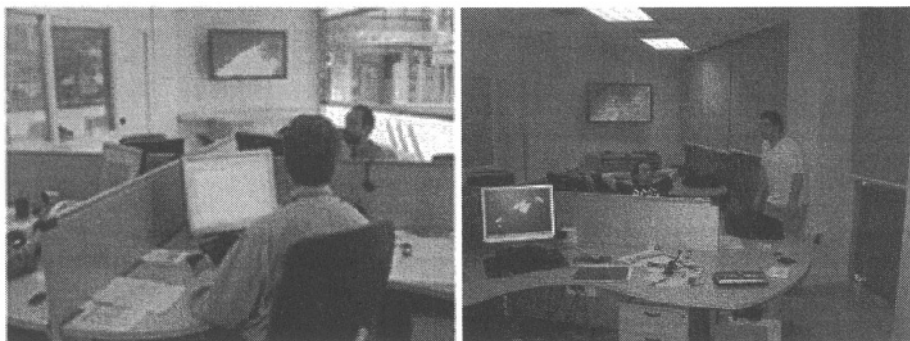
Fig. 6. The Control System Room.
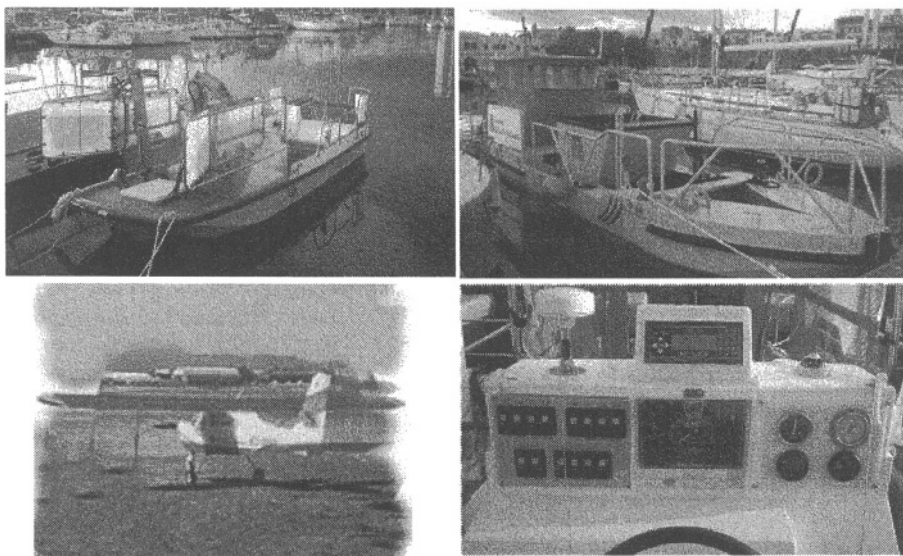
Fig. 7. Left right and top down: beach boat, costal boat, plane and Movilcom. In the right down picture you can observe the mobile communication devices (on the left you can observe the GPS anthem, on center the display of the Movilcom and on the right the GSM anthem).

Comparison of Real-Time Text Chat and Collaborative Editing Systems

David Chen and Chengzheng Sun

School of Computing and Information Technology, Griffith University, Australia
D.Chen@cit.gu.edu.au, C.Sun@cit.gu.edu.au

Abstract. Online text chat systems are effective group communication tools that have been used for many types of collaborative work. Real-time collaborative editing systems can be used for collaboratively compose documents. These systems can be used for communication and documentation in many tasks, including design and engineering. Until now, the developments of these two types of systems have been independent. This paper points out the close relationship between them: text chat is simply a restricted form of collaborative editing. Two major differences between them have been identified. (1) Standard text chat systems do not maintain some of the consistency properties in collaborative editing systems. (2) The user interface for standard text chat systems is less flexible. It has been shown that collaborative editing systems, when used for text chat, can overcome most of the previously identified problems associated with standard text chat systems. This study serve as a guideline for the design of the new generations of text chat systems.

1 Introduction

Online text chat systems have been developed and used since the early days of Internet computing, in the form of Internet Relay Chat or IRC. In the recent years, many more text chat systems have been developed, ICQ, AOL, and MSN Messenger, etc. These are very popular tools for real-time communication via the Internet, and have been used for serious work [5], decision making [3], and recreation [4].

In a typical user interface for text chat clients, there is a chat history area which contains text chat messages from all users. The bottom of the history area is usually the focus of the users as this is where new messages appear. Below the history area, there is an input area for typing and editing messages. The message typed is local to the client until the enter key is pressed, in which case the text message is sent to all participating clients. This style of user interface is widely used and has remained relatively stable over the years. In the rest of this paper, the term "standard text chat" (STC) will be used to refer to those typical text chat features which are common to most text chat systems. In the past few years, various problems with STC have been identified by researchers. It has been shown that better support for text chat is required and many researchers are currently working to towards this goal.

A real-time collaborative editing (CE) system allows multiple users to edit the same document at the same time [10]. A basic CE system provides a simple text edi-

tor user interfaces, where users from multiple sites are allowed to edit a document just like a single user editor (i.e. insert and delete text at any location). All editing actions performed at any site are propagated and displayed at all sites so that user at one site can see the actions of users at other sites. Examples of such systems are REDUCE [10], and Hydra [11]. There are additional features that can be added on top of the basic CE environment, such as: color highlighting of text to indicate text inserted by different user, undo executed operations [8], variable granularity of text propagation, and lock certain sections of the text [9].

Our research group have been using and experimenting with REDUCE ever since it went online. Whenever people start using REDUCE, they first interact with each other via some forms of text message through REDUCE, e.g. *"Hello, can you see this?"*. Furthermore, REDUCE has been used as a text chat communication tool for organizing systems demonstration, planning workshops or meeting schedules, debugging programs, and getting to know other people. From our experience of using a CE system and STC systems, it seemed that a CE system has advantages and also disadvantages over STC systems. Hence, it would be interesting to compare these two types of systems to identify their differences.

This paper is organized as follows; first, the problems with STC will be presented. Then a comparison between CE systems and STC systems will be made. A further comparison is made between an experimental text chat system and CE systems.

2   Problems with Text Chat

Despite its popularity, there are several problems with STC systems. This section briefly presents these problems which were identified previously by Smith et. al., [7], Voida et. al., [12], and Vronay et. al., [13].
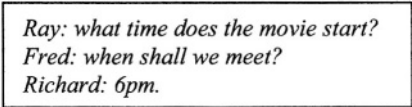
Lack of links between people and what they say. In a STC system, a message is preceded by the name of the participant who wrote that message. In the situations where there are many participants in a chat session, it may be difficult to determine who wrote the message. This problem is further aggravated by large number of short messages, especially when they are presented close together.

No visibility of listening-in-progress. Participants do not know whether other participants are currently listening (reading). Furthermore, there is no indication of the reaction of the listener. Such indication is important in voice conversations and, without it, misunderstanding between the text chat participants may occur.

Lack of visibility of turns in progress. In voice conversation, the listener knows whenever, the speaker is talking. However, in most chat systems, the listeners (or readers) do not always receive any indication that other participants are typing. In these chat systems, the message is transmitted to participants only after the "Enter" key is pressed. Hence, the only indication that a participant is responding appears after the whole message is composed and received by the listener. This delay in receiving a response may be due to the slow typing speed of the participant, or long network latency delay. In either case, other participants, listeners, may simply treat it as a long pause before responding by the speaker. Such a long pause between a question and a reply may give the listener the perception of negative response [6].

Lack of control over turn positioning. Participants may concurrently type messages. These messages will appear in the order determined by which site pressed the "Enter" key first. As the result, a pair of questions and answers (or messages on the same topic) may be interleaved by another pair. An example is as shown in Figure 1. In this example, it is unclear whether Richard's response is answering Ray or Fred's question.

Although having participants type concurrently saves time. The order these concurrent messages appear may be confusing to the participants. Hence, the benefit of concurrent interaction is lost.

Ray: what time does the movie start?
Fred: when shall we meet?
Richard: 6pm.

Figure 1. Confusion due to lack of control of turn positioning.

Lack of support for threaded conversations. Text chat is a unique medium which allows users to carry on multiple threads of conversation simultaneously. Heavy instant messaging users often have threaded conversations. However, STC interface is not designed to support threaded conversations. All new messages are displayed at the bottom of the chat window, messages from different conversation threads will be interleaved when displayed. So the message for one thread becomes the background noise for another.

Difficult to correct mistakes. Errors occur more frequently during text chat (e.g. typos) than voice conversation (e.g. pronunciation error). In voice conversation, errors can usually be spotted and corrected instantly. In text chat, errors are often spotted after it has been propagated and displayed on the message window (because that is the area of focus). It is also harder to correct typos by rephrasing as typing is much slower than talking.

Lack of useful chat history. The chat history/log can be important as it contains the record of how a decision is reached. However, due to the previous three problems, a chat log may become unnecessary long and difficult to understand. Hence, people would be reluctant to read through the log.

3   Comparing Collaborative Editing and Text Chat Systems

Real-time CE systems share a lot of similarities with text chat systems. The functionality these systems need to perform can be classified into three layers: user interface, consistency maintenance, and communication. The following subsections examines each of these layers.

3.1   Communication Layer

The communication layer is responsible for sending/receiving operations across communication networks to/from remote sites. There are two different communication models: peer-to-peer, or via a centralized server. Both approaches can be used by text chat and CE systems. However, almost all STC systems implement their communication layer using the central server model. One of the main reasons for this is to reduce the complexity in the chat client, making the client a relatively lightweight

process. For example, in the case of IRC where there may be hundreds of participants in the same channel, maintaining hundreds of communication channels in the peer-to-peer communication model is a very heavy burden on the client's machine. By using the centralized model, only one communication channel to the server is needed from each client site.

Both approaches have been implemented in different versions of REDUCE. REDUCE was originally implemented using the peer-to-peer model. Scalability was not considered as a major issue in the design of REDUCE, as it is expected that the number of participants in a CE session will be no more than ten people. Hence, the peer-to-peer model was used to avoid the need of a central server and the extra latency caused by transiting through the server. However, later on, a web-based REDUCE was implemented using the centralized model due to the security restriction of Java applets. Both models of communication will be considered in the next section during the comparison for consistency maintenance techniques.

3.2   Consistency Maintenance Layer

Consistency maintenance layer decides how, when, and where the messages are incorporated into the shared document. Consistency is a general term, hence, its precise meaning needs to be further defined. Sun et. al., [10] proposed a consistency model which defines three consistency properties for CE systems: causality preservation, convergence, and intention preservation. As there is no previously defined consistency model for text chat systems, this model will be used to determine which consistency properties have been maintained by STC systems.

The reason that consistency is an issue in REDUCE is due to the optimistic operation execution schemes used in REDUCE. With this operation execution scheme, whenever an operation is generated, it is executed locally before propagated to remote sites for execution. Optimistic operation execution ensures fast response time, a highly desirable feature for CE systems. However, with this method of execution, some kind of consistency maintenance mechanism is required to preserve the three consistency properties.

In REDUCE causality preservation is achieved by a vector time stamp system. This system is only necessary when the underlying communication model is peer-to-peer. In the centralized server model, the causality preservation can be maintained simply by ensuring that the server relays all operations to all sites in the receiving order. Convergence and intention preservation are preserved in REDUCE by operational transformation [10]. Serialization is also used in some situations to ensure convergence when concurrent operations insert text in the same location.

STC systems also use optimistic operation execution to achieve fast system responsiveness. Hence, unless there are mechanisms to maintain consistency, the three properties would not be preserved. In STC systems, all operations are relayed through a central server. Hence, causal orders between operations are preserved automatically through this communication model.

However, there is no special mechanism for convergence and intention preservation. Hence, convergence and intention of operations are not preserved. The implication is as follows. (1) The contents of the logs for the same session may be different

on different sites. (2) Messages are not placed in the intended locations. (3) These factors may result in confusion to the participants. A scenario with divergence and intention violation problems is as shown in Figure 2.

In Figure 2, the time-space diagram shows that the question from Ray, arrives at Richard's site first. Richard immediately typed his reply, to Ray's question before Fred's question, arrives at Richard's site. So as far as Richard can see from his local interface, his answer appears right after Ray's question, so there is no confusion that his message is intended to answer Ray's question. However, on the other sites Richard's answer is displayed after the two questions from Ray and Fred. Furthermore, these two questions are displayed in different orders on different sites; these results can lead to confusion.
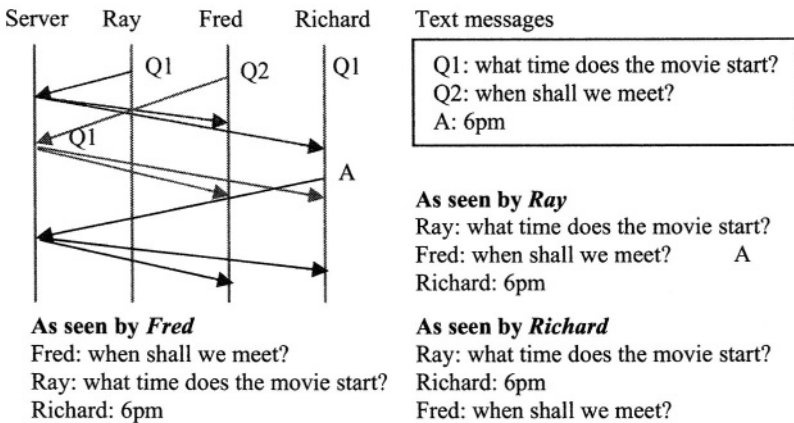
Figure 2. A STC scenario which violates convergence and intention preservation.

To further complicate the problem, not all users of text chat systems understand that divergence and intention violation may occur. It is natural for the users to assume that what they are seeing is what other people are seeing because in most situations, convergence is preserved. It is due to the occasional and unexpected occurrence of divergence which lead to confusion.

As shown above, divergence occurs as the copies of the shared documents are different, which also leads to intention violation as operations' local effects are different from their remote effects[1]. These two problems will lead to confusion for the users of text chat systems (without the users realizing what is causing the confusion). Convergence and intention preservation are maintained in REDUCE. Hence, all users will see the same messages in the same order. Therefore, this type of confusion caused by divergence and intention violation does not occur in REDUCE.

