End of First Year Report

Luís Manuel Borges Gouveia
luis@comp.lancs.ac.uk
lmbg@ufp.pt

CSEG Group
Computing Department

Lancaster University
England

Supervisor: Prof. Thomas Rodden
tom@comp.lancs.ac.uk

CEREM Group
Multimedia Resource Centre

Fernando Pessoa University
Portugal

Local supervisor: Prof. Feliz Ribeiro
fribeiro@ufp.pt

End of First Year Report

Luís Manuel Borges Gouveia
CSEG Group
Computing Department
Lancaster University
England
luis@comp.lancs.ac.uk

Supervisor: Prof. Thomas Rodden
tom@comp.lancs.ac.uk

September 1998

1. Introduction

This section introduces the report, its context and structure. In addition, some of the base assumptions for the work are reported.

This report is prepared for the first year assessment in the context of the Ph.D. studies at the Computing Department, Lancaster University. The main goals of this report are: (i) describe the work done in the first year; (ii) deliver an initial literature survey, and (iii) submit a project proposal based on the first year of work, started November, 97. The project proposal will outline the structure of the research to be undertaken in the next two work years.

The main areas of interest are Collaborative Virtual Environments, Information Visualisation and Educational Applications (using these technologies for supporting knowledge management). A proposed title to summarise the ongoing work can be *"Collaborative Virtual Environments and Information Visualisation: issues in integration and representation of knowledge"*.

The work done in my master's degree was about the study of Information Systems (IS) aiming at the characterisation of a service set based on Multimedia facilities [1]. It assumes the information management and information flow as critical success factors in the enterprise, based on the hypothesis that if these factors are handled conveniently it is possible to change dramatically the productivity of human resources. In order to obtain this kind of advantages, the information system must be improved with technology that enables the information flow and that integrates with the actual IS (abstract and keywords in appendix A).

As an emerging discipline, Information Visualisation can offer technologies that improve the way humans perceive and use large and complex datasets, and help manipulate information [2]. Stuart Card and others, introduce visualisation as the process of transforming data, information, and knowledge into visual form making use of human's natural visual capabilities [2]. Visualisation can also provide an interface between the human mind and the computer.

Virtual Reality technology offers a great potential to represent information and a new paradigm to represent information in 3D. Virtual Reality (VR) can be considered as the delivery to a human of the most convincing illusion possible that they are in another reality [3]. This reality exists in digital electronic format in the memory of a computer. Related terms with Virtual Reality (Jaron Lanier) are Artificial Reality (Myron Krueger), Cyberspace (Willian Gibson), and, more recently, Virtual Worlds, Synthetic Worlds, and Virtual Environments [4].

How can we relate Virtual Reality technology and visualisation? We can consider that the visualisation goal is to represent data in ways that make them perceptible, and able to engage human sensory systems [5]. As Artificial Reality makes it easier to interact with visualisations, and the user can have its own presence in a 3D space, there are more natural possibilities for manipulating 3D images. This opens the way to users interact directly with the data, to multiple users interact simultaneously with the same visualisation, and also serve as environments for supporting human/human interaction [5].

The text is divided in six sections, each one, with a specific purpose:

- introduction: gives the general context and structure of this document.
- aim and motivation: explains the aim and the motivation underlying the proposed work.
- related areas of research: introduce what and why the topics chosen for research are considered valid and the motivation for the work.
- enabling technologies: gives a first approach to the available technologies that may be used to implement the ideas. This section has three parts, introducing Web, CVE, and Information Visualisation concepts and technologies.
- literature survey: gives an outline of further literature review to be conducted in some selected topics within the studied research area.
- project proposal: presents and describes a first position to be followed as the action related with the undertaken research problem.

2. Aim and Motivation

This section explains the aim and the motivation underlying the proposed work.

The impact and use of VR technology to visualise information, and knowledge in an education environment along with the possibility to support knowledge management, is the intended subject of this study. Approaches to educational systems based on well-tested and conventional techniques have suffered from limitations due mainly to:

- the complexity resulting from large amounts of unstructured information, and the difficulty of keeping pace with updating, verification, and authoring information. This affects largely human computer interaction, and no novel solutions are in sight to solve this problem.
- the complexity of co-ordinating several information sources when one tries to move to decentralised or distributed solutions does not seem to be reduced as heterogeneity, and interoperability problems arise easily. Further, the user interaction problem remains untouched.
- the shift in information content from pure data to knowledge does not seem to fit well with conventional available systems. Knowledge changes and evolves continuously and needs to be certified, authored, and represented in various supports and dimensions.

The proposed approach in this work is to free information and knowledge from conventional and hardware-oriented supports and to easen user information management [6]. VR technology seems a promising start as it allows for the following improvements:

- the cost of VR technology is falling, and it is now becoming affordable for even small enterprises (taking VR to the “whole market”)
- although the visual quality of a VR system cannot, as of now, compete with traditional display, this is not a drawback in our context
- user interaction becomes more intuitive, and presents the possibility of extending routine work, with apparently no losses in productivity
- VR technology offers new possibilities to build system applications that improve or modify radically productivity

The described improvements in VR are also valid ones for Computer Supported Cooperative Work (CSCW) systems. The goal of CSCW is to discover ways of using computer technology to further enhance the group work process through support in the time and place dimensions, where the focus of CSCW goal is the social interaction of people, and not the technology itself [7].

When considering the use of VR as an enabling technology in CSCW systems, it will be possible to enhance co-operation by synchronising the focus of users attention (the *Do You See What I See* issue [8]). With users inhabiting a common world this problem is avoided. The creation of a virtual environment where users can collaborate using VR technology and CSCW principles, introducing 3D representations, user embodiment and enhanced interactivity is referred as a Collaborative Virtual Environment (CVE) [9].

This brings the essence of a CVE system: make possible to someone to interact with an information space and with other individuals to share, discuss and make as much visual and representation information organisations as wanted.

The emphasis on this work will be put on the following issues:

- representation of information and knowledge in 3D spaces (for potential use in a CVE system), which needs novel forms of doing
- creation, sharing, and modification of information and knowledge visual representation on 3D worlds
- productivity issues related to the systems use in an educational setting

Why consider a learning prototype system to test these ideas? Today educational systems are in change (see the Appendix B for an unpublished paper about this topic) and this can be seen as a great opportunity to apply some of the concepts regarding the ongoing research into real settings.

A recent European Commission document [10], confirm this perspective, by stating that the access to information alone is not the answer to better education, learning and training. There is also a need for skills and tools which enable users to turn the information into knowledge. The document concludes that "*what we are now beginning to witness is the evolution of the information society into the knowledge based society*".

3. Related areas of research

This section tries to justify why the study and the problems around this study are important, feasible, and can be researched.

The need for better ways for representing information and dealing with the increasing complexity and volume of information for a user or a group of users is not a new one. These topics constitute a central issue for many research projects and are part of the expected outcomes for many others. Among these projects is the Engelbart's Augmentation Human Intellect Research Centre, at Stanford Research Institute, which was set up to explore new forms of computer interaction [11].

Some people, like Sutherland, propose new forms of dialogue between users and computers - a graphical dialogue [12]. Lakin also proposes a performing medium where the focus is on live manipulation of text and graphics [13]. Laurel adds that "*graphical and, by extension, multisensory, representation are to both physical and emotional aspects of directness in interaction. Hence, it is worthwhile to examine the role and contributions of graphic design in interface systems*" [14].

Tufte introduces the roles that graphics and other visuals can have into help visualising information and convey meaning. His well known books are oriented, each one, to a specific topic: the first book focuses in introducing a graphics history and a language for discussing graphics. It also gives a practical theory of data graphics (in particular, statistical graphics) [15]. The second book treats the principles of information design (that are as universal as mathematics, in the author's perspective) [16]. The book is also about escaping flatland, this means, adding more dimensions to be represented and discuss how to represent the rich visual world of experience and measurement knowing that the world is complex, dynamic and multidimensional. The third Tufte's book deals with design strategies for presenting information about motion, process, mechanism, cause and effect [17].

Flatland is a word coined by Abbott, in a 1884 book with the same name, where he describes a two dimensional universe in which all the creatures were flat shapes [18]. The Flatland book also offers a demonstration of the difficulties of breaking out of the mental structures we use to make sense of the world, and serve as reflective model for the use of 3D facilities in actual computer systems. This was best described by Woolley comment about the book [19]: "*How would A. Square make sense of Spaceland, the three-dimensional world occupied by the strange Sphere creature that can be experimented in Flatland as a circle that could make itself large and smaller, and that could appear and disappear at will?*". A similar problem, concerning the use of perspective and spatial notion, is demonstrated in the Appendix E.

When dealing with visual information representation to human use, one first issue to consider must be the human itself, his perceptual limitations and the way he understands visuals. Norman defined humans as thinking, interpreting creatures, that are active, creative, social beings [20]. Hutchins states that cognition is socially distributed [21]. The same author adds that cognitive activity must be analysed in context, where context is not a fixed set of surrounding conditions but a wider dynamically process of which the cognition of an individual is only a part. This means that we must consider cultural factors and explicable effects that are not entirely internal to the individual [21, pp 355] - introducing a sociocultural perspective.

The concept of space and its use, has also value to the present study. Human cognition adapts to its natural surroundings and potentially interacts with an environment rich in organising resources. For [21], human cognition is a different cognition when compared with other animals, primarily because it is intrinsically a cultural phenomenon. This way Hutchins refers to three kinds of space: the physical space, the social space and the conceptual space. It is the last one - conceptual space - that will be the focus for the present study.

The main material each individual can use, share, and communicate is knowledge. A percussor system like the Memex system presents as its essential feature the associative indexing wich introduces the concept of creating an information space from new material and active links to existing material [22]. The Memex was described as an individual appliance to organise and access information. Ted Nelson (who coined terms like hypertext and hypermedia) introduces the Xanadu project in 1962, extending the Memex system and proposing a new type of a publishing medium, where the creation of links between existing and new contents, including its modification which turn possible the creation of new meanings and interpretations by elaborating dynamic structures. This time, the proposed system can be described as a collective appliance.

The system is also described by [19, pp 161], "*everything within Xanadu project exists by virtue of its links with everything else, and those links are constantly forged and broken. Every reader of every text contributes to its meaning by participation in the creation of the structures that place it*". If we consider not the database implementation but a information visualisation representation with an annotation linking system some of the described functionality can be achieved.

Although the Xanadu project has not been accomplished, a distributed hypermedia system - the World Wide Web (WWW or Web) [25] - with a client-server architecture has become a global system to access information. The Web is completely unstructured and is continuously changing its content. It links a huge amount of information that is increasing all the time. The Web has three characteristics that make its study challenging for current information visualisation research: its information is unstructured; the information is dynamic and complex; and the huge amount of available Web information originate scale problems, even if we considered just partial Web representations.

One of the important concepts about interfaces is the strategy of direct manipulation. It was coined by Shneiderman (1982) who listed three criteria for a direct manipulation system: (i) continuous representation of the object of interest; (ii) physical actions or labelled button presses instead of complex syntax; and (iii) rapid incremental reversible operations whose impact on the object of interest is immediately visible [23].

Shneiderman argues that the goal of direct manipulation is the creation of environments "*where the users comprehend the display, where they feel the control, where the system is predictable, and where they are willing to take the responsibility*" [24]. He also states that the future direction for direct manipulation is information visualisation with the focus on the remarkable human capabilities in the visual domain, under-utilised by current design [24].

The use of 3D visuals, the time and space representation, the ability to detect patterns and the representation of cause/effect relations seems to be some of the issues in the information visualisation field. Other important issues for the current research are interaction and sharing in allowing individuals to deal with information and share its visions of it. Virtual reality systems may play an important role on that giving way to new forms of interaction with information visualisations and in dealing with the dynamic characteristic of information.

Other important issue is the context where the information sharing is done. This introduces the concepts of collaboration and co-operation and the need to consider some of issues already beieng treated in

CSCW systems. As a functional combination of VR and CSCW systems, a CVE can offer an environment where more than one user is involved with an information space. In a CVE the need for information visualisation still exists and remains as one of the components to be studied, along with others. These will be the topics of the literature survey.

To share information we must deal with a common language that specifies and enables the basic communication operations to share meaning by known abstractions. This rises questions about symbols and semantics, that is, communication issues.

Hutchins also proposes that when the manipulation of symbols is automated, neither the cognitive processes nor the activity of the person who manipulated the symbols is modelled. The original source domain of language of thought was a particular highly elaborated and culturally specific world of human activity, that of formal symbol systems [21]. This way, the boundary between inside and outside became the boundary between abstract symbols and the world of phenomena described by the symbols.

Hutchins defends that "*people process symbols (even the ones that have internal representation), but those symbols are not inside the human mind, creating a distinction between cognitive and perceptual human activities*" [21]. Hutchins adds that "*the symbols were outside, and the apparatus that fell off is exactly the apparatus that supported interaction with those symbols. When the symbols were put inside, there was no need for eyes, ears, or hands. Those are for manipulating objects, and the symbols have ceased to be material and have become entirely abstract and ideational*" [21].

In cognition, based in Hutchins, we must distinguish between the tasks that the person faces in the manipulation of symbolic tokens and the tasks that are accomplish by the manipulation of the symbolic tokens. The same author presents human as good at detecting regularities in their environment and at constructing internal processes that can co-ordinate with those regularities. Humans spend their time producing symbolic structure for others. Hucthins concludes saying that "*ontogenetically speaking, it seems that symbols are in the world first, and only later in the head*" [21].

Giving the multidisciplinary nature of information visualisation and of the area been taken for research, it is important to define the problem to study. Information works as the raw material to be used. The main area of study will be the visual representation of information. The main problem is: *How far can 3D visual representations computer mediated be useful in helping the understanding and communication between individuals?*

When dealing with representations it's rather obvious that different representations can enhance the understanding level of a particular problem. The form of representation makes a dramatic difference in the ease of the task and their proper choice depends upon the knowledge, system, and method being applied to the problem [20]. As a simple example we can consider the comparison between the *Game of 15* and the *Tic Tac Toe*, which can share the same spatial representation, and easen the user perception of the *Game of 15* [20] (a complete description is on Appendix C).

Why consider information visualisation as the main research topic? We need better tools to deal with complex data sets, ill-structure and dynamic information settings that characterise actual systems (to deal with communication needs, understand and learning problems, info-glut, information overload, etc. [28]). Visual representations are more natural for humans and can be used to improve their perception to learn and as an aid for search and computation. We can give three examples: first, the influence of using better information displays that can offer visual clues for the user (Appendix D). Second, the description power of visuals compared with the use of just words (Appendix E). The third example is the common popular phrase saying that "*an image is better than thousand words*".

The data-information-knowledge pyramid (figure 1) can provide a starting point to the research discussion. The more higher the level, more symbolic abstraction is on use. A similar pyramid is proposed by Lengel and Collins [26] designated as educational pyramid, where the information level is referred as ideas level. The authors give a description for their educational pyramid: "*What education is supposed to do is to get students to see data (facts) in such as way as to inform themselves. The data in their mind are combined into information. Information is then related to other information to produce ideas in the students' minds - concepts that help explain the world. Some students combine these ideas to produce a wisdom that understands the whys and wherefores of life and truth. The aim of education is to move up the pyramid*" [26].

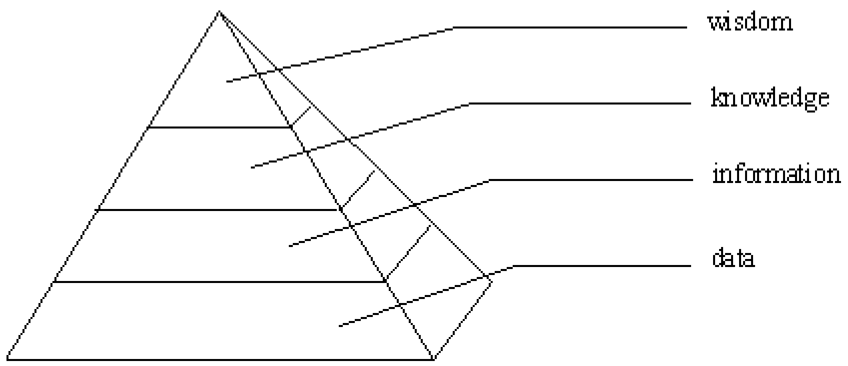


Figure 1: data-information-knowledge pyramid

In the lower level, *data* is considered as the base raw material to represent information [32]. In a more formal definition, data is the representation of facts, concepts, or instructions in a formalised manner suitable for communication, interpretation, or processing by human beings or by automatic means [27].

Information is based on data aggregation and is considered as the material to help and support decision or other actions [32]. A formal definition is proposed by [27] as the meaning that a human being assigns to data by means of the conventions applied to those data. For [31], information is the product of filtering and then processing raw data into a potentially useful form.

The knowledge level adds context and purpose orientation to the information level. Knowledge Management is an actual research topic in Management, Information Systems, and CSCW areas. *Knowledge* stems from the analysis of information within an expert frame of reference so that it becomes attributed with actual meaning [31]. Barnatt proposes a illustration for the data-information-knowledge progression (figure 2) [31].

Figure 2: data-information-knowledge progression

In the top of the pyramid (figure 1) we propose a higher level - wisdom - as the long term material to a high order structure models for representations of the reality. Wisdom is socially constructed.

The knowledge which is used in a given problem domain could transform itself into wisdom and became a base to the generation of action activity [29]. Cooley proposes a data to wisdom transformation, based in the signal/noise relation (figure 3) [30].

Data combined gives information. Information, placed in the appropriate context, forms knowledge. And knowledge, combined with experience, judgement and a whole range of other things, gives us wisdom [40].

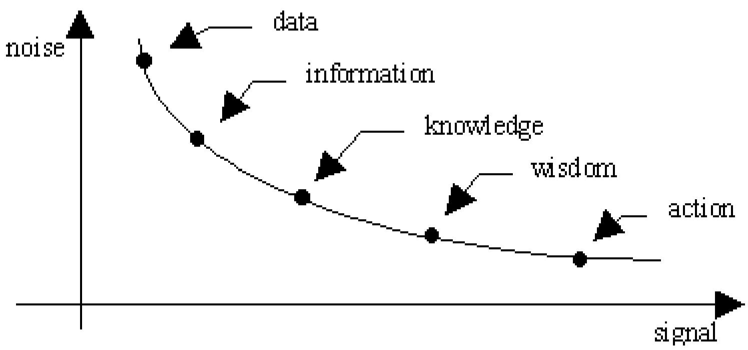


Figure 3: data to wisdom transformation

Norman proposes that external representations, especially ones that can be part of a workspace shared with others, require some sort of constructed device to support them: an artefact [20]. He also adds that the representations of the representations of thoughts and concepts is the essence of reflection and of higher-order thought. It is through *metarepresentations* that we generate new knowledge, finding consistencies and patterns in the representations that could not readily be noticed in the world [20].

As we step on higher levels of abstraction, better cognition artefacts are needed. Engelbart proposes a useful notion of artefact as part of a four basic classes of augmentation means (the others are language, methodology and training) [33]. The proposed cognition artefact differs from the Engelbart notion of artefact because he consider only the physical objects.

This way the proposed cognition artefact is more like the Engelbart's *language* class from the conceptual framework, defined as "*the way in which the individual classifies the picture of his world into the concepts that his mind uses to model that world, and the symbols that he attaches to those concepts and uses in consciously manipulating the concepts («Thinking»)*" [33].

Other important notions to be considered are the way we access and use the information, and the way we learn in a cognitive perspective.

Humans access information in several different ways. If we consider the amount of information available organised into an information space, we can distinguish three access types: search, browsing and reading [34].

In the search type access, one concept is key and that concept occurs just once (or a few times) in the information space. In the browsing access, several important concepts relate to several parts of the information space, some are relevant and some not. For reading access, the user takes all the information space to match the required concepts.

If we consider Swets´s definitions of precision (fraction of the retrieved information which is relevant) and recall (fraction of the retrieved information relevant versus all relevant information) [35] together with the amount of information, then we have a three dimensional criteria to evaluate information access (figure 4).

Search access must need few parts of the information space and should be performed in a system that provides high recall and, at least, medium precision. Browse access needs several parts of the information space, also needs high recall and, at least, medium precision. Any other access that needs greater parts of the information space corresponds to an understanding task. We have an understanding problem when precision and recall are low or when we need to consider large amounts of information [34].

These access types work better in small to medium information spaces where to less dimension correspond more structured concepts with a greater number of relations between them. This way, to perform search and browsing tasks in an information space, some understanding tasks must be performed in order to learn about the information space and map the amount of information, precision and recall values.

