Collaborating in Context: Immersive Visualisation Environments

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ABSTRACT

As visualizations of large systems get more and more complex, larger collaborative spaces are required so that a team of designers may work together while visualising their system. This paper describes the outfitting of a room to turn it into an immersive visualisation environment. The environment consists of large display areas, onto which are projected high resolution visualisations of software systems. Specialised hardware allows the environment to support multiple concurrent users, who are encouraged to collaborate on team-based tasks and interact with the environment using novel interaction metaphors. We will describe applications that demonstrate the efficacy of this new approach to collaboration.

Keywords

Visual interaction, information visualisation, visual interface design, computer-supported cooperative work.

1. INTRODUCTION

Recently, computer users have been moving away from a single monitor to increasingly numerous and disparate display devices [9], [10]. In modern office and research environments, multiple monitors per user are commonplace, and monitors and other display areas have consistently increased in size and resolution. Furthermore, there has been a proliferation of alternative display devices – mobile devices such as laptops, PDAs, tablet PCs, palmtops and smartphones – all of which offer viable means to view and manipulate data [1][9][18].

The emergence of new and more powerful display devices also opens the door for collaboration between system designers using large shared displays. Though this affords some limited means for interaction between designers, there is rarely any true interaction between them on-screen. One designer at a time will be controlling the simulation, and will decide for the others which data should be presented at a time, and where it should appear. This limits the collaborative possibilities for a team, and restricts potential actions that any one designer should be able to carry out without going through an intermediary colleague.

This paper will explore some of the work that is going on in the field of collaborative visualisation, and then describe the creation of a novel visualisation environment, one which is geared specifically to encourage collaboration between a team of designers. In this new model of collaboration in an immersive visualisation space, each team member can affect the data being displayed at any time, and so multiple designers can manipulate elements of the same data-set concurrently.

Additionally, operating a large system of interconnected devices and displays in concert with an arbitrary number of concurrent users requires the development of some non-traditional interaction methods to support them. Finally we will look at some possible applications scenarios that are available in this environment.

2. BACKGROUND

Ongoing research on multi-user, multi-modal interaction on multiple and large-scale displays for the visualisation of data has identified the need to move beyond the classical desktop-bound view of human computer interaction.

Collaborative tabletop display devices have emerged as a solution to the problem of supporting face-to-face interactions for multiple users where the single mouse paradigm is meaningless. Though they can be used by a single user quite successfully, their real benefit becomes apparent when a number of users gather around the table and work together, as with Sony's SmartSkin [15] or the Enhanced Desk system [13]. These devices effectively allow each user to have their own pointer in use concurrently, and allow for multiple users to control the same object together, opening the door for a number of new interactions unavailable with a single pointer.

Mitsubishi Electric Research Laboratories's (MERL) DiamondTouch [5] table is one such input device that responds to a user's touch, and recognizes gestures such as drags, and certain patterns 6. The interface is projected from above, down onto the DiamondTouch's surface. As each user's touch can be recognized individually, collaboration is facilitated. There is no need for users to take turns, as they can all independently manipulate objects displayed on the DiamondTouch's surface, or collaborate and manipulate objects in tandem.

SharePic [2] is an existing application designed for the DiamondTouch. Figure 1 shows a group of people using the application, which allows a number of users to examine, scale, rotate and pass photographs between each other. For example, a photo being displayed on the screen could be held at opposite corners and stretched between two users.

Large-scale tiled displays have increased in use as the need to explore, study and analyse ever larger data sets increases [11]. The requirements of both scientific and information visualisation are driving the demand for larger and higher resolution displays. In order to display images on multiple displays, more powerful rendering solutions are needed.

Figure 1. A DiamondTouch in operation, showing the SharePic photo-sharing application

IBM's Deep Computing Visualisation [7] (DCV) is a middleware infrastructure designed for efficient, parallel rendering of visualisation data. OpenGL rendering operations are passed out to a cluster of Linux machines (called "nodes"), which perform load-balancing operations, render the scene, and pipe the rendered output back to any number of display devices. This infrastructure is efficient and scalable, as new nodes can be added or removed from the rendering cluster as required.

DCV can be run in two modes, Scalable Visual Networking (SVN), and Remote Visual Networking (RVN). SVN is particularly adept at rendering scenes to be displayed on many connected displays. SVN renders the whole scene, and then cuts the scene up into multiple segments and pipes a segment to each device. This is easily configurable so that the scene is displayed across multiple contiguous display surfaces, giving the illusion of a single large display. RVN is designed for rendering scenes which will be viewed on many mobile devices. This allows remote use of an application through lower-powered devices like laptops and PDAs.

AT&T have also designed software for visualisation of massive data sets on a 14-foot-wide and 8-foot-high screen [3]. Their system allows for applications such as multi-digraph navigation, so that a user may move throughout a tree-like hierarchal structure. Each section of this tree can be visualised independently of the rest, with whichever visualisation technique is deemed most appropriate to the data.