---

[1] For standard text chat system, intention violation occurs as the result of divergence. But in other systems, intention violation may occur even if convergence is preserved.
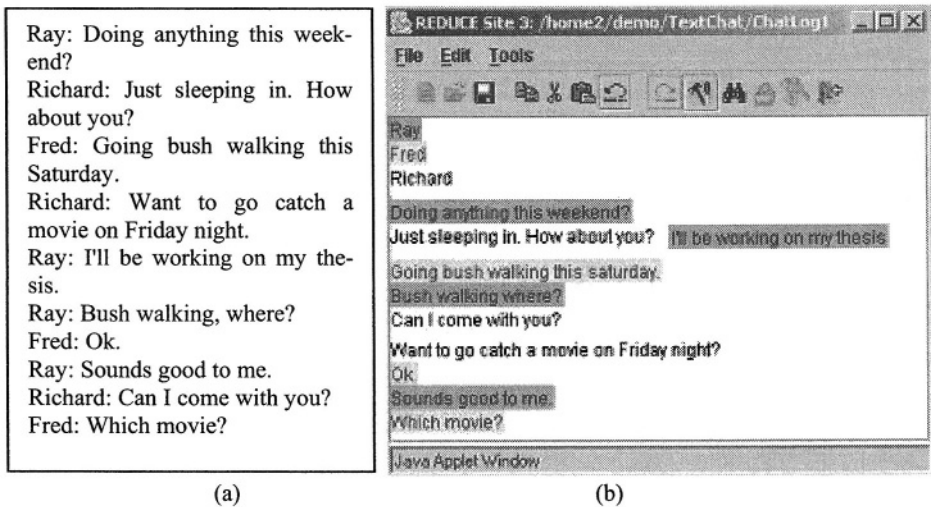
Figure 3. (a) A threaded conversation in STC. (b) A threaded conversation in CE.

It should be pointed out that, there are a small number of none-mainstream chat systems which do not use optimistic operation execution. These systems do not suffer from the inconsistency problems. However, from our usage experience of these systems, it is clear that the slow responsiveness of these chat systems is intolerable.

3.3   User Interface Layer

The user interface determines how users interact with the systems. CE and STC systems are different in the ways users interact with the user interface. With a CE system, users may edit any part of the document at anytime (just like a single user editor). In comparison, the text chat interface can be seen as a restricted editor interface. With STC systems, texts typed into the input area can only be added to the end of the document. Hence, users can only append new texts. Furthermore, no deletion is allowed. Such differences in the user interface have several implications.

The flexibility of editor interface gives users more control on where they want their messages to appear on the screen. Users can place their messages at the appropriate position to better express their meanings, e.g. on the same line as the question as shown in Figure 3(b). Similarly, it could happen that Richard simply placed his message in the line below Ray's question, because he did not anticipate that there would be a question from Fred. As the result, the situation in Figure 1 is produced. Realizing the possible confusion in this situation, Richard can move (cut and paste) his answer to either the same line as Ray's question, or the line below it. This scenario and the one above shows how the users can control their turn positioning to better express their meanings.

The flexibility and the control given to the user by the editor interface means that the users are able to separate different threads of conversation to different locations of the editing area. This allows more than two threads of conversation carrying on si-

multaneously during one session, without these threads interfering with each other. Users have the control as to when and how to separate these threads. An example is shown in Figures 3. Figure 3(a) shows how three threads of conversation may appear on a STC interface, where messages are simply appended to the end in chronological order. Figure 3(b) shows how messages for these different threads can be separated to different parts of the editing area so they can be easily read.

To fix a mistake in STC interfaces, a new message need to be written to explain what the mistake is and what the correction should be. With an editing interface, a mistake made on the previous message can be easily corrected, as mistakes can be fixed directly on the spot. In addition, editors can provide the undo feature, as implemented in REDUCE [8], for users to undo any previous operations.

As the result of being able to control turn positions, to separate threads of conversation, and to correct mistakes, the chat log in CE will be more concise and easier to understand. For logs which are considered important, they can be further edited for clarification and improving the readability. The save feature of the editor means that multiple versions of the log can be saved.

In CE systems, as each character is being typed, it can be propagated to the remote site and displayed. This provides indication that a participant is typing a message, hence, providing visibility of turns in progress.

CE systems provide the freedom for users to edit any part of the document. However, with such freedom there is a danger that uncooperative users may recklessly edit other people's message. This problem can be resolved by using a locking scheme [9]. For the purpose of text chat, locks can be applied such that text inserted by a particular user can only be edited by the same user.

With STC systems there is a single point of focus, the bottom of the screen where new message is appended/displayed. However, with CE systems, messages can be inserted anywhere in the document. This raises the issue of how participants can keep track or be informed of the arrival of new messages. Being able to see turns in progress can, to some extent, provide the information that new message at a specific location is being inserted. However, it fails when those messages are inserted outside of the current display area.

An important piece of information provided automatically by STC interface, which is missing from editor interface, is the relative insertion times of the messages. In STC systems, all messages are in chronological order, the oldest at the top, and the newest at the bottom. But in editor interface, there is no such distinction.

The lack of indication of where and when messages are inserted is a very serious problem in the editor interface for both text chat and CE. However, we do believe that these problems can be solved by the appropriate workspace awareness mechanisms. Here are some examples:

Tele-carets (similar concept to tele-pointers) can be adopted to display the caret position of other users. Tele-carets indicate where other users are likely to insert next.

Color highlighting can be used to indicate the age of the text (although currently it is used by REDUCE for indicating who inserted those text).

4   Comparison with Threaded Chat

An experimental text chat system called Threaded Chat [7] was developed by Micro-soft Research. With Threaded Chat messages are organized in a tree structure. Mes-sages concerning different threads of conversation are placed in different branches of the tree. Messages as a whole can be moved and edited. While a message is being typed, the location of that message is reserved at all remote sites to indicate turn in progress. However, one of the main draw backs of threaded chat is that users are forced to organize their text messages into the tree structure, This may be good for some situations, such as decision making, however, this is too restrictive for less formal types of interaction. With a CE system, users can organize their conversation into any structure they choose, or simply use it like a STC system.

In many ways, Threaded Chat is similar to CE systems. Threaded Chat can be seen as a CE system which allows users to edit the same tree. Similarly, Threaded Chat would suffer from the same set of inconsistency problems if no mechanism were implemented to handle them. Unfortunately, Smith et. al. [7], did not discuss the issue of consistency maintenance. From the lack of discussion, it would seem that conver-gence is preserved by using the centralized approach with pessimistic operation exe-cution. The reason being that maintaining convergence for CE of replicated trees with optimistic operation execution is a none-trivial task as shown in [1] (so it would at least deserve a mention it was implemented).

5   Conclusion

Text chat, in the form of IRC, has been in existence since 1988 (source: http://www.irc.org/history_docs/jarkko.html). Real-time CE system was first pro-posed in 1989 [2]. Until now, the developments of these two types of systems have been independent of each other. This paper has shown that these two types of systems are very closely related, in fact, text chat is simply a restricted form of CE. Hence, a unique comparison between these two types of systems is made in this paper. As many researchers are currently working on the development of a new generation of text chat systems, the results of this study serve as an important guide for the design of the new generation of text chat systems.

6   References

1. Davis, C. Sun, J. Lu: "Generalizing Operational Transformation to the Standard General Markup Language," *Proceedings of ACM 2002 Conference on Computer Supported Co-operative Work,* Nov 16-20, New Orleans, Louisiana, USA, pp.58-67.
2. Ellis, C. A. and Gibbs, S. J. (1989): 'Concurrency control in groupware systems'. In *Proc. of ACM SIGMOD Conference on Management of Data,* 1989, pp 399-407.

3. Farnham, S. Chesley, H. McGhee, D. Kawal, R. and Landau, R. (2002): 'Structured online interactions: improving the decision-making of small discussion groups'. In *Proc. of the ACM 2000 Conference on Computer-Supported Cooperative Work,* 2000, pp 299–308.

4. Grinter, R. E. and Palen, L. (2002): 'Instant Messaging in Teen Life', In *Proc. Of ACM 2002 Conference on Computer Supported Cooperative Work,* USA, 2002, pp. 21-30.

5. Handel, M. and Herbsleb J. D. (2002): 'What Is Chat Doing in the Workplace?', In *Proc. Of ACM 2002 Conference on Computer Supported Cooperative Work,* 2002, pp. 1-10.

6. Pomerantz, A. (1984): 'Agreeing and Disagreeing with assessments: some features of preferred/dispreferred turn shapes', In J. Heritage and J. Atkinson (eds): *Structures of Social Action: Studies in Conversation Analysis,* Cambridge 1984, pp 57-101.

7. Smith, M. Cadiz, J. and Burkhalter, B. (2000): 'Conversation Trees and Threaded Chats', In *Proc. of the ACM 2000 Conference on Computer-Supported Cooperative Work,* Philadelphia, USA, 2000, pp 97-105.

8. Sun, C. (2000): 'Undo any operation at any time in group editors', In *Proc. of the ACM 2000 Conference on Computer-Supported Cooperative Work,* USA, 2000, pp191-200.

9. Sun, C. (2002): 'Optional and responsive fine-grain locking in internet-based collaborative systems', *IEEE Transactions on Parallel and Distributed Systems,* 13(9), 2002, pp 994-1008.

10. Sun, C. Jia, X. Zhang, Y. Yang, Y. and Chen, D. (1998): 'Achieving convergence, causality-preservation, and intention-preservation in real-time cooperative editing systems', *ACM Transactions on Computer-Human Interaction,* 5(1), 1998, pp 63-108.

11. TheCodingMonkeys (2003), 'Hydra', http://hydra.globalse.org/index.html

12. Voida, A. Newstetter, W. and Mynatt, E. (2002): 'When Conventions Collide: The Tensions of Instant Messaging Attributed', In *Proc. of the SIGCHI conference on Human Factors in computing systems: Changing our world, changing ourselves,* pp 187-194.

13. Vronay, D. Smith, M. and Drucker, S. (1999): 'Alternative Interfaces for Chat', In *Proc. of the 12th Annual ACM Symposium on User Interface Software and Technology,* Asheville, USA, 1999, pp 19-26

Design of Cooperative Agents for Mobile Devices

Juan M. Corchado[1], Emilio S. Corchado[2] and M.A. Pellicer[1]

[1]Dep. Informática y Automática
Universidad de Salamanca
Plaza de la Merced s/n
37008, Salamanca, Spain
corchado@usal.es
http://gsii.usal.es/
[2]Department of Civil Engineering
University of Burgos, Spain
C/ Francisco de Vitoria s/n
09006, Burgos, Spain

Abstract. The paper presents an agent-based engineering system developed for mobile devices. The proposed system has been used for constructing a wireless tourist guide application that incorporates cooperative agents with the learning capabilities. It is shown how to construct cooperative agents with a goal driven design using a case-based reasoning methodology. The resulting architecture has been tested by real users during six months and the results obtained are here presented.

1 Introduction

Agents for mobile devices have introduced an interesting an exciting new paradigm in the telecommunication industry. In the competitive telecommunication world multi-agent systems have been success the drive for new and sophisticated services is fundamental. The new challenges of this field require new technology that facilitates the construction of more cooperative, dynamic and flexible applications, capable of working in a real time environment. Agent-based solutions intend to cope with such requirements. The development of agent for wireless devices is characterized by very limited, variable and asymmetric technology and bandwidth, frequent and prolonged disconnections, geographical mobility, severe resource restrictions and complex data management issues. In addition to these familiar issues there is also the crucial element of dynamism.

Agent technology has already been proposed as a possible solution to many of these problems. When the terms "cooperation" or "intelligent" is used it is clear the user means the software to be something more than a mere server, mobile or not. Often, the term is only a reference to a context of a community and technology. With respect to agents, the "intelligent" label in this case refers to a concern with abstract, domain-independent theories of agent architecture and communication and/or aspects of human characteristics. The terms cooperation and autonomy are essential in the development of distributed agent-based systems for wireless devices.

The amount of information available to users via wireless systems is changing and increasing continuously. Existing applications need to be continuously updated. In this context the use of dynamic agents based systems may help to reduce the developed costs and to facilitate the use of this technology. We propose the use of cooperative agents that use case-based reasoning (CBR) systems [1, 3]. The proposed architecture combines reactive and deliberative agents. The architecture used by the second ones includes the use of Beliefs, Desires, and Intentions (BDI). Under this model, agents have a mental state that consists of informational, motivational, and deliberative states respectively. Beliefs represent the information about the environment, the internal state the agent may hold, and the actions it may perform. The agent will try to achieve a set of goals, and will respond to certain events [9, 11].

The deliberative agents are built on a case-based reasoning system [3,6]. The proposed method starts by identifying agent roles and goals, and the design and implementation of the agent architecture follows the form of CBR systems, which facilitates learning and adaptation, and therefore a greater degree of autonomy than with a pure BDI architecture. This is made by mapping the three mental attitudes of BDI agents into the information manipulated by a CBR system. This direct mapping between the agent conceptualisation and its implementation is the main difference with respect to other proposals that have also tried to combine BDI and CBR [2, 7, 8, 10].

A tourist guide service through mobile devices has been used to validate the system. The system has been validated by users who have used it when visiting the city of Salamanca. The system is able to program a tourist route, and modify it according to the conditions of the places to visit and the available time for the tourist. The following section describes the agent based architecture. The conclusions are finally presented and the results evaluated.

2   Agent-Based Architecture

A tourist guide application has been developed using a multiagent architecture. The agents assist potential tourists in the organization of their tourist routes and enable them to modify their schedules on the move using wireless communication systems. This system has been constructed using an engineering framework developed to design and implement an agent-based tool, as well as integrating existing state of the art in order to create an open, flexible, global anticipatory system with mobile access for the promotion and management of inland and cultural tourism, which will be user-friendly, cost-effective and secure.

The integrated, multi-platform computer system is composed of a guide agent (Planner Agent) that assesses the tourists and helps them to identify tourist routes in a city with a given visiting period of time and under a number of restrictions related to cost, tourist interest, etc. There is one assistant agent for each user of the system, the Performer Agents. Each user willing to use the system has to register and solicit one of these agents. Finally, there is a third type of agent, the Tracker agent, which maintains updated information about the monuments, the restaurants, public transport conditions, etc. This agent maintains horizontally and vertically compiled information on hotel accommodation, restaurants, the commercial sector and transport, in order to

meet the needs of the potential visitor on an individually customized basis, and re-
sponds to requests for information, reservations and purchases in the precise moment
that they are expressed. The user may decide whether to install the corresponding
Performer Agent on a mobile phone or PDA, or run it on the server and interact with
it via its mobile device. The first choice supposes a reduction of the cost, since the
tourist can interact with his agent as much as needed at no cost because it is installed
in the wireless device. Nevertheless, the agent will have to contact regularly with the
Planner Agent. Fig. 1. describes the system architecture from a very high abstraction
level. Users may interact either with their performer agents installed in their wireless
devices or in an internet server.
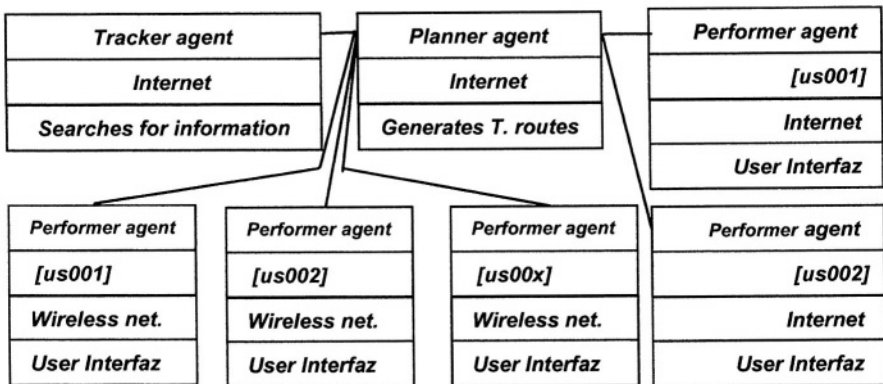
Fig. 1. System architecture
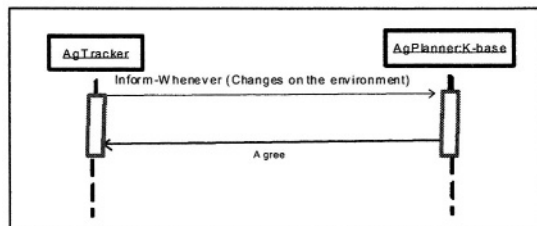
Fig. 2. Sequence diagram for the Tracker agent and the planner agent

The performer agents interact with the planner agent looking for plans, and the
tracker agent interacts with the planner agent to exchange information. The planner
agent is the only CBR-BDI agent in this architecture. The performer agents can be
considered assistant agents and the tracker agent is a reactive agent. Figure 2 and 3
show the sequence diagram for the multiagent system.

