Dynamo: A public interactive surface supporting the cooperative sharing and exchange of media

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ABSTRACT

In this paper we propose a novel way of supporting occasional meetings that take place in unfamiliar public places, which promotes lightweight, visible and fluid collaboration. Our central idea is that the sharing and exchange of information occurs across public surfaces that users can easily access and interact with. To this end, we designed and implemented Dynamo, a communal multi-user interactive surface. The surface supports the cooperative sharing and exchange of a wide range of media that can be brought to the surface by users that are remote from their familiar organizational settings.

Keywords

Large interactive surfaces, multi-user interfaces, sharing, exchange, collaboration

INTRODUCTION

Occasional meetings, where colleagues and friends gather to undertake a process of catch-up, exchange and coordination, are a common part of many people's lives. These meetings range from being ad-hoc in nature to those that underpin more structured longer-term cooperation. The importance of these meetings is reflected in the availability of meeting rooms at airports, common areas in public buildings and in the provision of meeting spaces at conferences and tradeshows.

When people meet up in these public spaces they often carry a range of physical and digital information that they wish to share and exchange with others. There is a level of spontaneity and fluidity when we consider the sharing and exchange of physical media brought to these spaces. For example, users can display information using overhead projectors and flipcharts, place the physical media on tables for others to take, and use wall space to organize items. In essence, the communal physical surfaces (flipcharts, tables, boards, walls etc) within the space become the focal point in the sharing and exchange of the physical information.

The highly familiar and lightweight experience afforded by physical media is somewhat in contrast to that of digital media. With digital media, there is no longer an emphasis on the shared surfaces within the space but rather a shift towards the more private display surfaces associated with the personal devices (such as laptops) brought to the space. When larger electronic surfaces (such as electronic whiteboards or PCs connected to projectors) are available they can only be used in restrictive ways that limit the sharing (for example, allowing only one person to take over the entire surface in order to present a prepared talk). Without shared surfaces, users regularly find that they can only share media by transferring it from one personal device to another (for example copying a file from one laptop to another), which can be awkward when sharing between large groups of people.

In this paper we propose a novel way of supporting occasional meetings that take place in unfamiliar public settings. Our central idea is that the sharing and exchange of digital information should occur across *public interactive surfaces* that all users have access to and can easily interact with. Our goal is to allow people meeting in public spaces to use these surfaces as an extension of their physical setting, where documents, video, images, and other digital information can be accessed, shared, viewed, annotated or copied in a seamless fashion.

The deployment of these surfaces within public places requires us to reconsider the interactive facilities provided by large displays. Within these settings, users often seek to exploit the display in an ad-hoc (or opportunistic) manner, interactions may be highly transient or long-lived, and a wide range of activities will need to be supported (both concurrently and asynchronously). The display is no longer a single-purpose meeting tool (such as an interactive whiteboard or shared drawing/editing/writing application) but rather a communal surface used for different tasks by an open-ended community of users. This communal aspect suggests that the facilities provided for users to appropriate the surface and manage its shared use are as important as the mechanisms for sharing and exchanging the digital information itself.

To explore these issues, we designed and implemented Dynamo a communal multi-user interactive surface. The surface supports the cooperative sharing and exchange of a wide range of media that can be brought to the surface by users outside from their familiar organizational settings.

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The surface has been designed to promote lightweight, visible and fluid interactions that are readily understandable by users, based on familiar actions that are easy to accomplish and do not require technical expertise. In the rest of this paper, we describe the Dynamo system and outline the key interactive features that enable the shared surface to be communally available to peripatetic people, meeting in public places. We also present some findings from our initial evaluation of the Dynamo system used in two different settings.

RELATED WORK

Nowadays, many organizations are equipped with some kind of large display, be it interactive whiteboards, projection screens or plasma screens. This trend has led to the increased growth of large display systems that serve a range of purposes within organizational and more public settings. Below, we give a brief overview of the developments in this research area, classifying in terms of the types and functions of the displays that have evolved. The categories identified are not mutually exclusive and some of the display systems fall into several categories.

