Amplified Collaboration Environments

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Abstract
Amplified Collaboration Environments are distributed extensions of traditional warrooms or project-rooms, in which a group of people collect to intensely solve a problem together. Prior work in project-rooms has been mainly restricted to co-located groups. The technology is now available to realize affordable collaboratoriums that can support intensive work between distributed organizations. This paper describes the Continuum, an Amplified Collaboration Environment specifically targeted for supporting collaborative scientific investigation.

1 Introduction

Warrooms or Project-rooms such as the ones shown in Figure 1 are rooms in which a group of people co-locate over a period of several days to months to solve a problem together. The rooms consist of numerous whiteboards, flipcharts, and corkboards on which the members of the group may post information during the course of a meeting. These meeting artifacts are kept persistent during the course of the campaign so that group members can refer back to them from time to time.

Examples of applications of project-rooms include: emergency response management; group planning for product launch deadlines; brainstorming; and analysis of large data sets. Prior research [Olson98, Covi98, Teasley00] has shown that in some cases productivity can be enhanced by as much as two-fold when working in these concentrated collaboration scenarios.

Amplified Collaboration Environments are an evolution of project-rooms that take advantage of two trends- firstly, scientists can no longer work alone- they must work together to make significant gains in their fields; secondly, powerful computing, networking and display technologies are becoming highly affordable commodities. National Science Foundation initiatives that are embracing these trends include the Grid Physics Network (GriPhyN); Earthscope- for gathering high resolution seismometer data in the entire U.S.; and the Network for Earthquake Engineering Simulation (NEES).

The goal of Amplified Collaboration Environments (ACE) is to provide a future-generation collaboratorium for scientific investigation, by augmenting the traditional concept of the project-room with technologies that permit *distributed* scientists to reap, and preferably exceed the benefits of traditional co-located project-rooms.

In designing an ACE one first has to understand the characteristics of the traditional project-room that has made them so effective. These characteristics include:

Persistence of Information
Project-rooms allow for the depositing of diverse informational artifacts such as notes that are written on flipcharts; or drawings, schematics, and printouts, that are pinned on the walls. These notes are present every day of the collaboration. Collaborators in a project-room may spontaneously and simultaneously modify these artifacts by writing over them, or moving them.

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Figure 1: The Traditional Warroom or Project Room. The room consists of flipcharts, whiteboards and corkboards on which information artifacts may be deposited. (Images courtesy of Gary Olson- University of Michigan.)

Spatiality and Deictic Referencing

In project-rooms, because the whiteboards/flipcharts/corkboards are arranged around the room, collaborators have a spatial memory of where the artifacts are located and can quickly refer to them by pointing at them.

Group Awareness

Furthermore, even if several participants are simultaneously posting information there is a constant awareness of the overall state of the meeting.

Immediacy of Access to Knowledgeable Experts

Since the collaborators are all present in the room, questions can be answered immediately and participants may form multiple sub-groups to attack sub-problems once a good partitioning of an overall problem has been established.

These are the capabilities that ACEs should support. The challenge is in developing the correct balance of technology that will support these requirements. However, one of the realities of working in companies, research labs and universities, is that group meeting rooms are a scarce resource, and therefore need to be scheduled ahead of time. This makes it difficult to leave information artifacts persistent for long periods of time. ACEs therefore must simulate persistence by allowing the state of a meeting to be saved so that all the information artifacts can be resurrected the next time a meeting reconvenes.

EVL's **Continuum Project** is currently developing the hardware and software technology, and human factors techniques, for supporting ACEs. The questions we are asking in this research are as follows:

- If someone were to build an ACE, what technology should he/she buy and put together?
- How would someone decide how to arrange this technology once it has been gathered?
- What is the software framework needed to support smooth integration of these technologies?
- What will be the observed patterns of behavior of the collaborators who work in ACEs on a variety of tasks, and on a variety of arrangements of the technology? Tasks might include information querying, integration and presentation; and design brainstorming.
- How can we measure the benefits of ACEs?
- What new technologies still need to be built to support initially unanticipated user requirements?

This paper will focus mainly on the technologies with which we have chosen to implement the Continuum, and the rationale behind their development. Specifically the Continuum is intended to support collaborations amongst scientists who have a real need to display, manipulate, and discuss large data sets together. We are currently performing human factors research to understand how these types of users interact in ACEs. The results of these studies will be presented in future papers.