Fig. 3. Sequence diagram for the performer agents and the planner agent

The planning agent incorporates a CBR system [1]. The relationship between CBR systems and BDI agents can be established implementing cases as beliefs, intentions and desires which led to the resolution of the problem. When the agent starts to solve a new problem, with the intention of achieving a goal, it begins a new CBR reasoning cycle, which will help to obtain the solution. The retrieval, reuse and revise stages of the CBR system facilitate the construction of the agent plan. The agent's knowledge-base is the case-base of the CBR system that stores the cases of past believes, desires and intentions. The agents work in dynamic environments and their knowledge-base has to be adapted and updated continuously by the retain stage of the CBR system. Based on this relationship, agents can be implemented using CBR systems. This means, a mapping of agents into CBR systems. The advantage of this approach is that a problem can be easily conceptualised in terms of agents and then implemented in the form of a CBR system. So once the beliefs, desires and intentions of an agent are identified, they can be mapped into a CBR system.

To set up an agent using the CBR-BDI agent architecture [3] we need to identify an initial set of beliefs, desires and intentions and include them in the case-base of the agent in the form of cases. Then, a number of metrics for the retrieval, reuse, revise

and retain steps has to be defined. Besides, rules that describe the Expert's knowledge must be established, if available. Once the agent has been initialised it starts the reasoning process and the four steps of the CBR system are run sequentially and continuously until its goal is achieved (or there is enough evidence for a failure situation).
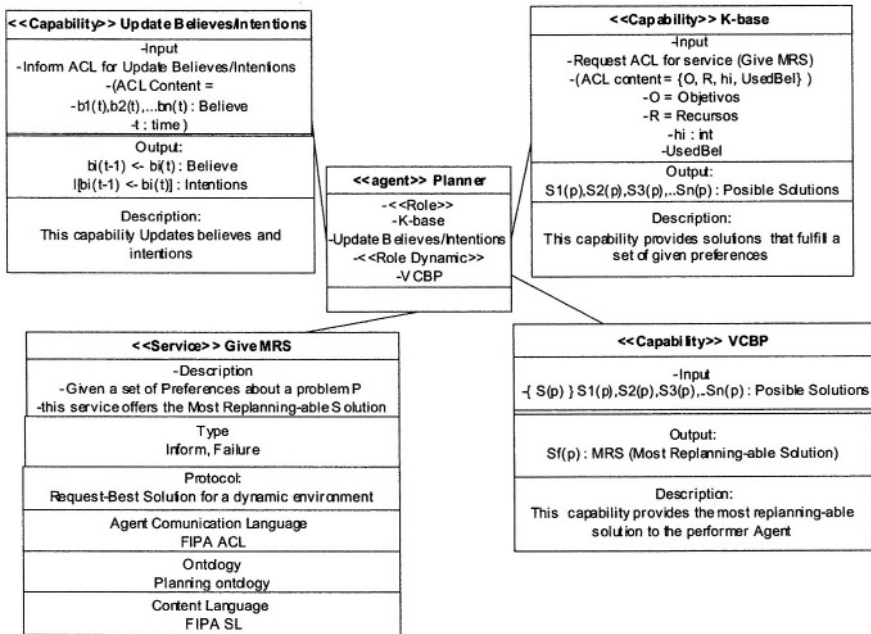
Fig. 4. Planner Agent class diagram

Fig. 4 shows the AUML class diagram (www.auml.org) of the Planner Agent. In these types of diagrams, the roles and goals of the agents are represented as Capabilities that may change with the time. In particular, the roles of the Planner Agent are to update the believes and intentions, which are stored in the form of cases, to identify those believes and intentions that can be used to generate a plan n, and to provide adequate plans to the Performer Agent given a number of conditions. These roles allow the agent to generate the closest to the optimum plan, which in this case has also to be the most replan-able solution. In this context, when the Performer Agent asks for a tourist route, given a number of constraints such as the money the tourist is willing to spend, the number of monuments to visit, the type of restaurants to eat, the time availability for the holiday, etc. the Planner Agent generates a plan that fulfils such conditions. This plan is easy to modify at execution time if the user changes of mind. The Planner Agent is a CBR-BDI agent, where the first role is carried out during the Retain stage of the CBR life cycle, the second role is the Retrieval step, and the third role is the Reuse stage.
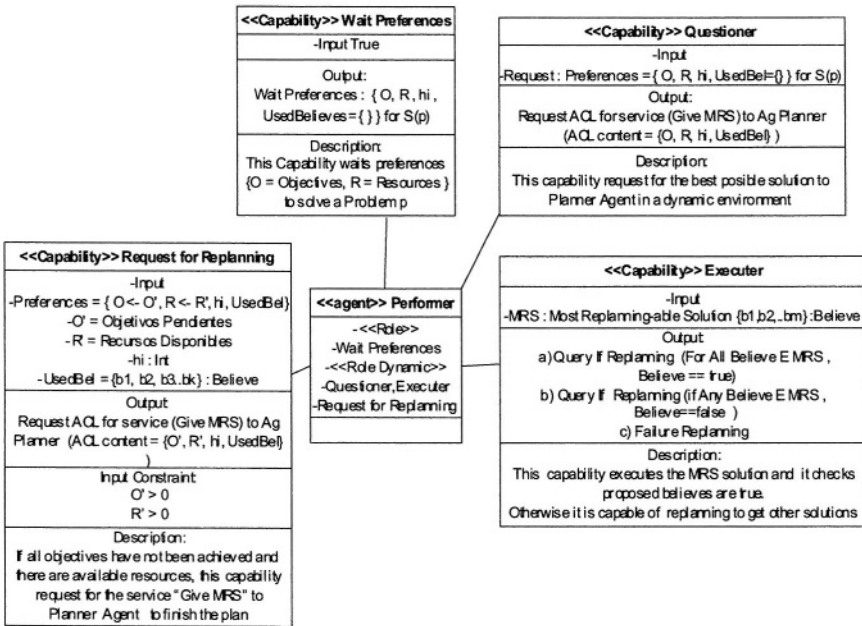
Fig. 5. Performer agent class diagram
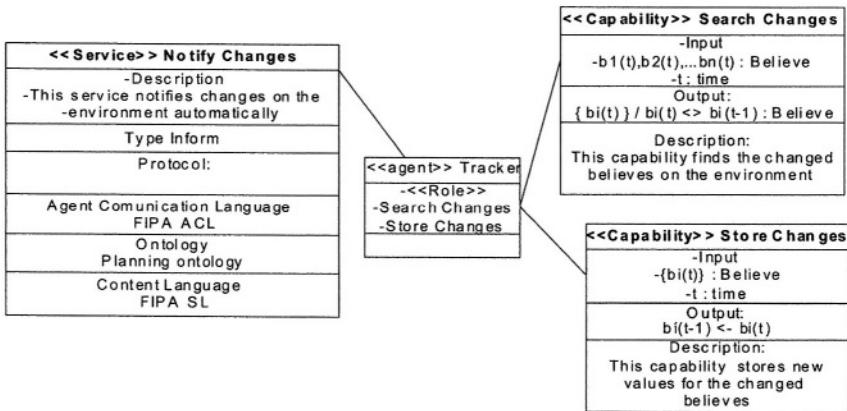
Fig. 6. Tracker agent class diagram

The Performer agents are assistant agents. Each of them is associated to one user and contact the Planner Agent to request a plan. These agents may be in waiting mode, waiting for a request from the user, may ask to the Planner Agent for a plan, or request a modification in a plan (replanning) to the Planner Agent. Fig. 5 shows the AUML class diagram for the Performer agent. The Tracker Agent is always looking for changes in the visiting conditions of the different sites, and keeps a record of them. The Planner Agent regularly contacts the Tracker Agent looking for changes in the environment. Fig. 6 shows the AUML class diagram for the Tracker agent.

3 Conclusions

The previously introduced architecture has been implemented using JADE and JADE-LEAP. This initial prototype has been successfully tested in Salamanca during the past few months. The tourists could use mobile devices to contact their agents and to indicate their preferences such as monuments to visit, visits duration, dinner time, amount of money to spend, etc. The cases store information about the environment, for example the opening and closing times of monument. This type of information can be seen as agents believe, for example, and average dinner in the casino restaurant costs around thirty five Euros. Cases can also be previous successful routes (plans), that includes the monuments to visit, the time to spend visiting each monument, information about the cost of the visit, the time required for going to one place to another, the characteristics of the route (museum route, family route, university route, roman route, gothic route, etc.), etc. Once a tourist contacts the system he has to describe his profile, to select the type of visit in which he is interested in, to determine how much money he wants to spend and for how long, and the type of restaurants he, she or a family like more. This information is used to construct the problem case. Then the reasoning mechanism of the planning agent generates the plan [5,6].

Table 1. Tourists evaluation.

	%	Evaluation - degree of satisfaction				
Tourists that…		8-10	6-8	4-6	0-4	No answer
Used the help of the agent	18 %	63,8	4,2	3,1	12,6	16,3
Used the help of a tourist guide	37 %	65,7	15,2	9,4	5,8	3,9

The initial system was tested during the fist four moths of 2004. The case base was initially filled with information collected during ten months. Local tourist guides provided the agent with a number of standard routes. Three hotels of the city offered the option to their 3410 guests to use the help of the agent or a professional tourist guide, around 18% of them decided to use the agent based system and 37% of them used the help of a tourist guide. The Planner agent had stored in its memory 2234 instances of tourist circuits, which covered a wide range of all the most common options that offers the city. On the arrival to the hotel the tourists were asked to evaluate their visit and the route. Table 1 shows the responses given by the tourists after their visit. The tourists that used the help of the agent-based tourist guide provided the answer directly to the agent. As it can be seen, in Table 1, the degree of satisfaction of the tourist that used the help of a professional tourist guide is higher that in the other two cases. Nevertheless, the percentage of the tourists whose degree of satisfaction was very high (between 8 and 10) is very similar in the case of the tourists that use the help of the agent and in the case of the tourists that use the tourist

guide. 16,3% of the tourists that used the agent based system did not answer the test or let us know that the system did not work successfully due to technical reasons (possibly the server was down, there was a lack of coverage, the tourist did not use the wireless system adequately, etc.) If we take this into consideration, we can say that most of the tourist (81,24%) that used the help of the agent and did not have technical problems had a high or very high degree of satisfaction (6-10). This degree of satisfaction is similar to the one of the tourist that used the help of professional tourist guides. The CBR component of the architecture provides a straight and efficient way for the manipulation of the agents knowledge and past experiences. The proposal presented in this paper reduces the gap that exists between the formalization and the implementation of BDI agents.

Acknowledgements

References

1. Aamodt A. and Plaza E. (1994). Case-Based Reasoning: foundational Issues, Methodological Variations, and System Approaches, AICOM. Vol. 7. No 1, March.
2. Bergmann, R., Muñoz-Ávila, H., Veloso, M. and Melis, E. (1998). CBR Applied to Planning. In Lenz, M. Bartsch-Sporl, B., Burkhard, H. and Wess, S. (Eds.) Case-Based Reasoning Technology: From Foundations to Applications. Lecture Notes in Computer Science 1400, pp. 169-200. Springer 1998, ISBN 3-540-64572-1.
3. Corchado J. M. And Laza R. (2003). Constructing Deliberative Agents with Case-based Reasoning Technology, International Journal of Intelligent Systems. Vol 18, No. 12, December.
4. Corchado J. M. and Lees B. (2001). A Hybrid Case-based Model for Forecasting. Applied Artificial Intelligence. Vol 15, no. 2, pp. 105-127.
5. Glez-Bedia M. and Corchado J. M. (2002) A planning strategy based on variational calculus for deliberative agents. Computing and Information Systems Journal. Vol 10, No 1, 2002. ISBN: 1352-9404, pp: 2-14.
6. Glez-Bedia M., Corchado J. M., Corchado E. S. and Fyfe C. (2002) Analytical Model for Constructing Deliberative Agents, Engineering Intelligent Systems, Vol 3: pp. 173-185.
7. Martín F. J., Plaza E., Arcos J.L. (1999). Knowledge and experience reuse through communications among competent (peer) agents. International Journal of Software Engineering and Knowledge Engineering, Vol. 9, No. 3, 319-341.
8. Olivia C., Chang C. F., Enguix C.F. and Ghose A.K. (1999). Case-Based BDI Agents: An Effective Approach for Intelligent Search on the World Wide Web, AAAI Spring Symposium on Intelligent Agents, 22-24 March 1999, Stanford University, USA.
9. Rao, A. S. and Georgeff, M. P. (1995). BDI Agents: From Theory to Practice. First International Conference on Multi-Agent Systems (ICMAS-95). San Franciso, USA.
10. Wendler J. and Lenz M. (1998). CBR for Dynamic Situation Assessment in an Agent-Oriented Setting. Proc. AAAI-98 Workshop on CBR Integrations. Madison (USA) 1998.
11. Wooldridge, M. and Jennings, N. R. (1995) Agent Theories, Architectures, and Languages: a Survey. In: Wooldridge and Jennings, editors, Intelligent Agents, Springer-Verlag, pp. 1-22.