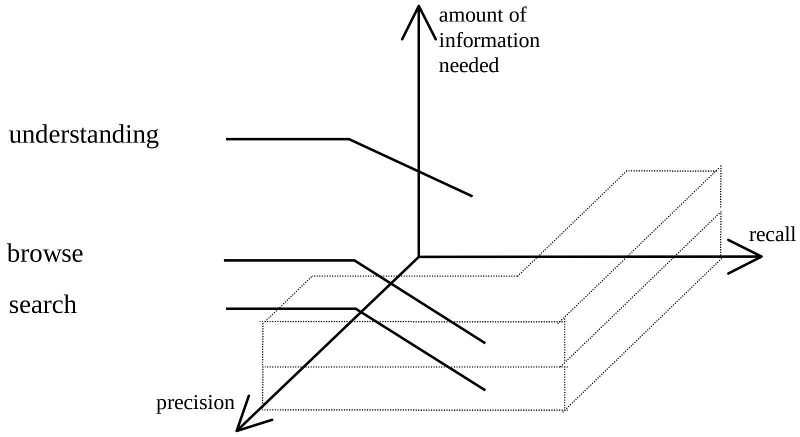


Figure 4: Three-dimensional criteria to evaluate information access type

The understanding problems can be filtered by the use of better and more abstract information visualisations schemes. The medium, is important for helping in understanding tasks, like in the case of paper that can be more attractive than computerised information based on its familiarity, tangibility, and portability [36].

In an alternative perspective, Laura Leventhal defines navigation as "*the cognitive process of acquiring knowledge about a space, strategies for moving through space, and changing one's metaknowledge about a space*" [37]. Furnas and others [37], proposed a definition of some concepts related with navigation where a distinction between task (search and browse) and tactics (query and navigate) was made. This way, search is considered a task of looking for a known target. The browsing is the task of looking to see what is available in the world. The querying tactic consists in submitting a description of the object being sought to a search engine which will return relevant content or information. The navigation is presented as moving sequentially around an environment, deciding at each step where to go next based on the task and on the environment seen so far.

Furnas presents *map building* as one of the navigational subtasks and describes it as constructing a representation - mental or physical - with spatial structure to aid multiple route following and finding tasks [37]. Apperley, Carl, Jul, Leventhal and Spence proposed a three level structure to the navigational design where the users cognitive map is based on the user's previous knowledge, experience and their views of the imposed structure (figure 5) [37].

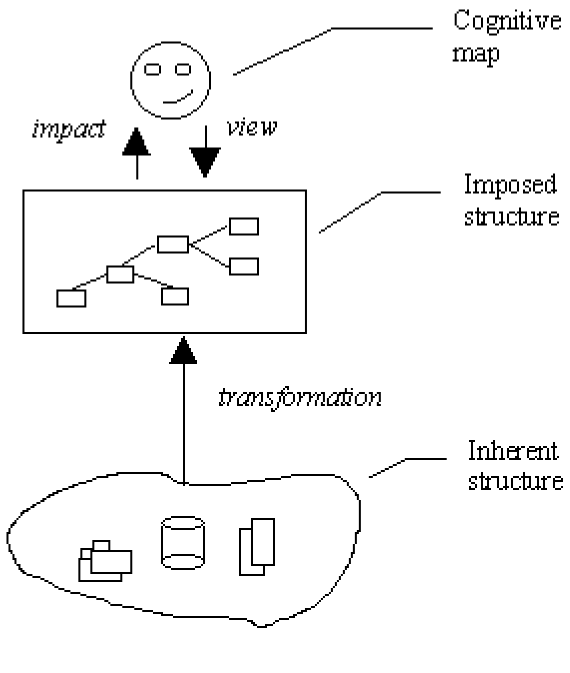


Figure 5: Levels of structure for navigational design

For our purposes, the generation of cognitive map visualisations can be of interest. McAleese suggests that the concept map functions as an aid, helping the learner interpret and organise personal knowledge [38]. The same author proposes the use of concept maps to the representation of knowledge and its application to support learners with external learning spaces [38].

The way we learn as a cognitive experience can be a result of many kinds of cognition. Norman propose two modes that are relevant when a discussion of cognitive artefacts is made (in a human centred view); the two modes are: experiential and reflective [20]. The experiential mode leads to a state in which we perceive and react to the events around us, efficiently and effortlessly. The reflective mode is that of comparison and contrast, of thought, of decision making. The first mode is related with an expert behaviour and efficient performance, and the second, with the creation of new ideas and novel responses.

Human cognition is a multidimensional activity, involving all the senses, internal activities and external structures; this way Norman recognises that the division in only two categories of human cognition is a simplification, although useful for design proposes of human centred systems [20]. Norman proposes that experiential thought "*is reactive, automatic thought, driven by the patterns of information arriving at our senses, but dependent upon a large reservoir of experience. (…) it involves data-driven processing*" [20]. The reflective mode "*is that of concepts, of planning and reconsideration. (…) tends to require both the aid of external support and the aid of external people".*

Norman suggests that the environments used to aid cognition must be designed accordingly: "*the external representations have to be tuned to the task at hand if they are to be maximally supportive of cognition. Reflection is best done in a quiet environment, devoid of material save that relevant to the task. Rich, dynamic, continually present environments can interfere with reflection: These environments lead one toward experiential mode, driving the cognition by the perceptions of event driven processing, thereby not leaving sufficient mental resources for the concentration required for reflection. In the terms of cognitive science, reflective cognition is conceptually driven, top-down processing* " [20]. The focus on designing the action is also proposed by Laurel [14]. Bodker adds that in performing a task [39], the person has a focus and a goal, this way the attention must in the task, not upon the tool. Tools must be in the background, becoming a feeling of directly working on the task.

Rumelhart and Norman propose three kinds of learning: accretion, tuning, and restructuring (that extending the experiential and reflective cognition framework). Accretion is the accumulation of facts, adding to the stockpile of knowledge. With the proper conceptual framework, accretion is facilitated and efficient [20].

Tuning is based in massive practice. It tunes the skill, shaping the knowledge structures in thousands of little ways so that the skill that in early stages required conscious, reflective thought can now be carried out automatically, in a subconscious, experimental mode. Experimental thought is tuned thought [20]. Tuning is necessary to reach expert levels of performance, and then essential to maintain them.

Restructuring, is about forming the right conceptual structure. Accretion and tuning are primarily experiential modes and restructuring is reflective. This third way of learning is where new conceptual skill are acquired. It is necessary to use the right tools to reflect, explore, compare, and integrate.

In figure 6, Coelho proposes a learning triangle, with three main learning activities and general Knowledge transformations [29]. This represents an Artificial Intelligence perspective view of learning activities. The proposed path for knowledge handling gives the possibility to obtain solutions and more knowledge from actual situations.

Hutchins proposes learning or conceptual change as a kind of adaptation in a larger dynamically system [21]. It also states that one scale of learning or change in the organisation of cognitive systems are the opportunities for the development of new knowledge in the context of practice. Experimental artefacts provide mediation between the mind and the world. Reflective artefacts allow us to ignore the real world and concentrate only on artificial, representing worlds.

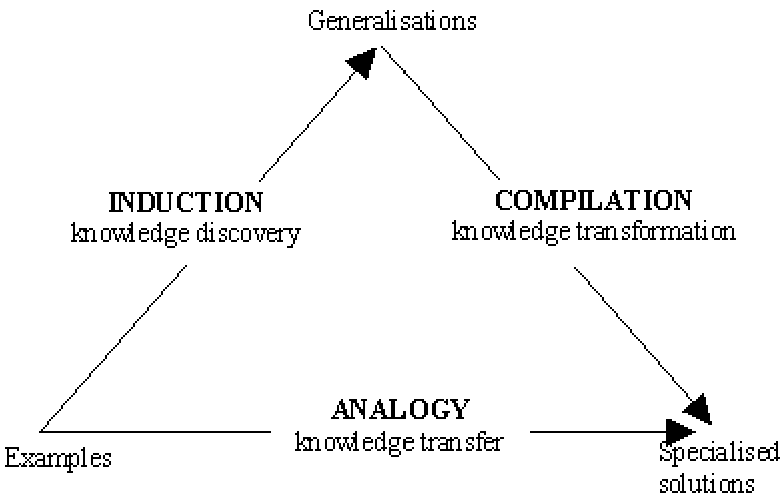


Figure 6: the learning triangle

The research application can be now stated as the use of 3D facilities to improve information visualisation providing a useful way of sharing workable knowledge representations to be shared as collective cognitive maps constructs, based on the individuals own visualisation filters (of potential use for education settings).

Education, learning and training mediated by computer has been selected as the application area, for this study. Among the research activity conducted in the first year period, some effort was directed to relate the use of a computer mediated setting for learning in classrooms and extending classroom outside his physical and time restrictions. As a result, several papers where published in international and national (Portuguese) conferences dealing with issues like the impact of web and network use in the classroom and the campus, group mediated computer work, virtual environments to support interaction between students, supporting issues to rich technological environments, new forms of evaluation and assessment in classroom, and the teacher's role changes in a rich technology environment (see Appendix F, for a complete list of published papers).

The main problems that arise in the intended research are:

- dealing with the problems put by the n-dimensionally; addind one more dimension, a whole new class of problems can be considered in a new way, however most of them are not just three-dimensional but n-dimensional which means that some restrictions must apply to a 3D representation in order to be a useful one;

- model a workable set of parameters to represent as useful knowledge representations, for an information visualisation like extending concepts maps to use 3D facilities. This must take into account the particular needs of a learning environment;

- develop an usable set of 3D symbols to serve as demonstrators for 3D concept maps

- use an enabling set of technologies to implement the 3D space for (i) individual control and (ii) for sharing by several users.

Select an application where the described ideas can be tested based on the background given, the use of a learning space we propose a model to answer the problem. The model will setup an environment, and learn and generate workable knowledge representations as information visualisations.

This way, the main goal is recurring to 3D use to information visualisation enhancing direct manipulation interfaces in a perspective of enabling, as Laurel states, "*think of the computer, not as a tool, but as a medium*" [14].

4. Enabling Technologies

This section introduces some of the technologies that may have a direct impact or at least can contribute to the development of test applications related with the study

4.1 WWW as a development lab

World Wide Web

The World Wide Web also known as WWW or Web, took a start in August 1990 by Tim Barners-Lee and Robert Cailliau. The Web authors submited a proposal at CERN (the European Laboratory for Particle Physics, in Geneva) where they worked, at the computer science department.

Particle physics research often involves collaborations between institutes from all over the world. Barners-Lee had the idea of enabling researchers from remote sites right across the world to organise and pool information together. But far from simply making available a large number of research documents as files which could be downloaded, he suggested that they could be linked in the text files themselves. This way, reading one research paper, could quickly display part of another paper which held directly relevant text or diagrams. Documentation of a scientific and mathematical nature would thus be represented as a “web” of information held in electronic form on computers across the world [56].

The Web is a large scale distributed hypermedia network based on a client-server model, with a wide range of services and standards. It can be seen as a global information system. The organisation that co-ordinates all the standardisation efforts, formed in October 1994, is the World Wide Consortium (http://www.w3.org/Consortium/), headed by Tim Barners-Lee. Since 1990 until now, the Web is gaining world-wide acceptance and every day more people in the world use, publish and work with this information system.

Hypertext Transfer Protocol

The Hypertext Transfer Protocol (HTTP) is an application-level protocol designed for fast and efficient transfer, retrieval, and searching of resources in hypermedia information systems. HTTP works on the client/server and request/response model as shown in figure 7.

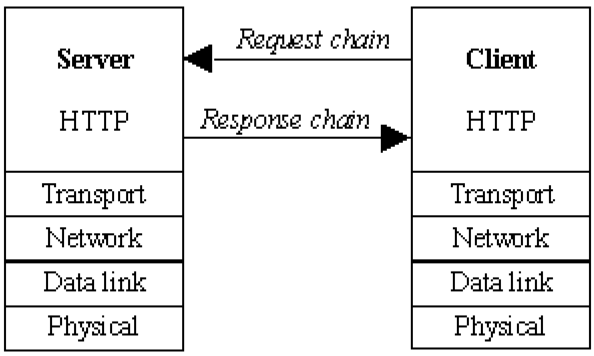


Figure 7: the HTTP protocol stack

On the Internet, the HTTP communication typically runs over the TCP/IP protocol suite, using the default TCP port 80, but others ports may be used. The protocol HTTP does not specify that the protocol must be implemented over TCP/IP, it only assumes reliable transportation and, therefore, it can be used with any other transport/network protocol or network.

The HTTP communication is usually initiated by a user agent, or client application such as a web browser. The client establishes a connection with the server and sends an application layer protocol data unit (PDU) - request chain. The server responds with an application layer PDU - response chain. The protocol is a generic, stateless, object-oriented protocol, designed to be used for multiple purposes.

The requested chain consists of a request line, request header information, and possibly data. The request line consists of the method, the request uniform identifier (URI) and the HTTP version. The method token specifies the method to be performed on the resource identified by the request URI. Three types of methods are GET (indicates to the server that the client wishes to retrieve the resource identified by the request URI); HEAD (used to test the validity and accessibility of hyperlinks); and POST (informs the destination server to accept the enclosed data in the request chain, used for web form submittal).

The request URI is used to identify and locate the hypermedia resource as an HTTP uniform resource locator (URL) [57] or an absolute path on the origin server. The message passing scheme used is similar to the Internet mail and Multipurpose Internet Mail Extensions (MIME) [58]. A detailed description of the HTTP protocol, with description of the general information structure of PDUs, can be accessed at http://www.cis.upenn.edu/~nvu/TCOM/section1.html.

More information about the Hypertext Transfer Protocol version 1.1, revision 05, can be obtained at http://www.w3.org/Protocols/. Some information about HTTP related protocols is available at http://www.w3.org/Protocols/RelevantProtocols.html. At http://www.w3.org/Protocols/HTTP-NG/ the HTTP-NG (next generation) is presented.

Hypertext Markup Language

Most documents on the Web are stored and transmitted in HTML. HTML stands for Hypertext Markup Language and is a simple language well suited for hypertext, multimedia, and the display of small and reasonably simple documents. HTML is based on Standard Generalised Markup Language (SGML), an ISO8879 standard system for defining and using document formats. It is a non-proprietary format that uses tags (elements between the symbols < and >) to identify the different elements of the HTML page, as demonstrated in the following example:

```
<!doctype HTML public “-//W3C//DTD HTML 4.0 Transitional//EN”>
<HTML>
<HEAD>
        <TITLE>Example page</TITLE>
        <META name=”AUTHOR” content=”Luis Gouveia”>
</HEAD>
<BODY>
        <H1>Links to some resources</H1>
        <HR>
        For more information about the <B>Web</B>:
        <A HREF=”http://www.w3.org”> World Wide Web Consortium<A>
</BODY>
</HTML>
```

The first line is a Document Type Definition (DTD) and is what defines the source as HTML version 4.0, and give some details as the type of mode used in the code (it can be Strict, to use cascade style sheets; transitional, to not use cascade style sheets; and frameset, to use frames to partition the browser window).

Next to this first line, the HTML tags. First, the HTML that initiates and finishes the code (when a tag is repeated to close the first one, it has a slash before the its first character, /HTML. Inside the HTML, the page code is divided into two sections: the HEAD (which contain elements about the page and the name of it to be visualised in the window bar), and the BODY section, where the rest of the page code is placed. In the example, a heading and a link is made.

Between the tags, the elements to be visualised are placed. Inside the tags can be some elements, like the one in the A tag, that refers to a link to be used (HREF) by the value after the symbol =. Some tags do not have a finished equivalent tag, like the HR (horizontal rule). The corresponding image in the browser is shown in the figure 8 (note the information in the bottom of the window, indicating the URL of the selected link).

More examples of HTML pages using frames, images, tables, forms and other facilities are available at http://www.ufp.pt/staf/lmbg/. See the ITET paper for a detailed discussion of my personal homepage, at

Fernando Pessoa, including use, structure and motivation [93]. Other objects used in HTML pages are graphics. Their use helps turning the hypertext into hypermedia, allowing colour, image and visuals to be integrated in web design. More information about graphics, current state and related activity can be reached at http://www.w3.org/Graphics/Activity.

The current HTML version is 4.0 and includes support for style sheets, internationalisation, accessibility to Web pages for people with disabilities, frames, richer tables and forms. Information about HTML standards and history is available at http://www.w3.org/MarkUp/.

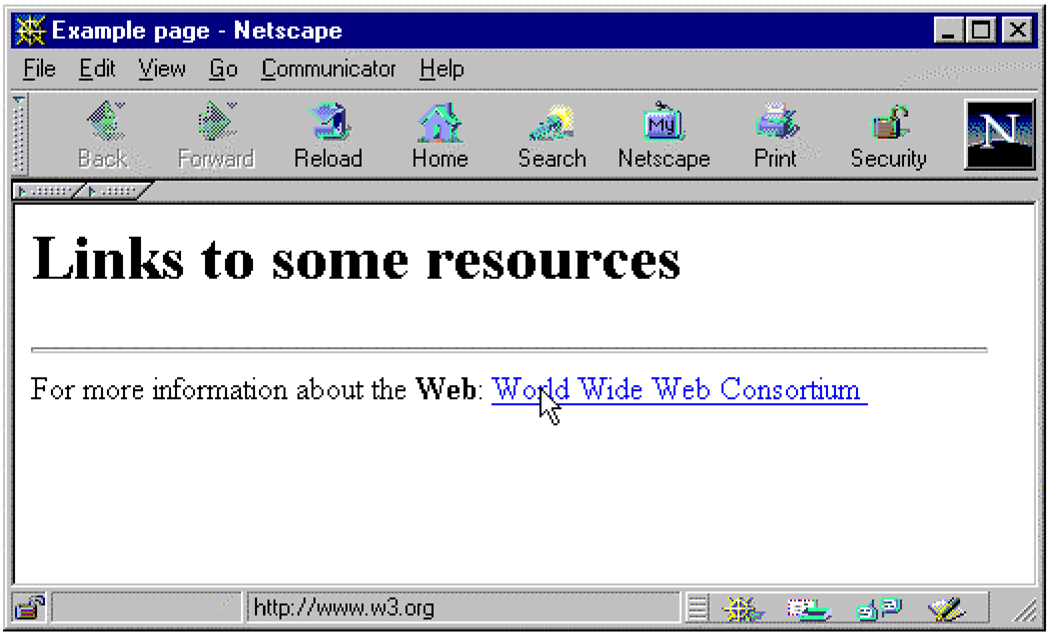


Figure 8: the rendering of the example HTML page

The HTML just implements part of functionality that has been associated with the concept of hypertext systems. Only the simplest form of linking is supported (unidirectional link to hardcoded locations). Other hypertext linking mechanisms are: location-independent naming; bi-directional links; links specified and/or managed outside documents where they apply; N-ary hyperlinks (like rings and multiple windows); aggregate links (multiple sources); transclusion (where the link target document appears to be part of the link source document); and attributes on links (links types). For a more complete discussion on hypertext see [53]. The author defines hypertext as "*an approach to information management in which data is stored in a network of nodes connected by links. Nodes can contain text, graphics, audio, video, as well as source code or other forms of data*" [53].

One of the claims about HTML is that it has been turned into a presentational language for Netscape and MSIE by the vendors and their users. This way some markup is presentational rather than semantic [54].

Cascade Style Sheets

Style sheets and cascading style sheets (CSS) separate structure and content from presentation. Applied to the Web and HTML, the use of CSS take off HTML, from all the presentation features. The following example illustrates this [51]:

In HTML

```
<H1 ALIGN=center><FONT COLOR=red>My heading</FONT></H1>
```

In HTML plus CSS

```
<H1>My heading</H1>
```

and attach a separate style sheet that contains all the elements to be used in H1 tags

```
H1{text-align: center; color: red}
```

This way, the presentation specifications pass to the style sheet that can be used with different HTML documents. CSS (the actual version is CSS2 - level 2 - http://www.w3.org/TR/REC-CSS2/) addresses presentation issues that can not be handled in HTML. The CSS provide simple means to style HTML pages, allowing the control of visual and aural characteristics.

A CSS tutorial can be obtained at http://www.stack.nl/htmlhelp/references/css/). A browser can apply several style sheets to a document as a cascade, allowing this way, to take into account an enterprise own style and an employer own style sheet, based on strict preferences rules, when conflict between these style sheets occurred. The CSS1 is supported in IE 4.0 and Navigator 4.0 browsers.

Extensible Markup Language

XML stands for Extensible Markup Language and is a simplified form of SGML, also used to define the syntax of markup languages like HTML. The XML metalanguage can define the formal syntax of a language, such as nesting rules for elements.

The World Wide Web Consortium (starting in the summer of ’96) has developed XML to address the requirements of more elaborated Web publishing and enable the further expansion of Web technology into domains of distributed document processing. The main goal is to propose a system that resolve the HTML problems with extensibility (HTML does not allow users to specify their own tags); structure (HTML does not support structures) and validation (HTML does not support the checking of structural validity on imported data).

