Application Design of Learning Grid in Computer-Mediated Communication

Duska ROSENBERG [a,1], Mirja LIEVONEN [a], Pedro CONTRERAS [b], Fionn MURTAGH [b], Guido KUEHN [c] and Ralf DOERNER [d]

[a] *I-COM Research Centre, Royal Holloway, University of London*

[b] *Computer Science, Royal Holloway, University of London*

[c] *Electronic Arts, Cologne*

[d] *Wiesbaden University of Applied Sciences*

Abstract. Developing e-Learning applications concerns issues of human communication and facilitating technology. One of the key research issues in Computer-Mediated Communication (CMC) is the participation of remote audience in a communicative activity. This is particularly important in learning contexts. In the two studies reported here, we discuss systems infrastructure by presenting the concept of the Virtual Observatory through the AstroGrid project. We explore how such a Grid can be used in the future as an e-Learning service platform and as a tool for wider audiences that require access to documents and similar information resources. However, an integrated e-Learning environment has to provide access to people (teachers and students) as well. In order to explore how the two kinds of facility may be integrated, we discuss the design of communication tools that provide access to both people and information. We also present Augmented Reality (AR) applications that facilitate teacher interaction with remote student audience by increasing the interactivity of the virtual classroom. Studies of virtual classrooms have identified limitations of computer-mediated learning environments since they do not provide sufficient contextual information to support communication. The virtual information space is critically dependent on the visualization aspects of the user interface. This has been designed with additional functionality to enable the lecturer to navigate the remote information space.

Keywords. e-Learning, grid, visualization, augmented reality.

Introduction

Developing e-Learning environments requires consideration of both technical and human communication aspects. First, what kind of infrastructure is suitable for e-Learning is a wide-ranging issue of systems architecture. Grid technologies provide access points to the web-based communication tools that are needed for teachers and learners to interactively manage the learning content, such as giving feedback, participating in chat discussions and contributing to the news.

From the perspective of human communication, these facilities support indirect communication where participants use the facilities in order to jointly write documents, create news items and build communities that share the same interests and concerns. In

[1] Corresponding Author: I-COM Research Centre, Royal Holloway, University of London, Egham, Surrey TW20 0EX, United Kingdom; E-mail: d.rosenberg@rhul.ac.uk.

addition to this, e-Learning environments should support direct communication by providing facilities for conversations in the virtual classroom. Traditionally the technologies such as video-conferencing, virtual reality and other facilities for computer-mediated communication have been developed independently from web-based communication tools. In this chapter we attempt to bring the two together by exploring design issues of e-Learning environments where video-conferencing enhances the range of communication tools originally provided by the AstroGrid platform. In particular, we focus on the user interface to the integrated Learning Grid portal and discuss what kind of interface design is suitable in this context.

One of the key research issues in Computer-mediated Communication (CMC) concerns the participation of a remote audience in a communicative activity and the associated use of informational resources to support conversations in the virtual classroom. This is particularly important in learning contexts, as studies of virtual classrooms have identified strong tendencies to treat remote students as observers, rather than active participants. The key design issue of the integrated Learning Grid portal is thus to support both direct and indirect communication primarily by providing a user interface that appropriately represents people and information required for learning to take place.

In this chapter, we discuss e-Learning environments and their development first by describing two ongoing projects; AstroGrid that focuses on software architecture, and Augmented Reality that concentrates on the user interface to e-Learning applications. We then discuss usability issues and the experimental design that we have developed in order to evaluate the impact of these applications on teacher-student communication (both direct and indirect) in an integrated e-Learning environment.

1. Requirements for e-Learning environments

1.1. Continuous integration and collaborative work in AstroGrid

The AstroGrid [1] development process is an open collaboration between researchers and technologists. To allow these people to work in partnership effectively, a range of web-based tools is required. In such a collaborative software project there are different obstacles to overcome before the collaborative development can become effective. Firstly, good communication is essential in many aspects. Developers need to be aware of information regarding the project as a whole, information regarding specific sections, and they need to be able to directly communicate with other developers. The latter is of high importance in the AstroGrid case.

Developers working within the project are assigned tasks in so-called development cycles, which are specified by astronomers through the definition of science cases. Developers will work on a certain task or project module for a few months before being moved to another area. In some cases more than one cycle or iteration is necessary to achieve a goal. In any case task assignment is under constant review by the project leaders, with a view towards reallocating human resources when and where they are needed.

The benefit of an approach like this is a highly cross-trained development team. For example in the case of a member’s absence, another developer who has previously worked in that area can be assigned to the task. The fact that, at some point, they would have worked in the particular area means they can quickly re-integrate themselves into the development team for the particular project modules. However, an adequate facility for communication must be in place for developers to be able to exchange ideas and to make and to respond to queries, so that the development process is as efficient as possible.

One important issue in relation to this cyclic development process is development by second parties. As well as providing communication facilities there are other ways to ensure that the collaboration is as effective as possible. Standards play an important role in facilitating code development by second and third parties. Standard forms of software design and standard coding styles all play a part in reducing development time.