A Building Maintenance Decision Tool for PFI Projects

Farzad Khosrowshahi[1], Rodney Howes [2] and Ghassan Aouad[3]

[1] Professor of Construction Information Technology, University of Salford
United Kingdom

[2] Professor of Construction Management, Chair; Innovation and Research Committee,
Construction Industry Council, United Kingdom

[3] Professor of Construction Information Technology, University of Salford
United Kingdom

Abstract. The growth of PFI (private finance initiative) and PPP (private public partnerships) is fundamentally changing the nature of the construction industry from a product and to service base. This involves moving the balance from capital investment to revenue generation. As a consequence the costing and scheduling associated with the maintenance phase has gained significant importance. This paper constitutes part of a broader research work which proposes a holistic model that provides a radical approach to decision making concerning the design, construction and maintenance of buildings and structures. This is in reaction to the need for buildings and structures to provide increased functional performance through their design life at reasonable cost, while including measures aimed at conservation and sustainability of the earth's non-replaceable resources. A model is proposed comprising of three parts namely, data, simulation and presentation. With an associated web-based decision tool that consumes data and generates knowledge, the supply side of data is primarily through facilitating access by product suppliers and manufacturers, as well as data generated through lab-based research work and actual monitoring of material degradation. The knowledge generated by the system will benefit a whole range of stakeholders within and peripheral to construction industry.

1. Introduction

The advent of PFI occurred in the United Kingdom as a consequence of policies adopted by the Thatcher Government to sell off publicly owned industries in the 1970's. The concept of PFI is mainly project orientated and is predicated on revenue earned by providing a public service which will ultimately cover all capital and operational costs with sufficient left over to provide an adequate return on investment. In this manner public projects, for which there is no immediately available funding, can be brought forward by inviting private organisations to provide the necessary investment and expertise [1].

Private investment in public service is not new, however the introduction of PFI has given rise to a more sophisticated approach to investment that has led to various

forms of PPP that have been adopted worldwide [2]. A key element in all PFI and PPP projects is the knowledge and ability to visualise and predict the performance of proposed projects, in whole and in part. The selection of the final design must be in accordance the appropriate choice of materials and components and their expected life and performance. Current knowledge of the impact of construction activities on the environment is perceived as becoming increasingly important. To this end, Lifecycle Assessment (LCA) has become internationally recognised as an all-embracing methodology. Several international agreements have been formulated under the ISO 14000 series, which are aimed at a methodology that harnesses compatibility. In line with European directives, the European governments have placed great emphasis on the role of LCA as the gateway to an all-round remedy for all environmental mishaps.

The relevance of this paper relates to the proposition to provide the means whereby design decisions can be informed by the ability to visualise and evaluate life cycle outcomes relative to cost and performance [3]. In this manner the true life cycle effects of design changes can be determined and compared before a final selection of the optimal solution is made. This paper proposes a model that extends 3d visualisation to include the 4th dimension of time. In this manner the physical form of the building can be viewed in simulation mode to allow designers, constructors and users to examine in more detail the characteristics of life cycle function and performance. This will enable more informed design decisions to be taken in the light of simulated performance of building materials, components and elements, together with their running costs. The intention is to explain the generic context of the model and its relationship with a simulated environment designed to replicate "in use" conditions experienced during the life cycle of a building.

2. Effects of the Physical Environment of the Building

Construction projects comprise one or more buildings or structures that are erected on individual sites. Each site will possess different characteristics that are likely to directly affect function and performance. The location and the availability of service utilities e.g. electricity, water, sewerage and waste disposal will have a substantial impact on design, as well planning restrictions and the proximity of essential transport and other urban infrastructure.

Exposure condition will have a direct influence on structural forces caused by wind, and where applicable, in combination with rain and snow. The external envelope will be designed as cladding, which may also contribute structural strength to the main structure. Heat loss and solar gain must also be considered alongside the need for air conditioning and cooling, both of which will have major influence on the energy consumption and resultant running costs. Vortices and updrafts caused by the proximity of buildings or structures and the physical surroundings of the site must be fully appreciated to ensure that the building envelope performs properly under all anticipated conditions.

Climatic and atmospheric conditions throughout the annual seasonal cycle should be established, especially temperature changes between night and day, humidity

variation and the nature of atmospheric pollution. The presence of pollutants will need to be assessed to inform the selection of materials that are best able to accommodate pollution present without premature discolourisation, corrosion and deterioration in the form of decomposition, de-lamination, cracking and crazing. The visualisation model must be provided with sufficient environmental information to enable consideration of all possible circumstances, given the selection of a site in any geographic location.

3. Physical Nature of Buildings and Structures

The physical nature of a built facility is derived from the design concept and the utilisation of construction technology in the form of materials, components and elements that comprise the major parts of the building. Selected materials and components will be used in accordance with the design to create the elements of the building, all of which will be connected to form the structure and the internal environment. By utilising a construction method as defined by a selected Work Breakdown Structure, human resources supported by equipment will be project managed to enable construction. The Work Breakdown Structure will be defined as a sequence of operations necessary to construct the completed building.

Building components can be categorised as those constructed on site *e.g. insitu reinforced concrete walls* and those processed off site *e.g. steel frame components, cladding panels and door sets.* The former will require human intervention in the form of site engineering and quality control to ensure compliance with drawings and specifications. The latter will require fixing in place by human resources and equipment according to manufacturers' instructions and will invariably be dependent on dimensional accuracy of insitu site constructed components and elements.

The total quality of the design and the construction process will have a direct impact on the efficacy of the completed building and its life cycle performance and associated running and maintenance costs [4]. It is therefore vital that the design is fit for purpose, as defined by the intended use of the building and its physical environment. Design failures can manifest themselves in many different ways, however broadly speaking these may be categorised as: aesthetic, spatial, structural, exposure, functional and incompatible component/material interaction. Construction process failures can be caused by poor workmanship, non-compliance with drawings, specifications and manufacturers requirements, together with non-conformance with construction sequences and damage caused by adverse environmental conditions. These failures can be largely avoided by tight project control and the implementation of adequate protection measures to counter environmental damage.

The quality of the completed built facility will have a direct bearing on its ability to meet and exceed the expected design life while maintaining full functional performance within anticipated running and maintenance costs. To assist architects and engineers it is vital that they have the ability to visualise the life cycle effects and implications of alternative design options, given intended use and function, set within the context of the built facility's physical environment. The philosophy proposed is

the development of a built facility to simulate the construction process and subsequently every aspect of the whole life cycle ,using visualisation made available by the latest developments in information technology [5].

4. The Design and Maintenance Model

The model has the potential to generate a *just-in-time* maintenance programme for project lifecycle. It offers an easy-to-use tool with a multi-view interface that is tailored to the needs of individual end-user. The decision component is based on the choice of either a knowledge-based or a visual system. The lifecycle behaviour of building components is simulated in a virtual building and this knowledge is translated into a maintenance programme. In the visual environment, the observer makes informed decisions about the timing of actions; but this process will also be automated through the use of a knowledge-based system.
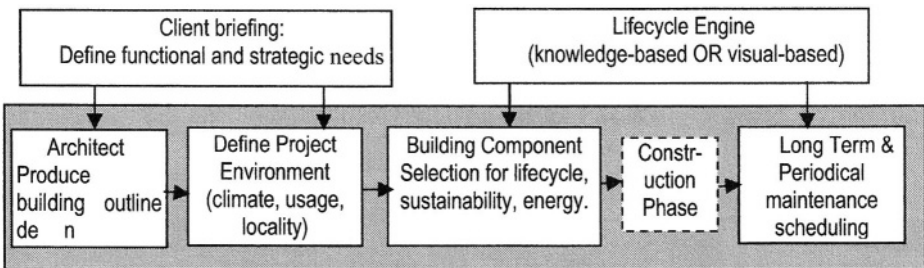
Fig.1. use model to design for lifecycle and generate repair & maintenance program

The ultimate goal of the model is to develop a holistic system for lifecycle design and maintenance of buildings that utilises both immersive realistic visualisation and knowledge-based decision rules. The idea is in itself innovative and the resulting product is based on a novel notion that, it is possible to visualise the degradation of an entire building throughout its lifecycle. As shown in Figure 1, the following three independent phases could be applied individually or in combination:

The core technology of the visualisation model is its 'maintenance engine'. Its purpose is to assist the generation of *just-in-time* planned maintenance by mathematically simulating the behaviour of components over their lifecycle and making data available through the visualisation mechanism.

5. Basis of the Maintenance Model

The environmental effects previously described are referred to as *"hard events"* that may occur continuously, intermittently or periodically. Likewise *"soft events"* relate to issues involving humans and their social behaviour, such as vandalism and

workmanship. In both cases their resulting impact on a building assumes a physical form. The *"soft events"* are divided into external and internal. The external events relate to peoples' social behaviour, whereas, the internal events fall under the boundaries of anthropology and time-geography. *Events* are deconstructed into their respective constituent *Agents* (e.g. Rain means water and pulsation). *Events* act upon building *components* through their *agents*. There are several building *components* each with a number of layers of aggregation [eg. internal **finishes➔wall finishes➔doors➔handles**]. These will be classified according to accepted current practice. The boundaries of a building are extended to include the outer *components* such as pavements.

The impact of an *event* (or its *agents*) on a building *component* can be realised only when the *component* is deconstructed into its respective *materials*. E.g. water (*agent* of rain) comes into contact with the metal comprising part of the cladding-*component*, the *Effect* of which may be corrosion and erosion of the metal. The next stage is to examine the inter-link between different *events:* the combination of two or more interrelated *events* can give rise to the introduction of additional agents namely *Auxiliary Agents* e.g. pollution and water introduce an additional agent - acid. Similarly, two or more *events* can lead to the creation of *Auxiliary Elements* e.g. vandalism can expose the metal part of cladding, so when combined with water can result in the corrosion of cladding. Also due consideration will be given to the *Interaction* between building components (rain can damage a flat roof which may then damage cladding).   It will therefore by necessary to create *project event simulation* for a given building definition (type, social and physical environments). In this manner a series of rules will be developed to reflect the type, nature and extent of all active *events* and the likelihood of their occurrence. This analysis is not an exact science, solutions will be based on various heuristic, statistical and AI techniques, and the results will be expressed in ranks, scales, fuzzy output, and rules [6].

6. The Top Level Model

The overall generalised model is given in Figure 2. There are three parts to the visualisation model, namely, data, simulation and presentation. The knowledge associated with the subject domain is encapsulated into data-objects that will be incorporated into a heterogeneous **database** containing component details, time-related behaviour and their visual attributes.

The process commences with the CAD drawing that represents the **initial state** of the building. It contains the usual CAD data as well as extended attributes such as parameters, component specifications and project environmental definition. Also present is the **Alternative Design** mechanism where different building components are examined and selected. This task contains an additional set of rules and data attributes relating to energy evaluation, fiscal parameters and indices, and Whole Life Costing.
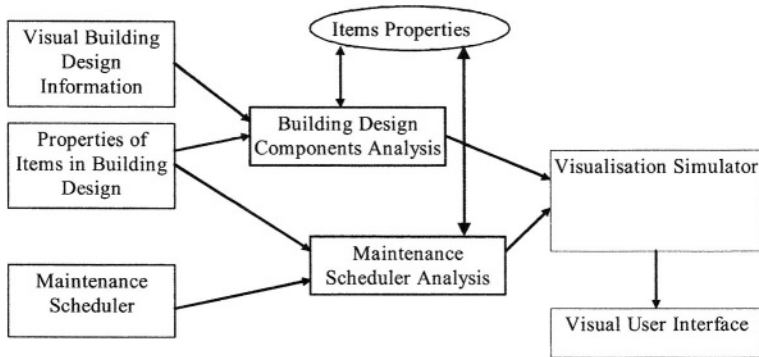
Fig 2. Generalised Simulation Model

The CAD drawings will set the basis for creating the 3D information model and the use of standard structures such as Industry Foundation Classes (IFC). Henceforth, all data flow through the system will be in XML (the industry defacto, XML format has been selected as the transportation file format and to manage the information in a hierarchical form). For a given project situation under certain event conditions (simulated by Event Simulation System), the lifecycle simulator transforms the Object-based Building from state t_i to state t_j. This IFC-XML-based data at state t_j is then submitted to the visualisation module.

The purpose of this task is to develop a virtual reality-based component. This component will couple the CAD geometry model to the maintenance model of the building and provide a 3D virtual environment to allow for visual examination of building degradation [7]. This component will support a sophisticated navigation model that includes object examination, scene fly-through and walkthrough modes. The Visual User Interface controls the entire process from data to 3D views. The core graphics technology is X3D, as it supports a broad range of 3D applications and complies with VE requirements. X3D has proven itself by evolving the widely supported 3D functionality of VRML97. The choice of X3D yields market advantage and provides access to more tools, content and compatibility with other applications. It also facilitates flexibility, compatibility and a path for MPEG-4 support. The model is extended to 4D by the introduction a network scheduler that introduces the timescale related network analysis of the project work breakdown schedule. The database generated by the project schedule module provides the component data for the time related vista characteristic. This will facilitate consideration of the necessary objects to visualise the project at any stage during its design, construction and life cycle.

The model uses web capability to facilitate access by product suppliers and manufacturers who will provide data about materials and components. Designers, constructors and facility managers, who will be the beneficiaries, participate remotely by providing project information prior to participating in interactive analysis visualization resulting in maintenance reporting. The holistic and integrative nature of

the model is further enhanced through collaborative visualization. The model provides a host of hitherto unavailable facilities initially aimed at providing designers with the ability to visualise the consequences of design decisions that extend throughout the entire life cycle. Subsequently constructors and facility managers will be provided with post construction maintenance and repair planning and monitoring..

7. The Visualisation Mechanism

Statistical analysis of data will be undertaken in order to develop mathematical representation of the lifetime status and expectancy of all items of the design [7]. Once the behaviour of a component is statistically determined and its visual attributes are defined, then its physical appearance can be visually demonstrated through the proposed Visual User Interface system. The following examples show the visual effect of light manipulation in VRML. By simply altering some VRML parameters, the lighting status in Figure 3 is changed to more degraded status, shown in Figure. 4. This is reflected in the values of the Red/Green/Blue Colour attributes changing from 1,1,1 in figure 3 to a compromised position depicted by 0.2, 0.21, 0.058 values. Also, the intensity of the light is reduced by 50% from 1 to 0.5, from Figure 3 to Figure 4.
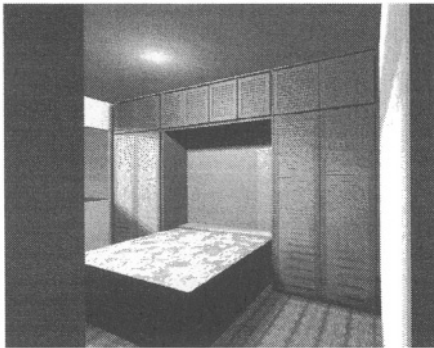
Fig. 3 Before light parameters'
manipulation
DEF LocLight Pointlight
(Colour 1 1 1 on TRUE
location 0.2 0.21 0.058intensity 1)
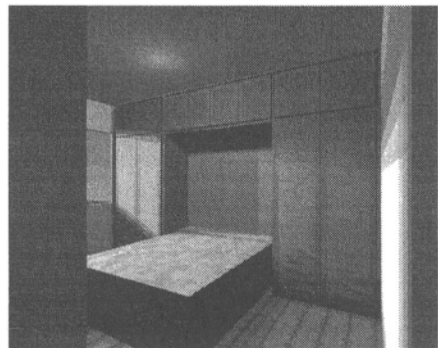
Fig. 4 After light parameters'
manipulation
DEF LocLight Pointlight
(colour 0,976 1 0.847 on TRUE
location 02.21 0.058
intensity 0.05

8. Conclusions

The proposed model is a sophisticated entity that provides a host of hitherto unavailable facilities initially aimed at providing designers with the ability to visualise the consequences of design decisions that extend throughout the entire life cycle. In

this way life cycle costs can be determined to cover repairs and maintenance for each specific design solution. Each design option can be further analysed financial and for conformance to sustainability principles.