2 The Technology

Figure 2 is a photograph of the displays that comprise the Continuum at EVL. The Continuum uses plasma screens for video conferencing; a plasma touchscreen as a shared flipchart; a tiled display for sharing information artifacts; a passive stereo display for immersive display of visualizations; and wireless laptops, PDAs and tablet PCs for remote access to the numerous displays. Figure 3 illustrates the proposed overall architecture of Continuum. The Central Coordination Server (CCS) provides groups with secure single sign-on access to the Continuum and holds the meta-data to resurrect the information that was displayed from prior meetings. Furthermore the CCS mediates remote access to the ACE using wireless devices. Application-specific collaboration servers manage the software that drive the video conferencing displays, the immersive displays and the shared flipchart display. These are servers that manage software rather than hardware resources because a variety of applications can run on a single display type. All these coordinate with the CCS as plug-ins in the overall Continuum framework so that new tools can be introduced as they are developed. A special instance of an application-specific server is the TeraVision Server (described later in this paper) which support multicasting of high resolution graphics on tiled displays. The Central Collaboration Repository provides a network accessible disk service for holding meeting artifacts such as documents and hyperlinks to Web pages as well as to large simulations and data sets.

Figure 2: The Continuum- an Amplified Collaboration Environment. Top left is a passive stereo display for showing immersive 3D content; next to it are vertically stacked plasma screens that are used for AccessGrid video conferencing; to the right of this is the plasma touchscreen. The small screens in front of the students form a tiled display that can be mounted in a 2 X 2 matrix as show in Figure 6.

A full Continuum therefore requires a cluster of computers to drive the displays, and a cluster to support content sharing services. The cluster for content sharing must also be able to connect to other distributed computing clusters, which might house massive data sets that are being shared in the collaborative environment.

At EVL, we have developed a computing paradigm called the **Optiputer** as the primary means for supporting future generation networked applications such as the Continuum [OP]. The Optiputer is a National Science Foundation funded collaboration between CALIT^2 at the University of California, San Diego, and UIC to interconnect distributed storage, computing and visualization resources using photonic networks. The main goal of the project is to exploit the trend that network capacity is increasing at a rate far exceeding processor speed, while at the same time plummeting in cost. This allows one to experiment with a new paradigm in distributed computing - where the photonic networks serve as the computer's system bus and compute clusters taken as a whole, serve as the peripherals in a potentially, planetary-scale computer. For example, a cluster of computers with high performance graphics cards would be thought of as a single giant graphics card. In the Optiputer concept, we refer to compute clusters as LambdaNodes to denote the fact that they are connected by multiples of light paths (often referred to as Lambdas) in a photonic network. Each computer in a LambdaNode is referred to as a nodule, and collections of LambdaNodes form a LambdaGrid. We differentiate photonic networks from optical networks as networks comprised of optical fibers and MEMS optical switching devices. There is no translation of the photons to electrons and hence no routing within photonic switches. Applications that control these networks will direct photons directly from the start point to the end point of a series of photonic switches and hence will have full control of the available bandwidth in these allocated light paths.

The Continuum is intended as the future-generation collaboratorium for the LambdaGrid. It is no longer possible for off-the-shelf collaboration tools such as Netmeeting to support the kind of interaction that occurs in real science campaigns. Scientists want more than just being able to video conference and share spreadsheets with each other- they want to be able to collaboratively query, mine, view and discuss visualizations of enormous data sets in real time. The data sets that scientists routinely work with are on the order of terabytes. The visualization systems that are capable of displaying data sets of this size require more than desktop PCs. In the following sections we will describe the technology behind the Continuum, which was specifically designed to support collaborative scientific investigation.

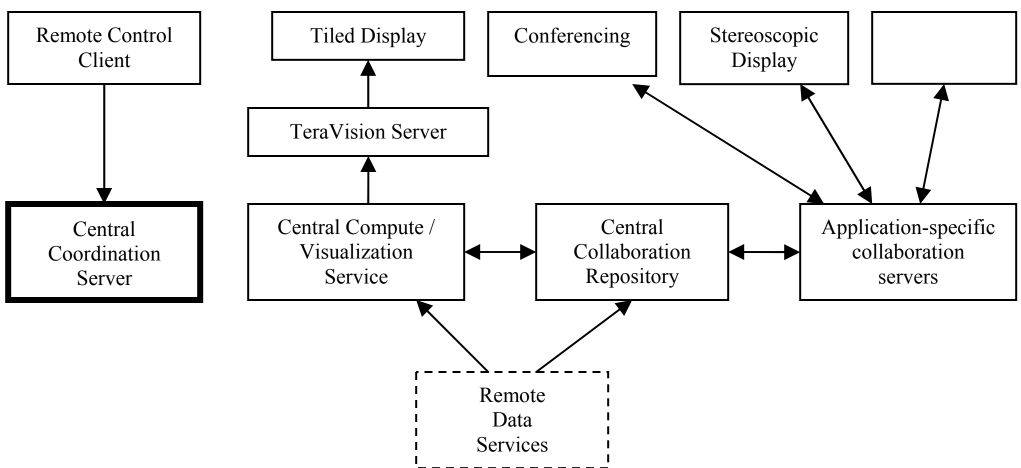

Figure 3: The Continuum's Architecture.