As a simple example, the definition of a markup language with XML for a FAQ (adapted from [55]):

```
<?xml version= “1.0” encoding= “UTF-8” standalone= “yes”?>
<!DOCTYPE FAQ SYSTEM “FAQ.DTD”>
<FAQ>
   <INFO>
     <SUBJECT> XML                    </SUBJECT>
     <AUTHOR> Luis Gouveia *          </AUTHOR>
     <EMAIL>    lmbg@ufp.pt           </EMAIL>
     <VERSION> 1.0 *adapted                  </VERSION>
     <DATE>     20.set.98             </DATE>
   </INFO>
   <PART NO=”1”>
   <Q NO=”1”>
     <QTEXT>  What is XML?    </QTEXT>
     <A>      SGML light.     </A>
   </Q>
   <Q NO=”2”>
     <QTEXT>  What can I use it for?      </QTEXT>
     <A>      Anything        </A>
   </Q>
   </PART>
</FAQ>
```

In XML, the markup language shown above (that can be FAQML) had a DTD like this:

```
<!ELEMENT      FAQ          (INFO, PART+)>

<! ELEMENT     INFO         (SUBJECT, AUTHOR, EMAIL?, VERSION?, DATE?)>
<! ELEMENT     SUBJECT      (#PCDATA)>
<! ELEMENT     AUTHOR       (#PCDATA)>
```

```
<! ELEMENT    EMAIL        (#PCDATA)>
<! ELEMENT    VERSION      (#PCDATA)>
<! ELEMENT    DATE         (#PCDATA)>

<! ELEMENT    PART         (Q+)>
<! ELEMENT    Q            (QTEXT, A)>

<! ELEMENT    QTEXT        (#PCDATA)>
<! ELEMENT    A            (#PCDATA)>

<!ATTLIST     PART         NO      CDATA  #IMPLIED
                           TITLE   CDATA #IMPLIED>
<!ATTLIST     Q            NO      CDATA #IMPLIED>
```

The tag ELEMENT is used to define elements with the structure (element, name, contents); the name gives a label to the element, and contents describes which elements are allowed inside the element defined. A, B (like INFO, PART) means that you must have a part, followed by a B part. The use of the ? symbol after an element means it can be skipped; the use of the + symbol, means that it must be included one or more times, and the symbols *, mean it can be skipped or included one or more times. For ordinary plain text, use #PCDATA. The elements in XML which do not have any content (like IMG and BR of HTML) are written with a slash before the final > (<IMG SRC=”hello.gif”/>. This means that a program can read the document without knowing the DTD, that IMG does not have an end tag, and what comes after IMG is not inside the element. The <!ATTLIST> defines the attributes of an element. In the example, PART has two attributes: NO and TITLE with plain text that can be skipped. The element Q also has one more attribute called NO with plain text that can be skipped.

In [52], Bosak summarises the differences between XML and HTML as: (1) with XML, users can define new tag and attribute names; (2) document structures can be nested; and (3) any XML document can contain an optional description of its grammar for use by the application that needs to perform structural validation.

The XML language is not backward-compatible with existing HTML documents. However, documents conforming to the W3C HTML 3.2 (or later) specification can be converted to XML in the same way SGML documents and documents generated from database documents are [52].

Some people defend the use of CSS with XML as a replacement for HTML; a discussion of it is made in [51]. However the standard Document Style Semantics and Specification Language (DSSSL, ISO/IEC 10179) has also been used to create a DSSSL subset to be the XML stylesheet programming language - the Extensible Stylesheet Language (XSL).

An example (not complete) of a XSL to specify how the FAQ.DTD is to be displayed on screen:

```
<!doctype style-sheet PUBLIC “-//Author name// DTD DSSSL Style Sheet// EN”>
; --- DSSSL stylesheet for FAQML
; --- Constants
(define *font-size*          10pt)
(define *font*               “Arial”)
; --- Element styles
(element FAQ
        (make   simple-page-sequence
                font-family-name:           *font*
                font-size:                  *font-size*
                input-whitespace-treatment: ‘collapse
                line-spacing:               (* *font-size* 1.2)
                (process-children)))
(element INFO
        (make   paragraph
                quadding:                   ‘center
                space-after:                (* *font-size* 1.5)
                (process-children)))
```

```
(element SUBJECT
        (make   paragraph
                font-size:              (* *font-size* 2)
                line-spacing:           (* *font-size* 2)
                space-after:            (* *font-size* 2)
                (process-children)))
(element VERSION
        (make   paragraph
                (make   sequence
                        (literal “Version: “))
                (process-children)))
(element PART
        (make paragraph
                font-size:              (* *font-size* 1.5)
                line-spacing:           (* *font-size* 2)
        (make sequence
                (literal (attribute-string “NO” (current-node)))
                (literal “. “)
                (literal (attribute-string “TITLE” (current-node)))
                )
                (process-children)))
```

XML will provide the foundation for managing documents and information components of which the documents are composed. In XML, documents can be seen independently of files, where a document can comprise many files, and one file can contain many documents, enables, what Freter calls, the physical and logical structure distinction of information [54]. More information about XML is available at http://www.w3.org/XML/.

Document Object Model

Document Object Model (DOM) is an application program interface (API) under development, to be supported by XML and HTML browsers. This API will make possible to make JAVA applets (or Javascript snippets) that can change the display of XML encoded information in web browsers.

More information about the Document Object Model, is available in the World Wide Web Consortium site, at http://www.w3.org/TR/PR-DOM-Level-1/, where DOM Level 1 is released (version 1.0).

As an example of DOM potential we can think of VRML redefined in XML and with VRML viewers written as Java applets using DOM. This would mean that VRML could be used together with HTML with no need for extra software on the client side (apart from the applets that both install and remove themselves) [55].

Common Gateway Interface

Common Gateway Interface (CGI) is an agreement between HTTP servers implementators about how to integrate scripts or programs used as a gateway to a legacy information system (like a database or a document collection) [62]. The specification for the actual CGI version, (GCI/1.1) can be consulted at http://hoohoo.ncsa.uiuc.edu/cgi/interface.html. The CGI specification is maintained by the NCSA Software Development Group.

A plain HTML document is static, which means it exists in a constant state as a text file that does not have any change (unless someone, edits the file and makes changes). With a CGI program, it is possible to have dynamic information, because a CGI it is executed in real time, when requested by a user (it runs on the server side - remote), as shown in figure 9.

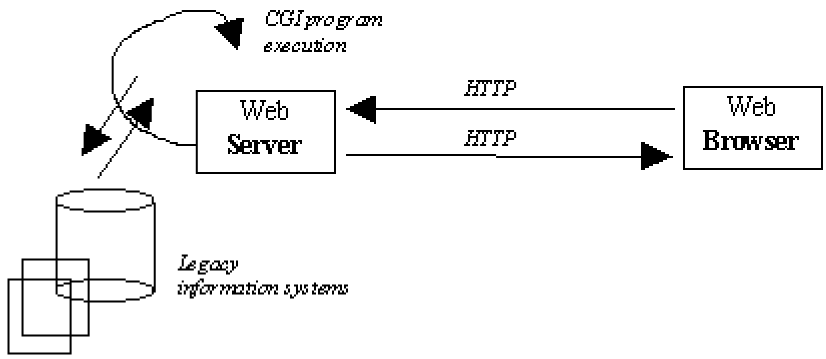


Figure 9: the CGI program is executed on the server side

To give access to a server file or a database to all Web users, we need a CGI program that the Web daemon executes to access a file or transmit information to the database engine, and receive the results back again and display them to the client - a particular interaction between web server and local resources, like the described above is an example of a gateway. To develop a CGI program it is possible to use a programming language like C++ or C or a scripting language like PERL or TCL. In the Appendix G, is given the C++ listing of the complete program of the example used.

The CGI is invoked as an URL resource in a HTML page, using the form tag and one of the available methods of the HTPP protocol. The following HTML code is an example of an workable form (the rendering of it is in figure 10). A form is an HTML element that allow users to input information, which then is used as part of postprocessing. The form is the equivalent of stdin or, alternatively, argc and arv[ ], in languages like C and C++. There are two methods to input data from an HTML form into a CGI program: GET and POST. The two methods are similar to the use of argc and arv[ ] in the GET case, and the use of stdin such as getchar( ) or gets( ) is similar to the POST case. An example of HTML code for use with forms is given below (see figure 10 for the page displayed by the browser).

```
<html>
<head>
     <title>Formulario tres</title>
</head>
<body>
   <h1>Asking for support</h1><hr>
   <FORM ACTION=http://paula/scripts/lmbg/seven.exe METHOD=post>
      <p><strong>Send mail to:</strong>
      <SELECT name="mailto_name">
         <option selected> technical support
         <option> field support
         <option> product support
         <option> engineering
      </SELECT>
      <p><strong> enter your email address:</strong><p>
      <INPUT type="text" name="your_email" value="" size=60>
      <p><strong> enter message:</strong><p>
      <TEXTAREA cols=50 rows=6 name="message" value="">
      </TEXTAREA><p>
      <INPUT type="submit" value="mail message">
      <INPUT type="reset">
   </FORM>
</body>
</html>
```

In this example, in the FORM tag, the action value is an URL of an CGI, located at http://paula/scripts/lmbg/seven.exe, that the server will execute in real-time. The normal way to complete a form from an HTML Web page is to submit a form. This is a button option placed in the form (identified by the line <INPUT type="submit" value="mail message">, in the example). The

information of the form is passed the method specified (in this case POST, which means that the information is passed to the CGI program as stdin).
The information from the form is encoded in the standard URL format of changing spaces to +, and encoding special characters with %xx hexadecimal encoding (Appendix G lists a program in C++ that decodes URL format lines). Figure 11 shows the information received in the stdin, first decoded, giving the variables values and, at the bottom, displaying the original URL line.

The HTML page resulting from the CGI with the data from the forms is visualised in figure 11. It is the result of the formatted output to the HTTP server by the C++ program on Appendix G. A CGI can return many document types like an HTML document, a plaintext document, an image, or an audio clip. This way, the CGI program needs to place a short header in his output. This header is ASCII text, consisting of lines separated by linefeeds (it can be also carriage returns), followed by a single blank line. The output body then follows in whatever native format.

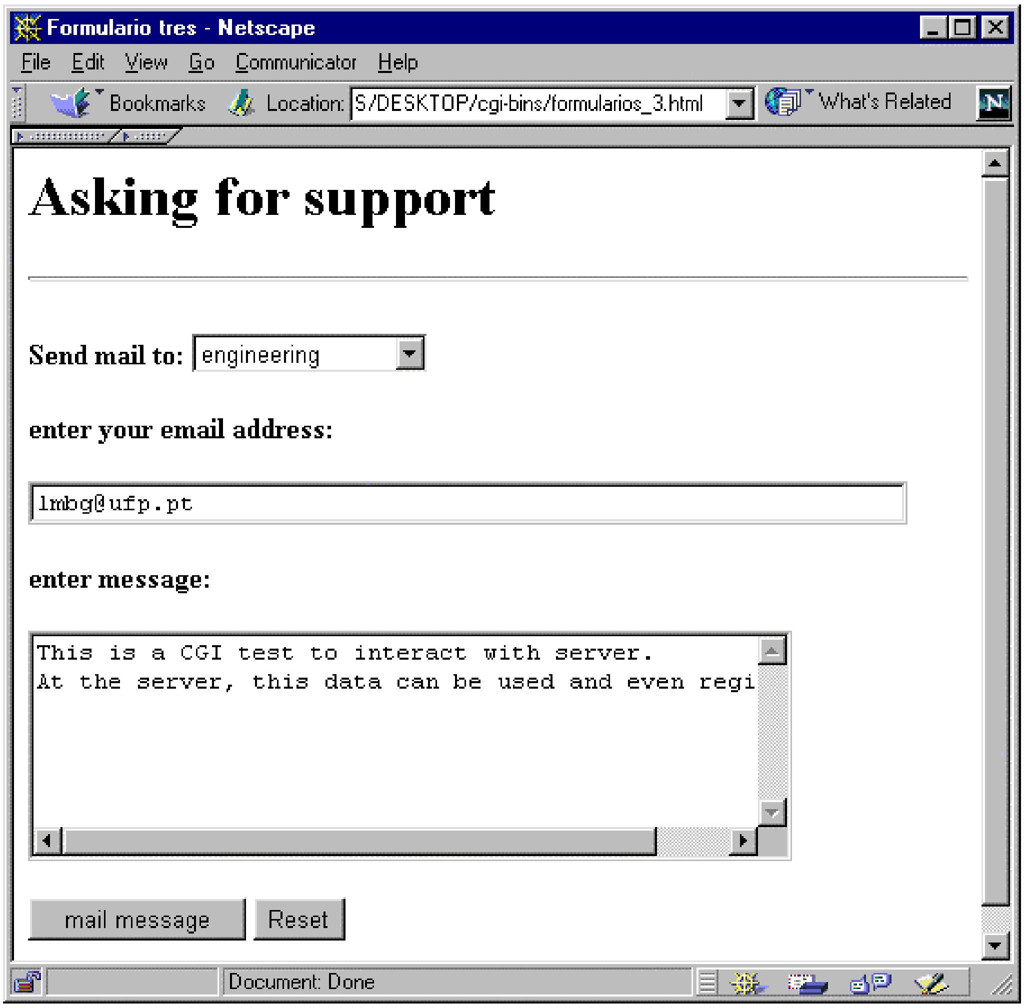


Figure 10: the rendering of the input HTML page that use the example CGI

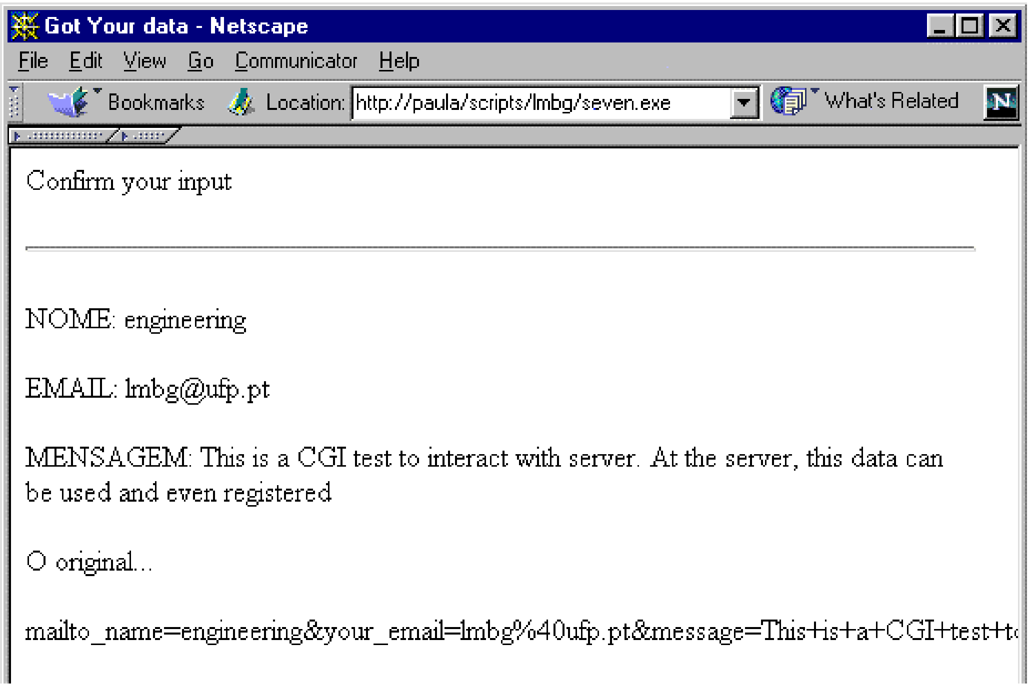


Figure 11: the rendering of the output HTML page that use the example CGI

The outpu from a CGI program can be a full document with a corresponding MIME type like text/html, for HTML; text/plain, for ASCII text; text/pdf, for Adobe pdf format (http://www.adobe.com); image/gif, for images in the gif format. An alternative to a full document it is possible to use a reference to another document, using a second line that starts with the word location followed by the URL to which the reference is intended to, with the following sequence: (Content type: text/html - new line - Location: http://www.ufp.pt/staf/lmbg/ - empty line).

The Java Language

Java is a portable programming language, object-oriented, that can interoperate on any computer which includes a Web browser that understands and decodes Java Applets. It can also be used to develop applications for traditional environments. With Java we can develop small size programs (called Applets) that are executed in the client side (local). The Applet must be downloaded from the server with a browser that understands Java. The Java language can also be used to develop normal application code.

Figure 12: the Applet is executed in the client side

To be compatible with all sorts of web clients, the Applet is compiled in a special binary code that can be understand by all the machines - bytecode. This bytecode is compiled to be run into a virtual machine - the Java Virtual Machine. An implementation of the Java Virtual Machine for a specific platform permits the execution of the Java bytecode in this machine. An overview of the Java language environment is given by Gosling (one of his creators) in [61]. Some security issues related to the use of Java are also discussed (chapter 6) of [61].

To support the development of Applets, Sun offer the Java Development Kit, (the JDK is actually in version 1.1.6, for Windows platforms) that can be downloaded as a freeware working environment at http:java.sun.com/products/jdk/1.1/download-jdk-windows.html. This environment contains several utilities along with the Java compiler (javac) and a debug applet viewer (appletviewer). The available product and APIs for the Java Development Kit (v 1.1.6) are available for download at http://java.sun.com/products/index.html.

As a Java Applet example we can consider the following program:

```
import java.awt.Graphics;
public class palavras extends java.applet.Applet {
   String n, txtj;
   int c, num;
   public void init( ) {
     txtj=getParameter("texto");
     n=getParameter("numero");
     num=Integer.parseInt(n);
   }
   public void paint(Graphics g){
     g.drawString("First parameter: " + txtj, 10, 75 );
     g.drawString("Second parameter: " + n, 10, 100);
     for (c=1; c<=num; c++) {
          g.drawString("turn: " + c + "->" + txtj, 10, 100 + c*25);
     }
   }
}
```

This program receives two parameters from the HTML page that calls him, and perform a report of the value of the two parameters and makes a loop print of the first parameter the number of times given by the second parameter. The rendering image is shown in figure 13.

The HTML code, with the APPLET tag, used with the above program is:

```
<HTML>
<HEAD>
<TITLE>Values passed to the Applet</TITLE>
</HEAD>
<BODY>
<H1>Test of parameters for an Applet</H1>
Give the text (Work) and the replication number (3) as parameters...
<HR>
<APPLET CODE="palavras.class" WIDTH=300 HEIGHT=300>
<PARAM NAME="texto" VALUE="work">
<PARAM NAME="numero" VALUE=3>
</APPLET>
</BODY>
</HTML>
```

The Java Platform Documentation can be used as a primary source for information about JDK, at http://java.sun.com/docs/index.html. A general overview of the Java language is given by [59]. Yourdon discusses the impact of Java language and the emergent of a new type of software development in [60].

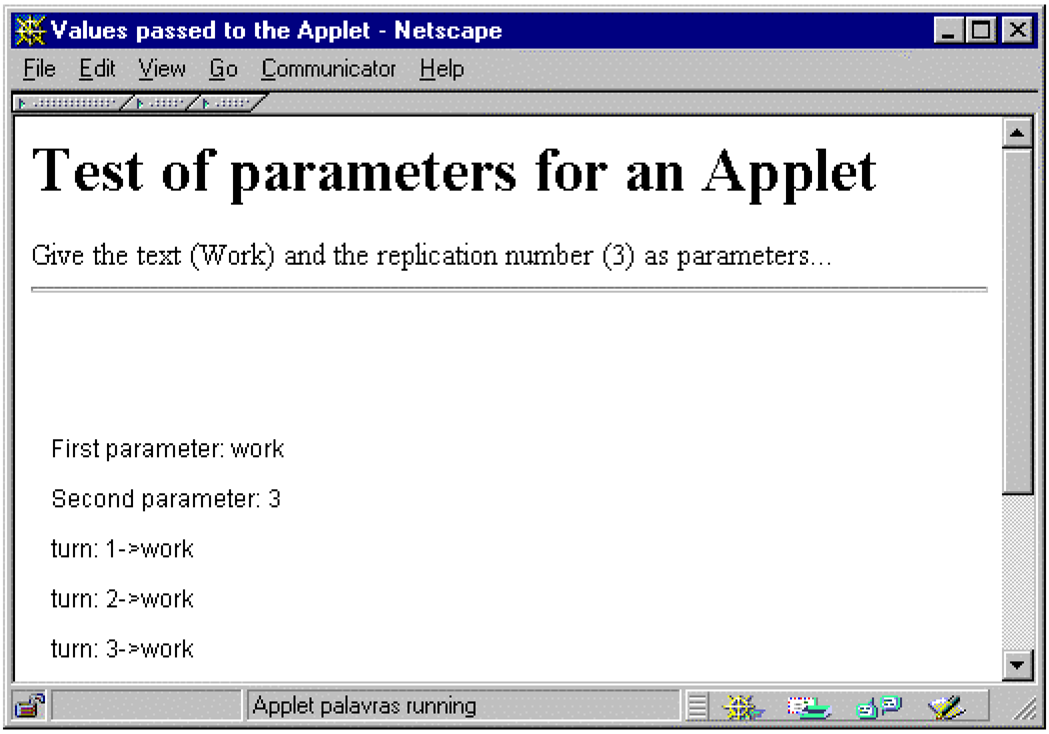


Figure 13: the rendering of the example Java Applet

Virtual Reality Modelling Language

The Virtual Reality Modelling Language (VRML) is the standard file format for 3D multimedia and shared virtual worlds on the Internet. As stated by the VRML Consortium (the discussion forum that manages the VRML standard, http://www.vrml.org) "*just HTML let to a population explosion on the Internet by implementing a graphical interface, VRML adds the next level of interaction, structured graphics, and extra dimensions (z and time) to the online experience. The applications of VRML are (…) educational applications, and of course to 3D shared virtual worlds and communities*".