Spatially Immersive Displays (SID), or environments, have been found to increase the potential for collaboration, since many more designers can be involved when the display areas are so large. This allows more than a limited number of designers to participate, and since the displays are digital, they allow designers to display their actual work on the screens, an improvement over basic whiteboard sessions.

The University of Illinois' CAVE (CAVE Automatic Virtual Environment) virtual reality theatre [4] sets up three or more walls and the floor of a cubic room into display areas which, in combination with a set of stereoscopic glasses, turn the room into a fully immersive visualisation environment. These projections often require the rendering power of an SGI workstation. Dozens of CAVE theatres have already been built and put into operation in research centres around the world.

The CAVE system has been revised and expanded into the CANVAS system, also developed at the University of Illinois [8]. A CANVAS is similar in design to the CAVE system, though at much lower cost; even being operable on a modern desktop PC. The use of either of these systems results in large display areas suitable for an immersive visualisation environment.

3. MODEL

To fully examine (and later demonstrate) the benefits of collaboration in an immersive visualisation space, a lab in the Computer Science department of UCD has been transformed into a visualisation environment. This has involved setting up a projector system that would project over the full surface of three walls of a room. Users interact with the system via a DiamondTouch table situated in the centre of the room. The following is an in-depth look at the components of our visualisation lab, and a look at the possibilities of the setup.

3.1 Display Technology

An IBM DCV cluster [7] of four nodes is used to render images for all of the display devices in the system. This provides us with ample rendering power to get started. If there is a requirement for more processing power, it is a straightforward operation to add more nodes to provide this.

The visualisation lab has a large display space, made up of four projected displays across three walls of the room. Two projectors are pointed on the longer front wall of the room, and a third and fourth are pointed at the left and right wall respectively, giving a total resolution of 5120 x 1024 pixels spread over $36m^2$. The displays are positioned so that they join seamlessly in the corners of the room, so some elements may stretch over the boundary of their wall, and be projected on the wall beside it. This gives the room a truly immersive feel. Figure 2 shows a representation of this environment in operation.

In parallel to this, parts of the visualisation can be migrated from the main displays onto any number of portable devices. This allows a user to choose a certain element or section of the visualisation that they are interested in, and to take that down from the screen to their local device, where they can continue to manipulate it, and then 'save' their modified version back onto the main displays.

Allowing the same visualisation to be displayed on such a large main display and also portable devices of more diminutive resolution means that some accommodation must be made for scaling the level-of-detail (LOD) of the visualised data down, so that it can be comfortably displayed and studied on the mobile devices. This may involve scaling the resolution of the render down considerably, or simply only showing part of the model at any one time.

Displaying parts of the visualisation on a laptop screen will not be a problem. Most modern laptops come outfitted with enough power to allow a user to migrate a large element off one of the main displays and work on it by themselves for a while before placing it back on the shared display.

However, we also want this system to be usable by designers with all manner of devices, including low-powered devices such as PDAs and smartphones. These devices are unlikely to be capable of displaying and manipulating a complex visualisation, although they may be used as remote controls for the full visualisation. A rudimentary representation of the element the user is controlling can be shown on their device's screen, with a number of options for manipulating it, such as rotate, zoom and minimize.

3.2 Face-To-Face Collaboration

The primary means of interaction with this system is through the central DiamondTouch table. The table allows users to add elements to the main displays, remove them, and move and arrange them among the three walls of the environment.

The DiamondTouch's display shows a representation of what is currently visible on the walls in a strip along its centre. Above and below this strip, we have an area which can be used to store minimized data objects not 'in play' at the moment. Users may intuitively touch an element in this holding area, and then drag and drop it onto the active strip. The system will react by placing the element at the corresponding position on the walls. Similarly, if a designer doesn't want an object to be visible at a certain time, they can drag it off the main viewing strip into the holding area.

By allowing all the system's users to gather around this central table to change the state of the visualisation as a whole, we *encourage* collaboration, as they mediate and find the best way to present the data on the screens.

3.3 Methods of Interaction

Though the DiamondTouch is seen as the main control to the system, there are other ways to influence the objects being displayed on the walls. Part of the impetus for putting this system in place is to explore the styles of interaction possible across different devices in a heterogeneous computing environment.

As already mentioned, designers may wish to pull a particular object or visualisation off the wall onto their mobile device to study in more depth. The question remains, how do we mark elements on the wall to be migrated to a laptop or a PDA?

Rather than requiring the user to continually point-and-click elements to control them, we would like to explore some more natural interactions such as gestural interaction [14] based on the use of computer vision to determine hand-arm gestures by a collection of individuals [14],[19]. The designer in question can approach the wall directly, bringing his mobile device within a certain distance from the wall. Then some easily-recognisable gesture can be carried out, such as tapping the desired element with their hand. The system then communicates with the mobile device and sends the necessary data to it.