The client will be provided with a predetermined schedule of planned maintenance and servicing for the entire building. Replacement will be determined from information contained in the database using principles associated with "just-in-time", to mitigate breakdown or component failure. Variations from the planned maintenance will be logged and converted into feedback to the database. Similarly periodic inspection will provide information on variances in wear and deterioration, which will be subjected to further evaluation in regard to exposure, use and site conditions. This data will also be used to update the database. In this manner the model will become a learning entity whereby its performance and predictive powers will be subject to continuous improvement.

Further work will include the development of a knowledge based broker that is based on a web-based data capture system that will enable manufacturers and suppliers to input their data into the model for conversion into knowledge. Other areas requiring significant generic research work will include the use of case-based and multi-agent reasoning techniques in order to generate the knowledge model that underpin further development. Potential development of the use of the model will not be limited to producing new knowledge. It will also initiates a change process by facilitating a smooth integration into the modern age whereby the building design process will be more integrated, transparent, and reflective of strategic goals rather than the current practice of placing company strategy at the mercy of project objectives.

References

1. Levy S.M., *BOT: paving the way for tomorrow's infrastructure,* Wiley 1996
2. Akintoye A., Beck M. & Hardcastle C., *Public private partnerships,* Blackwell Publishing London 2003
3. Alshavi, M. and Faraj, I., *Integrating CAD and Virtual Reality in construction,* Proceedings of the Virtual Reality and Rapid Prototyping for Engineering Conference, Salford University, 1995.
4. Greene W.H., *Econometric Analysis,* Second edition, Macmillan Publishing Company, 1993.
5. Griffin, M., *Applications of VR in architecture and design.* Proceeding of the Information Technology Awareness Workshop., University of Salford, January 1995.
6. Lapin, L.L., Probability and Statistics for Modern Engineering, Thomson information/ publishing group, Boston, 1990.
7. Rad, H.N and Khosrowshahi, F., *Visualisation of Building Maintenance Through Time,* Proceedings International Conference on Information Visualisation IV'97, 27-29 Aug., London, England, 1997.

Collaborative Role Management for Sharing Protected Web Resources

Sylvia Encheva[1] and Sharil Tumin[2]

[1] Stord/Haugesund University College, Bjørnsonsg. 45, 5528 Haugesund, Norway
sbe@hsh.no
[2] University of Bergen, IT-Dept., P. B. 7800, 5020 Bergen, Norway
edpst@it.uib.no

Abstract. In this paper we consider a security framework for sharing protected Web resources among independent organizations using groups and roles. Very important components of our model are a collaborative, distributive management of user membership in a group in one organization, resources management by the service provider and security enhancement. Each organization manages its own users and groups independently of others. User authentication and user authorization on a protected resource in one organization is determined by user group membership of other organizations. Collaboration is based on mutual trust, agreed upon common policies.

Keywords: Collaborative group, role management

1 Introduction

Security has become one of the most significant problems in managing large networked systems. This is particularly true for organizations that are attempting to reduce the complexity and cost of security administration in distributed multimedia environments such as those using World Wide Web services. Computer-based access controls can prescribe not only who or what process may have access to a specific system resource, but also the type of access that is permitted [3], [4]. In Role-Based Access Control (RBAC), access decisions are based on an individual's roles and responsibilities within the organization or user base [1], [2], [5].

Most information and communication technology (ICT) based learning systems require user authentication and authorization data to reside locally in their users database. Therefore, organizations using such a system have to export their users' data to the system. This will involve a complicated data synchronization mechanism.

We propose a model which does not involve export of user authentication and authorization data across cooperating organizations which really simplifies user management. Another important advantage of this model is security enhancement since user authentication and authorization data never leaves its home organization.

This inter-organizations authorization framework is based on groups and roles in independent collaborating organizations both nationally and internationally. Each organization manages its own users and groups independently of others. Organizations cooperate their users and groups data across organizations through a common communication mechanism using Simple Object Access Protocol (SOAP). User authorization on a protected resource in one organization is determined by user group membership of other organizations. Collaboration is based on mutual trust, agreed upon common policies.

2   Basic Terms and Concepts

Definition 1. *A* user **u** *defines a valid user in an organization.*

Definition 2. *A* group **G** *contains a set of users.*

A group is used to help administration of users. The security settings defined for a group are applied to all members of that group. User administration is simplified by creating a group for each solution's roles and add that group to the solution. One can add or remove users from roles by managing the membership of these groups.

Definition 3. *A* role **R** *contains a set of groups associated with similar duty and authority.*

Definition 4. *A* resource **S** *defines a set of objects* $p_j, j = 1, ..., m$.

Objects are protected Web-based resources. Authorization gives certain set of permissions (read, write, update, execute) on a specific set of resources (file, directory, program). As an example we consider a collaboration in ICT based teaching among universities.

Definition 5. *An* action $\mathcal{A}$, *where*

$$\mathcal{A} = \begin{pmatrix} (o_1, p_1) & ... & (o_1, p_m) \\ ... & ... & ... \\ (o_n, p_1) & ... & (o_n, p_m) \end{pmatrix}$$

is a matrix of operations $o_i, i = 1, ..., n$ *on objects* $p_j, j = 1, ..., m$ *of a resource* **S**.

Example 1. If operations are read (r), write (w), delete (d) on objects file1 (f_1), file2 (f_2), file3 (f_3), then the action is

$$\mathcal{A} = \begin{pmatrix} (r, f_1) & (r, f_2) & (r, f_3) \\ (w, f_1) & (w, f_2) & (w, f_3) \\ (d, f_1) & (d, f_2) & (d, f_3) \end{pmatrix}$$

Definition 6. *A permission* **P** *defines rights of a role* **R** *to perform action* $\mathcal{A_R}$ *on a resource* **S**.

By $\mathcal{A_R}$ we denote the matrix $\mathcal{A}$ when some of it's elements are 0.

Example 2. If operations are read (r), write (w), delete (d) on objects (f_1, f_2, f_3), then

$$\mathcal{A_R} = \begin{pmatrix} (r, f_1) & 0 & (r, f_3) \\ (w, f_1) & (w, f_2) & 0 \\ 0 & (d, f_2) & (d, f_3) \end{pmatrix}$$

Definition 7. *A user* **u** *has a role* $\mathbf{R_G}$ *when* $\mathbf{u} \in \mathbf{G}$ *and* **G** *has a role* **R**.

Users automatically inherit the permissions associated with any groups' roles to which they belong.

Authorization controls what actions an authenticated user can perform within a Web-based system. A non zero element of an action matrix defines a permission. All non zero elements of an action matrix define the permissions of a role within a system. An authenticated user belonging to a group in an organization will have permissions to perform actions at another organization if the group defined at the first organization is a member of a role in the second organization. Users are associated with groups, roles are associated with permissions and group-role relations provide users with access control and permissions on a resource. The framework provides distribution of users-groups and roles-resources management (Fig. 1).
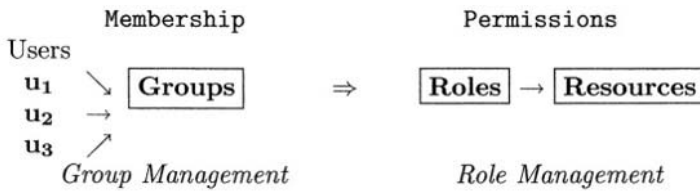
Fig. 1

3   Collaboration Model

The users-groups management in an organization provides a centralized accounts identity database from which users belonging to that organization authenticate them selves. The management system must also provide a centralized database for groups membership of users. Group membership of a user can be queried at any time by service providers.

The roles-resources management in another organization (service provider) provides a centralize permissions' database where operations-resources action matrices are defined. The management system must also provide database for roles membership of groups.

Collaboration between two organizations entails that both must agree on the name of the group to be used in user-group and group-role relations. The group name acts as a bridge for inter-organizations authorization mechanism. All users and groups are qualified using domain-name of their organization. The organization providing services will define which domains can share its resources by giving a specific role membership to a group from another domain.

3.1   Role's Conflict

The collaborative management model can be used by a security administrator in enforcing a policy of separation of duties. Separation of duties appeared to be of great value in a case of collaboration among various job related capabilities where roles have been specified as mutually exclusive and cannot both be included in a user's set of authorized roles.

Separation of duty requires that for particular sets of transactions, no single individual is allowed to execute all transactions within the set. The system administrator can control access at a level of abstraction that is natural to the way that enterprises typically conduct business. This is achieved by statically and dynamically regulating users' actions through the establishment and definition of roles, relationships, and constraints.

Static separation of duty enforces the mutual exclusion rule at the time an administrator sets up role authorizations, while dynamic separation of duty enforces the rule at the time a user selects roles for a session. Dynamic separation of duty places constraints on the simultaneous activation of roles. A subject can become active in a new role only if the proposed role is not mutually exclusive with any of the roles in which the subject is currently active.

Defining disjoint groups permission is a duty of role managers at service provider domain and assigning users to proper groups is a duty of group managers at service client domains. These managers need to cooperate very closely. Policies and rules governing resource usage must be documented and understood by both parties. The managers at service provider domain have the right and the mean to block any domain users in the event of conflict.

A dynamic separation of duty requires that a user can not hold two conflicting roles in the same session, f.ex. examinee and examinator of a subject. Conflict of interest constrain must be checked by the application. An audit track of user assigned roles can be used to expose conflicts.

Another way is to only allow the minimum permission if a domain user has conflicting roles on the same resource. This is possible only if related roles can be ranked. A role with less permissions has lower rank then a role with more permissions. Role managers need to work very closely with the service implementors.

The service provider administrators have the right to place a user and/or an external group in a '*quarantine group*' in relation to a protected resource. Users and groups' members in quarantine group loose all their rights on the corresponding resource as long as they are in the quarantine group.

A group manager assigns permissions to roles in the solutions and adds groups to the appropriate roles.

User-group management enforces static separation of duty by defining a set of disjoint groups for a particular role. A user cannot be a member of several disjoint groups at the same time.

Group role management enforces dynamic separation of duty by defining a set of disjoint roles for a particular resource. A user cannot be granted permission from more than one role at the same session.

4   Management Framework

Suppose users at the domain **hsh.no** are clients of services provided by the domain **uib.no.** A user *stud04@hsh.no* belonging to a group *math1@hsh.no* in the domain **hsh.no** will have a permission to use a resource at the domain **uib.no** if there is a role *math1* where *math1@hsh.no* is a member.

Managers at the domain **hsh.no** manage a central users' and groups' database. A person should have one and only one user identity. Users' and groups' management should be done centrally at an ICT center, while groups' membership management may be done by local departments' managers.

To participate in this framework, the domain **hsh.no** must have a domain *authentication server* on which the domain users can do their authentication and provide a *single-sign-on* mechanism for a user to access published services. We propose a simple Web form authentication mechanism applying user identification, password, session number and cookies.

A system at the domain **hsh.no** must also provide an *authorization server* from which other domains can access authenticated user's valid session number and group memberships on demand. Any authenticated user can access any of the shared services at other domains provided that she belongs to the proper groups at her home domain.

Since users' management is done on independent sites, it is difficult to guarantee uniqueness of users across inter-organizational boundaries. A person can be affiliated to many organizations at the same time. This problem is difficult to solve and may not be a major issue if interests' conflict can be resolved in role-group relation.

Managers at the domain **uib.no** manage a central roles and resources database. Relations between operations and resources in the form of action matrices are also managed centrally and are defined in the central database. Resource names and data are provided by a service provider at the local departmental level. The central ICT managers manage roles membership of domain groups and roles permissions on resources.

To participate in this framework the domain **uib.no** must provide a portal service through which all services published by the domain can be reached. This portal accepts authenticated domain users applying the agreed single-sign-on mechanism from its own domain and other participating domains.

Once the portal at **uib.no** domain accepts a user, the user can then access any services accessible by the users domain group defined by role membership. Each time authenticated domain users want to access a protected resource, the **uib.no** portal needs to query domain user membership of a particular domain group at **hsh.no** depending on domain group's role membership for that particular resource.

We propose a SOAP communication mechanism for determining domain user authentication and authorization (Fig. 2), where in a collaborative independent management among organizations

- *Group management* assigns users u_{ij} membership to the group G_i at the organization Org_i
- *Role management* assigns group membership to a role R.

Organizations   Users   Groups   Role   Resource
$Org_1 \ni \{u_{11}, u_{12}, u_{13}, ...\} \to G_1$
$Org_2 \ni \{u_{21}, u_{22}, u_{23}, ...\} \to G_2 \to \boxed{R} \Rightarrow \boxed{S}$
$Org_3 \ni \{u_{31}, u_{32}, u_{33}, ...\} \to G_3$
      Group Management   *Role Management*
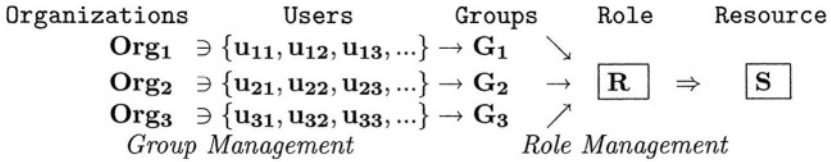
Fig. 2

Roles data in a service provider domain contain references to external groups data from clients domains.

Example 3. Let $R_{uib.no}^{(m)} = \{G_{ntnu.no}^{(m)}, G_{uib.no}^{(m)}, G_{uio.no}^{(m)}, G_{hsh.no}^{(m)}\}$ be a defined role (m) at the university UiB *(uib.no)* and a user $u \in G_{hsh.no}^{(m)}$ also belongs to $R_{uib.no}^{(m)}$. Then the administration for each group in $\{G_{ntnu.no}^{(m)}, G_{uib.no}^{(m)}, G_{uio.no}^{(m)}, G_{hsh.no}^{(m)}\}$ is done locally at the corresponding domains (NTNU, UiB, UiO, HSH), while the administration for $R_{uib.no}^{(m)}$ is done by resource owner (UiB).