The VRML Consortium adds that VRML "*blends the intuitive human sense of space and time with user interface interaction and programming language (…)*", and comments the evolution of the Web as a movement from command line to 2D graphical, and from that, to emergent 3D interfaces, defining that last stage as a more immersive and responsive computer-mediated experience".

VRML is an International Standard (the ISO/IEC 14772-1:1997). VRML97 (the standard name) functional specification can be accessed at http://www.vrml.org/Specifications/VRML97/index.html.

As a curiosity we could say that the ISO international standard VRML97 established a record as the first specification to be standardised within 18 months. The history and evolution of VRML is described at http://www.vrml.org/about/historyofvrml.html.

VRML enables platform-independent interactive three-dimensional graphics across the Internet, and can be used to compose sophisticated 3D virtual environments. The standard includes the rules for incorporating Java inside a VRML scene which open the potential to implementing virtual worlds on both high-cost and low-cost hardware in a portable way and permit the visualisation and sharing of a world on any computer with a network connection and a web browser.

The VRML language allows the description and specification of an 3D space that can and viewed in browsers with appropriate plug-ins. The browser acts as an ASCII file interpreter of VRML scenes that is capable of scene rendering from the user point of view perspective, equivalent to the textual description of the scene. The VRML ASCII file format was designed to be platform independent, extensible and sufficiently compact to work well over low-bandwidth connections.

VRML allows the development of virtual worlds using a format that can be considered as a graphic extension of languages like C++ and Java, with an object oriented approach.

A VRML file is composed by of number of elements called nodes (descriptions of discrete scene elements) that represent geometry, light, grouping as well as event routing statements to create behaviours and interaction, within 3D space.

Each object node has common properties such as type name, default field values, and the capabilities to send and receive messages (events in VRML) that set field values. When a derived class is instantiated, it is possible to override the default values; a benefit of VRML is that when you instantiate a node, you generally obtain a visually tangible result [63].

VRML offers many predefined nodes, such as a library of objects from which your scene elements may inherit characteristics, and also enables you to derive and use your own nodes by prototyping. VRML has the ability to reference standard web HTML documents from within scenes (as demonstrated in the VRML scene in figure 14).

An example of a VRML file is given in the following listing. This listing is the complete description of the scene represented in the figure 14. The browser VRML plug-in used is the Community Place, from Sony (http://vs.sony.co.jp).

```
#VRML 2.0 utf8
#cena.wrl - complete listing
DEF TRUNK Transform {      #graph father node
    translation 0.0 1.0 0.0       #all the son nodes are shifted one meter in Y
    rotation 0.0 1.0 0.0 0.39    #all the son nodes suffer a rotation of 22.5 degrees around Y
    children [
      DEF BOLA Transform {     #son of the node TRUNK Transform
          translation 3.0 0.0 0.0   #the sphere is moved three units in X
          children [
             Shape {
               appearance Appearance {
                  material Material {
                    emissiveColor 0 0 1
                  }
               }
               geometry Sphere {
                  radius 1
               }
             }
          ]
      }
      DEF CUBO Anchor {
          url [ "http://www.ufp.pt/staf/lmbg/" ]
          children [
            Shape {
              geometry Box {
                   size 1 2 2
              }
            }
          ]
      }
]
}
```

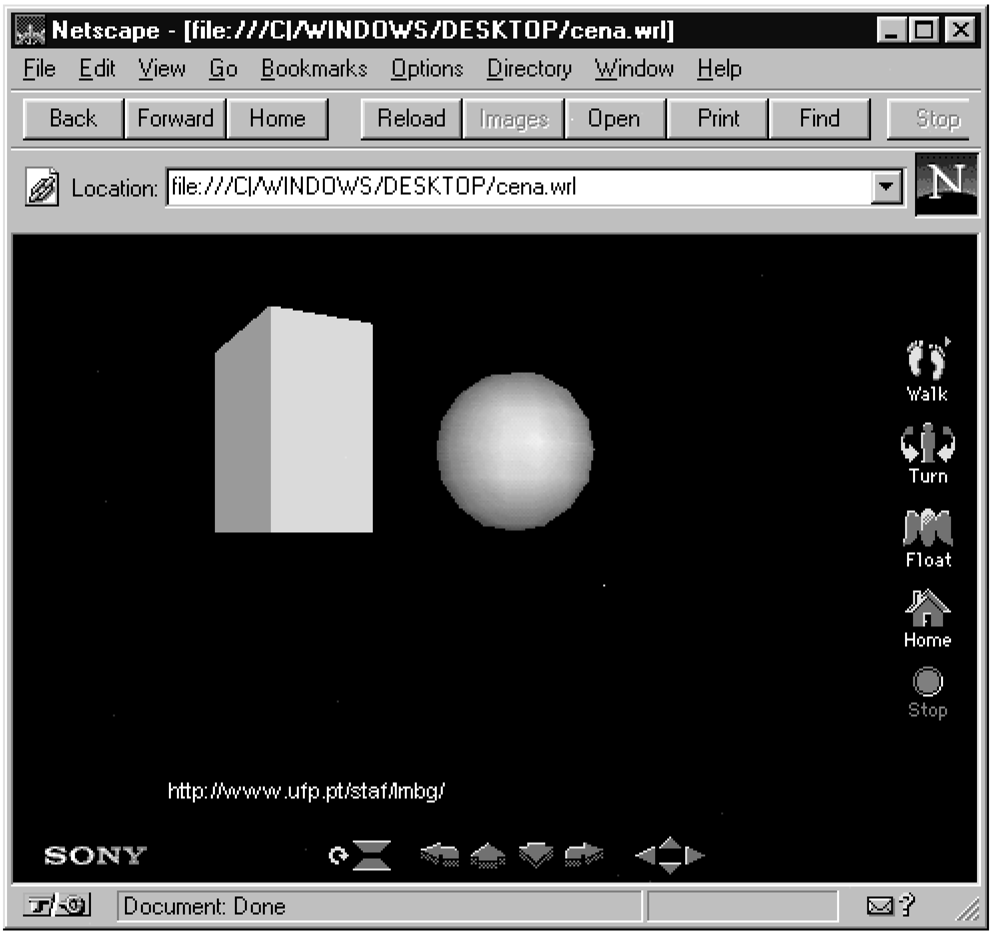


Figure 14: the rendering of the VRML scene using the Sony Plug-in

Two working groups in the VRML Consortium are of special interest for the present work: The Living-Worlds group (http://www.vrml.org/WorkingGroups/living-worlds/), and the DIS-Java-VRML working group (http://www.stl.nps.navy.mil/dis-java-vrml).

The goal of Living Worlds Working Group is to define a set of VRML 2.0 (named VRML97, after it became an ISO standard) conventions that support applications which are both interpersonal and interoperable. The interpersonal means support the virtual presence of many people in a scene at the same time, where people interact both with other people and with the object within the scene. The interoperable means that the created applications can be assembled from libraries of components developed independently by multiple suppliers and used by client system that conform with the VRML standard. The group intends to define a conceptual framework and specify a set of interfaces to support the creation and evolution of multi-user, multi-developer applications in VRML.

Draft 1.0 (feb. 97) of Living Works, include interfaces for co-ordinating the position and state of shared objects in a scene; information exchange between objects in a scene; personal and system security in VRML applications; a library of utilities to overcome VRML limitations; and identifying and integrating at run-time interaction capabilities implemented outside of VRML and its scripts.

The DIS-Java-VRML Working Group is developing a free software library, written in Java and interoperable with both DIS and VRML. The Distributed Interactive Simulation (DIS) Protocol is used to communicate state information (such as position, orientation, velocities and accelerations) among multiple entities participating in a shared network environment.

The group proposes the implementation of large-scale virtual environments (so called LSVEs) using DIS, Java, and VRML, using these three technologies in a collaborative way. DIS is essentially a behaviour protocol tuned for physics-based many-to-many interactions. Java is the programming language used to implement DIS protocol, perform math calculations, communicate with the network and communicate with the VRML scene. VRML 3D graphics are used to model and render both local and remote entities in shared virtual worlds.

World Wide Web issues

The World Wide Web is a major information base and it can be considered as a digital library. However, this huge hypermedia repository seems unreliable (with many misses: document not found), information lacks context (Where am I? Can I trust this information?), and there is also navigation problems (Where should I go next?). The Web is vast, growing rapidly, and filled with transient information. Estimated in 1996 figures, at 50 million pages with the average page online for only 75 days [41], the turnover is considerable, and the number of pages is reporting to double every year. In 1996 figures, there where about 400,000 Web sites with an estimate total data of 1,500 GB and a change rate of 600 GB per month [41]. Some efforts are made to introduce semantics into Web pages that can be used to help retrieve the information - metadata - one example are the initiatives in the education field [125].

The Web is referred as a "*linking medium*" by Nielsen [44]. For Berners-Lee, states that the original main problem that motivate his work with the Web, was support better ways for helping groups of people work together [45]. Berners-Lee adds that its vision for the web is "*less of a television channel and more of an interactive sea of shared knowledge*" [45].

Many of the issues about information visualisation addressed by the present study stay not resolved in day-to-day use of this service. The web is also an ideal environment to test some of the research ideas due to its minimal investment cost, technology availability, opportunity to use real users and data availability settings. This is also complemented with well documented protocols and reliable technology to be used to support development.

In a 1996 presentation, Berners-Lee list the needs for Web development as: share knowledge - with semantics; notification of change built into web; structuring aids; better access control - trust web; integration with audio and video and whiteboard; enabling group editors and distributed simulation environments with object manipulation capabilities [42].

Web services have become more accessible, allowing users to easily publish their own information on the Web. This way, as technology is better integrated into the classroom and educational settings, Web is being used more as an instructional tool [43].

One aspect to be considered is the Web design, where some interfaces issues be considered and adapted for this medium. In [44] some considerations are on the use of narrative structures. In [46] a list of top ten mistakes in Web design is proposed. Some specialised campanies propose a general issues list for Web design as the one's in [47] - "*Hints for a Successful Web Site*"; [48] - "*How to Build a Better Web Site*"; and [49] - "*Planning and Vision are Keys to Internet Success*". Some authors also propose methodologies for Web development like the one by December [50].

Kerckhove proposes that the Internet is not a medium. He adds that "*it is not a one-way medium. It is not even a two-way medium. It's a «my-way» medium. When everything and everybody is on-line, everybody has a word to say about what's worthy to read, hear, see, watch and do on-line. That means that the user, not the producer of information is in the driver's seat*" [124]. In the same paper, Kerckove makes some consideraction on the impact and future of communication formats.

4.2 CVE systems as the intersection of CSCW and VR

A CVE system brings some of the work done in the last years about groups and co-operative settings, together with the promising potential of 3D representation and interaction use, merging the results obtained by the research in the CSCW area and virtual reality technology.

Collaborative Virtual Environments

A global concept and one that is used frequently is cyberspace. The term itself was coined by Gibson, in 1984 [64], as a name for a virtual environment, in a science fiction book. Besides its origin, it lead to a concept that had significant influence on both theorists and designers of virtual reality systems [65]. According to [66], cyberspace is a "*post-industrial work environment predicated on a new hardwired* *communications interface that provides a direct and total sensorial access to a parallel world of potential work spaces*".

A more useful definition for our purposes is done by Benedikt, in 1991 [67] where he states: "*Cyberspace is a globally networked, computer-sustained, computer accessed and computer-generated, multidimensional Artificial, or "virtual" reality. In this reality, to which every computer is a window, seen or heard objects are neither physical nor, necessarily, representations of physical objects but are rather, in form, character and action, made up of data, of pure information*".

This last cyberspace characterisation lead us to design a potential project that takes advantage of the environment at Fernando Pessoa (characterised in [68]), and actual inexpensive information technologies to propose a service that could evolve as described by Benedikt. This potential project has a focus on representation of information and knowledge as virtual objects that can be manipulated by users. Laurel proposes a useful definition for the use of the adjective virtual as "*describe things (worlds, phenomena, etc.) that look and feel like reality but that lack the traditional physical substance. A virtual object may be one that has no real-world equivalent, but the persuasiveness of its representation allows us to respond to it as if it were real*" [14].

The research area related with Collaborative Virtual Environments (CVEs) gives the opportunity to implement and assess the validity of the described concepts in terms of today technology and their evolving applications. A CVE system is defined by Benford [69] as a "cyberspace meeting point" which allows several people to interact through their computers in order to obtain a common goal.

A CVE involves the use of distributed virtual reality technology to support group work. In [9], two conditions are presented in order to a system be considered a CVE: the provision of simultaneous multi-user access to a virtual reality system and explicitly consider and support the needs of users who wish to work together.

One important aspect in this kind of systems is the existence of a virtual space that [71] defined as an immaterial world which allows distance interaction to several users via a set of networked computers. He also states that the interaction can be accomplished from an exchange of written ideas up to a 3D space with the possibility of movement and voice exchange. In more open definitions, systems like the Multi-User Dungeons (MUDs) systems and Internet Relay Chat (IRC) are included. Both MUD and IRC systems are discussed as well as their social implications in [72].

However both perspectives share the point that each user needs to be aware of other users. In fact, in [9], Benford states the essence of CVEs as that users are explicit represented to each other within a shared space. For [74], a CVE can be stated as shared spaces existing within the machine, who are inhabited by users who have their representation in the space and that is already realised in a number of stable technologies (like the MUDs and MOOs, for 2D and Distributed VR environments, for 3D).

In [73] are given three main reasons to develop CVEs. First, the support for natural spatial social skills which offer a more natural way to human interaction; second, the inherent scaleability, to address the interaction of a large number of users. Third, applicability to co-operative spatial tasks, where current VR-applications offer design support that can be extended to support collaboration.

A short introduction to CVEs is available at http://www.crg.cs.nott.ac.uk/~sdb/CVEs.html. Several working in progress web pages about CVE methods for usability evaluation and design issues are available at http://www.crg.nott.ac.uk/research/technologies/evaluation/. A description of CVE's types and issues of collaborative work in virtual environments are presented by Jaa-Aro at http://www.nada.kth.se/~kai/lectures/CWVE.html.

In [98], a discussion of user embodiment is made. It states that user embodiment means the provision of users with appropriate body images so as to represent them to others and also to themselves. In [99], the Shared Space concept is discussed, where some form of overlaying the real-world and computer generated world in a setting that augmented reality to include open shared workspace paradigms. In [100], the same authors describe two pilot studies which imply that wearables may be able to support tri-dimentional collaboration and that users perform better with these interfaces than immersive collaborative environments. Smith proposes that CVE's can extend the WYSIWIS abstraction by the use of shared interfaces, presenting a model to manage the use of subjective views in CVEs [104].

Tennison and Churchill report their study of the impact and usage of Virtual Environments for semantic structuring of the information space and as means for collaboration between users of information systems [101]. They conclude as preliminary results that virtual environments can be used to present a metaphorical instantiation of an information resource and, also, that information retrieval is facilitated by the use of virtual environments. In an experiment with 2D and 3D visualisation settings for network information, the results stated that three times as much information can be perceived in the head coupled stereo view as in the 2D view [105].

Other issues to be considered are Populated Information Terrains (PITs), awareness and the spatial model of interaction, scooping presence and network saleability, and space, place and mixed realities; these all covered in the Collaborative Virtual Environments tutorial [9].

Computer Supported Cooperative Work

One important contribution area to the development of a CVE is Computer Supported Cooperative Work (CSCW). As stated by Greif [75], CSCW has emerged as an identifiable research field focused on the role of the computer in group work. One of the primary CSCW characteristics pointed out in [76] has been its interdisciplinary as a research field, involving people from both computer and human sciences. A CSCW system must provide means to give answers for questions like how groups of people can collaborate using computers? How can people plan to work together using the computer as a medium? How group work must be redefined to take advantage of computers? For [75], the focus on helping people work together is the unifying theme of CSCW.

Agostini and De Michelis [76] propose general requirements that new CSCW systems should meet as completely as possible: openness, multimedia continuity, contextualisation and integration of communication and action added to personalised and selective workspaces interfaces.

Also Wexelblat [8] defends two principles of CSCW, namely, the co-operation is not a separable activity, meaning that some computer support to be used must fit into the normal users work pattern. The second principle is that CSCW applications must allow people to cooperate by overcoming barriers of space and time that are imposed on people. This leads to a time-space functionality discussion.

One important factor in CSCW applications is the degree of collaboration aware, that Wexelblat [8], defines as the degree to which knowledge of, and support for, the co-operative activity has been designed specifically into the application. Wexelblat was also among the first to propose virtual technology as an enabling technology for CSCW [8].

CSCW as a study area, can be considering as a sub-topic within the broader field of Information Systems [78]. With the use of Computer Supported Computer Work systems one can expect to extend the study of learning environments to work environments.

In the keynote address to the Fifth ECSCW conference (1997), at Lancaster, Checkland states that a CSCW system implies four items: a group of people; their would-be co-operative activity: an organisational context of some kind and technology supporting the group activity [78].

A core rationale for CSCW is proposed by [78] and visualised in figure 15 where when information technology (IT) is in an enabling role its possible to envisage new forms of purposeful action (both individual and group action) which would not otherwise be possible. We must note that information systems process relevant data in order to support or help people undertake purposeful action and IT enables such support to be realised.

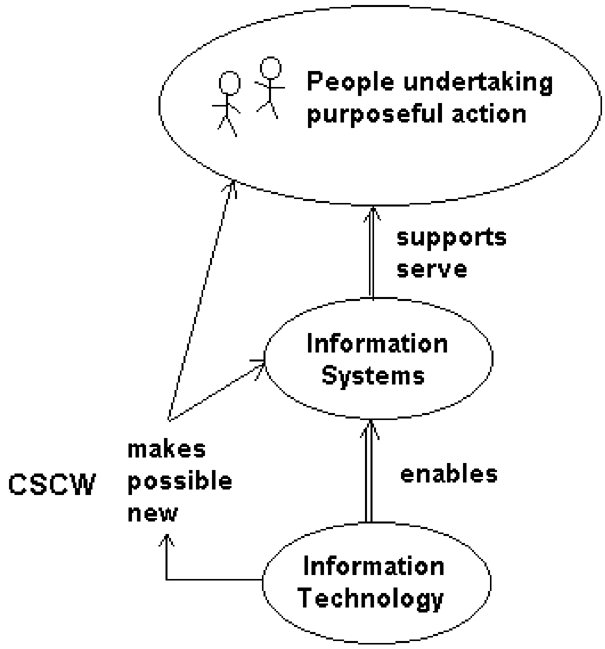


Figure 15: a proposed rationale for CSCW [78]

The Marmolin and Sundblad paper introduces the Collaborative Desktop where a number of tools designed for supporting collaboration are presented make use of direct manipulative human-computer interfaces [139]. The proposed tools are a team map (visual overview of members activities), a telephone exchange (for establishing connection between members), an answering machine (similar to real world answering machines), a whiteboard (for exchange and drawing of graphic messages), and a tool for asynchronous and synchronous collaboration on writing documents [139]. The author demonstrated how a collaborative environment can be designed and implemented based on three principles: a tool approach, a room metaphor and an electronic hallway metaphor (also described in the paper) [139]. The paper also describes a model, named TheKnowledgeNet, with four layers, as a CSCW environment for distributed design. The model base layer is the Knowledge Base, the second layer, the basic communication services, the third layer, the CSCW tools, and the last layer, the task, as a pre-defined combination of tools [139].