2.1 Conferencing

The Continuum uses the AccessGrid for multi-site video conferencing (Figure 4) [AG]. The AccessGrid was originally developed by Argonne National Laboratory, and makes use of open source tools such as Vic and Vat for video and audio multicasting. A typical AccessGrid node is driven by at least two PCs (one Windows PC for video playback; one Linux PC for video capture.)

The Windows PC has a total of two graphics cards (one AGP and one PCI) to allow it to drive four projectors. The AccessGrid also has four pan-tilt cameras that are distributed throughout the meeting room. This affords each site the ability to provide multiple simultaneous viewpoints into a meeting. These viewpoints are important because a single camera simply does not have sufficient resolution and field of view to depict all the meeting attendees.

EVL's AccessGrid is unique in that it is driven by plasma screens rather than projectors. There are several advantages to this. Firstly, to ensure that participants on camera are well lit, studio lights are mounted in the ceiling. The intensity of these lights tends to detract from images that normally come off projectors. Plasma screens however, are still viewable in a very bright room (see Figure 4). Plasma screens can be left on for extremely long periods of time without display degradation, whereas projector bulbs need to be replaced after about 2000 hours of use. One disadvantage of plasma screens is that they are smaller in size than projected images. Hence it is more suitable for small group collaborations, rather than large audience presentations. For this we have provided a projector that can be ignited for that purpose. This is perfectly acceptable because the majority of the meetings in ACEs are concentrated work sessions rather than formal presentations.

Figure 4: AccessGrid using plasma screens rather than projectors. This picture was taken on a conference show floor. Notice that even in full lighting conditions, the plasma screen image is prominently visible.

2.2 Content Sharing

Content sharing is the most difficult problem to solve in ACEs. The end goal is to be able to manipulate a remotely located data set, document or visualization collaboratively as if everything is being done locally. There are three possible strategies:

Full Replication

The first strategy involves fully replicating the data at both sites and accepting local inputs from all collaborators and broadcasting the state changes to all other collaborators to effect the same state changes at all sites. This strategy is commonly used in real time interactive applications such as Tele-Immersion[Leigh97]. While this solution is suitable for small to modest sized data sets, it is not suitable for working with large data sets such as terabyte databases; unless smaller portions of the data are streamed to each participating site during the course of a collaboration. This strategy also requires that the application provide the facility for collaborative control.

Local Serving

The second strategy involves running the application at a local site and streaming the screen updates to all the remote sites. When a remote participant takes control of the application he/she may experience considerable interaction lag since the application is running at a remote site- the minimum lag that a user would experience is the sum of the time it would take to stream a frame of animation + the network round trip time. However the local user will always experience high interaction rates. Hence the initiator of the application always enjoys the most fluid response from the application. This is the Netmeeting or VNC model. VNC (Virtual Network Computing) is a tool developed by AT&T that streams a remote desktop to one's local computer, allowing a user to interact with the desktop with their mouse and keyboard[VNC]. This model requires that the computer on which the application is running, has sufficient processing power to work with the data set and stream the desktop interface to all the collaborators at the same time. This strategy is therefore not optimal for real time visualization applications. The main advantage of this model is that the application does not have to explicitly support collaboration because an independent piece of software captures the image of the desktop, and streams it to the remote sites.

Central Serving

The third strategy involves hosting a central collaboration server and streaming all interactions to remote collaborators. This strategy does not favor any one collaborating site. The server may be placed at a remote site with the largest amount of available network bandwidth- such as at the StarLight facility in Chicago, which has as much as 10Gb/s to Amsterdam, and 2.5Gb/s to Switzerland[SL]. Furthermore this central server can also consist of a powerful compute cluster with access to large amounts of memory and data from networked RAIDs.

We have developed two technologies, the *AGAVE*- a passive stereo display, which uses the full replication strategy to support collaboration; and *TeraVision*- a graphics streaming hardware system, which can be used to support either the local serving, or central serving strategy.