A permission $P_{uib.no}^{(m)}$ defines right of the role $R_{uib.no}^{(m)}$ on a resource $S_{uib.no}^{(m)}$.

An unauthenticated user belonging to $G_{uib.no}$ (for example) must first be authenticated (login) at her home domain (UiB) where she has her identity defined. After a successful login a user will have a unique session identification (SID). The service provider (UiB) will have the users SID and home domain name as the current active session identifier for that particular user. When the user tries to access the resource $S_{uib.no}^{(m)}$ with permission $P_{uib.no}^{(m)}$ the service provider (UiB) connects to the clients' authorization services' port at the user's home domain (HSH) to check user membership for group $G_{uib.no}^{(m)}$ using the SID as a parameter.

5   System Architecture

Let us denote the service provider domain by SPD and a service client domain by SCD. In the collaborative user/resource framework SPD provides a Web portal, from which all domain Web services can be reached by the clients. A

SDC provides a Web based authentication application (domain user login) and a SOAP based authorization services (group membership check) for its domain user.

- SPD portal checks for valid users. An unauthenticated user, who does not have a valid SID, will be redirected to her home SCD for login. A user having a valid SID can proceed to the portal's resource area.
- Each SPD Web application/service is protected by a roles-resources control defined at SPD. An authenticated user needs authorization to access protected resources. The SPD opens a connection to a SCD authorization service port to check for user valid group membership at her home SCD. The SPD portal will grant user access to the protected resources if the user belongs to a valid role's group at her home SCD.
- SCD users' login Web application provides a single official login point for all domain users. The SCD's login application is located at a common URL name like f.ex. https://login.uib.no and is an officially published application. All domain users will see and learn to know the same login interface for domain login.
- SDC's authorization provides a SPD with the mechanism to check users' authentication and authorization at their home domain. A SPD will connect a particular SCD's SOAP based server and do a remote procedure call with a user's SID as a parameter to the call. The SCD will use the SID to authenticate and authorize a domain user on the behalf of a SPD.

```
(i)   user →           SPD Portal
              (Is this an authenticated user ?) yes → (ii)
                            ↓
                     no → SCD login
                        (valid login ?)   yes → SPD Portal
(ii)  user →      SPD protected resource
              (Is this an authorized user ?)   yes → (iii)
                     ↓
              no → SCD authorization
                     (valid group ?)        yes → SPD Portal
(iii) user →     access SPD's protected   resource
```
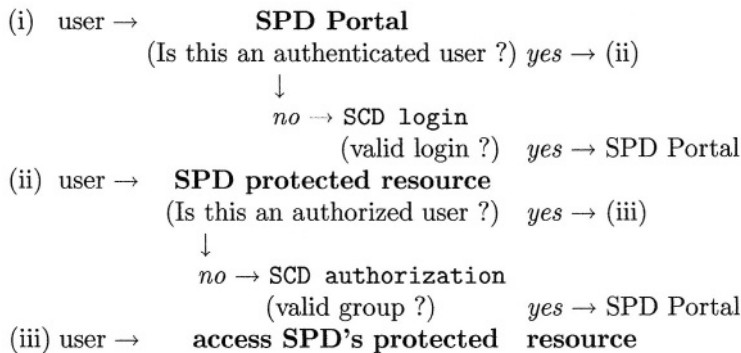
Fig. 3

An authenticated user at her home domain will have her browser session cookies set with a valid SID. The SCD login application will also save the SID in the database together with user's PC IP-address, user identification and timestemps.

At (i, Fig. 3) when SPD Portal redirects user to SCD login an authenticated user already has a valid session and needs not login again. The SCD login application simply redirects back to SPD Portal sending user's SID as a parameter. This provides a simple singe-sign-on mechanism among domains.

At (ii, Fig. 3) SPD Portal checks if the user belongs to a valid role with permission to access a resource. The role's definition contains a list of valid client

domains groups a user must belong to. The SPD Portal opens a communication channel to user's home SCD authorization port and sends user's SID and domain group name as the call parameters. The SCD authorization server replays with a 'yes' if the user is a member of the domain group, else a 'no' is returned.

A user can access a protected resource (iii, Fig. 3) after a valid authentication and authorization at her home domain.

We propose the use of open source software for the implementation of the framework. The required supporting systems are:

- Web server. Apache with Secure Socket Layer (SSL) and Python module (PyApache)
- Database. PostgreSQL for the back-end database system.
- SOAP server. Python and SOAPpy (SOAP module for python).
- Python scripts. Python is used to produce dynamic HTML, SOAP method and database integration.

The framework can be install on any operating system on which all the above supporting systems can be installed (Linux, FreeBSD, Solaris, Window 2000 server).

Remark 1. A user can have several user accounts from different domains. This can introduce collusion of rights in the framework. Suppose a person possesses two user accounts from two different domains. She is a student in one domain and a teaching staff member on another domain. A simple role policy was set to permit access to a resource where the student role can only submit and read her own documents while the teacher role can read all submitted documents. One method to solve such a problem is to assign a global unique key (personal number) to each person. The key must be unique to all collaborating domains. A central key management is needed and may not be practical. Another method is to make a more detail roles' policy and access audit trail to expose collusion of rights problem.

A domain maintains its own users. The framework supports one level of 'chain of trust' only. A SPD refer only to the user home domain. A SCD does not refer to other domains for a user authentication and authorization. The framework security mechanism can go into loop if multi-level chain of of trust is allowed.

6   Conclusion

Arranging users into groups and roles makes it easier to grant or deny permissions to many users at once, reduces errors in administration and reduces cost of administration. We argue that our model may be used

- across organizations; based on the group structure and independent collaborative administration
- in the future, because it provides high level of flexibility and usability.

Organizations cooperate their users and groups data across organizations through a central framework.

References

1. Andress, M.: Access control. Information security magazine, April, (2001)
2. Barkley, Beznosov, and Uppal:Supporting Relationships in Access Control using Role Based Access Control,Fourth ACM Workshop on Role-Based Access Control, (1999)
3. Ferraiolo, D., and Kuhn., D. R.: Role-based access control. 15th National Computer Security Conference, (1992)
4. Ferraiolo, D., and Kuhn., D. R.: NIST/ITL Bulletin, December, (1995)
5. Ferraiolo, D., Kuhn., D. R., and Chandramouli R.: Role-Based Access Control. Artech House, Computer Security Series, (2003)

Envisioning Environmental Futures:
Multi-agent Knowledge Generation, Frame Problem, Cognitive Mapping

D. Borri, D. Camarda, A. De Liddo

Dipartimento di Architettura e Urbanistica, Politecnico di Bari
via Orabona 4, 70125 Bari, Italy
d.camarda@poliba.it

Abstract. In environmental planning, the new communicative approach is replacing the traditional linear cybernetic approach, with a multilogic rationality that challenges the absolute rationality of planning. In this light, a crucial role is played by communication and representation platforms insofar as they support the exchanging and fine-tuning of knowledge, behaviours, emotions lying in each agent. Particularly, this paper explores cognitive mapping as a methodology to support interactive processes aiming at eliciting and sharing knowledge representations. However, cognitive frames in individuals and groups may play intriguing roles, at times fostering or hampering the contribution of knowledge in environmental planning processes. Starting from this standpoint, the present paper explores the abstraction levels of reasoning, as well as the possibility of improving the outputs of cognitive maps. Exploration concerns characters and modifications induced in single and multiple agents when the knowledge representations of agents are exchanged. Such cognitive exploration is carried out by setting up an experimental session oriented at building collaborative future visions in the environmental domain for the city of Bari, Italy.

1. Introduction

The scientific basis of what we call multi-agent knowledge generation (M-AKG) in the present paper, refers to Multiple Source Knowledge Integration (MSKI), a major field of interest in group decision and negotiation research. Research on socio-environmental futures is a spill-over effect of the physical and emotional impacts of global socio-environmental change. Many facets of this change are blind to standard scientific research and call for integrated expert and non-expert, rational and 'non-rational' (for instance emotional) knowledge approaches [10]. In various fields, from computer science (distributed knowledge, network architectures) to policy science (learning organisations, problem solving and setting), M-AKG is becoming a way to cope with these troubles, drawing from large knowledge bases (multi-agencies). More recently, it has made increasingly use of knowledge forums with many participants.
The frame problem is a well known problem in artificial intelligence [6]. It influences the cognitive agents' ability to navigate without loosing themselves in huge 'problem

spaces', using framing for context-based and case-based pruning of dangerous and unfruitful regions of those spaces. Some recent advancements of neuroscience have emphasized the role of non-rational knowledge in the agent's decision-making [1].

In research on planning the frame problem has not been widely addressed yet, probably because of the simplicity of the current generation of intelligent plans, which does not reflect the complexity of environmental domains. But where the number of knowledge agents is enlarging, knowledge framing parallels methods and heuristics, raising both suggestions and doubts.

A deeper reflection on the potentials and drawbacks of the frame problem in planning processes is therefore increasingly important, and structures the present paper. After this introduction, the second chapter sets up the frame problem and discusses it theoretically. Chapter three shows the methodological approach used in carrying out the participatory process, while chapter four discusses the main substantial issues. Some brief final considerations are carried out in chapter five.

2. The Frame Problem

Framing is a well-known problem in cognitive science, dealing with the ability of agents to escape cognitive paralyses in exploring huge "problem spaces" [6, 11].

In fact, the mere enunciation of the subject of cognition exercise activates a frame of cognitions in the agent's relations and procedures. Their limits are defined by the agent's previous cognition and may prevent the her/him from essential cognitive focusing because of both vagueness (non expert agent) and generality (agent expert of theory but ignoring the case) of her/his previous cognition [7, 9].

In the generation of knowledge occurring in standard multi-agent forum, an explicit frame is usually set up, variously wide and structured, usually exogenous. It is prepared *ex-ante* by the knowledge engineer who is an intermediate agent responsible for knowledge facilitation, focusing, mediation [4].

Previous *exogenous* framing generally creates risks of either self-fulfilling prophecies or modest cognitive performance. Previous *autogenous* framing is either an implicit frame in the agent or a collection of the various agents' frames by spontaneous grouping in group interaction. Therefore, what is needed is a dynamic generation of the frame while the exercise is contextually evolving [12].

A remarkable logical contradiction of using frames in multi-agent forum knowledge generation is in knowledge focusing and selecting (a typical feature of frames), which hampers inherent aspirations both to freedom and creativity[1] and to democracy and neutrality in cognitive exercises. In fact, systematic criticisms from involved cognitive agents generally address all framing components and phases.

Moreover, many impediments affect the formation of both previous exogenous frame and previous autogenous frames. The problem of the indefinite logical tractability of the frame is particularly urgent in the start phase of the exercise, that is when its generation and dynamics are characterized by a 'structural' potential of uncertainty. Even if still affected by framing, the subsequent phases – refinement, evolution,

---

[1] In exercises of 'vision', future image of facts or processes, reason and emotion must coexist 'freely'.

dialogue, convergence, divergence, etc. – are streamlined along problem spaces more tractable by interacting cognitive agents, driven by a sort of inertial motion influenced by the start and the push impressed to a well defined cognitive path [8].

However, we should admit that in practice such *aporias* are rather easily overcome (at least operationally) by the agents' ability of interacting with the real world or with their own ontologies and creative imagination [3].

Actually, in strategic planning forums framing is a useful but unessential activity of support to multi-agent cognition, especially when what matters is problem setting more than solving. In problem setting and typical representational features, creative vantages compensate for disadvantages in pertinence and investigation coming from scarce or null conditioning by previous framing [13]. Hence, in cognition exercises, exogenous and/or autogenous framing can be seen as intriguing and variably meaningful corollaries of contexts (both real and imagined), which are activated by mere enunciation of subjects or by the presence per se of (a set of) cognition agents.

3. Approach and Methodology

This interaction experiment is intended as a part of a research program carried out by DAU (Department of Town Planning of the Polytechnic of Bari), aimed at exploring the cognitive, learning and substantial characters of a multi-agent decisionmaking process, when a participatory interaction architecture structures the process itself.

Specific objectives of such research, started in the late 1990s, are basically twofold. On the one hand, trying to reflect on, and build up, possible architectures to support decisions in the complex environmental field. On the other hand, trying to understand the extent to which information, either exchanged by mutual interaction or achieved during the process, can both modify cognition frames and enrich the quality of outcomes.

Experiences during a 5-year EU-funded project, carried out with Mediterranean partners on sustainable development policies, explored the potentials of IT-based iterative interactions among stakeholders to build up strategic shared visions of development futures on urban/regional contexts [4]. In the present case study, the background was the political participatory campaign set up by the candidate mayor in Bari, Italy, to build shared visions on Bari futures. Our experiment dealt with university & research issues, and a number of experts on various scientific fields were invited to reflect on the impacts of a large development project of new academic areas and premises on agricultural land.

Conceptual maps were drawn using *Decision Explorer,* by *Banxia.* It was decided to use this tool with a multi-agent bottom-up approach, by letting the participant agents build concepts on their own, in order to explore, rather than synthesize, individual contributions to problem structuring . This approach was supposed to reduce semantic ambiguity of the agents' arguments by preserving deep conceptual ramifications, so allowing a more complex concept handling within the process flow. This was a key feature in the process, particularly crucial for a research program focused on supporting decisions in the environmental field -an intrinsically complex domain.

The aim of that exercise, as complementary to the methodological objective coherent with the whole research program, was to provide decision makers with a more

structured and accurate vision of the issues and problems involved, in order to support policy decisions. Unfortunately, entrepreneurs did not join the meeting, which was therefore set up with researchers, academics and a graduating engineering student. The session lasted four hours as a whole, and was carried out in a computer lab of the Polytechnic of Bari, with the participation of 9 persons. The process flow of the session is sketched in figure 1.
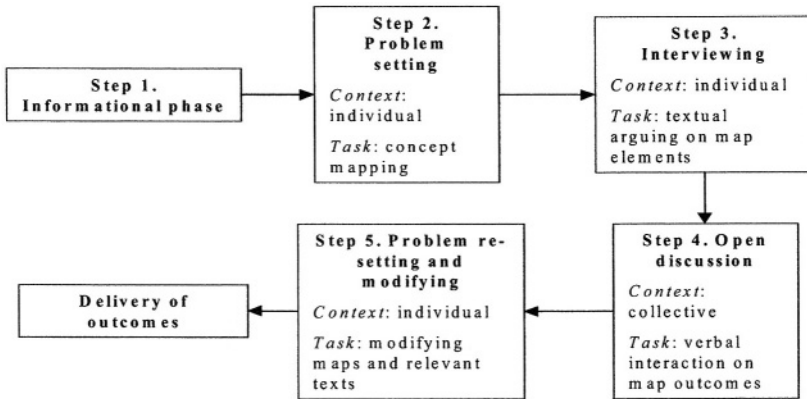
Fig. 1. The process architecture.