An excellent reference to CSCW is the tutorial notes from ECSCW'97 tutorial 1 by Grudin and Poltrack [113]. In Web there are some resources that give more updated information on CSCW issues, like a survey report of CSCW (at http://arirang.snu.ac.kr/~leeko/CSCW/Survey/survey.html), CSEG bibliographies for CSCW (at http://www.comp.lancs.ac.uk/computing/research/cseg/bib/cscw.html).

There are also two global directories available in the Web: the ACM SIGGROUP, a special interest group, from ACM, with interest in topics related to computer-based systems that have a team or group impact in workplace settings (at http://www.acm.org/siggroup/text.html); and the Usability First Web site, where we can find more information on CSCW and Groupware issues (at http://www.usability.com/groupware).

The paper [115] gives an overview of the more important issues in the CSCW area, presenting an interview with Dourish, Greenberg, Grudin and Rogers. An early discussion of requirements for a CSCW platform is made by Schmidt and Rodden [117]. CSCW systems can also be extending to deal with coordination issues like the ones reported in the Maurer paper that summarises the results from WET ICE 96 [118].

Some applications can be usefull for the present study; in [116], Twidale, Rodden and Sommerville present the Designers' NotePad (DNP) as a supporting tool for collaborative dialogues and report the influence of the interface on usabillity and efectiveness of the system that use short text fragments positioned two dimensionally and supported by graphical notations such as links, shapes and colour use.

To help design CSCW systems that offer a better support of co-operative activities, the developers can use wokplace studies [121], in particular ethnography that gives a path to gather information from field studies of co-operative work and organisational analysis [119]. The Project Report for CSCW Symposium gives a framework of methods for the design of CSCW system [120].

In [122], Araujo et al. proposes a summary of approaches to cooperative software development support grouping them into four different aspects: group memory; awareness; communication; and coordination.

Greenberg makes some considerations about real time distributed collaboration, defining terms as telepresence and teledata, and presents a concept map groupware application. It also refers to some important issues to be consideed into this kind of systems [123].

Virtual reality

Virtual reality (VR) is one of the enabling technologies for CVE systems. Chorafas [79] treats VR as a new generation of solutions that address multimedia, direct end-user interaction, the ability to visualise one's ideas, and user-activated visual programming processes.

There are several introduction papers on virtual reality available in the Web, most of them describe VR technology as a mix of hardware devices and software techniques. A short introduction [4], from 1996, is made by Beir from the VR Laboraty, University of Michigan. Other introduction paper is Wells's paper at http://www.cs.uidaho.edu/lal/cyberspace/VR/docs/vr.primer. The Kazan site has also a section about VR, at http://pcvr.kazan.co.kr/about_vr.html. The Information Market Observatory (IMO) also have one introduction paper about VR and its applications [95]. A description of VR interfaces is available at http://www2.msstate.edu/~cms2/hcifinal.html. One more VR introduction, although old, is the classic 1993 paper from Isdale [96].

Chorafas proposed that VR bring change in three levels: at the strategic level, with the emergence of the virtual organisations [79]; at the implementation level, the change will be in the way we work (the virtual office); at the tactical level, interactive 3D graphics play an important role along with artificial intelligent artefacts and object orientation.

McGreevy sees VR as "*a display and control technology that can envelop a person in an interactive computer-generated or computer-mediated virtual environment*" [80]. The same author proposes VR as a technology that "*creates artificial world of sensory experience, or immerses the user in representations of real spatial environments that might otherwise be inaccessible by virtue of distance, scale, time, or physical incompatibilities of the user and the environment*".

Cadoz presents the idea that the humans interact with real-world through the use of machines. This way the computer (as a machine) represents a reality medium and it is through it that humans interact with reality. In this perspective, the user has just an invoked environment (and not reality), with which interacts directly. A resulting interaction with the real-world is accomplish via computer interaction [94]. This perspective is represented in a schema in figure 16.

Chorafas [79] sees the essence of virtual reality as a multimedia environment within the user's reach. Harrison proposes VR [4] as "*the delivery to a human of the most convincing illusion possible that they are in another reality, where this reality exists in digital electronic form in the memory of a computer*".

VR can be seen as an enabling technology in the sense that it can bring new metaphors for interaction between human and machines. A metaphor (for information technology) is used to create things that people and machines can understand. As [79] refers, VR "*is a metaphor of the real world*". Spatial information analysis and handling requires the use of three cognitive spaces: haptic, pictorial and transperceptual; in [106] a VE is proposed as an add-on to enhances user ability to explore and visualise data in a geographical information systems (GIS).

Among the potential applications for VR are education (Harasim, [81]) and information visualisation (Chorafas, [79], and Fairchild, [6]). Harasim, report also the importance of simulation, as used by the US Army, as the biggest applications already developed, for education [81].

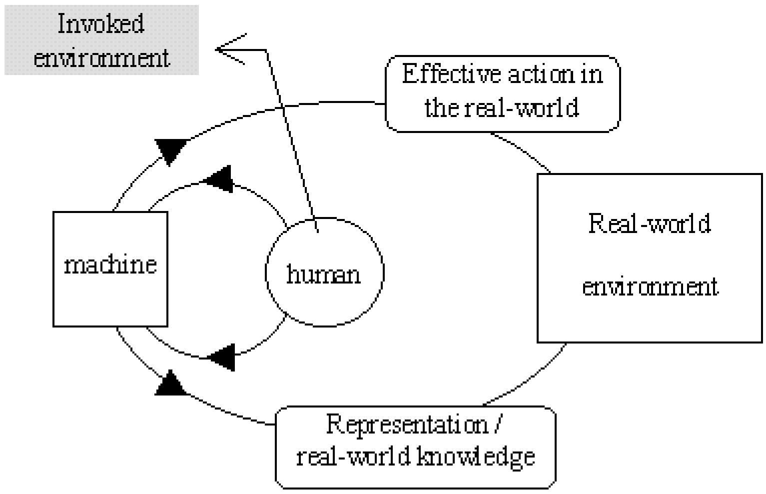


Figure 16: the human and the real-world through a machine [94]

In [138] the TelePresence from the MultiG project is defined as distributed virtual reality. In this paper, Fahlén states that "*TelePresence is about visualisation, interaction and distribution. The visualisation is done in a simulated 3D-world where the interactive manipulation is done by the use of interface units that have more degree of freedom than conventional keyboard and mouse in a practical way can supply*". The author comments about the MultiG TelePresence system that "*certain objects and processes have an obvious visual representation. But how should we visualise abstract things that have no «natural» visual appearance? (…) There is a great potential for combinations of this new technology and conventional data processing*" [138].

In [97], a virtual environment (VE) is defined as a setting where the user has a sense of presence in, and is able to navigate around, a computer generated three dimensional environment, and can interact with that environment in real-time. It may also be defined as the most advanced, intuitive, and user transparent man/machine interface. In this 1993 report, other names for VEs are proposed as VR, Virtual Worlds, Cyberspace and Artificial Reality [97].

Computer Supported Collaborative Learning

One of the dimensions that must be preserved in the context of open and distance learning (ODL) and also in general education and learning is the interaction between students as an essential learning requirement [82]. Some technologies prove to have potential dealing with co-operation requirements and interaction demands, like the more oriented to education, Computer Supported Collaborative Learning (CSCL), and the more general purpose CSCW systems, already discussed.

Co-operation is defined by Argyle [83] as "*acting together, in a co-ordinated way at work, or in social relationships, in the pursuit of shared goals, the enjoyment of the joint activity, or simply furthering the relationship*". McConnell [84] refers that co-operation "*is seen as central to our everyday lives* and *co-operative learning is process driven*". In the definition of the group, [84] states that a human group is a collection of individuals, who have interdependent relations, and who perceive themselves as a group that is recognised by non members. Finally, group members have interdependent relations with other groups and whose roles in the group are functions of expectations (internal and external). Ramage presents a more complete discussion the nature of co-operation and cooperative systems [114].

McConnell concludes its reasoning saying that people working co-operatively in CSCL environments do work in groups and that these groups work in complex ways [84]. In open learning situations where there are many different simultaneous influences on the group including distributed systems and the use of virtual technologies to augment the group environment it is possible to add some influences from beyond the social structure of the group itself [8].

Co-operative (or collaborative, as it is also called) work produces information products like decisions, designs, analysis, minimises information loss, and operates at finer levels of detail [85]. However, Dillenbourg make a clear distinction between co-operation and collaboration. Co-operation is the work division between participants with which one be responsible by a part of it. Collaboration is based in an agreement between participants to resolve one problem in a unified and co-ordinated way.

What are the outcomes of co-operative learning? In their work, Slavin [86], states that co-operative learning increases the positive effect of classrooms, and that students working co-operatively become more co-operative; they learn pro-social behaviours such as how to get with others, how to listen and so on.

In addition to the individualistic and competitive learning goal structures, the co-operative one can be relevant to education, learning and training, justifying the introduction of ICT that supports it. This way, to enhance a CVE system, some CSCL principles can be adapted to take advantage of the referred outcomes.

Internet and ICT based ODL are rapidly gaining popularity and importance as means of providing lifelong learning (LLL) [70]. Use of new technologies like CSCW and VR can enhance collaboration, foster knowledge representation and developed systems that provided vicarious experience.

It also provides means to augment teaching and learning skills of all the users involved, creating new forms of interaction, dynamic information representation and relations with the learning community in multiple time/space alternatives. Shneiderman and others discuss the emergent patterns of teaching/learning in electronic classrooms, based on their own experience [108]. Other example is the use of Web and network as a support for assessment in a collaborative format [110].

Komers discuss the impact of using telematics for collaborative learning and relates it to more ideological changes in educational settings, like situated learning; distributed knowledge and constructivism [109]. Psycho-pedagogical studies in the educational field have shown that students can better learn by managing, manipulating and organising the information on their own [77] (we can expected that the same applies to teachers).

Implementation issues

Some classifications arise when we think of a CVE as an immersion tool. This way, we can have a classification from the user interface perspective where we can historically list text base interfaces and virtual reality interfaces. Some examples from the first type are the traditional MUD and IRC systems (although these systems cannot be considered strictly as pure CVEs systems, at least, as we have define them). Examples from the virtual reality interfaces are the Distributed Interactive Virtual Environment (DIVE, http://www.sics.se/dive) who provides a general development environment and the MASSIVE-2 system, from Nottingham University [73].

Osberg proposes a four-step process and discuss related project management issues to develop virtual environments to be used into learning settings [102]. A discussion of multimedia user interfaces, considering virtual environment and ubiquitous computing is made in [103], where some of the advantages of using 3D are discussed.

In order to support communication, we need specified links between parts. As [87] states, the communication among group members depends upon the existence and the potential of these links. These links include mechanisms for message exchange, electronic meetings and discussion forums. Different approaches to support communication can be identified. One of these approaches is based on shared workspaces. In shared workspaces participants share a common area where they express ideas and build products. Shared workspaces are the most used resources for co-operative interaction support. As referred by [88] this information sharing model to support collaboration involves the use of conferencing facilities, real-time conferencing systems, desktop and multimedia conferencing and electronic meeting systems. Benford [89] classify shared spaces into four types: media spaces; spatially oriented video conferencing; collaborative virtual environments, and telepresence systems.

An alternative way for classifying CVEs is by their application: some examples are computer games and VR CVEs. The last ones are the more promising and are designed to support a medium to a large number of users with virtual representations. A virtual world can have many users represented but also can exist some autonomous agents whose behaviour is controlled by a computer program [90]. In http://www.nada.kth.se/~kai/lectures/CWVE.html, a general classification is proposed with references to existent systems.

Some of the challenges for using CVEs in higher education are: adding video, stabilising the platform on PC's, a managed set of services and Campus Building Facilities [74].

A detailed discussion of the implementation issues for virtual environments is presented in [91], also available on-line at http://www.stl.nps.navy.mil/~brutzman /vrml/vrml_95.html. For an early introduction discussion on the software required for developing virtual environments a value source is the Zyda et al. papers [90] and [111]. As an example of a protocol implementation for network communication in a distributed virtual environment, Kessler and Hodges propose the use of an updatable queue [112].

In an early project on distributed collaborative environment, the MultiG, is propose the need to further study of 3D interaction, virtual worlds and the potential of telepresence as computer-human interfaces [137]. In the same paper, is proposed a classification of generic collaborative task into four categories: (i) conferencing, including exchange of experience and knowledge between two or more team members, like briefing, negotiation, idea generation, problem solving, among others. (ii) co-working, including any activity for synchronous or asynchronous co-production. (iii) information exchange, like the exchange of documents or other kinds of information structures. (iv) management, like the need for co-ordination and supervision including scheduling, planning, etc.,[137].

To assist in virtual spaces building, the AC3D tool provides the necessary software for the rapid construction of 3D objects in virtual environment and allows these models to be saved in formats like VRML, MASSIVE and DIVE [92]. More information about the AC3D tool is available at http://www.comp.lancs.ac.uk/computing/users/andy/ac3d.html.

Some of the technical issues when develop CSCW systems are the support for collaboration, discussed by Rodden in [127], and [128]. Smith and Rodden presents the development of a simple mechanism that enables dynamic support for tailoring user interfaces in [129], for use in shared interfaces.

In [130], Chen and Gaines develop a model of virtual co-operative interaction through the Web and make a comparison between groupware and socioware. The development of groupware system over the Web is made by many research groups, [130] describes the InterConnect prototype, where are exploited interface aspects, connectivity problems and difficulties of interaction using a Web browser [131].

Other systems use the browsers bookmarks facility to base on that an information sharing system [132]. In [133] the use of Web browsers is combined with a textual MOO to create an information rich spatial interface, named Juggler system. The Web can also be used to support constructivist models of education, as in the case of the Henre project [134], where the extension to normal Web pages is made by recurring to CGI scripts, creating workspaces tools and workspaces connections.

Web can also be used as a distribution medium of contents, as described in [135] where their authors propose an environment that supports interactive presentations to distributed audiences over the Web. In [136] some guidelines to the Web interfaces design are made based on usability studies. The paper also presents a field study with the corresponding values for a real-time collaboration setting .

Two systems that enables collaboration over the Web are the BSCW and Habanero. The Basic Support for Cooperative Work (BSCW) developed by GMD, in Germany. The BSCW actual version is 3.2, and the server software is available for several platforms in Unix and Windows NT systems. More information about BSCW is available at http://bscw.gmd.de/. The other system is the collaborative framework and set of applications called Habanero. The Habanero Framework or API, developed by NCSA, provides methods for developers use to create or convert existing applications into collaborative applications. The system is written in Java and supports JDK 1.1.6, in the version 2.0 beta 2. A description of the Habanero is presented in [126]. The Habanero (server, client, and tools) is available at http://www.ncsa.uiuc.edu/SDG/Software/Habanero/.

4.3 Information visualisation systems

"*The purpose of computing is insight, not numbers*".
Richard Hamming [153]

Looking at data to provide information is an old subject. Abstract displays of information (graphs, plots, etc.) are a recent invention at around 1750-1800 [15]. Andrews defines Information Visualisation as the visual presentation of information spaces and structures to facilitate their rapid assimilation and understanding [149]. In the same document, the authors give a collection of Information Visualisation pointers (references also available at http://www.iicm.edu/hci/ivis).

A more complete on-line document for Information Visualisation, from Andrews is available at http://www.iicm.edu.hci/ivis/node2.htm. A report on three-dimensional Information Visualisation is given by Young, also available on-line, at http://www.dur.ac.uk/~dcs3py/pages/work/documents/lit-survey/IV-Survey/ [150]. This report gives a visualisation techniques enumeration and a survey of research visualisation systems. Two other Web resources for Information Visualisation are Olive (On-line of Information Visualisation Environments - http://otal.umd.edu/Olive/), and the CS348 course at Stanford University (http://graphics.stanford.edu/courses/cs348c-96-fall/resources.html).

McCormick et al. define Information Visualisation as the transformation of the symbolic into the geometric. Bertin proposes that Information Visualisation as an intelligence augmentation, finding the artificial memory that best supports our natural means of perception. The main goals for Information Visualisation are related with an human aid for analysis, explanation, decision making, exploration, communication, and reasoning about information.

Visualisation offer a support structure (like spatial or graphical representations), as an aid to pattern finding, change detection, or some visual cue to help reasoning about usually large datasets and multiple and heterogeneous information sources. These factors are also reasons for the need to develop cognition artefacts that use information visualisation techniques.

Vision is the highest bandwidth human sense [140]. Humans are good at scanning, recognising, recalling images. Information Visualisation takes advantage of human perceptual abilities [146]. If we consider the dictionary definition of the word Visual, we get a number of definitions relate to information gained from the use of the human eye. However, na alternative dictionary definition, suggests the conveyance of a mental image. If we now look at the dictionary definition of visualisation, we get that Visualisation is "*the power to process of forming a mental picture or vision of something not actually present to the sight*".

These definitions opens the way to consider that a visualisation can result from input from any combination of the human senses., which is not restricted to "visible" images. More specifically, it is possible to summarise that: visualisation should make large datasets coherent and present huge amounts of information compactly); present information from various viewpoints; present information from various levels of detail (from the more general overviews to fine structure); support visual comparisons; turn visible the data gaps; and tell stories about the data [147].

An example of research visualisation systems are the populated information terrains (PITs). The PITs concept aims to provide a useful database or information system visualisation by taking key ideas of CSCW, VR and database technology. A PIT is defined as a virtual data space that may be inhabited by multiple users. One particular characteristic is that users work co-operatively within data [152]. At http://www.comp.lancs.ac.uk/computing/research/cseg/projects/qpit/, is presented a prototype of a PIT [152] that follows the Benediktine approach [67].

The use of computers facilitate the access to large datasets, interaction, animation, range of scales, precision, elimination of tedious work, and new methods of display [147]. We can see visualisation as a process with six steps, represented in figure 17. The enumeration of the proposed steps is adapted from [140].

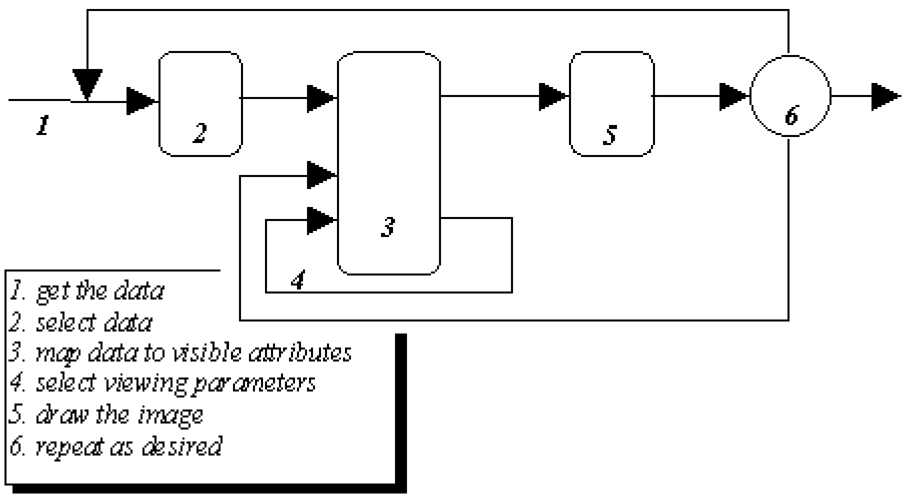


Figure 17: the visualisation process

Uselton states that Visualisation extends the graphics paradigm by expanding the possible input [140]. In particular data analysis is a process of reducing large amounts of information to short summaries while remaining accurate in the description of the total data [143].

An overview of graphics visualisation is made by [145], where the main issues with visualisation techniques are listed as: space; time; stability; and navigation, based on the hierarchy notion. The paper also presents an overview of classical visualisation techniques (pan an zoom, multiple windows, and map view strategy), and focus+context techniques (fish-eye, hyperbolic browser, cone-trees, intelligent zoom, treemaps, and magic lens). Also in [145] are introduced a novel approach (Cheops), and a discussion of strengths and limitations of focus+context techniques (for which the Cheops approach belongs). A taxonomy of information visualisation user-interfaces is proposed by North at http://www.cs.umd.edu/~north/infoviz.html.

One particular graphics use is for statistics. Yu proposes a framework for understanding graphics based on the idea of balancing summary with raw data, analysing ten different visualisation methods for multivariate data [143]. The author concludes that the use of colour in statistical graphics has long been neglected but this tends to change due to better hardware availability, changing the type of graphics that can be created and used. He also proposes the process of visualisation as an adjustment of noise and smooth (blocking understanding or facilitate it) [143].

An extension of graphics is the concept of interactive displays of information. The Interactive Graphical Methods are defined as the class of techniques for exploring data that allow the user to manipulate a graphical representation of the data [144]. The interactive graphics are also referred as direct manipulation graphics or dynamic graphics.