1.2. Communication tool

To facilitate good communication practice, any person with expertise or simply an interest in the Virtual Observatory [2] concept, Grid technologies or e-Science is free to post or comment upon news articles, to participate in the forum exchanges or to post documents making use of the AstroGrid portal. The portal provides an access point to the various communication tools available. The **Wiki** pages provide support for relevant documents posting. Wiki is a leading-edge, web-based collaboration platform targeting the corporate Intranet world. TWiki [3] fosters information flow within an organization.

The groups deal with site-related topics, project-specific topics and general areas such as virtual organizations and Grids. A news section is also available to allow developers to be kept up to date with various information about articles posted, items of **news**, events and polls. A central portal providing access to the various communication platforms is essential to effective collaboration. There is no confusion over how to contact other members as all contacts are made through the use of one central site. Further to these web-based community-oriented communication tools, one-to-one contact is necessary in order to ensure that developers can carry out their tasks efficiently.

For example in the case of second party development, the ability to contact a previous developer to query some aspect of the work greatly reduces re-development time. To facilitate the necessary direct communications between project members, project contracted people keep close contact through **e-mail, telephone conferences, chat** programs and **regular meetings**. An extension to these facilities that is explored in this chapter concerns the use of video-conferencing enhanced with Augmented Reality applications that allow simultaneous access to people and documents they are working on. This would provide a richer, more effective and more natural channel for direct communication, thus making it possible for users to jointly author or edit the documents and solve problems in virtual meetings as well.

1.2.1. Wiki

AstroGrid's Wiki pages (http://wiki.astrogrid.org) is a web site that allows the registered user to change the pages on a browser and to add their own pages. Pages can be formatted using either simple Wiki formatting marks (like *this* to make this) or the full range of HTML markup tags. The site includes help pages, a tutorial and an experimental Wiki where users can try out adding pages, comments and other kinds of contribution.

1.2.2. Forum

The AstroGrid forum pages provide a number of grouped discussion areas. The groups deal with site-related topics, project-specific topics and general areas such as Virtual Observatories (VO) and Grids. They can browse the forums and, if registered, add comments or new topics for discussion.

1.2.3. News

AstroGrid's news pages (http://www2.astrogrid.org/news) are the central part of the AstroGrid site. Articles are posted here, as well as items of news, events and polls. Any registered user can add to any of these. The item will be checked by one of the administrators and then released to the site. Users can also comment on most items. Comments can be viewed in nested, threaded or flat form.

1.2.4. Content Management System

A content management system (CMS) is a web application designed to make it easieer for non-technical users to add, edit and manage a website. Some of the most important characteristics of CMS systems are to:

- automatically generate navigation elements
- make content searchable and indexable
- keep track of users, their permissions and security settings.

AstroGrid-2 uses Plone (http://plone.org/) as CMS, but there are several others available, with implementations in a wide area of technologies, such as Java, PHP, C++, Perl, Phyton, ASP, just to name a few.

1.2.5. Other tools

A list of further available tools is presented below.

- e-mail and e-mail lists. This is essential for the day–to–day work
- Messaging. Chat rooms and messaging programs can be important when communicating with other developers. AstroGrid uses the Jabber protocol, which allows different clients to connect when registered
- Telephone. Teleconferencing is carried out often in AstroGrid
- Meetings. This includes specific working group meetings as well as conferences.

1.3. Programming tools and languages

1.3.1. Coding standards and Java

Code integration is tackled using Current Version System [4] to store, modify and keep track of code changes. This has various uses in software development practice helping returning developers to identify and understand changes that have been made since they last worked on a particular project area. JUnit [5] Test is used to prove code integrity and ensure quality of service. JUnit is a regression-testing framework for code made with Java. Usually a unit test exercises some particular method in a particular context in order to prove that a specific piece of code does what it is supposed to do. Code bugs are tracked using Bugzilla [6], a "Defect Tracking System" or "Bug-Tracking System". Defect Tracking Systems support individuals or groups of developers by keeping track effectively of outstanding bugs in their software. Once an error, misbehaviour or an unexpected answer has been detected, this will be described and assigned to a developer in the form of a ticket that contains all the information related to the bug.

To provide standard coding practices a number of tools are used in the AstroGrid project. A range of free Integrated Development Environment (IDE) tools such as Eclipse [7] and JBuilder Foundation are used during the development process. These, in conjunction with code design standards (e.g. UML), are needed to establish the basis on which to allow different people in different places to modify each others' code easily, the philosophy being that if everybody is using the same tools to build a product, the components of the product can be more easily modified or enhanced.

The main programming language used in AstroGrid is Java. Different standards such as UML, XML and Web Services are used for the process design to maintain consistency. When coding in Java a standard is used, which allows different people to understand the work of each other, and maintain coding style and consistency. This leads to a cleaner and easier coding process. AstroGrid code guideline standards are described in Vermeulen et al. [8], but a good set of standards can be found easily on the Internet.