After the distribution of information (step 1), the agents were asked to build their own conceptual maps representing their personal way of structuring the issues at hand (step 2). Steps 2 and 3 had been conceived as individual tasks, in order to elicit original expert contribution and knowledge frame avoiding the influence of the group. Step 3 had crucial importance. In order to better clarify the concepts put down in the map, the agents were asked to explain the different typology of inferential rules among concepts (temporal, spatial, associative links, etc.). In so doing, they were forced to reflect on the relationships among concepts and, indirectly, to signify the concepts and make them more effective and manageable within the process [13]. With the same aim, the agents were asked to 'label' each concept as a 'fact' or a 'value' [2], and to further argue on one concept on which she/he was more emotionally involved. The general rationale of this step is both to allow a self-made gradual fine-tuning of concepts by the agents, and to deliver more clarified and situated outcomes to be managed by the process (the multi-dimensional 'coordinates' of the concept in the process).

Step 4 is a cooperative phase, in which the agents were invited to discuss individual outcomes and compare different views by looking at the collection of maps and textual statements. This step is similar to a sudden irruption of new information in the process, under the form of cooperative interaction, which allows each agent to explore new elements and consequently to re-calibrate cognitive levels. This irruption was supposed to modify the contents, approaches, representations of the issues at hand: a 'card-shuffling' which should stimulates a re-thinking in the subsequent phase.

The final step was intended to verify if substantial and/or cognitive changes had really occurred after the previous interactions. Agents were asked to modify the maps in terms of either conceptual contents, or inferential rules, or value/fact categorization.

In presence of remarkable changes, it is possible to deduce a "change of abstraction levels" in each agent, often outlined in literature [9]. This would represent a fair contribution to calibrate the architecture on the management of remarkable problems, such as cognitive scales and hierarchies, and the need to navigate among abstraction levels. They are general problems in several intelligent environments but specific problems in intelligent spatial environments, essential for the management of complexity in spatial reasoning [10].

In the present experiment, cognitive maps were utilised as bottom-up explorative tools. During the second step of problem setting, participants could draw maps freely: hence, they expressed all the creative potential of cognitive mapping. The third step did not put constraints on the creative phase, but just allowed the researcher to set the maps representation in a clearer way, without modifying or distorting the cognitive contents.

4. Discussion of Substantial Results

Analysis has been carried out on 6 maps out of 9 participants, because 3 participants had to leave the sessions in advance. Their maps were considered as being largely incomplete and therefore it was decided to expunge them from further analyses The aim was therefore to understand if, (i) by improving and enriching the readability of maps and (ii) by paralleling this action to appropriate analysis procedures, it is possible to enhance the effectiveness of using cognitive maps technique both for individual self-reflection and for the representation of the cognitive path of each agent, before and after the interaction. A content analysis, which refers to the first phase of individual reflection and interviewing, is synthesised in a matrix of concept occurrences in participants' computer-seat position (an excerpt is in figure 2).

COMPUTER SEAT POSITION	15	16	17	18	19	20	R
CONCEPTS							
Revitalisation of suburbs	1			2	1		4
The new university center must be strongly integrated with the region	1					2	3
Transportation network enhancing the relations with city and neighbourhood	1		1	1			3
Need to plan the location of firms and/or public boards interested in interacting with the center	1		1			1	3
Greatest care to be put on agricultural environments when building	1			2			3
Service network to support the center: student/visitor accommodation facilities, like in campuses	1		1				2
Commercial activities to be integrated in the area	1			1			2
Relations with other universities, scientific/technological parks, industries…	1					1	2
Drainage of meteoric water		1				1	2
Enhance occupation				1	1		2
Development of commercial, cultural, tertiary activities				1	1		2
Prevention of juvenile delinquency					1	1	2
[42 more statements follow, scoring 1 each]	0	5	17	10	5	6	
C	8	6	20	18	9	12	

Fig. 2. Concepts/participants matrix (17 top items selected out of 55)

The sum of the row elements (R) represents the sharing degree of each concept among the agents. The sum of the column elements (C) in the matrix represents the degree of the variety of contributions (number of concepts) provided by each participant, regardless of concepts differences. As a whole, a major concern in linking development and actual context, attentive to programming issues, shows up.

By carrying out a centrality analysis, the first concepts are compared with the "emotional" argumentation expressed in the interviewing step. In all cases, at least the first concept represents also the key concept expressed in emotional argumentation.

A further analysis aims at singling out further discussing themes and cognitive issues during the cooperative interaction phase (step four). The researcher analyzed the maps resulting from the two individual phases (steps 2-3 with step 5). The procedure of comparison was mainly focused on (i) listing the new concept added/modified, (ii) building a new occurrence matrix with added/modified concept per each participant.

New or modified concepts were identified in the maps with different colour shades (figure 3), whereas other considerations (linkages, etc.) were added in separate sheets.
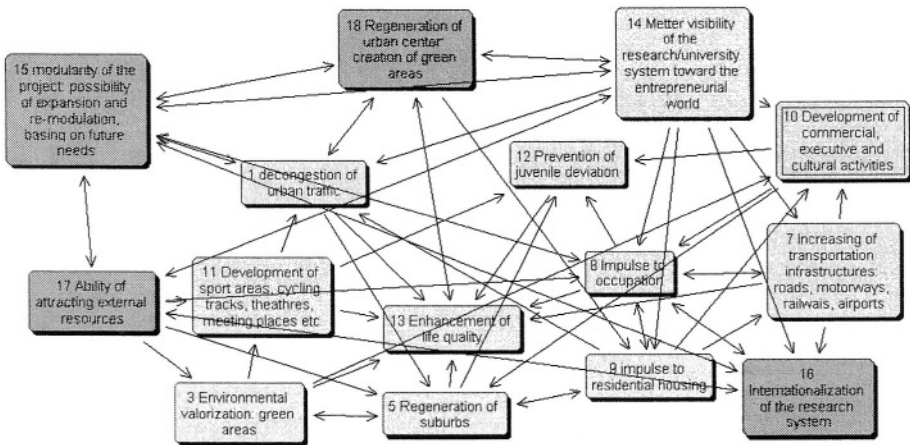
Fig. 3. Example of modified map (step 5)

After extracting and listing the new concepts, a new matrix was drawn out (figure 4). The sum of row elements in the matrix represents the number of participants who added the same concept. This number gives information on the most and least important concepts identified after the debate. Some concepts were clearly recognized as important and therefore added to the maps in subsequent steps, whereas some other statements (e.g., on green areas) were withdrawn. The total number of modifications on the maps proved to be a fairly reliable proxy to measure the impact actually occurred on individual cognitive levels, caused by the interaction.

The last analysis aims at showing an analytical indicator of propensity to change the cognitive frames of each participant. This indicator is the ratio between the number of changing in the final individual map (number of concepts added + number of links added + number of links eliminated) and the total number of the concepts generated in the first individual map (figure 5).

Concept	Occurrence
Revitalization of the area: creation of green areas and green regeneration of dismissed areas	4
Building campus colleges and university residential areas	2
Need of a complex and complete structure, open to technological transfer	2
Decongestion of many areas in Bari city	2
Ability tp attract external resources; better visibility of the university/research system toward the entrepreneurial world	2
Internationalization of the research system, with particular attention to didactical issues	2
Respect of archaeological areas	1
New transportation infrastructures	1
Eco-compatible design	1
Development of cultural activities	1
High total costs	1

Fig. 4. Most discussed subjects

PARTICIPANT	17	18	19	20
INDICATOR	0.10	0.33	0.30	0.56

Fig. 5. Analytical indicator of propensity to change

Despite the low number of stakeholders who completed the whole process, such indicator suggests some reflections on the individual cognitive paths. In particular, the agents who drew out maps too much focused on specific subjects, especially if highly structured (strong frame), show a very much lower propensity to enrich or change their own maps (low frame). On the contrary, the agents who set up the problem with a broader perspective, producing maps with concepts relevant to several knowledge contexts, carrying out a more qualitative and less structured analysis (less complex map, fewer concepts and links, but dealing with different subjects), show the highest propensity to change and enrich their frames with the outcomes of the interaction.

An excessive complexity of maps may then involve an excessive structuring and rigidity of reasoning. In this concern, autogenous framing may represent a strong limitation to the evolution of the knowledge levels of the interacting agents.

5. Conclusions

This study is the outcome of a theoretical as well as experimental research carried out in supporting decision-making in complex socio-environmental systems. In such participatory processes, the agents' substantial knowledge and cognitive frames are involved, being dynamically influenced by the interaction itself. Knowledge frames evolve relentless and dramatically, changing both as a group outcome, and in each agent's cognitive patrimony. In this light, some brief considerations can be drawn out. Exogenous framing seems to be hampered by many theoretical/practical factors in forum-based M-AKG so that standard problem structuring methods for group knowledge elicitation are vain. Moreover, the absence of exogenous framing does not prevent (i) the agents in forums from generating individual knowledge and (ii) group knowledge from being progressively generated and refined in the forum. Autogenous framing is highly context- and group-dependent, and is conditioned by the agents' 'prejudices' on issues. Therefore, aspirations to 'optimal' preliminary framing must be replaced by efforts for interactive evolutionary framing as the forum goes on.

As far as cognitive mapping is concerned, it proves to be a good method for managing M-AKG, particularly in knowledge forums. In this concern, hybridisation and de-standardisation of methods of knowledge generation and representation are crucial in large group forums that work on ill- or non-structured subjects and problems.

These considerations represent the limited but intriguing outcomes of the research experience. They are nevertheless significant in pointing out methodological pathways to set up and manage intelligent decision support systems in the environmental domain. In this light, further research is needed to more thoroughly explore the measure of potentials, as well as of drawbacks at hand.

References

1. Damasio, A.: The Feeling of What Happens. Body and Emotion in the Making of Consciousness. Harvest Books, San Diego (2000)
2. Forester, J.: The Deliberative Practitioner. Encouraging Participatory Planning Processes. MIT Press, Cambridge (1999)
3. Ishida, T.: Real Time Search for Learning Autonomous Agents. Kluwer, Dordrecht (1997)
4. Khakee, A., Barbanente, A., Camarda, D., Puglisi, M.: With or Without? Comparative Study of Preparing Participatory Scenarios Using Computer-Aided and Traditional Brainstorming. Journal of Future Research, 6(4), 45-64 (2002)
5. Kolodner, J.: Case-Based Reasoning. Morgan Kaufmann, San Mateo, Ca. (1993).
6. Minsky, M. L.: Society of Mind. Simon and Schuster, New York (1986).
7. Minton, S.: Learning Search Control Knowledge. Kluwer, Dordrecht (1988)
8. Sacerdoti, E.D: Structure for Plans and Behaviour. Elsevier, Amsterdam. (1977)
9. Schank, R.C.: Dynamic Memory. A Theory of Learning in Computers and People. Cambridge University Press, Cambridge (1982)
10. Shakun, M.: Consciousness, Spirituality and Decision/Negotiation in Purposeful Complex Adaptive Systems, Group Decision and Negotiation, 8, 1-15 (1999)
11. Shanahan, M.: Solving the Frame Problem. MIT Press, Cambridge (1997)
12. Simon, H.A.: Models of Bounded Rationality. MIT Press, Cambridge (1982)
13. Watts, D.J.: Small Worlds, The Dynamics of Networks between Order and Randomness, Princeton University Press, Princeton (1999)

A Hierarchical Visualization Tool to Analyse the Thermal Evolution of Construction Materials

Emilio Corchado[1], Pedro Burgos[1], María del Mar Rodríguez[2], Verónica Tricio[2]

[1] Department of Civil Engineering. University of Burgos, 09006 Burgos, Spain
escorchado@ubu.es,pburgos@ubu.es
[2] Department of Physics. University of Burgos,
09001 Burgos, Spain
foulquie@arquinex.es,vtricio@ubu.es

Abstract. This paper proposes a new visualization tool based on feature selection and the identification of underlying factors. The goal of this method is to visualize and extract information from complex and high dimensional data sets. The model proposed is an extension of Maximum Likelihood Hebbian Learning based on a family of cost functions, which maximizes the likelihood of identifying a specific distribution in the data while minimizing the effect of outliers. We present and demonstrate a hierarchical extension method which provides an interactive method for visualizing and identifying possibly hidden structure in the dataset. We have applied this method to investigate and visualize the thermal evolution of several frequent construction materials under different thermal and humidity environmental conditions.

1 Introduction

We introduce a novel method which is closely related to exploratory projection pursuit. It is an extension of a neural model based on the Negative Feedback artificial neural network [2]. This method is called Maximum-Likelihood Hebbian learning (ML) [3, 6, 5].

In this paper we provide a hierarchical extension to the ML method. This extension allows a dynamic investigation and visualization of a data set in which each subsequent layer extracts structure from increasingly smaller subsets of the data. The method reduces the subspace spanned by the data as it passes through the layers of the network therefore identifying the lower dimensional manifold in which the data lies.

The Negative Feedback neural network has been linked to the statistical techniques of Principal Component Analysis (PCA) [2], Factor Analysis [1] and Exploratory Projection Pursuit (EPP) [4]. The originality of this paper is the development and application of Hierarchical Maximum Likelihood Hebbian Learning (HML) to provide a novel approach.

2   A Family of Learning Rules

Consider an N-dimensional input vector, $\mathbf{x}$, and a M-dimensional output vector, $\mathbf{y}$, with W_{ij} being the weight linking input j to output i and let η be the learning rate.

The initial situation is that there is no activation at all in the network. The input data is fed forward via weights from the input neurons (the $\mathbf{x}$ -values) to the output neurons (the $\mathbf{y}$ -values) where a linear summation is performed to give the activation of the output neuron. This can be expressed as:

$$y_i = \sum_{j=1}^{N} W_{ij} x_j, \; \forall i \tag{1}$$

The activation is fed back through the same weights and subtracted from the inputs (where the inhibition takes place):

$$e_j = x_j - \sum_{i=1}^{M} W_{ij} y_i, \; \forall j \tag{2}$$

After that, a learning rule is performed between input and outputs:

$$\text{Weight change: } \Delta W_{ij} = \eta . y_i . sign(e_j) | e_j |^{p-1} \tag{3}$$

This architecture is called Maximum Likelihood Hebbian Learning [3, 6, 5]. It is expected that for leptokurtotic residuals (more kurtotic than a Gaussian distribution), values of p<2 would be appropriate, while for platykurtotic residuals (less kurtotic than a Gaussian), values of p>2 would be appropriate.

By maximizing the likelihood of the residual with respect to the actual distribution, the learning rule is matched to the pdf of the residual. Maximum Likelihood Hebbian Learning (ML) [3, 5, 6] has been linked to the standard statistical method of EPP [4, 6].

3   A Hierarchical Extension of the Model

There may be cases where the structure of the data may not be captured by a single linear projection. In such cases a hierarchical scheme may be beneficial.