Eick and Wills list a number of reasons why interactivity significantly improves static displays, like: clarity; robustness; power; and possibility. The purpose of an interactive graphical display is to use graphical elements to encode the data in such a way as to make pattern apparent and invite exploration and understanding of the data by manipulating its appearance. In [144], a general discussion of interactive graphics is made.

Making good visualisations requires consideration of characteristics of the user and the purpose of the visualisation. Knowledge about the human perception and graphic design is also relevant [140]. A good display will have three characteristics: (i) be obvious as to what is displaying; (ii) focus attention on the data, and (iii) give indications of scale and location of the data [144]. Cleveland gives an ordering of difficulty of decoding visual cues, starting with easiest ones: position along a common scale; position along identical, nonaligned scales; length; angle; area; volume; colour hue; colour saturation; and density [140].

One of the application areas for Information Visualisation is Scientific Visualisation, where some applied computational science methods produce output that could not be used without visualisation. This happens because huge amounts of produced data require the high bandwidth of the human visual system (both is speed and sophisticated pattern recognition), and interactivity adds the power [140]. The use of visualisations systems provide a single context for all the activities involved from debugging the simulations, to exploring the data, and to communicate the results.

Other application area is the Software Visualisation, defined by [141] as the use of "*the crafts of typography, graphic design, animation, and cinematography with modern human-computer interaction technology to facilitate both the human understanding and effective use of computer software*". By computer software, the author intends to include all the software design process from planning to implementation. Price, Baecker, and Small present a taxonomy for systems involved in the visualisation of computer software [141].

As research opportunities, [140] points out, among others, the need for new interaction tools and techniques; new mappings of data to visual attributes; new kinds of visuals, and automatic selection of data or mappings. [147] report that many of the new information visualisation methods have not been evaluated.

In the DARPA's Intelligent Collaboration & Visualisation (IC&V) program aimed to enhance collaboration between teams through distributed information systems, one of the main specified key challenges is to develop team-based visualisation software for sharing views, in particular, visualising abstract spaces [142]. They report research challenges in mapping real object with data about them; methods for augmenting real spaces with superimposed information that adds value, and the more difficult problems of develop techniques to visualise abstract N-dimensional spaces, where is a need to research to develop methods for representing abstract information spaces and for navigating such spaces [142]. In [148], Turner et al. describe a 4D symbology (3D symbols plus time-dependence) for battlefield visualisation where data come from real-time sensors and from simulations and is positioned on high-fidelity 3D terrain.

5. Literature survey

This section presents the direction to take further literature survey in the relevant areas to the ongoing research work.

The work will focus on Information Visualisation issues and their use in Virtual Environments, specially, the Collaborative Virtual Environments. In order to gather more information about these topics that are actually a focus of intense research world-wide, a constant survey of new methods, architectures, concepts, technologies, and results must be done. As an example, an expected book on the Information Visualisation research area is the one edited by Card, MacKinley and Shneiderman (its preview information is available at http://st1.yahoo.com/softpro/1-55860-533-9.html) [107].

An additional literature survey will be conducted in order to collect data based on the following questions:

- What are the important issues when dealing with information?
- What are the actual main themes and research questions in information visualisation?
- What are considered good representations?
- What are the relevant findings in cognition and human factors that contribute to good representations, and visualisation settings?
- What is the value of using non-linear textual forms of representation, of multimode representations, considering image issues like 3D, and time/spatial issues?
- What is the relevance of these questions to areas of study like CSCW, CSCL, and CVE?
- What technology systems can support the proposal project?

This will constitute one of the deliveries of the project proposal for the second work year.

6. Project proposal

In this section, a proposal for continuing research is made, oriented to obtain achievable results in the remaining working time. An outline of the work to be developed is also presented.

Develop the idea (model) of a visualisation system that can share an information space without imposing one particular visual representation to the user. This will lead to a dynamic model of an alternative representation set that can be shared by giving the representation description, allowing different visual representations for the same information space. In particular, the study of 3D elements that can augment the users perception of information is considered.

The main application to test these research ideas will be in the education area where some work has already done. In particular the prototype to test these ideas will concentrate mainly in the representation issues and intends to address information sharing and information spaces just as support technologies.

The study intends to propose a model for taking advantage of the use of 3D in information visualisation that enables each user to share information spaces with others in better ways than with systems that use 2D representations. To achieve results and gain insight for dealing with this problem, a project is proposed to develop and test a metaphor to organise information and knowledge in an education application: *the creation and visualisation of interactive information spaces*.

Context and goals

The starting point and motivation for the project proposal was the attempt from organising in a different way from the traditional access to the contents of the Information Systems class at Fernando Pessoa University (UFP), for which I am responsible (a description for the available electronic resources are in [68]).

The project proposal tries to get advantage of the technological environment available at UFP, where every student has its own laptop computer to access a TCP/IP network. This gives a potential environment where the ideas and implementations of the project proposal can be tested, using technologies like the Web, VRML, Java, C++, and use of a CSSW and/or Virtual Reality system. Often the use of these technologies in educational settings has revealed to be a disadvantage or, at least, not bringing any clear added value.

The challenge is to create a proposal for information visualisation (particular for the Information Systems class) which opens the way for a new form of presenting its contents, simultaneously intuitive, interactive and effective, using 3D facilities.

The education setting must allow a learning atmosphere where students and teachers could interact and contribute in an active form for the construction of the knowledge. On the other hand, as the proposed project would work in the Web environment, where the access to multiple information resources is possible, this means that some information visualisation of this must have to be considered to be part of the system (integrated with).

The proposed metaphor

Let us sum up a little more. The main goal of the metaphor is to facilitate the students that organise its own information, building its personal dossier, in “constellation” lively and falling back upon 3D elements, starting from a group of information base, of the type used in the normal class (a “star”) supplied by the teacher. New contents (stars and planets) are added such as bibliography, multimedia objects, comments, sounds, images, graphics, representations, references, and three-dimensional objects, that the students organise in constellation for best results in visualising and relating them in space.

The teacher has access to this space of information that constitutes each student's constellation in construction and, whenever some information be not adapted or it is not correct or with a value position and relations, the teacher can “bomb” the wrong data.

This activity is a punctuation activity that turns visible the connections of the constellation (or of some of its elements - stars and planets) that become, like this, to be available not only for the own student, but for all other students. As each element (each star and each planet) is being developed in a correct way, its visibility will become global and it will be accessible for the group, for the course, for the university and, in a later stage in the Internet.

The “universe” (knowledge area in study) is being built and enriched with analyses, bibliography, and other students' important considered works. It is possible to consult all the developed works, to pick up information near other works (that are also part of that universe) that can be used to start new constructions. Each student's goal is to keep moving inside a inter-planetarium system, as a growing process, adding new planets, and stars.

When students reach a certain knowledge level they can have contributed to the creation of guided courses that offer a perspective and conductive thread of the space of information (named as “ship"), guaranteeing this way, the necessary linearity for the introductory study of a knowledge area.

One important advantage of system like this it is that the group work and the sum of the learning of the different elements, opens the way to the formation of a task-based oriented collaboration. In a final phase of the work the universes developed by each one of the groups will be gathered in a complex, composed mega-universe, this way, for different learning cells: the different universes take part of an whole where different perspectives, schools of thought and other valid differences can be integrated.

The individual learning converges for a group work and the universes of information and of knowledge of the groups become part of an all organised and structured unit, as a result of the work of everybody and to the service of many other.

Expected results of the project

Why is that, instead of this strange metaphor, the option was not for other more accessible, intuitive, easier to identify, closer of the habits of the day-to-day? Why not name files to the planets, folders to the stars, and constellations, links instead of stellar roads? In fact for being different and because we wanted to remove part, on one side of this difference, and for another, of a characteristic of our physical world that, of so much we are used to it, we forgot about its existence: the three-dimensional characteristic.

The real value of using 3D facilities for representing the real world and visualise information remains unknown. It seems that presented data, information, and knowledge using 3D can help data of difficult perception and relationship become more tangible, turn clearer the hierarchies and connections, the apprehension of the data, and its metamorphosis in information. Can the interaction between the virtual world and the user become deeper and the manipulation of the components of the simulation become more intuitive? These questions remain without a conclusive answer.

An atmosphere of this type is, almost always, in first place, a game, that generates, naturally, motivation, and the motivation for the learning is fundamental in order to the learning become effective. In a three-dimensional universe the real-time interactivity, the manipulation and control of the atmosphere by the user still reinforces more the referred motivation and it allows the student to feel more comfortable, dominating an universe that understands and it apprehends more easily.

Each space is individual, since it is the student that is going to create it, multiply it, and developing it (with the teacher's aid). But the work, that it begins by being individual, quickly becomes a shared work, where each element contributes to a particularly goal. The collective work constitutes an added value that should not be, never, despised, not only for the results that it allows to reach but, also, for the human liaisons that it allows to develop.

Work outline proposal

The research work to be developed next year will follow the general lines from the present report. It will focus on gaining insight for the presented problem, and using a practical education environment as a platform test. This way, starting from November 1998, until September 1999:

- deliver a literature survey for the information visualisation area and virtual environments that explore the question set presented in section 5 of the first year report
  - *end January*
- work and develop a practical model to represent information and knowledge issues
  - *end July*
- develop an implementation of the proposed project, as an Web application
  - *end September*

Giving these deliveries, a six group task has been defined to manage the project timeline. The six group activities are: Literature survey, Model development; Prototype implementation; Usability tests, Holiday Time and writing second year report. In figure 18 is given a PERT representation of the project. In figure 19, is given the Gantt chart.

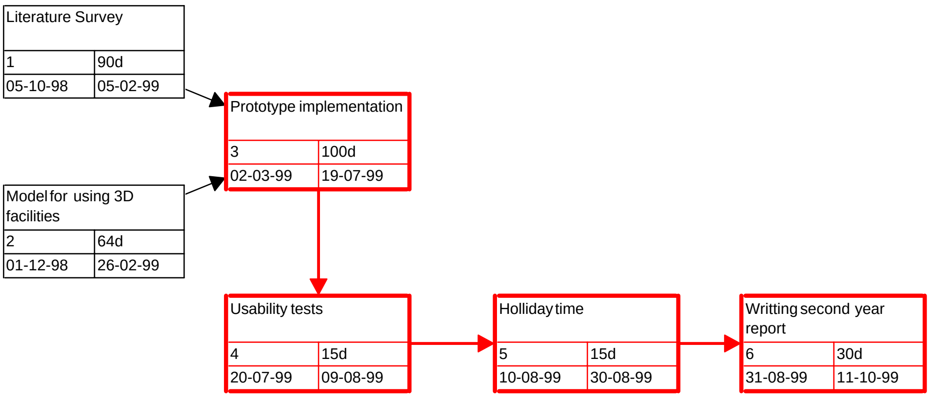


Figure 18: PERT chart for the second year

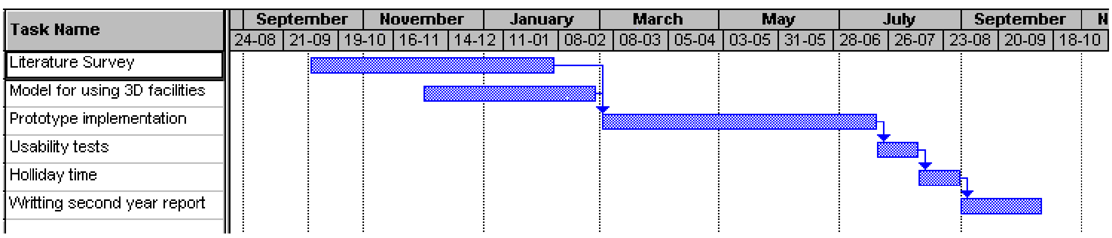


Figure 19: Gantt chart for the second year

Appendix A

Synopsis of the Master dissertation

University of Porto, Faculty of Engineering
MSc Degree in Electrical and Computation Engineering, Telecommunications specialty

Title:
"Multimedia for Enterprise Information Systems"

Author:
Luís Manuel Borges Gouveia

Date:
December, 1994

Abstract
This work describes the study of information systems in organisations aiming at the characterisation of a service set based on multimedia facilities. These multimedia facilities are now affordable given the increase of computer systems capacity and became a key factor to boost creativity and productivity. Multimedia is changing the relationship between users and the information system. The present work assumes the information management and the information flow as critical success factors in the enterprise; if these factors are handled conveniently it is possible to change dramatically the productivity of human resources. In order to obtain this kind of advantages the information system must be improved with technology that enables the information flow.

The contribution of multimedia to telecommunication applications is analysed to determine its impact in the information system. The work introduces three types of applications that meet the requirements identified by the study and two applications are described: telework and telelearning.
The support technologies that serve as the base for the specification and development of the applications are also presented; they are multimedia, databases and data communications.

Keywords:
Value added services; Data; Data Communications; Databases; Information; Information Management; Information Systems; Multimedia; Multimedia Applications.

Language:
Portuguese

Appendix B

On education, learning and training: bring windows where just walls exist (Information) Technology with a global politic impact

Luís Manuel Borges Gouveia
PhD student, Computing Science, Lancaster University
{lmbg@ufp.pt; luis@comp.lancs.ac.uk}

Abstract

Turning a century is always troublesome for common and well-established systems. Like in other historical contexts, several questions arise to challenge our values on the way the world is working.

What are the real effects that the evolving education system will bring to the society and the political global balance that we knew? What will be the new forms, institutions models and power relations that will have success in bring education to the people? What will be predominant form of interaction on society: personal, collective, in-groups of common interest or in a combination of some of these situations? and they will be emergent ones or complete new?

There is no easy (or even just one) possible answer to these questions, however one important factor is the role of technology in breaking the traditional time/space continuum and its natural impact in society in general.

1. Introduction

> "*There is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who would profit by the preservation of the old system, and merely lukewarm defenders in those who should gain by the new one*"
>
> The Prince, Machiavelli

Education, learning and training is on move. Each day we see new signs of more difference between what students want, and what society needs and what institutions can do. Even the teachers seems somewhere lost by the pace of change and by the lack of interest among students to attend, discuss, and make things work in a traditional education environment [1].

Never less, the great majority of these students believe that the key for their future is education, but not the traditional one. Recently, they can learn more specific contents in order to leverage their know how. It is more important to them, to get diploma certifications from enterprises that have a major market share (this is yet more visible on some areas, like information technology, but eventually it will cover all the areas, including medicine, and at an undergraduate level).

This situation introduces some of the differences that regular education can not be easily handled. Why? Change and innovation is more difficult in older and bigger systems. And, also crucial, it can not be regulated nor can it be based on recommendations. It must be an inside “each one” impulse and it will need to be a place where we can celebrate difference. Another situation that occurs in the last years was the vulgarisation of education which is an excellent thing but have their own drawbacks in the need to a fast transformation on the number of professors needed, and on the number of students per class: these factors change but the practice in class have not [2].

So, what can be the role of information technology (IT)? We can state that it will be a regulator one. In fact, with technology we can balance quality and quantity and return to the situation where teachers are more than terminal output devices in the regular education system.

At last, IT can be used to make some change. In fact, education experts coin a term for the use of these facilities: ICT - information and communication technologies. They study the use of ICT in systems to deliver ODL (open and distance learning) systems.

What is the relation that ODL have with traditional face-to-face classes? They may be more related then a first analysis will show. We think that it is already a trend announced, and that its adoption will grow up in the next years. The trend is the use of on-line applications in classroom education, an already widespread trend in industrialised societies, that can be distinguished from on-line education. The on-line education is now an important trend: in U.S., where it has been estimated that 55 per cent of all the 2215 four-year colleges and universities have courses available off-site [3]. Many of the top-rated universities in the U.S. offer on-line degrees and act now as dual-mode education (providing distance education and on-campus) [4]. When it will be possible to have a similar situation in countries like Portugal?

To close this section, how can educate people cope with change? The common answer to this is life long learning (LLL), where people return to education, learning and training situations several times in their life. We can characterise that education (r)evolution in many possible ways [5] but our discussion will be concerned with time/space continuum change.

2. Technologies that reinvent time and space

Students can now have access to the same information that teachers have, using Internet, CD-ROMs, computers and networks. They can also communicate with other people (students, teachers, professionals, institutions, and enterprises) and gather information, share problems and solutions and be part of the Information Sea available both as consumers and producers. This means a real difference with strong impact in the education system.

This means things like passing from *stockknowledge* to *flowknowledge*, which is passing from a situation where knowledge is a cumulative activity based on a well oriented line of thought to gather related information, to a situation where interaction and discussion brings new re definitions of structure in base knowledge.

That way, we also propose a future need to connected classrooms to new forms of interaction. Regular lectures to alternative forms of lecturing where students have their own active roles and make them believe that they are individuals belonging to a potential group where they offer, create, influenced and modify value in the form of knowledge.

When basic skills are related with information we have to have strong competencies in information technology. Old IT for knowledge is paper and pencil hardware and language software. Nowadays, we need more in order to cope with the strong connection needs to cooperate, collaborate, compete, discuss, communicate, to relate, compare, decide, store and, of course, create [6].

We can do this asynchronous or synchronous way, connecting whom we want to at different or same time. We are reinventing our physical perception because we are start using technology as a possible way to "be there". We can combine place and time to make four different possible relations with other people (figure A). Artefacts like cellular telephones and electronic Internet versions of newspapers make their roles in put people connect by related needs believes and matters, creating new notions of communities.

So what? Many years before computers, we belong to clubs, have correspondents by post mail, travel a lot and can become citizens of the world. But now is different, with technology, the grown number of people doing that bring a new reality. Physical place is no longer the more important factor, (it is just the easiest one). We can buy books by Internet and expect then arrive faster then the same ones we buy in a normal bookstore (it actually happens to me!). We also can contract people from other places without communications problems (at least really different from the same problems that we have with local people).

Two aspects very important to distinguish modern systems from old ones are the predominant interaction mode and its dynamic characteristic to represent and visualise information. What makes the difference is our capacity to interact: the ability to take advantage of technologies offer to cope with knowledge and communication skills. Preparing the future education system using technologies and innovation is a must for all kinds of institutions, because nobody can wait for this answer: is education the more important industrial sector of the next century?

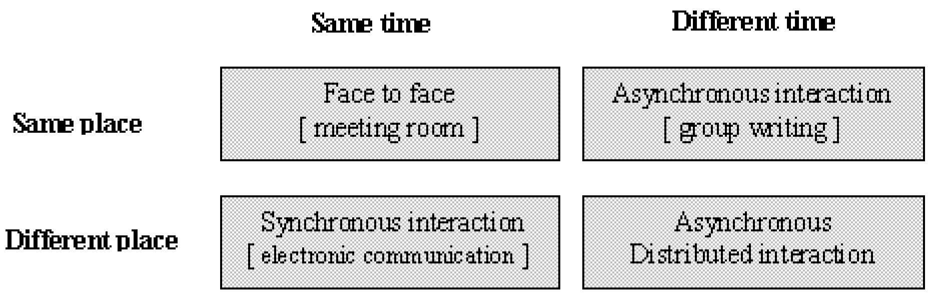


Figure A - time and space dimensions in which technology may be used to support social interaction

3. References

[1] L. Gouveia, "Expectativas dos alunos em relação ao seu curso e saídas profissionais", UFP relatório interno, Fevereiro, 1998.

[2] D. Puttnam. "Communication and education". The ninth Colin Cherry lecture. Imperial College, London, June 1996.

[3] L. Gubernick and A. Ebeling, "I got my degree though e-mail", Forbes, 19 June 1979.

[4] M. Bastos, "Globalisation and On-line Degrees: opportunities for students and threat to Universities in Developing Countries?", BITE'98 international conference, March 1998.

[5] D. Kerkhove. "Will education change? The impact of the new education technologies on students, teachers and schools", 2º Conferência Sociedade de Informação Interactiva, reinventar a educação, December 1996.

[6] L. Gouveia. "Sociedade digital, que oprtunidades?". Congresso internacional Pós-Colonialismo e Identidade, UFP, Porto, 1995.

Appendix C

Influence of the form of representation in the ease of the task

Adapted from Norman, 1993 [20].

Game of 15
Consider the nine digits: 1, 2, 3, 4, 5, 6, 7, 8, 9
Each payer takes a digit in turn (each digit can be use only one time)
The first player to get three digits that sum to 15 wins

try to play the game following the rules.

Tic Tac Toe
Consider a table with three lines and three columns: nine cells
Consider two plays, one with the mark O, and other with the mark X
Each player put his mark in turn, into the available free cells
The first player to get three of its marks in a straight line, wins

try to play the game following the rules.

Now compare the following game visualisations, that turn possible to arrange the two games into the same spatial organisation (this makes the first game easier to play).