1.3.2. Documentation

Code management and documentation is addressed mainly through the use of standard Java Docs and Maven [9]. This is a Java project management and project comprehension tool. It is based on the concept of a project object model (POM) where all the Maven objects are a result of a well-defined model. Builds, documentation, source metrics, and source cross-references are all controlled by the POM. Maven aims to make the developer's life easier by providing a well-defined project structure, well-defined development processes to follow and a coherent body of documentation that keeps developers aware of what is happening within the project.

Maven alleviates a lot of what most developers consider a problem. This is essential in projects where there are not many people dedicated to the task of documenting and spreading the critical information about the project, which is necessary in order to dedicate resources to other critical tasks such as coding and code testing.

1.4. File access and security

One issue that has not been included in the above section is security and the identification of information that can be publicly accessible. Because AstroGrid is an open project, almost every document is publicly accessible through the Internet. One exception is the code, as there are restrictions in place as to who is authorised to upload and to integrate code. Here SSH [10] protocol is used to allow secure communication between developers and the server repository.

Though remote login is the primary use of SSH, the protocol can also be used as a general-purpose cryptographic tunnel, capable of copying files, encrypting e-mail connections, and triggering remote execution of programs. Currently AstroGrid uses

SSH Version 2, which operates over TCP. In its simplest mode of operation, it connects to a server, negotiates a shared secret key, and then begins encrypting the session. A username and password are passed over the encrypted session and, if authenticated, the server starts a command shell over the encrypted session.

1.4.1. Version Control System

Version control system software is a key technology when sharing code between programmers. Some important advantages are listed by Thomas and Hunt [11]:

- It gives to the project the ability to undo the code to previous versions
- It allows multiple developers to work on the same code base in a controlled manner
- It keeps a record of the changes made over time
- It support multiple software releases at the same time so the development process can continue.

The most widely used version control systems are Subversion [12] and the Concurrent Version System (CVS). AstroGrid uses CVS to manage its code. Version control system has named its processes with a common vocabulary. Some of the most important terms are the following:

- **Repository:** This is where the files are stored, often on a server.
- **Working copy:** This is the local copy of files from a repository, at a specific time or revision. All work done to the files in a repository is done to a “local” working copy.
- **Check-out:** This creates a local working copy from the repository. Either a revision is specified; a module, or the latest code is used.
- **Commit:** This happens when a copy of the changes made to the working “local” copy is written to the repository in the server side.
- **Update:** This merges the changes that have been made in the repository (e.g. by other people) into the local working copy.
- **Module:** This is a name given to a project, or project part in the repository, which can also be a branch. When checking out, a module name can be specified, and doing so simplifies the development process in a large project through support of small modules.
- **Branch:** A set of files may be branched at a point in time so that, from that time forward, two copies of those files may be developed at different speeds and in different ways independently of each other.
- **Merge:** This brings together two sets of changes to a file or set of files into a unified revision of that file or files.
- **Tag:** This refers to an important snapshot in time, consistent across many files. These files at that point may all be tagged with a user-friendly, meaningful name or revision number. This is relevant when a specific tagged version may be needed.
- **Conflict:** This occurs when two changes are made by different parties to the same document or place within a document. Since the software may not be

intelligent enough to decide which change is "correct", a user is required to resolve the conflict.

The repository is usually created in a server. In the CVS case the repository can be accessed using the *Pserver* or *external* techniques. In Pserver mode, CVS runs a server process on the repository machine, and all clients connect to it. Pserver mode has some advantages:

- It is relatively simple to set up.
- It can enforce read-only users.
- It supports anonymous access.

As mentioned above, the AstroGrid is a central portal that provides access to the various communication platforms and in this way it fosters information flow between users in different teams, groups and sections of the virtual organization. It is therefore essential not only to effective collaboration, but also to learning in an interactive setting. In a real-life learning environment, group contact, as well as one-to-one contact are necessary in order to ensure that users can carry out their tasks efficiently.

To facilitate the necessary direct communications between project members, project contracted personnel keep close contact through **e-mail, telephone conferences, chat** programs and **regular meetings**. In the section that follows, the support for learning through interaction in virtual meetings is described with the aim of identifying the requirements for a user interface to the central portal.

1.4.2. AstroGrid architecture

In concordance with the construction of the VO (Virtual Observatory), AstroGrid has a modular architecture [13], open to all contributions from data, services or resources. The following modules are present in AstroGrid:

- **Portal:** the portal is a server-based component, which provides an interface for accessing services in the VO. In AstroGrid all components that interact with the users will do so through a Portlet. A portlet gives a modular and flexible layer. Any developer is able to add his/her own functionality by wrapping it on a portlet.
- **Community:** this module allows a group to construct an online community. A resource centre can then assign permission to use its resources to one or more groups within a community instead of having to name the individuals themselves. Within a community, the administrator of the community can assign rights to individuals and groups, including the right to add members and create groups.
- **AstroPass:** this is a central server that stores users' credentials. Once permission has been assigned to a user, he/she decides how much information of its profile is passed to other VO portals.
- **Workflow:** this enables the construction of complex tasks such as building queries and data analysis, upload/download of data and rendering the output in a different format such as tables or images.