2.2.1 TeraVision

TeraVision [Singh02] is a way to remotely display moving graphics or high-definition video over gigabit networks. A basic TeraVision system consists of a PC server with commodity video capture hardware for grabbing high-resolution VGA or DVI inputs, and a PC client which can receive these streams and display them at various resolutions. The client does not require any specialized hardware for displaying the incoming video streams; it needs the video capture hardware if and only if it has to act as a video server during a collaborative session. TeraVision is designed to be as easy to use as hooking up a laptop to a projector, something nearly anyone can do nowadays.

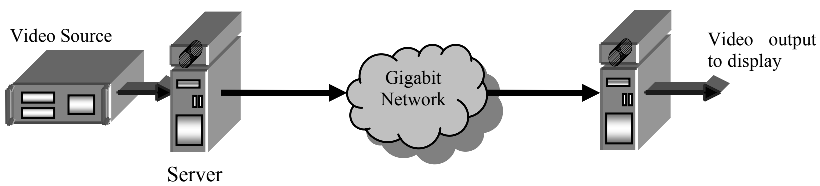

Figure 5: Basic TeraVision setup. Note: The PC acting as a server needs to have the video capture hardware (and Windows drivers) for capturing the input video streams. The client on the other hand needs only to be a Linux/Windows PC with a GigE adapter and a fast graphics card.

Two TeraVision servers can be used in parallel to stream stereo imagery to multiple client sites. The two streams (left-eye and right-eye high-resolution video) are synchronized during capture on the servers and then synchronized again on the clients before the display. Similarly, multiple TeraVision boxes can be used for streaming the component video streams of a tiled display; all the servers synchronize with each other to capture the component streams, and the clients synchronize before displaying all the component streams simultaneously. At EVL we have constructed a tiled display for the Continuum using a matrix of LCD panels. We use the tiled displays as a large “corkboard” over which information artifacts may be publicly posted to enhance group awareness in a meeting. For example, one tile of the display can show a web page, while another shows a spreadsheet. A third tile could show a visualization of a large data set. LCDs were chosen over projectors because LCDs have even intensity across the entire display and can be left on indefinitely. Furthermore it is extremely difficult to align the projection cone of low-cost commodity projectors because they do not provide shift lenses to perform optical keystone corrections. Instead most tiled displays align their projection using an adjustable platform under each projector.

2.2.2 The AGAVE Passive Stereo Display

The AGAVE employs the full replication strategy for supporting collaboration. The AccessGrid Augmented Virtual Environment (AGAVE) is a passive stereoscopic 3D display system driven by a twin-headed commodity PC and two DLP projectors [Leigh01]. Circular polarizers are used to project both the left and right eye images simultaneously on a polarization-preserving screen (often called a “silver screen”). The observer wears low cost polarizing “movie” glasses to see the stereoscopic effect. EVL has two versions of the AGAVE, one uses a front projection screen, while the other uses a rear-projection screen (the Continuum pictured in Figure 2 uses a rear-projection screen). We have found the rear-projection screen to provide greater contrast and less ghosting than the front projected system. Furthermore rear-projection screens allow users to walk up to the displays without blocking the projected images.

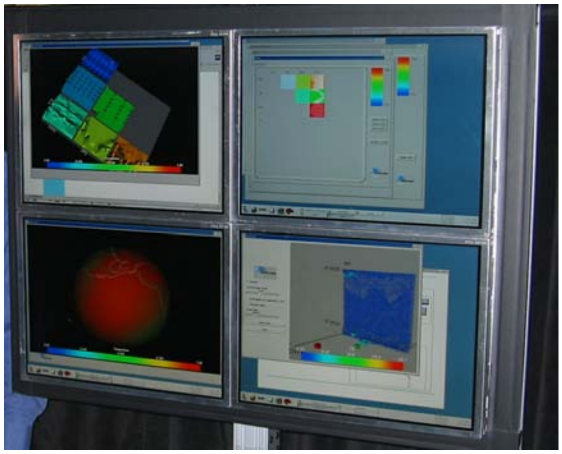

Figure 6: The Continuum's Tiled Display. Illustrated are multiple visualizations of atmospheric datasets. The tiled display allows viewers to compare high resolution visualizations side by side.