O		
X	X	O

4	3	8
9	5	1
2	7	6

Player X: choose 5
Player O: choose 4
Player X: choose 9
Player O: choose 1
Player X: …

Appendix D

Illustration of some pitfalls for an information display

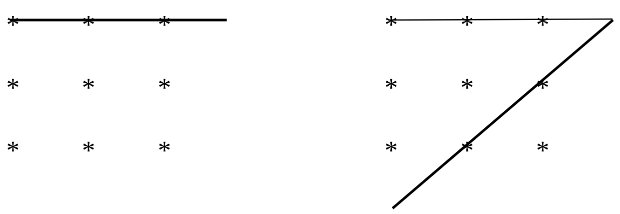
The major tasks that the user must perform are finding the relevant information and computing the desired conclusion

Problem
Consider nine point in a surface that are displayed in a three by three grid.

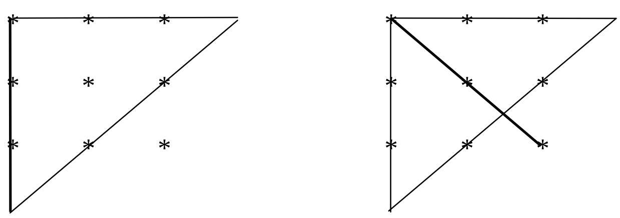
```
*    *    *

*    *    *

*    *    *
```

Try to pass by all the nine dots with four straight lines keeping the pen in the surface (paper).
One possible solution (path) is the following

Consider the first and second straight lines:



Consider the third and fourth straight lines, that cover all the nine points:



With a better information display, the problem will be easily solved. Consider the following start grid of points for the same problem (where the points to be considered are represented by the symbol *):

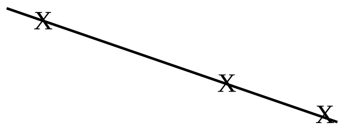
```
-    -    -    -    -

-    *    *    *    -

-    *    *    *    -

-    *    *    *    -

-    -    -    -    -
```

Appendix E

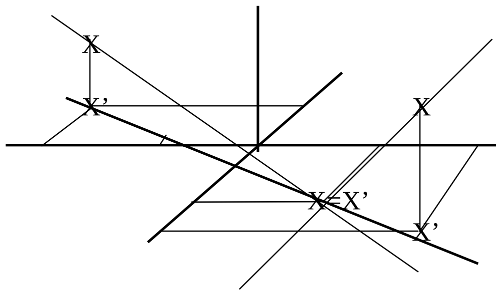
Mapped points and projected points

One common test to prove a mental misinterpretation is the three aligned points problem. Consider three perspective aligned points and the challenge to make with them, a surface.

Most people fail to form a surface with three aligned points because use a sheet of paper (surface) to work on the problem, and project them there. This way, the projected three points into a surface can be visualised in the following figure.

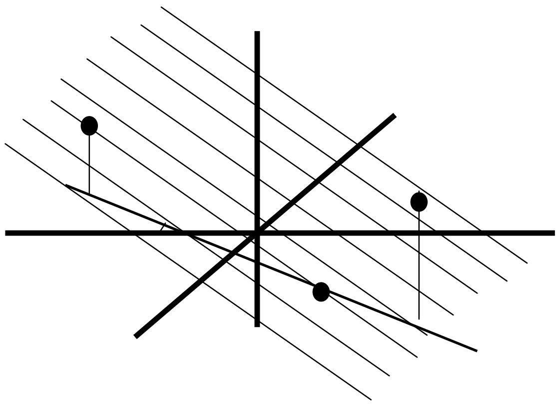


If we use the same paper with some perspective representation, we end up with a different conclusion:



Points projection in XZ surface - represented by X'

The three point have the same aligned projection in the XZ surface, but when considered in the 3D space XYZ, they permit they can generate a surface, as represented in the following image.



The three points give the surface

Appendix F

Papers published in the period

(since November 97 until September 98)

Gouveia, L. "A technological related discussion on the potential of change in education, learning and training". Euroconference'98 - New Technologies for Higher Education. 16-19 September, Aveiro, Portugal
International referee committee

Gouveia, L. "Será a Internet/Intranet uma plataforma viável para a sala de aula? Lições retiradas do uso de computadores portáteis e da web em sala de aula". 3º Simpósio de I&D de Software Educativo, Universidade de Évora, 3-5 September, 1998. Évora. Portugal.
National referee committee

Camacho, L. and Gouveia, L. "Criação de espaços de informação interactivos". Comunicação breve ao 3º Simpósio I&D de Software Educativo. 3-5 September, 1998. Évora. Portugal
National referee committee

Gouveia, L. "The Role of Teachers in Rich Technological Environments". 1st Workshop on Current Advances/Practice on Internet/Intranet Based ODL. 26th June, 1998. Porto Portugal.
By personal invitation

Gouveia, L. "Feasibility discussion of a Collaborative Virtual Environment, finding alternative ways for university members interaction". Twelfth biennial conference ITS´98 - beyond convergence, communication into the next millennium. 21-24 June, 1998. Stockholm, Sweden.
International referee committee

Gouveia, L. "Digital support for teachers teaching. Current experience on using Internet facilities in virtual university environments". ITET Information Technology in Education and Training, International Conference. 20-22 May, 1998. Macau, Portugal.
International referee committee

Gouveia, L. "Group assessment: alternative forms to evaluate student skills". UFP Journal nº2, Vol. 2, pp 519-526. May 1998, Portugal. ISSN 0873-8181.
National referee committee

Gouveia, L. "Sociedade Digital: que oportunidades?" in Da Rosa, V. and Castilho, S. (eds.) Pós-Colonialismo e Identidade, Edições UFP, pp 181-189. May 1998, Portugal. ISBN 972-8184-30-1.
International referee committee

Gouveia, L. "The NetLab experience, moving the action to electronic learning Environments". BITE, Bring Information Technology to Education, International Conference. 25-27 March, 1998, Maastricht, The Netherlands.
International referee committee

Notes:
If title in Portuguese, the paper is written in the Portuguese language, other papers are in English.
The list is presented by date order, with the early dates first.
All the papers can be accessed in the following Web URL: *http://www.ufp.pt/staf/lmbg/lg_com.htm*

Appendix G

```
//
// Luis Manuel Borges Gouveia
// April 98, JULHO 98
//
// Versão correcta e funcional:
// extrai dados de um formulário e reenvia valores das variaveis para o utilizador
//
// portuguese statement to saying in a more formal way that the program is working
//
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <iostream.h>
#define MAXLINE 2000
#define COMMLINE 2000
//
// class to process input stream from html forms
// _Form
class _Form
{
private:
	/* cleanup routines */
	char* clear_space(char* msg);
	char* clear_amp(char* msg);
	char* clear_plus(char* msg);
	char* clear_control(char* msg);
	int ahextoi(char* msg);
	char input_msg[COMMLINE];
	char out_msg[COMMLINE];

public:
	_Form() {;};
	char* clear_all(char* msg);
	char* get_variable(char* msg, char* start);
	int check_msg(char* variable_value, char* expect_value);
	inline char* out_to_in(char* output_message)
	{
		strcpy(input_msg, output_message);
		return(input_msg);
	};
};
#define EOM 0
#define NULL 0
// class subroutine, cut double spaces
//
char*
_Form::clear_space(char* msg)
{
	int i=0;
	char tmp_msg[MAXLINE];
	while(*msg != EOM)
	{
		if((*msg ==' ') && (*(msg+1) == ' '))
		{
			++msg;
		} else
		{
			tmp_msg[i++] = *msg;
		}
		++msg;
	}
	tmp_msg[i] = NULL;
	strcpy(out_msg, tmp_msg);
	return(out_msg);
}
```

```
//
// class subroutine, change & and separate variables
//
char*
_Form::clear_amp(char* msg)
{
	int i=0;
	char tmp_msg[MAXLINE];
	while(*msg !=EOM)
	{
		if(*msg =='&')
		{
			tmp_msg[i++]='\n';
		} else
		{
			tmp_msg[i++] = *msg;
		}
		++msg;
	}
	tmp_msg[i] = NULL;
	strcpy(out_msg, tmp_msg);
	return(out_msg);
}
// class subroutine, change + to space
//
char*
_Form::clear_plus(char* msg)
{
	int i = 0;
	char tmp_msg[MAXLINE];
	while(*msg != EOM)
	{
		if(*msg == '+')
		{
			tmp_msg[i++]=' ';
		} else
		{
			tmp_msg[i++] = *msg;
		}
		++msg;
	}
	tmp_msg[i]=NULL;
	strcpy(out_msg, tmp_msg);
	return(out_msg);
}
//
// class subroutine, change hexadecimal to decimal
char* _Form::clear_control(char* msg)
{
	char val_msg[3];
	int i=0;
	char tmp_msg[MAXLINE];
	while(*msg != EOM)
	{
		if(*msg == '%')
		{
			val_msg[0]=*(msg+1);
			val_msg[1]=*(msg+2);
			val_msg[2]=0;
			tmp_msg[i++]=ahextoi(val_msg);
			msg +=3;
		} else
		{
			tmp_msg[i++]=*msg;
			msg++;
		}
	}
	tmp_msg[i] = NULL;
```

```
        strcpy(out_msg, tmp_msg);
        return(out_msg);
}
//
// class subroutine, convert a hex string to a dec string
 int _Form::ahextoi(char* value)
{
        int dec_value=0;
        int i=0;
        while(*(value+i) != EOM)
        {
                if((*(value+i) >= '0') && (*(value+i)<='9'))
                {
                        dec_value = ( *(value+i)-'0') + (dec_value * 16);
                } else
                if ((*(value+i) >= 'A') && (*(value+i) <= 'F'))
                {
                        dec_value=(((*(value+i)-'A')+10)+(dec_value*16));
                } else
                if ((*(value+i) >='a') && (*(value+i) <='f'))
                {
                        dec_value=(((*(value+i)-'a')+10)+(dec_value*16));
                }
                i++;
        }
        return(dec_value);
}
// class subroutine, clear the extra charaters in the message
//
char* _Form::clear_all(char* msg)
{
        char local_msg[MAXLINE];
        strcpy(local_msg, clear_space(msg));
        strcpy(local_msg, clear_amp(local_msg));
        strcpy(local_msg, clear_plus(local_msg));
   strcpy(local_msg, clear_control(local_msg));
        return((msg));
}
/* decision routines */
//
// class subroutine
// obtain the variable value
char* _Form::get_variable(char* msg, char* start_msg)
{
        int start_flag=0;
        int length;
        int start_length;
        int j;
        int i=0;
        char tmp_msg[MAXLINE];
        length=strlen(msg);
        start_length=strlen(start_msg);
        tmp_msg[0]=0;
        while(i<=length)
        {
                if(strncmp(msg+i,start_msg,start_length-1) !=0)
                {
                        i++;
                } else
                {
                        start_flag=1;
                        break;
                }
        }
        if(start_flag==0)
        {
                return "";
        }
```

```
        i+=start_length;
        j=0;
        while(i<=length)
        {
                if((*(char *)(msg+i) == '&') || (*(char *)(msg+i) ==' ')
                        || (*(char *)(msg+i) == 13) || (*(char *)(msg+i) == 0))
                {
                        break;
                }
                tmp_msg[j++]=*(msg+i);
                i++;
        }
        tmp_msg[j]=0;
        strcpy(out_msg, tmp_msg);
        return(out_msg);
}
#define TRUE 1
#define FALSE 0
// class subroutine, check a value from input
//
int
check_msg(char* variable_value, char* expect_value)
{
        if(strcmp(variable_value, expect_value) == 0)
        {
                return TRUE;
        } else
        {
                return FALSE;
        }
}
/*   +++++++++++++++++++++++++++++++++++++++   */
//
// color codes
#define WHITE "#ffffff"
#define BLACK "#000000"
#define GREY "#f0f0f0"
#define DARK_RED "#800000"
#define DARK_GREEN "#008000"
#define DARK_YELLOW "#808000"
#define DARK_BLUE "#000080"
#define RED "#ff0000"
#define GREEN "#00ff00"
#define BLUE "#0000ff"
#define YELLOW "#ffff00"
#define LIGHT_BLUE "#a6caf0"
#define CREAM "#fffbf0"
#define CYAN "#00ffff"
#define MAGENTA "#ff00ff"
#define DEFAULT_COLOR GREY
//
// html standard class (it can be used in any program dealing with CGIs
//
class Standard { //used to standard parts
        char color[8];

public:
        Standard(); //overload contructor
        Standard(char* start_color);
        void start_msg();
        void startmsg(char* start_color);
        void start_msg(int start_color);
        void set_color(char* color_to_set)
                {strcpy(color, color_to_set);};
        void normal_head(char title);
        void normal_head(char* title); //standard header
        void color_head(char* title); //colored background header
        void end();
```

```
		void comment(char* mycomment);
		void image(char* myimage); //overload image
		void image(char* myimage, char* alt);
		void image(char* myimage, int n, ...);
		void anchor(char* link, char* hottext);
};
Standard::Standard(char* start_color)
{
		cout <<"Content-type: text/html\n\n";
		strcpy(color, start_color);
}
Standard::Standard()
{
		strcpy(color, DEFAULT_COLOR);
}
// inform http server that we want to send html code..., with some color live
void Standard::startmsg(char* start_color)
{
		cout<<"Content-type:text/html\n\n";
		strcpy(color, start_color);
}
// add a classic html begining page...
void Standard::normal_head(char* title)
{
		cout<<"<HTML><HEAD>\n";
		cout<<"<TITLE>\n"<<title<<"</TITLE>\n";
		cout<<"</HEAD>"<<"<BODY>\n";
}
// inform http server that we want to send html code...
void
Standard::start_msg()
{ cout<<"Content-type: text/html\n\n";}
// give colors...
void
Standard::color_head(char* title)
{
		normal_head(title);
		cout<<"<BODY "<<" BGCOLOR=\""<<color<<"\>\n"<<"</BODY>\n";
}
// to add the html close tags...
void
Standard::end()
{
		cout<<"</BODY></HTML>\n";
}
// to add comments
void Standard::comment(char* mycomment)
{
		cout<<"<!--"<<mycomment<<"-->\n";
}
// to add images...
void
Standard::image(char* myimage)
{
		cout<<"<IMG SRC=\""<<myimage<<"\">\n";
}
// to add images with alternative text
void
Standard::image(char* myimage, char* alt)
{
		cout<<"<IMG SRC=\"" <<myimage<<"\"ALT=\""<<alt<<"\">\n";
}
// to add links...
void
Standard::anchor(char* link, char* hottext)
{
		cout<<"<A HREF=\""<<link<<"\">"<<hottext<<"></A>\n";
}
```

```
/*   ++++++++++++++++++++++++++++++++++++++++   */
//
// main program
//
// receive input from http server and compute the value for each form variable
// next give feedback to web user via a html response
//
void main()

{
        char indata[MAXLINE];
        _Form Form;
        Standard myStandard(GREY);
        char mailtoname[MAXLINE];
        char emailad[MAXLINE];
        char msg[MAXLINE];
        // get the input from http
        cin >> indata;
        // obtain the value for three variables, from form
        strcpy(mailtoname, Form.clear_all(Form.get_variable(indata, "mailto_name=")));
        strcpy(emailad, Form.clear_all(Form.get_variable(indata,"&your_email=")));
        strcpy(msg, Form.clear_all(Form.get_variable(indata,"&message=")));
        //
        // here it is possible to include an access to a database, a file or other
        // task usually made by a programming language!
        //
        // give feedbak to user, via a html page
        myStandard.normal_head("Got Your data");
        cout <<"<p>Confirm your input<p><hr><p>";
        cout<<"NOME: " << mailtoname;
        cout<<"<p>EMAIL: "<<emailad;
        cout<<"<p>MENSAGEM: " << msg;
        cout<<"<p><p>O original...<p>";
        cout<<indata<<"<p>";
        myStandard.end();
}
```

Glossary

2D	Two-dimensional
3D	Three-dimensional
CGI	Common Gateway Interface
CSCL	Computer Supported Collaborative Learning
CSCW	Computer Supported Cooperative Work
CSS	Cascading Style Sheets
CVE	Collaborative Virtual Environment
DIS	Distributed Interactive Simulation
DOM	Document Object Model
DSSSL	Document Style Semantics and Specification Language
DTD	Document Type Definition
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technologies
IS	Information System
IT	Information Technology
LLL	Life Long Learning
LSVE	Large Scale Virtual Environment
ODL	Open and Distance Learning
SGML	Standard Generalised Markup Language
VE	Virtual Environment
VR	Virtual Reality
VRML	Virtual Reality Modelling Language
WWW	World Wide Web
XML	Extending Markup Language
XSL	Extensible Stylesheet Language

References

[1] Gouveia, L. (1994). "Aplicações Multimédia para o Sistema de Informação da Empresa". Master Dissertation, FEUP-DEEC, University of Oporto, Portugal, December.

[2] Card, S. and Eick, S. and Gershon, N. (1998). "Information visualization" in Interactions, ACM, march + April, volume V.2, pp9-15.

[3] Harrison, D. and Jacques, M. (1996). "Experiments in Virtual Reality". Butterworth Heinemann.

[4] Beir, K. (1996). "Virtual Reality: a short introduction" University of Michigan, Virtual Reality Laboratory. On-line in http://www-vrl.umich.edu/intro.html.

[5] Erickson, T. (1993). "Artificial Realities as Data Visualization Environments: Problems and Prospects" in Virtual Reality, Applications and Explorations. Wexelblat, A. (ed.). Academic Press, pp 3-22.

[6] Fairchild, K. (1993). "Information Management Using Virtual Reality-Based Visualizations" in Virtual Reality, Applications and Explorations. Wexelblat, A. (ed.). Academic Press, pp 45-74.

[7] Pfeifer. "The domain and goals of CSCW". University of Calgary, 1995.

[8] Wexelblat, A. (1993). "The reality of: virtual reality and CSCW" in Virtual Reality, Applications and Explorations. Wexelblat, A. (ed.). Academic Press, pp 23-44.

[9] Benford, S. and Greenhalgh, C. (1997). "Collaborative Virtual Environments, tutorial 6". ECSCW'97, The Fifth European Conference on Computer Supported Cooperative Work, Lancaster, UK, 7 September.

[10] European Commission. (1998). "Review of Research and Development in Technologies for Education and Training: 1994-1998". European Commission, DGXIII, Telecommunications, Information Market and Exploitation of Research.

[11] Engelbart, D. and English, W. (1968). "A Research Center for Augmenting Human Intellect" in Greif, I. Ed. (1988). Computer-Supported Cooperative Work: A Book of Readings. Morgan Kaufmann, pp 81-105.

[12] Sutherland, I. (1963). "Sketchpad: A Man-Machine Graphical Communication System". In proceedings of the Spring Joint Computer Conference, pp 329-346.

[13] Lakin, F. (1988). "A Performing Medium for Working Group Graphics" in Greif, I. Ed. (1988). Computer-Supported Cooperative Work: A Book of Readings. Morgan Kaufmann, pp 367-396.

[14] Laurel, B. (1993). "Computer as Theatre". Second Edition. Addison Wesley.

[15] Tufte, E. (1983). "The Visual Display of Quantitative Information". Graphic Press.

[16] Tufte, E. (1990). "Envisioning Information". Graphic Press.

[17] Tufte, E. (1997). "Visual Explanations". Graphic Press.

[18] Abbott, E. (1986). "Flatland". Penguin.

[19] Wooley, B. (1993). "Virtual Worlds". Penguin.

[20] Norman, D. (1993). "Things that make us smart, defending human attributes in the age of the machine". Addison Wesley.

[21] Hutchins, E. (1995). "Cognition in the Wild". MIT Press.

[22] Bush, V. (1945). "As We May Think" in Greif, I. Ed. (1988). Computer-Supported Cooperative Work: A Book of Readings. Morgan Kaufmann, pp 17-34.

[23] Shneiderman, B. (1987). "Designed the user interface, strategies for Effective Human-Computer Interaction". Addison Wesley.

[24] Shneiderman, B. and Maes, P. (1997). "Direct Manipulation vs Interface Agents, excerpts from the debates at IUI 97 and CHI 97" in Interactions, ACM, November + December, volume IV.6, pp42-61.

[25] Berners-Lee, T. and Cailliau, R. and Luotonen, A. and Nielsen, H. and Secret, A. (1994). “The World Wide Web”. Communications of the ACM, 37 (8), pp 87-96.

[26] Lengel, J. and Collins, s. (1990). “HyperCard in Education: Perspective from the Field” in Ambron, S. and Hooper, K. Ed. (1990). Learning with Interactive Multimedia, Developing and Using Multimedia Tools in Education, pp 189-198.

[27] American National Standards Committee. (1982). “American National Dictionary for Information Processing Systems”. X3/TR-1-82.

[28] Forrester, T. (1987). “High-Tech Society”. Blackwell.