- **Registry:** this contains metadata descriptive information about resources available, which is based on IVOA standards. A resource can be a data set, web service, service, information on other registries, etc.
- **Common execution architecture:** this concept – also called by the initials CEA – is an abstraction of application components and the necessary parameters to run it.
- **Astronomical tools:** a number of essential astronomical tools such as object catalogue builder SExtractor and photometric redshift analyzer HyperZ (which are freely available) are incorporated into AstroGrid through a portal wrapper. Some of the tools currently included are: AstroScope, Helioscope, Aladin, and TopCat.
- **MySpace:** this defines a virtual space to allocate both temporal and long-term data, such as data sets generated by queries submitted to databases. MySpace is not necessarily in a local repository, but it will interact with the user as easily as if it were on a local machine.
- **Authorization/Authentication:** this is the component in charge of identification and granting of access to users, as well as maintaining security in AstroGrid.
- **Grid middleware**: this allows AstroGrid to integrate different astronomical data centers and to share resources in a coordinated way.
- **Data sets:** data is allocated in a distributed way in different data centres, across the United Kingdom in AstroGrid's case, and across the globe once the Virtual Observatory alliance will be fully working.

On the basis of these modules a number of tools (as mentioned above) are available to the end user. The figure 1 shows a screenshot of workbench data discovery tools.

- **AstroScope**: this allows positioning an object in the sky along with a region. As a query is submitted a process is started looking up various catalogue and image servers, asking them for data based around the query. If results are found then information is displayed in a graphical form on the screen allowing the user to surf the result in the form of various nodes. By default objects are seen in a "radial" form, requiring a "click of the mouse" to browse up and down the various nodes. Another option is the "Hyperbolic" view which shows everything in a tree state, where by a click of the mouse the system re-

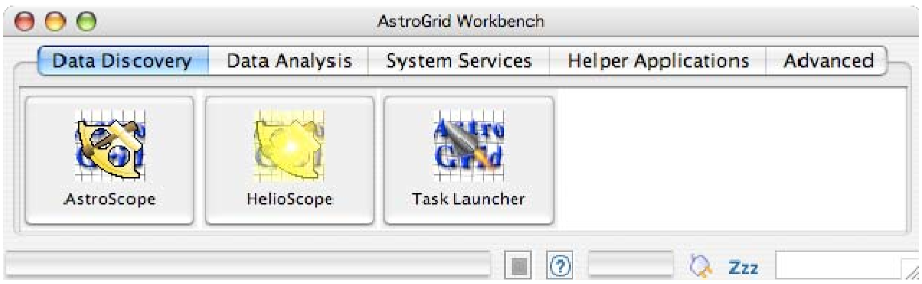

Figure 1. AstroGrid WorkBench data discovery.

centres the selected node. The user may then select a particular object to have the data (including images) saved to MySpace or their computer.

- **HelioScope**: this tool allows to query archives of images, spectra and catalogue data around a given position, visualize the results and download data files either to a local machine or to a storage space on the AstroGrid storage system MySpace.
- **Task launcher**: this executes a single task on the AstroGrid system. A task can be either querying an archive for data or running a tool that, for example, operates on data files or runs a model.

As shown in Figure 1 a number of additional user interfaces are also available (e.g. Data Analysis, System Services, Helper Application and Advanced). The relevant point here is that AstroGrid tools allow us to visualize and to interact within the context of Computer-mediated Communication applications.

1.4.3. User interface

Augmented Reality (AR) applications were originally developed in order to facilitate teacher interaction with remote student audience. The working assumption was that improving the information space of each participant will increase the interactive potential of the virtual classroom. The virtual information space is critically dependent on the visualization aspects of the user interface, which has been designed with additional functionality – to enable the lecturer to navigate the remote information space.

This is achieved by AR applications that are capable of integrating the video images of the remote audience with virtual pointers using as input technology a game console controller that allows performing natural pointing gestures. This enables the lecturer to navigate the remote information space in order to highlight individual students, thus “inviting” them to take the floor, or to use the pointer for identifying remote objects to focus audience attention.

Usability experiments have shown that such pointing helps people to naturally identify participants and establish the topic of conversation. Pointing is normally defined as a form of “deictic reference” that emphasizes a particular feature of the context in order to facilitate mutual understanding and the creation of the common ground amongst participants. Research is in progress and focuses on experiment design to investigate the usability of the hybrid interaction space, notably how visualizations can bridge the gap between the physical and virtual information space.

Use of AR in making communication for collaborative work more effective has been studied in laboratory conditions where the focus was on subject responses to different AR representations on the screen. However, in order to bring the AR interface to the real-life classroom we need to address the technology platform issues – that is, what configuration of technologies will be required to make this a learning facility. Issues of privacy also need to be addressed, not only with respect to access to information but also the visibility of people on the screen. AR applications allow for different degrees of focus on people and information, thus enabling a richer set of “privacy” setting.

2. Scenarios of Use in e-Learning Environments

We consider e-Learning as use of any electronic device to assist the education or training process, taking advantage of the Internet or any other communication channel to connect other devices to deliver information and knowledge.