This can be done in two ways, firstly by projecting the data using the ML [3, 5, 6] method, select the data points which are interesting and re-run the ML network on the selected data. Using this method only the projections are hierarchical.

A second more interesting adaptation is to use the resulting projected data of the previous ML network as the input to the next layer. Each subsequent layer of the network identify structure among fewer data points in a lower dimensional subspace.

The Hierarchical Maximum Likelihood method (HML) can reveal structure in the data which would not be identified by a single ML projection as each subsequent projection can analyse different sections of the subspace spanned by the data. This method has an additional advantage that with each sub-projection the number of samples and dimensionality of the data is reduced. As this is a linear method, by the linear combination of all previous layers we can identify the manifold in which the data points of interest lie.

4 Artificial Data Set

We have use an artificial data set make of 1200 samples, each of them define in a three-dimensional space.

In Fig.1, we show the artificial data set in three dimensions. By means of this three-dimensional representation it is difficult to determine the structure of this data set.

To obtain more information about the structure of the data, we apply the method called Principal Component Analysis, Figure 2, and Maximum Likelihood Hebbian Learning, Figure 3. Comparing both methods, we realize that PCA projection gives less information that the one provides by ML.
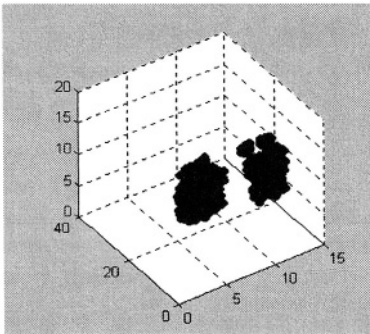
Fig 1. The figure shows a tree dimen sional artificial data set.
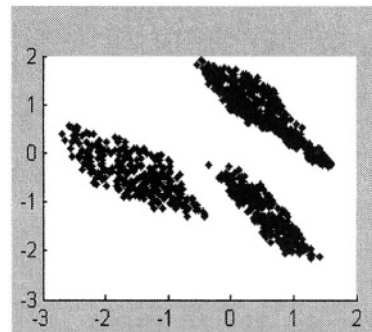
Fig 2. The figure shows the results of the Principal Component Analysis network.

We have applied our novel method, Hierarchical Maximum Likelihood (HML), to identify structure of the data which is not captured by a single linear projection of the data. In these cases, a hierarchical architecture may be advantageous. Our method allows selecting dynamically a subset of the data and then subsequently selecting one or more clusters in which to investigate new structure. We have applied this neural architecture to cluster C3 in Fig.3. We see initially two clusters and after applying our method, HML, we can identify four clusters in a very clear way, Fig.4.
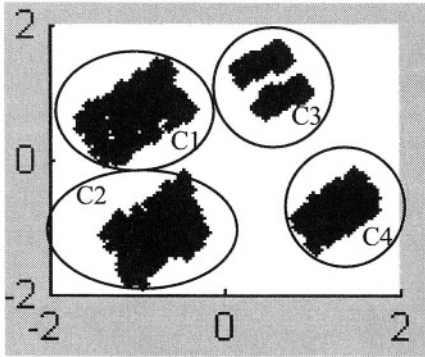
Fig 3. The figure shows the results of the Maximum Likelihood Hebbian Learning network using p=2.
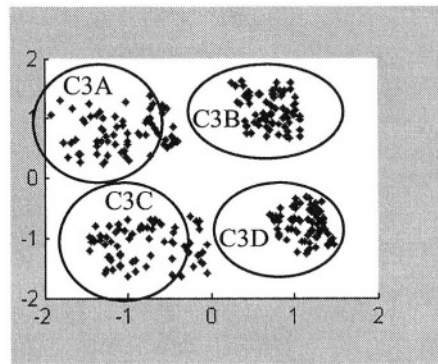
Fig 4. The figure shows the results obtained applying HML on cluster C3 of Fig.3.

5   Construction Materials Data Set

The real data used to illustrate our method is obtained from an experimental work which goal is the analysis of the thermal transmission of several construction materials [7]. We want to analysis their similarities and differences of behaviour. For that reason we have studied, in an independent way, the thermal transmission of these materials in a stationary state and in a transitory state. The data is collected from a simple "thermal house" prototype with a heat source inside the house controlled by a thermostat outside of it. The house was inside of an inhabited building. It is a closed cube, in which all of the four vertical faces are made of different materials:

A piece of plywood (3 cm of thickness),	a simple glass (1,8 cm of thickness),
A piece of plaster (1,5 cm of thickness),	a piece of polystyrene (4 cm of thickness)

6   Experimental Results

The experiment has been designed to register representative variables and them have been measured inside and outside the house. So we have measured experimental values of the inside and outside environmental temperature, the inside and outside relative humidity, the inside and outside surface temperature of each vertical face and the thermal flux of each vertical face.

The initial situation is an equilibrium state between the inside and outside temperature for both series. These are the surface temperature and the environmental one. Then the heat source is switched on until it reaches a stationary state. Once this state is reached, we kept the heating on for a while and then we switched it off. The data recorded belong to a period which starts before the heating is switched on and finishes when the equilibrium state is reached after the heating is switched off.

We perform two series of measures with the same inside heat source. We do not provide humidity in the first serie and we do it during the second serie of measures. We have performs the same experiment several times.

In the following sections we analyse the performance of the neural method (HML) and highlight the differences in the projections obtained by PCA and ML. We demonstrate also the HML method.

Comparison of PCA and ML on the Construction Materials Data Set

Figure 5 and Figure 6 show the behaviour of some thermal features (the inside and outside environmental temperature, the inside and outside relative humidity and the inside and outside surface temperature) of the four vertical faces during the ascending transitory state.

Symbol	●	*	▢	▷
Material	Polystyrene	Plywood	Plaster	Simple glass
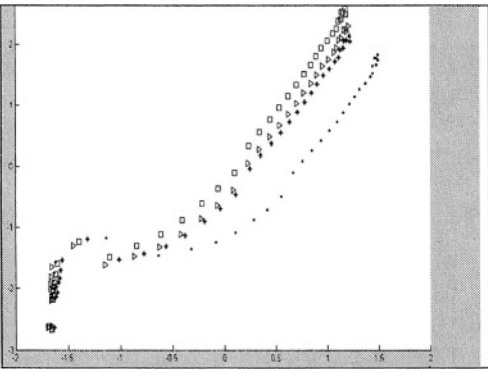
Fig.5. PCA on construction materials data.   **Fig.6.** ML on construction materials data.
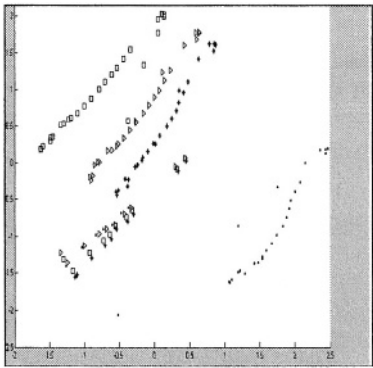
In Figure 5 and Figure 6 we show the comparison of PCA and ML projections of the construction material data. ML (Fig.6) clearly shows greater separation in the behaviour of different materials than is achieved with PCA (Fig.5). Figure 6 (ML) shows that Polystyrene behaves very different than the other three materials. These three materials (plywood, glass and plaster) have a similar behaviour. We could go further and say that plywood and glass have some times almost the same behaviour.

Behaviour of Two Vertical Faces, One Made of Glass and the Other One Made of Wood

For the last experiment, we show in Figure 7 a representation of the behavior of the materials (plywood and simple glass) which have shown a similar response after ap-

applying ML. The thermal features used in this experiment are: the inside and outside environmental temperature, the inside and outside relative humidity and the inside, outside surface temperature and the internal and external thermal flux. The first four features are common for all the samples.

The results in Figure 7 show that the vectors related to surface temperatures keep similar behavior in only one group. The vectors related to the thermal fluxes keep a certain level of similar geometry but pretty separated to each other. This representation visualizes, in a very clear way, the behavior derived from the different thermal transmission coefficients.

Symbols	Thermal Features
●	Plywood thermal flux
*	Simple glass thermal flux
□	Temperature of plywood
▷	Temperature of simple glass
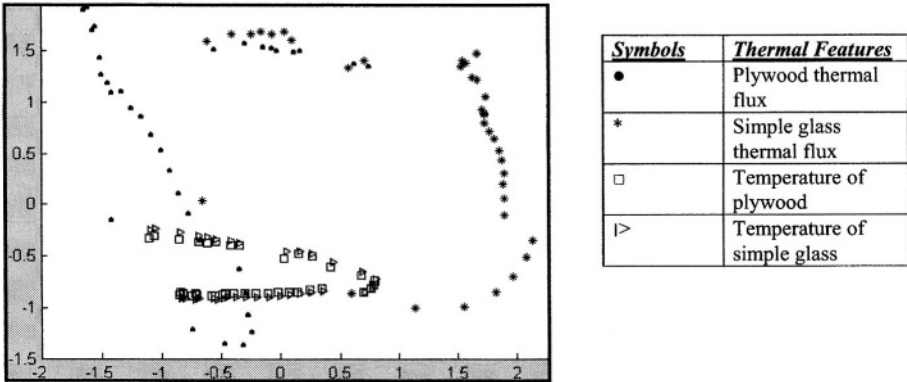
Fig.7. ML on construction materials data.

If we analyse Figure 7 we could see that these two construction materials have quite the same behaviour in terms of temperature, but the thermal fluxes are different. These logic similarities and differences can not be observed by other classic models used by physicists [7, 8].

Visualization Using Hierarchical Maximum Likelihood Hebbian Learning

Fig.8. For each vertical face of the four materials, we have analyzed the temporal evolution of the descending transitory state of the inside and outside environmental temperature, relative inside and outside humidity and the inside and outside surface temperature of each vertical face versus time. Fig.8 represents the results obtained using ML. We have found changes of the curvature for the four materials. These curvatures are stronger for plaster and polystyrene.

The used of HML over sub-cluster C1 in Figure 8, provides a better visualization to analyze the thermal evolution. An important advantage of the hierarchical model is that it provides more information in terms of inflexion points. This allows a better visualization and identification of different states in the studied transitory state and the identification of changes of state as we could see in Fig.9.
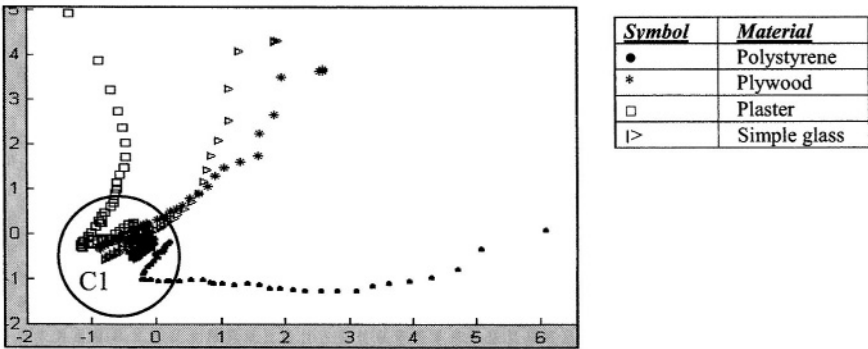
Fig.8. ML on construction materials data.
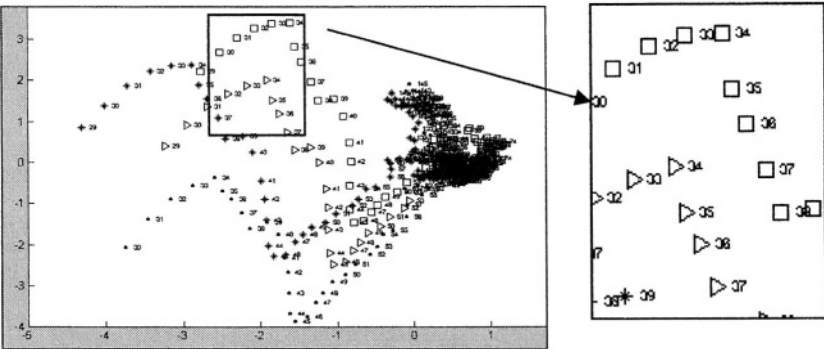
Fig.9. Result of HML on left cluster C1 in Fig.8

Fig.10. Inflexion points.

In Fig.9 we can see that HML identifies the inflexion points for the construction materials in a very clear way and gives us a new projection. It shows the inflexion points of the four materials which correspond to the same experimental time as we can see in Figure 10. If we look at Figure 9 and Figure 10, we can identify small fluctuations related with the thermal variables, temperature and relative humidity, when the experimental process is achieving the equilibrium state.

7 Conclusions

We have presented a novel visualization tool which provides an interesting and robust way to extract more information from a particular good and interesting projection and gives a very clear method to analyse the thermal behavior of construction materials. Future work will investigate further more complex data sets in order to study these materials and novel ones with an unpredictable behavior and in extreme conditions of temperature, radiation, humidity, etc. This may help to improve the security, habitability and sustainability of the buildings.

References

1. Charles, D. Unsupervised Artificial Neural Networks for the Identification of Multiple Causes in Data. PhD thesis, University of Paisley. 1999
2. Fyfe, C. Negative Feedback as an Organising Principle for Artificial Neural Networks, PhD Thesis, Strathclyde University. 1995
3. Fyfe, C. and Corchado, E., Maximum Likelihood Hebbian Rules. European Symposium on Artificial Neural Networks. 2002.
4. Friedman, J. and Tukey, J. A Projection Pursuit Algorithm for Exploratory Data Analysis. IEEE Transaction on Computers, (23): 881-890. 1974.
5. Corchado, E. and Fyfe, C. Orientation Selection Using Maximum Likelihood Hebbian Learning, International Journal of Knowledge-Based Intelligent Engineering Systems Volume 7 Number 2, April 2003. ISSN: 1327-2314. Brighton, United Kingdom.
6. Corchado, E. MacDonald, D. and Fyfe, C. Maximum and Minimum Likelihood Hebbian Learning for Exploratory Projection Pursuit, Data Mining and Knowledge Discovery, Kluwer Academic Publishing. Vol. 8, no.3. May 2004.
7. Tricio, V. and Viloria, R. Microclimatic Study in a Historical Building: Protection and Conservation of the Cultural Heritage of the Mediterranean Cities. Topic: Environmental parameters of the Mediterranean Basin. 2002. Pg: 67-70.
8. Corchado E., Burgos P., Rodriguez M., Tricio V. An Unsupervised Neural Model to Analyze Thermal Properties of Construction Materials. ICCS 2004, 4th International Conference, Kraków, Poland, 2004, Proceedings, Part II. Pp. 204-211.

This page intentionally left blank

Author Index

Lecture Notes in Computer Science

For information about Vols. 1–3107

please contact your bookseller or Springer