Another option for tracking devices is to employ a specialised location detection system such as Ubisense [17]. We already have a Ubisense system installed throughout the Computer Science building. Ubisense uses ultra-wideband (UWB) technology to locate people and objects in real-time to an accuracy of 15cm in 3D space. The Ubisense system requires the careful installation of sensors on the walls of enabled rooms with a map of the dimensions used for calibration. The system tracks active Ubisense tags as they move through space, recording locations on a server running the core Ubisense services. Tags and sensors communicate over standard radio frequencies with requests sent to tags to periodically emit UWB signals. Sensors use a combination of time and angle of arrival of the UWB wave to calculate the location of tags. If a user walks up to the display wall bringing a tagged device within a certain distance from the object they are interested in, it will migrate off the main screen and onto their device.

4. APPLICATION SCENARIOS

The room setup described here is useful in many collaborative tasks that involve a number of designers. There is great potential in the expansive displays as well as the multi-user interactions that the system makes possible. Below are three example applications currently in development using this technology.

4.1 Combining Scientific and Information Visualisation

One application of this display technology is to present a large amount of statistical data that can be manipulated by a group of designers concurrently. This is compelling because of the ease of interaction between designers, and the possibility of them organising the data in the most useful way possible. For example, when designing the sensor network inside an automobile, designers must contend with a constantly expanding stream of information coming from the system.

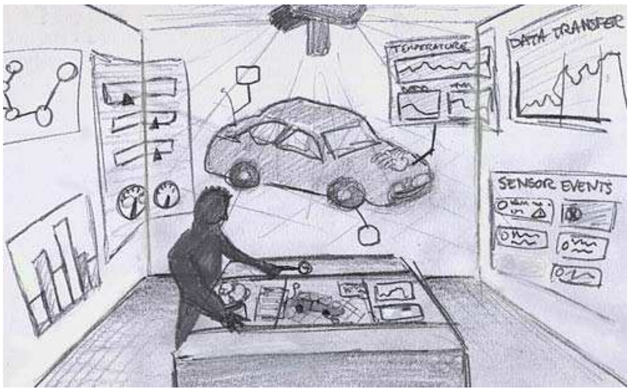

Figure 2. A sketch of the room in operation, showing a visualisation of the internals of a car's sensor system.

Figure 2 shows a representation of a three dimensional model of a car's internal systems being presented on the central display, describing the sensor network within a car. This acts as a spatial representation of the layout of the system. Each of the sensors can then be clicked to query their state, resulting in this information being visualised. For example, when querying heat readings inside the engine, a graph of recent activity will be displayed. This graph can then be manipulated in the system like any other. An interface like this allows designers to have a high-level overview of the system, and to seek details on demand.

Elements of the data stream may be changing rapidly, for example the data transfer rate within the car's internal processing network. The designers will wish to arrange the data feeds so that the elements of the car's systems that they are currently analyzing are viewable. They can then rearrange these visualizations, and some designers may take elements off the screen to their mobile device for further study.

4.2 Visual Data Mining

Another application utilising the enhanced screen area and touch-controlled input is to perform real-time visual data mining. As a live data feed is scrolled from right to left on the central wall, users may watch to pick out patterns in the data. When a user sees an interesting piece of data in the flow, they use the DiamondTouch to manipulate the flow of data and scroll to the right in order to "rewind" the data stream to an earlier state.

As this temporal navigation is in progress, the right wall display is used to queue up pending data. The left display is used for saving instances of interesting data, which can then be placed back on the central display for further review. This system is envisioned for use in statistical applications, but would also work equally well for reviewing data such as stock quote tickers.

4.3 Distributed CATS

Distributed CATS is a multi-user system incorporating a number of component systems including: CATS [12], a multi-user recommender system designed around use of the DiamondTouch, and Construct [16] a distributed, decentralized infrastructure for ubiquitous computing environments.

The aim of DCATS is extending these applications to stretch the interface environment across two physically remote DiamondTouch tables. To support collaboration between remote locations, we use webcams and speakers to allow the groups to see and hear each other, and we display the remote DiamondTouch interface on the wall surfaces. The wall displays are also used to display contextual information like a team's work calendar, airline timetabling etc.

5. CONCLUSION

In this paper, we describe a specialised immersive visualisation environment that we have created, which allows the creation of applications that facilitate greater collaboration between teams of designers. It comprises a large shared display space with an interface that allows multiple users to concurrently interact with the system using a heterogeneous array of input devices.

This environment allows us to explore non-traditional methods of interaction between users and computer systems and is allowing us to develop a number of applications that facilitate greater collaboration between teams of users. The environment allows users to view components of these applications at different granularities and interact with them on demand.

6. REFERENCES

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