The Virtual Observatory presents big challenges for the e-Learning community; the Virtual Observatory is expected to provide a data-grid platform for astronomers and the scientific community. But it can also provide an opportunity for students to experience grid computing in a real-case scenario. Students will be able to implement experiments in areas such as image processing, algorithms and data mining in computer science related areas, just to name a few.

But e-Learning does not stop there: it will be possible for e-Learners to use this platform to implement experiments or to investigate theories. The most interesting aspect would be the interaction of these individuals doing work as a group driven by common interest. Just as research projects such as AstroGrid work as a collaboration of individual researchers, students can re-enact this by working in interdisciplinary groups, using the platform to learn to effectively share individual knowledge and expertise.

This scenario, however, needs adequate tools to coordinate, support and monitor such virtual groups. A starting point is to take Open Source software to generate an adequate bundle of software that will enable students to organise such a group. The scenario presented above is not just a challenge for teachers and students: it also presents a challenge for the scientist working in today's Virtual Observatory.

Questions such as the following are on the agenda:

- What kind of service would we like to offer to e-Learners? The findings of the AR project suggest that the key issue we need to address is how interactive the e-Learning environment should be.
- How are we going to present such information in a friendly, open way? The findings of the AR project suggest that an interactive learning environment should represent information about both people and the documents they work with in an integrated 'interaction space'.
- How will effectiveness and efficiency of VO e-Learning systems be evaluated? So far, the findings of the AR project suggest that usability experimentation may provide the basic framework for identifying the critical features of the interaction space in support of effective collaborative learning.

In summary, the key issues that need to be addressed concern the capability of the architectures of today to incorporate future e-Learning schemes. Essentially all Virtual Observatories are based on open standards such as XML and Web Services. This makes the architecture transparent for incorporating customised plug-ins or extensions in the case of designing e-Learning modules. The problem we find here, and must address, is that VO architectures can reach very complicated states, and the more complicated this is the more difficult it will be to incorporate additional modules that can respond adequately to the learning process.

As our starting point we can consider Gilly Salmon's model for understanding learning via CMC [14] for implementing e-Learning modules that can be on the top of AstroGrid architecture. This model, shown in **Figure 2** is derived from analysis of

Computer Mediated Communication and it has become established as a course design tool. Salmon presents a five-layer process leading to knowledge construction.

The advantage presented by this model is that it is rather close to the AstroGrid philosophy, since this approach is not formally but intrinsically related to the way that AstroGrid is developing today. Also it is a non-exclusive model, for example to ensure quality of services. Learning via the CMC model can interact with Allison's [15] layers of distributed learning environments.

The Salmon model helps to understand the kind of service that we would like to offer to potential e-Learners. In a more concrete scenario we can consider the implementation of the Intelligent Web Teacher Platform (IWT) as described by Capuano et al. [16]. IWT is a distributed learning platform, which offers external plug-in connectors that can be designed specifically to connect AstroGrid Portal. Since AstroGrid supports special designed portlets to access its resources, IWT presents a potential solution that facilitates the creation of an e-Learning environment.

The effectiveness of such an e-Learning environment has been evaluated in usability experiments focused on the interactive features of the distributed learning setting. Several usability issues of the interface design for e-Learning applications were addressed when testing an Augmented Reality application. AR technologies were used to manipulate the video stream with a game controller as an input device (Wii™ Remote). The controller makes it possible to move visual representations of a pointer in 3D (up-down, left-right, back-forth) and in this way it was possible to augment the video with the visual pointer representation. Simple shapes such as a dot, a circle, an arrow, a highlighted area were used to point to people and objects on the screen.

The Wii™ game controller was connected to a PC running Windows operating system via Bluetooth. In order to calculate the target pointing position on the screen, the Wii™game console uses a sensor bar containing two IR light sources. We have replaced the sensor bar with our own hardware using infrared LEDs, which were placed on either side of the target display. Tacking these beacons in the sensors' view filed, the Wii™remote processes the captured images from the PixArtIR chip and sends the minimum information that is required to calculate the target position.

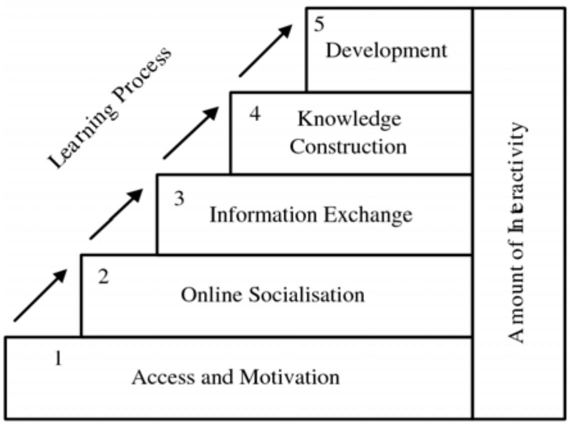

Figure 2. Model for understanding learning via CMC.

The software used to access the information from the game controller was GlovePIE (Glove Programmable Input Emulator). This provides a basic scripting language for mapping events from different devices to mouse and keyboard events. For implementing AR functionality, we used the OSGART library which extends the OpenSceneGraph framework with the functionality provided by ARToolkit. The visual representations of our pointer have been realized by writing a GLSL shader and interiting from the OSGART xlass GenericVidoeShader.