We built the first AGAVE prototype in 2001 and a year later, over 70 have been built amongst the Geoscience community. Some of the more notable adopters include the U.S. Geological Survey, the Southern California Earthquake Center, and Scripps Institute of Oceanography. Geoscientists find the AGAVE (which they fondly call the GeoWall) particularly compelling because much of their data is three dimensional and consist of abstract structures which are difficult to resolve with non-stereoscopic depth cues such as foreshortening and perspective. To assist in the further deployment of software and sharing of data sets within the community we have formed the GeoWall Consortium (www.geowall.org). Geoscientists in the consortium use the GeoWall to display earthquake hypocenters, mantle flow simulations, and topography for both research and use in undergraduate classrooms. For example, Universities of Minnesota, Michigan and Arizona now teach topography and map reading to approximately 3000 undergraduate students a year using the GeoWall. We have deployed a GeoWall at the SciTech museum in Aurora, Illinois; and are now working towards deploying one at the Museum of Science and Industry in Chicago.

Figure 7: GeoWall in use in an undergraduate geology lab at the University of Minnesota.

2.3 Collaborative Annotation

The annotation module serves as a digital whiteboard or flipchart on which collaborators may jot down notes and sketch diagrams. At EVL we use a plasma screen overlaid with the Matisse capacitive touch screen, by SmartTech (Figure 8)[ST]. A user can interact with the screen using a passive pen or one's finger. Touch screen solutions are also available for rear-projected screens, which provide a larger writing surface area. However, we have chosen the plasma screen for the same reasons we have chosen them for the AccessGrid- they require less maintenance and can be left on all the time. This means that users can use them as spontaneously as they would traditional dry-erase whiteboards. In practice the plasma screens are a little bit smaller than desired, but the accompanying software overcomes this by being able to create multiple note pages and allowing the user to jump to any of the pages by touching one of the thumbnails.

2.4 Wireless Access

There are several ways in which one can use technologies such as wireless PDAs, tablet PCs and laptops in this environment. One frequent requirement is to have the ability to drag-and-drop a document from one's laptop or PDA, and place it on the Continuum's content distribution screens to share with remote audiences. Once the file has been transferred, the user will want to open the document and begin working with it. This leads us to the second application of mobile technologies. In order to encourage users to work on these displays collectively we are developing *SpaceGlider*, a software interface for VNC to allow a laptop or tablet PC to navigate across any of the displays on the Continuum. SpaceGlider makes use of VNC's ability to control a remote keyboard and mouse to turn a user's laptop or tablet PC into a wireless KVM switch. At the present time a user selects the screen to work with by pressing a function key on the laptop. In the future the user will be able to glide their mouse pointer across the displays as if they were working on one large seamless display.

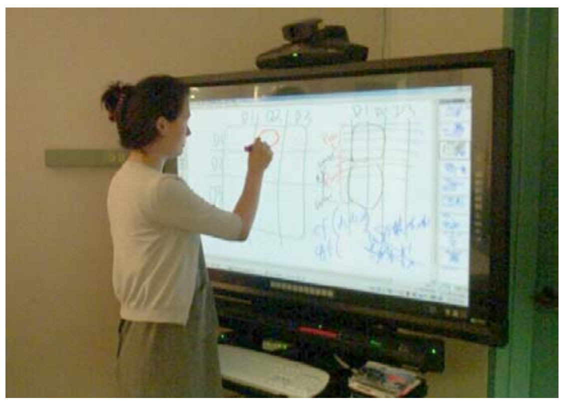

Figure 8: A Plasma Touch Screen used as a digital whiteboard. The column on the right of the screen are the thumbnail pictures of all the note pages that have been created on the whiteboard. A user can jump to any of the pages by touching the thumbnail.

3 Conclusion

In the past year we have built two Continuum rooms and are in the process of building a third at the Technology Research Education and Commercialization Center (TRECC) in Dupage County, Illinois[TR]. The rooms in EVL are being used to conduct careful human factors research, and the one at TRECC is used to educate industry on what can be achieved with this technology. Furthermore we are working with the National Center for Microscopy and Imaging Research (NCMIR) at UCSD (a partner in the Optiputer project) and the Synoptic Lab at the National Center for Supercomputing Applications (NCSA) to apply our Continuum technology to support collaborative neurobiology and weather simulation.

The technologies currently used in the Continuum are constrained to what the present state of the art in computer displays can provide. In the ideal case, the display technology that one might use to drive the Continuum is a seamless touch-screen wall that can be wrapped around an entire room. This wall will be able to show high resolution, two dimensional- as well as three dimensional stereoscopic images. Users will be able to interactively manipulate both the 2D and 3D imagery. While organic LEDs that are capable of this are unlikely to materialize any time soon, we are able to simulate what it would be like to use such a wall with presently available technologies. We are presently building this "OmniWall" with passive stereo preserving, rear-projection screens, a wireless ultrasonic tracking device (such as the Mimio – www.mimio.com) for 2D input; and a camera-based tracking system for wireless 3D input.

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