[29] Coelho, H. (1996). “Sonho e Razão. Ao lado do artificial”. Círculo de Leitores.

[30] Cooley, M. (1988). “Creativity, Skill and Human-Centered Systems” in Granzon, L. and Josefson, I. Eds. (1988). Knowledge, Skill and AI. Springler-Verlag.

[31] Barnatt, C. (1997). “Challenging Reality. In Search of the Future Organization”. Wiley.

[32] Wilson, M. (1997). “The Information Edge, successful management using information technology”. Pitman Publishing.

[33] Engelbart, D. (1963). “A Conceptual Framework for the Augmentation of Man’s Intellect” in Greif, I. Ed. (1988). Computer-Supported Cooperative Work: A Book of Readings. Morgan Kaufmann, pp 35-65.

[34] Rada, R. (1995). “Interactive Media”. Springler-Verlag.

[35] Swets, J. (1969). “Effectiveness of Information Retrieval Methods”. American Documentation, vol. 20, nº1, pp 72-89.

[36] Hansen, W. and Haas, C. (1988). “Reading and Writing With Computers: A Framework for Explaining Differences in Performance”. Communications of the ACM, vol 31, nº9, pp 1080-1089, September.

[37] Jul, S. and Furnas, G. (1997). “Navigation in Electronic Worlds”. Workshop Report. Workshop on Issues in Navigation in electronic Information Environments. CHI’97.

[38] McAleese, R. (1998). “Coming to Know: the role of the concept map - mirror, assistant, master?”. Euroconference 98. Aveiro, Portugal. 16-19 September.

[39] Bodker, S. (1989). “A Human Activity Approach to User Interfaces”. Human-Computer Interaction, 4, pp 171-195.

[40] Weir, H. (1996). “Digital education”. Digital Knowledge Conference. Toronto. February 6-7.

[41] Kahle, B. (1997). “Archiving the Internet”. Scientific American. March, 97 issue.

[42] Barners-Lee, T. (1996). “Collaboration on the Web”. DARPA IP&V meeting 9, October, (available at http://www.w3.org/pub/WWW/Talks/9610icv/all.htm).

[43] Aken, R. and Molinaro, M. (1995). “What I Really Want from the World Wide Web is… - How do we establish access to ever expanding resources?”. In Proceedings of 1995 CAUSE Annual Conference, pp 8.2.1-8.2.5.

[44] Nielson, J. (1996). “Inverted Pyramids in Cyberspace”. Alert Box, sun on-line magazine. June, (available at http://www.sun.com/columns/alertbox/9606.html).

[45] Barners-Lee, T. (1995). “Hypertext and our Collective Destiny”. Talk at the Bush Symposium, notes, (available at http://www.w3.org/pub/WWW/Talks/9510_Bush/Talk.html).

[46] Nielson, J. (1996). “Top Ten Mistakes in Web Design”. Alert Box, sun on-line magazine. May, (available at http://www.sun.com/columns/alertbox/9605.html).

[47] McKim, B. (1996). “Hints for a Successful Web Site”. M\S Database Marketing, (available at http://www.msdbm.com/hintsfor.htm).

[48] McKim, R. (1996). “How to Build a Better Web Site”. M\S Database Marketing, (available at http://www.msdbm.com/howto.htm).

[49] McKim, R. (1996). “Planning and Vision are Keys to Internet Success”. M\S Database Marketing, (available at http://www.msdbm.com/10_Mist.htm).

[50] December, J. (1998). “Web Development: Processes”. December Communications, (available at http://www.december.com/web/develop/processes.html).

[51] Korpela, J. (1998). “Lurching Toward Babel: HTML, CSS, and XML”. Computer magazine, July, Volume 13, number seven.

[52] Bosak, J. (1997). “XML, Java, and future of the Web”. Sun Microsystems, (available at http://sunsite.unc.edu/pub/sun-info/standards/xml/why/smlapps.html).

[53] Balasubramanian, V. (1994). “State of the art review on hypermedia issues and applications”. Rutgers University, New Jersey.

[54] Garshol, L. (1998). “An Introduction to XML”. (available at http://www.stud.ifi.uio.no/~larsga/download/xml/xml_eng.html)

[55] Freter, T. (1998). “XML: Document and Information Management”. Sun Microsystems.

[56] Raggett, D. and Lam, J. and Alexander, I. (1996). “HTML 3. Electronic publishing on the World Wide Web”. Addison-Wesley.

[57] Berners-Lee, T. and Masinter, T. and McCahill, M. (1994). “Uniform Resource Locators”. RFC 1738, CERN, October.

[58] Rose, M. (1993). “The Internet Message, closing the book with electronic mail”. Prentice Hall.

[59] Hamilton, M. (1996). “Java and the Shift to Net-Centric Computing”. Computer, IEEE, Computer Society. Vol.29 Nº8, August.

[60] Yourdon, E. (1996). “Java, the Web, and Software Development”. Computer, IEEE, Computer Society. Vol.29 Nº8, August.

[61] Gosling, J. and McGilton, H. (1995). “The Java Language Environment, A White Paper”. Sun Microsystems.

[62] W3C. (1998). “CGI:Common Gateway Interface”. World Wide Web Consortium (at http://www.w3c.org/CGI/).

[63] Lea, R. and Matsuda, K. and Miyashita, K. (1996). “Java for 3D and VRML Worlds”. New Riders.

[64] Gibson, W. (1984). “Neuromancer”. New York: Ace Books.

[65] Moulthrop, S. (1993). “Writing Cyberspace: Literacy in the Age of Simulacra”. In Wexelblat, Alan Ed. (1993). In Virtual Reality. Applications and Explorations: Academic Press, pp 77-90.

[66] Tomas, D. (1991). “Old Rituals for New Space: Rites de Passage and William Gibson's Cultural Model of Cyberspace” in Benedikt, M. ed. (1992). Cyberspace, first steps, Third printing: The MIT Press, pp 31-47.

[67] Benedik, M. (1991). “Cyberspace: Some Proposals”. Benedikt, M. ed., in (1992). Cyberspace, first steps. Third printing, The MIT Press, pp 119-224.

[68] Gouveia, L. (1998). “The NetLab experience. Moving the action to electronic learning environments”. In proceedings of BITE international conference, Maastricht, The Netherlands, 25-27 March, pp. 395-405.

[69] Benford, S. and Fahlén, L. (1993). “A Spatial Model on Interaction in Large Virtual Environments”. In proceedings of Third European Conference on CSCW. Italy. September.

[70] Ask, B. and Haugen. (1998). “Learning by doing - an Internet course on methods for ICT based ODL”. In proceedings of BITE international conference, Maastricht, The Netherlands, 25-27 March, pp. 164-173.

[71] Trefftz, H. (1996). “Virtual Classroom project”. Web pages at http://sigma.eafit.edu.co/~virtualc /introduction.html, captured in March, 23 1998.

[72] Rheingold, H. (1993). “Virtual Community”. Minerva. (also online at hhtp:// www.rheingold.com/vc/book/intro.html).

[73] Benford, S. and Greenhalgh, C. (1997). “Introducing Third Party Objects into the Spatial Model of Interaction”. Hughes, J. et al. Eds., in proceedings of the Fifth European Conference on Computer Supported Cooperative Work: Kluwer Academic Publishers, pp 189-204.

[74] Rodden, T. (1997). “Building a Virtual Campus. Workshop on CVE's in Higher Education - Virtual Campus”. Nottingham University, 1st July.

[75] Greif, I. (1988). “Overview”. Greif, I. Ed. In Computer-Supported Cooperative Work: A Book of Readings. Morgon Kaufmann Publishers, pp. 5-12.

[76] Agostini, A. and De Michelis, G. (1997). “Rethinking CSCW systems: the architecture of Milano”. in proceedings of the Fifth European Conference on Computer Supported Cooperative Work: Hughes, John et al. Kluwer Academic Publishers, pp 33-48.

[77] Ronchi, A. (1998). “Real virtuality: use of hypermedia and VR in the field of education and training”. In proceedings of BITE international conference, Maastricht, The Netherlands, 25-27 March, pp. 152-163.

[78] Checkland, P. (1997). “CSCW in context of IS: can reality match the rethoric?”. Invited Lecture in ECSCW’98. Lancaster University, England.

[79] Chorafas, D. and Steinamann, H. (1995). “Virtual Reality, practical applications in business and industry”. Prentice Hall.

[80] McGreevy, M. (1993). “Virtual Reality and Planetary Exploration”. In Wexelblat, A. Ed. (1993). In Virtual Reality. Applications and Explorations: Academic Press, 163-197.

[81] Harasim, L. et al. (1995). “Learning Networks”. The MIT Press.

[82] De Meuter, G. (1998). “Implementing Integral Training Strategies In Higher Education Didatic and Organisational Considerations”. In proceedings of BITE international conference, Maastricht, The Netherlands, 25-27 March, pp. 70-91.

[83] Argyle, M. (1991) “Cooperation: the basis of sociability”. Routledge, London.

[84] McConnell, D. (1994). “Implementing Computer Supported Cooperative Learning”. Kogan Page, London.

[85] Scherlis, W. and Kraut, R. (1996). “C-Space, collaboration information management”. IC&V Kick-off, USA, October.

[86] Slavin, R. E. (1990). “Cooperative learning: theory, research and practice”. Prentice-Hall.

[87] Araujo, R. and Dias, M. and Borges M. (1997). “A framework for the Classification of Computer Supported Collaborative Design Approaches”. III Cyted-RITOS International Workshop on Groupware. Madrid, Spain, October.

[88] Rodden, T. (1993). “Technological support for cooperation”. Diaper, D. and Colston, S. Eds. (1993). CSCW in Practice: na introduction and case studies: Springler Verlag.

[89] Benford, S. and Brown, C. and Reynard, G. and Greenhalgh, C. (1996). ”Shared spaces: transportation, artificiality and spatiality”. Proceedings of Computer Supported Cooperative Work' 96, pp 77-86.

[90] Zyda, M. et al. (1993). “The software Required for the Computer Generation of Virtual Environments”. Presence, Teleoperators and Virtual Environments, vol. 2, nº 2: MIT Press, Cambridge Massachusetts, pp 130-140.

[91] Brutzman, D. and Macedonia, M. and Zyda, M. (1995). “Internetworking Infrastructure Requirements for Virtual Environments”. VRML Symposium, SDSC, San Diego, California, December.

[92] Bullock, A. et al. (1997). “Building and Exploring CVEs”. Forsyth, J. et al. Eds., in Conference Supplement of the Fifth European Conference on Computer Supported Cooperative Work: Lancaster University, August, pp 15-16.

[93] Gouveia, L. (1998). “Digital support for teachers teaching. Current experience on using Internet facilities in virtual university environments”. Extended abstract accepted in ITET International Conference, Macau, Portugal, 20-22 May.

[94] Cadoz, C. (1996). “A Realidade Virtual”. BBCC. Instituto Piaget.

[95] IMO. (1995). “Virtual Reality the technology and its applications”. Working paper. Luxembourg.

[96] Isdale, J. (1993). “What is Virtual Reality? A Homebrew Introduction”. Isdale Engineering.

[97] Weets, G. Ed. (1993). “Preliminary Report on Virtual Environments”. CEC DG XIII C2, European Commission.

[98] Benford, S. and Bowers, J. and Fahlén, L. and Greenhalgh, C. and Snowdon, D. (1995). “User Embodiment in Collaborative Virtual Environments”. CHI’95 Proceedings.

[99] Billinghurst, M. and Weghorst, S. and Furness, T. (1997). “Shared Space: An Augmented Reality Approach for Computer Supported Collaborative work”. University of Washington.

[100] Billinghurst, M. and Weghorst, S. and Furness, T. (1997). “Wearable Computers for Three Dimensional CSCW”. University of Washington.

[101] Tennison, J. and Churchill, E. (1996). “Individual and Collaborative Information Retrieval in Virtual Environments”. University of Nottingham.

[102] Osberg, K. (1997). “A Teacher’s Guide to Developing Virtual Environments: VRRV Project Support”. HITL, University of Washington.

[103] Feiner, B. (1996). “Future Multimedia User Interfaces”. Multimedia Systemas. Springler-Verlag.

[104] Smith, G. (1996). “Cooperative Virtual Environments: lessons from 2D multi user interfaces”. CSEG Technical Report: CSEG/7/1996. Lancaster University.

[105] Ware, C. and Franck, G. (1994). “Viewing a Graph in a Virtual Reality Display is Three Times as Good as a 2D Diagram”. In proceedings of IEEE Conference on Visual Languages. St. Louis, Missouri, USA, pp. 182-183.

[106] Neves, N. and Silva, J. and Gonçalves, P. and Muchaxo, J. and Silva M. and Câmara, A. (1998). “Cognitive Spaces and Metaphors: A solution for Interacting with Spatial Data”. New University of Lisbon (available at http://gasa.dcea.fct.unl.pt/gasa/gasa98/papers/nelson/index.htm).

[107] Card, S. and Mackinley, J. and Ben Shneiderman. (1998). “Readings in Information Visualization”. Morgan Kaufman (to be published).

[108] Shneiderman, B. and Borkowski, E. and Alavi, M. and Norman, K. (1998).”Emergent Patterns of Teaching/Learning in Electronic Classrooms”. Work paper, University of Maryland, USA.

[109] Kommers, P. and Lenting, B. and Veer, C. (1996). “Telematic learning support and its potential for collaborative learning with new paradigms and conceptual mapping”. European conference on AI in Education. Gulbenkian, Lisbon, September.

[110] Gouveia, L. (1998). “Group assessment: alternative forms to evaluate student skills”. UFP Journal, nº2, vol. 2, May, pp 519-526.

[111] Macedonia, M. and Zyda, M. and Pratt, D. and Brutzman, D. and Barham, P. (1995). “Exploiting Reality with Multicast Groups: A Network Architecture for Large-scale Virtual Environments”. In proceedings of IEEE VRAIS, pp. 2-10.

[112] Kessler, G. and Hodges, L. (1996). “A Network Communication Protocol for Distributed Virtual Environment Systems”. In proceedings of IEEE VRAIS.

[113] Grudin, J. and Poltrock, S. (1997). “CSCW, Groupware and Workflow: Experiences, State of Art and Future Trends, tutorial 1”. ECSCW’97, The Fifth European Conference on Computer Supported Cooperative Work, Lancaster, UK, 7 September.

[114] Ramage, M. (1996). “On Cooperative Systems”. Personal web page. Lancaster University.

[115] Crow, D. and Parsowith, S. and Wise, B. (1997). “Students: The Evoution of CSCW – Past, Present and Future Developments”. SIGCHI Bulletin Vol. 29 No2, April.

[116] Twidale, M. and Rodden, T. and Sommerville, I. (1993). “Developing a tool to support collaborative dialogues and graphical representation of ideas”. Technical Report CSEG 7/93. Lancaster University.

[117] Schmidt, K. and Rodden, T. (1992). “Putting it all together: Requirements for a CSCW platform". Technical Report CSEG 9/92. Lancaster University.

[118] Maurer, F. (1996). “Computer Supported in Project Coordination”. In proceedings of the Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises, June 19-21, Stanford University. USA.

[119] Hughes, J. and King, V. and Rodden, T. and Andersen, H. (1994). "Moving out from the control room: ethnography in system design". Research Report CSCW/9/1994. Lancaster University.

[120] SYCOMT. (1996). "Systems Development and Co-operative Work: Methods & Techniques". Project Report for CSCW Symposium, 27-29 March.

[121] Plowman, L. and Rogers, Y. and Ramage, M. (1995). "What Are Workplace Studies For?". Technical Report CSEG/12/1995. Lancaster University.

[122] Araujo, R. and Dias, M. and Borges, M. (1997). "A Framework for the Classification of Computer Supported Collaborative Design Approaches". III Cyted-Ritos International workshop on Groupware. Madrid, Spain, October.

[123] Greenberg, S. (1998). "Real Time Distributed Collaboration". In Dasgupta, P. and Urban, J. Eds. Encyclopedia of Distributed Computing. Kluwer Academic Publishers.

[124] Kerckhove, D. (1996). "Webness". International Conference on The Future of Communication Formats, Ottawa, Canada, October.

[125] Wantz, L. and Miller, M. (1998). "Educational metadata in use". International Conference in World Wide Web. Australia, July.

[126] Chabert, A. and Grossman, E. and Jackson, L. and Pietrowicz, S. and Seguin, C. (1998). "Java Object-Sharing in Habanero". Communications of the ACM. June, Vol 41, number 6.

[127] Rodden, T. (1992). "Technological Support for Cooperation". CSCW Research Centre. Lancaster University.

[128] Rodden, T. (1992). "Supporting Cooperative Applications, position paper". Research Report CSEG/11/1992. Lancaster University.

[129] Smith, G. and Rodden, T. (1994). "Na Access Model for Shared Interfaces". Research Report CSCW/8/1994. Lancaster University.

[130] Chen, L. and Gaines, B. (1997). "Modeling and Supporting Virtual Cooperative Interaction Through the Web". In Sudweeks, F. and McLaughlin, M. and Rafaeli, S. Eds. (1997). Network and Netplay: virtual groups on the Internet.

[131] Cavalcanti, M. and Campos, M. and Blois, M. and Noya, R. (1996). "A Web Based Cooperative Environment: the InterConnect prototype". Internal Report. Universidade Federal do Rio de Janeiro, Brazil.

[132] Susaki, S. and Muramoto, T. (1998). "Information sharing system on the WWW with interactive communication". International Conference in World Wide Web. Australia, July.

[133] Dieberger, A. (1995). "Browsing the WWW by interacting with a textual virtual environment -- A framework for experimenting with navigational metaphors". Internal report, Georgia Institute of Technology, Atlanta, EUA.

[134] Lambert, P. and Walker, R. (1995). "Designing Collaborative WWW Learning Environments - the HENRE project". Asia-Pacific World Wide Web '95 Conference.

[135] Martinez, J. et al. (1995). "An Environment for Supporting Interactive Presentations to Distributed Audiences over the World Wide Web". CYTED International Workshop.

[136] Somers, P. and Rudman, C. and Stevens, C. (1997). "Designing Web Interfaces for Realtime Collaboration". Web conference proceedings at http://www.uswest.com/web-conference/proceedings/somers.html.

[137] Pehrson, B. and Gunningberg, P. and Pink, S. (1991). “MultiG - A Research Program on Distributed Multimedia Applications and Gigabit Networks. IEEE Network Magazine, December.

[138] Fahlén, L. (1991). “The MultiG TelePresence System”. SICS, Sweden.

[139] Marmolin, H. and Sundblad, Y. (1991). “The Collaborative Desktop: Interface and Functionalities”. IPLab, Sweden.

[140] Uselton, S. (1995). "Scientific Visualisation and Computational Science: Natural Partners". Talk at the American Association for the Advancement of Science Annual Meeting. Atlanta, EUA. February.

[141] Price, B. and Baecker, R. and Small, I. (1994). "A Principled Taxonomy of Software Visualisation". Journal of Visual Languages and Computing 4(3). Pp. 211-266.

[142] IC&V (1997). "Intelligent Collaboration & Visualisation". DARPA, available at http://ito.darpa.mil/research /icv/index.html.

[143] [143] Yu, C. (1995). "Visualisation Techniques of Different Dimensions". Available at http://seamonkey.ed.asu.edu/~behrens/asu/reports/compre/comp1.html.

[144] Eick, S. and Wills, G. (1991). "High Interaction Graphics". Bell Laboratories, available at http://www.bell-labs.com/user/gwills/ejor/Paper.html.

[145] Vroomen, L. (1998). "Information Visualization: An Overview". Draft report, available at http://www.crim.ca/~vroomen/writing/technical/reports/infovis.html

[146] Johnson-Laird, P. (1993). "The Computer and the Mind, an introduction to Cognitive Science". Second Edition. Fontana Press.

[147] Hearst, M. (1998). "Information Visualisation and presentation, introduction". SIMS 247, UC Berkeley.

[148] Turner, G. et al. (1997). "4D symbology for sensing and simulation". Army Research Laboratory.

[149] Andrews, K. (1997). "Information Visualisation Pointers". Graz University of Technology.

[150] Young, P. (1996). "Three Dimensional Information Visualisation". Computer Science Technical Report, No 12/96. University of Durham.

[151] Colebourne, A. and Mariani, J. and Rodden, T. and Twidale, M. (1994). "Populated informatin terrains: supporting the cooperative browsing of on-line information". Research report: CSCW/13/1994. Lancaster University.

[152] Benford, S. and Mariani, J. (1994). "Populated Information Terrains: Virtual Environments for Sharing Data". Research report: CSCW/4/1994. Lancaster University.

[153] Hamming, R. (1962). "Numerical Methods for Scientists and Engineers". McGraw-Hill.

Table of contents

Table of Figures