The developed prototype application shows smooth runtime behaviour, and there were no difficulties meeting real-time constraints. There can, however, be delays due to the distribution of the augmented video stream by the videoconferencing application (such as the commercial Polycom system). In some settings this delay can cause disruption in user communication and we have overcome this difficulty to some extent, by providing an additional monitor where users can see both the remote audience and the view of themselves as represented on the remote screen.

Our test setting was a simulation of a videoconference, where both sites had the two displays, one representing an augmented video stream from the participants at the remote site, and the other from the local site. We ran several test sessions with students and members of staff where the participants had to jointly carry out tasks, such as to decide which room of the floor plan shown at the remote site they would prefer as their office, or discussing where the problem points for pedestrians were on the road shown on a map hanging at the remote site, and making a group decision after a discussion. Three series of tests in addition to a pilot session were run, each session comprising 4-5 people. The tests were designed so that, in order on carry out the tasks, people had to rely on deictic gestures.

In order to support their communication over the video link, a specific pointer controller was used to facilitate the performance of deictic gestures. In our test setting, the camera shooting the local view to the remote site was above the display where the video stream from the remote site was represented. In the videoconferencing session, it seemed as if the local end participants were looking at the people at the remote site and vice versa – which is close to natural communication, and obviously beneficial in videoconferencing. In order to link the origin of pointing, that is, who was pointing, what was pointed at, people had to follow both screens.

This camera position gave us a good view to follow the back-and-forth gaze direction between the two displays when people kept track of possible pointing represented at the adjacent display. The two perspectives at both ends provided both of the groups with live video stream that enabled them to integrate the origo of pointing (the person using the pointer controller), with the reference of pointing (the person or the object pointed at), and thus overcome much of the fragmentation normally encountered in computer mediated communication.

Users could hold the controller in one hand in the same way as any pointing stick while they perform natural deictic gestures (pointing). The system tracks the movements and supports the collaboration over distance by providing a common context through visualizing the semantics of pointing gestures.

Multiple options of representations for pointing were mapped on the pointer controller such as highlighting an area when indicating a person, circles in three different colours, a smaller size dot and an arrow that could be turned in relevant direction and used as an alarm. In order to find out whether there are any preferences by the users between different visual representations, tests need to be run with a larger number of users than we had initially.

The way people seemed to adapt to a technical context novel for them and how they adopted a novel way of working was unexpectedly quick. The outcome of the usability test tends to suggest that increasing the shared information space by providing visual cues improves communication over distance. The sessions were video-recorded for analysis and the participants were interviewed after the session.

Even in our test situation it turned out that people intuitively tend to point at an object at the remote site, though realizing instantly that it does not work, since the remote participants have no clue what they are pointing at. Because pointing has a powerful role in normal collocated communication and collaboration, our motivation was to find ways of improving gestural communication in videoconferencing situations. Pointing and gestures are also typical of teaching and learning situations: lecturers often point when explaining something for the class, and in any hands-on activities the role of pointing and manipulating objects is crucial.

We found out in our usability tests that the participants quite effortlessly embraced the basic functionalities of pointing with the pointer controller at objects at the remote site, fully concentrating on the task, as if they were not dealing with anything new. Secondly, they adapted to the situation where they had to follow the two displays in order to keep track on what was going on as to gestural references.

Even in a situation where the person holding the pointer controller at the local end and a person at the remote end had to coordinate their actions while marking something on a map hanging at the remote site, they managed to do it without excessive procedural utterances: the remote person turned to look at the display to check the position of arrow representing the reference of pointing on the display, and then he marked it by pen on the real map behind him.

Their coordination was surprisingly smooth taking into consideration what a complex spatial navigation was in question. It seemed that pointing at an object at the remote site was no more difficult than pointing any object with a pen, and there did not seem to be any problems of precision either. These preliminary findings encourage us to carry on our work on exploring spatial navigation in the technology mediated work settings, in particular in videoconferencing and e-Learning contexts.

Pointing at *people* was another issue, as it is the case in human communication in general. First, when introducing people at the remote site, a person in question was highlighted by an AR representation. This obviously worked well from the *indicative* point of view, but the participants found it unpleasant if they were in the spotlight for a long time. The learning from such experience is to highlight the person only momentarily, as if calling them to take the floor.

This interpretation some participants gave as the communicative meaning of being pointed at: it was a call to say something. Pointing is a sensitive issue in human communication in general, and that became clear in our usability tests as well. First, a 'heavy-looking' representation such as a thick red arrow flying toward a user's face may evoke feelings as if an object be falling on the person; therefore the AR-representations should not evoke any feelings of concrete threat.

Once the communicative function of pointing is completed, the pointer representation becomes an immediate disturbance. If for instance an arrow representation of the pointer approached the head of the person, she would try to avoid it. Pointing and their representations have to obey the same social norms of appropriateness and etiquette as natural communication; for instance it is important to avoid pointing at sensitive parts of the body to avoid embarrassing situations and awkward feelings.

Our usability tests also showed the power of imitation as a strategy of learning. In the first usability test, we asked a participant to use the control after he had been given instructions and time to practice for about 10 minutes. It turned out in the test situation that managing both after such a short briefing was an excessive cognitive load for the person as he seemed to under-perform in his main task of chairing the session. The test design was then modified so that the designer himself was in the role of the chair, controlling the pointer and thus providing best practice to follow. This design was successful: it helped us find out how people coped with AR-information in carrying out joint tasks.

Another, and even more interesting finding was that the person sitting next to the chair soon learned from the chair how to utilize the pointer and started to use it when relevant to his/her contribution. Such learning did not take much time: one participant for instance quite naturally grabbed the pointer from the chair's hand after having used it only once before, when wanting to point something next time. The more familiar the functionality became in the course of the test tasks, the less attention people paid to the tools. They were concentrating on the contents of the task and were immersed in their shared information space, communicating effortlessly and effectively. Procedural utterances such as 'look at the display' were no more needed.

Using Augmented Reality made it possible for us to experiment also with markers and annotation of remote objects. In the beginning of the session, information about the names and affiliations of the participants was inserted and mapped to the markers that the participants wore during the test session. This gave the chair an option to check the name of the person and his affiliation during the session. Such a functionality might be beneficial for instance during a lecture or in a conference where the lecturer / chair might want to call a person by name instead of a long description of a-person-in-the third-row-with-a-green-cardigan.

There are also situations where it may feel embarrassing for the chair not to remember the name of a participant, and were such additional information readily available, he would save his face without needing to reveal that he has forgotten the name. That would, however, require an additional private screen as a prerequisite. If there are several people in a session, in particular in an international context, it is often difficult for the chair to know how to pronounce the name of some participants. Turning on the marker functionality would in such a situation help all participants in case the pronunciation of the name fails badly.

Augmented Reality turned out to be helpful also from the point of view of decision making: in the course of the conversation when people discussed problem points along the nearby road, represented on the map at the remote site, it was possible for the chair to take and save snapshots of the points mentioned during the discussion. When it was time to make a joint decision which of the points the group found as the most difficult, he could retrieve each of the snapshots as a reminder. The functionality seemed to support the process of making a group decision, and at least gave us an encouraging view of using AR-techniques in videoconferencing as a support of decision making as well.

The usability tests run in summer 2007 were designed for one-way pointing. In normal communication and collaboration situations, there are equal options of pointing. Therefore, we carry on our research and focus on two-way pointing in a setting that provides a pointer controller both for the local and from the remote site. This gives us a chance to examine strategies of spatial navigation and negotiation of space as well.

A tentative conclusion from the usability experiments is therefore that the user interface based on the spatial metaphor may provide an appropriate enhancement for Learning Grid. Its implementation using AR applications may form a part of the technology configuration that includes the grid infrastructure, the AstroGrid portal and the communication tools in an integrated platform. Such a platform would provide a powerful resource to support e-Learning. In the section that follows we discuss some usability issues arising from our attempt to design and implement a novel user interface that can appropriately handle the complexity of the Learning Grid applications.

3. Discussion of a Unified Conceptual Framework

A unified conceptual framework covering both human communication and technical issues was created to aid the work of developers and designers of e-Learning environments. Even shared terminology requires particular attention, as same words tend to be used in different ways depending on discourse in question. When for instance the term ‘information space’ is discussed in a technical context, the focus is on the physical features of space, whereas in human communication we are dealing with perceived and conceived space.

Navigation not only concerns a particular physical perspective or change of place in the physical space but also change in the contents of mind such as changing intention or meaning. It would therefore be helpful to make a distinction between these two types of space, physical and cognitive, for instance using *information space* when the physical aspects of space are discussed, and *infoscape* when dealing with human perception and interpretation of space.

Computer mediated communication unavoidably fragments natural communication into streams of sound and image. Multimodality of human communication therefore poses specific requirements for developing e-Learning environments. In order to capture the differences between natural and computer mediated communication, we need a conceptual framework robust enough to cover modality particularly well. For instance keeping track on what is going on – including signal failure or misunderstanding – relies heavily on multimodal resources.

The way humans naturally navigate space includes effortless and continuous switching of communication mode: for instance turning the head in the direction of the object to focus attention; giving feedback by establishing gaze contact, or nodding, pointing to a shared object or manipulating it, or uttering, drawing or writing something as response; establishing common ground by accessing the same room, or addressing a person by phone; expressing hesitation by changing body posture during discourse or intonation or delay during a speech. In collocated situation we are normally aware of what is also peripherally going on, for instance when a person enters the room or leaves it, whereas in videoconferencing such peripheral awareness is challenged as we only see what the camera focuses on.

In computer mediated communication providing feedback relies on few channels only, such as visual, auditory or at times haptic output. From the collaboration or communication point of view, deictic references have a paramount role in the spatial ‘choreography’ of communication as pointing and gaze direction are heavily used in natural communication. The location of the human body as the origin of experience and action is therefore a key issues in the design of tools and interfaces for computer mediated collaboration.

The position of the observer in his environment constrains the scope of information available for him/her in the physical and cognitive sense, but his/her cognitive ‘position’, i.e. history of experiences is the origin of motivation where to focus attention. The sensory array of a human body and its functionalities constrain what is possible as information available to the observer to be perceived. At the level of interpersonal communication, mutual understanding is the crucial thing. Without such ‘common ground’ human communication would simply fail.

A spatial access is a technically critical precondition to establish a common ground. Another critical precondition is finding a shared set of symbols in order to reach a flow of communication. At the interpersonal level, different communication modes and their role in establishing the common ground is an important issue. As to the interactions space, people also use various strategies to demarcate their mutual interaction space by guarding the confidentiality and privacy by leaving people non-relevant to the contents of communication out of their interaction space.

Cognitive level again is crucial for personal orientation, motivation, intentions and strategies. Each human perspective onto the world is a unique continuity of personal experiences and identification. Personal memory is a precondition for the process where new encounters are interpreted against previous personal experiences and included to maintain personal identity in the course of experiences. Therefore, all four levels and their interrelations are relevant for understanding human communication.

In order to cover technical and communication issues alike, the conceptual framework needs to embrace all relevant components of the human-human interface in natural and technology mediated settings, ranging from physical to cognitive phenomena, from individual perspective to multi-perspective, and from human to artefact as a node of coordination. Using a spatial approach may work well in order to interrelate/interface relevant issues/components as it allows the articulation of four different levels relevant to computer mediated communication and collaboration [17].

1. physical level - how events relate to each other
2. sensory level - how information is available to the observer in his/her location, i.e. establishing the origo of what Buehler called I-Here-Now-Origo [18]
3. level of interpersonal communication - how common ground is established and maintained among participants of communication and collaboration, and what kind of strategies people use to regulate interaction space in terms of inclusion of people relevant to ongoing communication and collaboration
4. cognitive level – how information available is interpreted in the individual mind

The two projects described in this chapter have thus provided distinct perspectives on key issues in the design of e-Learning environments. One perspective, illustrated by AstroGrid and the application of Augmented Reality in user interface design, focuses on the technology platform that makes e-Learning possible. The other perspective, that guided the usability experimentation, focuses on cognitive, social and organizational impacts on e-Learners. Both perspectives make crucial contributions to the application design of e-Learning environments.

Acknowledgements

The authors thank the German Academic Exchange Service (DAAD) and the Academic Research Collaboration of the British Council for funding this project. AstroGrid is a UK government funded project through the Particle Physics and Astronomy Research Council (PPARC, now LFRC, Large Facilities Research Council).

References

[1] AstroGrid. AstroGrid portal, 2007. http://www. astrogrid.org.

[2] IVOA, the International Virtual Observatory Alliance. 2007. http://www.ivoa.net/

[3] TWiki, Enterprise Collaboration Platform, 2007, http://www.twiki.org/.

[4] CVS. Concurrent Versions System, 2007. https://www. cvshome.org/.

[5] JUnit. Java™ Testing Framework, 2007, http://www.junit.org/.

[6] BugZilla, Bug-tracking system, 2007, http://www.bugzilla.org/.

[7] Eclipse, Eclipse Foundation, 2007, http://www.eclipse.org/.

[8] Allan Vermeulen, The Elements of Java™ Style, Cambridge University Press, Cambridge, 2000.

[9] Maven, Apache Maven Project, 2007, http://maven.apache.org/.

[10] SSH, Secure Shell, 2007, http://www.openssh.com/.

[11] Dave Thomas and Andy Hunt, Pragmatic version control using cvs, Pragmatic Bookshelf, Sep. 2003.

[12] Subversion, Subversion Version Control System, 2007, http://subversion.tigris.org.

[13] Tony Linde, Astrogrid Architecture Thesis, 2003, http://wiki.astrogrid.org/bin/view/ AstrogridArchitectureThesis#Bib3.

[14] G. Salmon. E-moderating: the Key to Teaching and Learning Online. Kogan Page Ltd, London, 2000.

[15] C. Allison. (2003) Quality of service requirement for the e-Learning grid. In 2nd International LeGE-WG Workshop on e-Learning and Grid Technologies: a Fundamental Challenge for Europe, March. http://ewic.bcs.org/conferences/2003/2ndlege/session2/paper3.htm

[16] N. Capuano, A. Gaeta, G. Laria, F. Orciuoli, and P. Ritrovato. (2003) How to use grid technology for building the next generation learning environments. In 2nd International LeGE-WG Workshop on e-Learning and Grid Technologies: a Fundamental Challenge for Europe, March. http://ewic.bcs.org/conferences/2003/2ndlege/session1/paper3.htm

[17] Lievonen, M. (2006). 'Spaces of Collaboration: Place Taking for Sense Making' [online]. APROS 11: Asia-Pacific Researchers in Organisation Studies 11th International Colloquium. Pp. 268-274. Melbourne: Asia-Pacific Researchers in Organisation Studies, 2006.

[18] Buehler, K. 1934. Sprachtheorie. Fischer, Jena.