Electronic whiteboards represent the starting point for much of the work on large displays. Systems such as Tivoli [19] provided an interactive display that supported freehand pen input, enabling a single user to draw on screen and share their drawings with others in a meeting. These systems initially mimicked many of the familiar features of existing whiteboards. More recent work on electronic whiteboards such as Flatland [16] has significantly enhanced their computational features.

Community noticeboards take as their starting point the noticeboards and bulletin boards found in communal areas, halls and foyers of organizations rather than the whiteboards found in meeting rooms. Systems such as Plasma Poster [3] and Community Wall [7] allow people to post information onto a large display that is available to a community of users.

With such systems material can often be posted to the display remotely, for example when users are at the desktop. Passers-by in the vicinity of the display are also provided with interaction capabilities enabling them to annotate and add material to the display.

Shared awareness systems exploit large displays to make information conveying the activity of others available across a community of users. The Notification Collage [8] augments features associated with community noticeboards with an aggregated overview of the activities of a community of users. Kimura [12] makes a user's current and past activities available to others. The system uses large peripheral displays to provide background awareness of activities that users have performed.

Single display groupware was developed to support shoulder-to-shoulder collaboration on a large display with multiple input points. Such systems allow multiple users to simultaneously interact with shared applications. Early examples include Cognoter [6] and MMM [2]. More recently, the Pebbles system [15] has explored how PDAs can provide concurrent input to a shared display. Similarly, Kidpad [1] supports multi-mice input with a view to promoting collaboration within the classroom.

Multi-screen systems extend the capabilities of large screens by considering how other displays can be incorporated into the set up. Speakeasy [17] and iRoom [10] provide users with interfaces to quickly discover, configure and connect up multiple networked displays (including large screens) for use in tandem. Researchers have also explored a range of techniques for moving information and control between multiple displays [11, 20].

A considerable number of such systems have been developed in the context of purpose built environments that contain a number of embedded large displays.

Situated displays are large screens that are built into an environment to support groups of users. The iRoom at Stanford [10] and iLand at GMD [24] are two environments that have a suite of touchscreen situated displays. A number of novel pen and gesture based techniques have been developed to interact with these displays [9, 24]. Researchers have also explored techniques for making these types of touchscreen displays support simultaneous input from multiple users [5, 13, 21].

Other notable work includes research into augmented tabletop displays [22, 25], which seek to mix physical and virtual objects to support forms of tangible interaction.

'Walk up and use' interactive boards explore how to design large displays that support lightweight walk up and use interactions. Examples include Blueboard [23], which allows identified users at the board to quickly display personal information (such as personal calendar and messages) held on the network, and share this with others via mediums such as email. These systems are often reliant on a network for access and transfer of information. They typically provide a single point of interaction either through a touch screen or a single pointing device.

We wish to extend the existing work on large displays by considering them as ***public interactive surfaces***. Existing research has shown that large electronic displays are integral in facilitating group collaboration in meeting rooms [10, 19, 24]. However, this research has primarily focused on formal and structured meetings held within private spaces inside organizations [10, 23, 24]. Public spaces such as conferences, airports, libraries and communal areas in buildings are becoming increasingly used for less formal (and sometimes completely impromptu) meetings. We seek to explore the interactive mechanisms that these surfaces will require and how these facilities can benefit users in more public settings.

PUBLIC INTERACTIVE SURFACES

Public spaces provide new challenges for supporting interaction with large displays. Within such spaces, any user can walk up and make opportunistic use of the display,

users may or may not know each other, and they may be working on different tasks simultaneously. Large displays need to be more general-purpose, supporting a wide range of activities (occurring concurrently or over a longer period of time). The inherent level of trust that exists in closed organizational spaces does not exist in public ones. In essence, the display is no longer a single-purpose meeting tool (such as an interactive whiteboard or shared drawing/editing/writing application) but rather a shared surface used for different tasks by an open-ended community of users.

Much research on public displays has focused on information kiosks where users browse on-line information [4]. More recent work has explored novel interaction techniques to draw in and engage the public [14, 18]. We consider the development of public interactive surfaces that can be appropriated by groups of users for a period of time in a lightweight and flexible manner. These surfaces should be readily available and easily appropriated by users who are remote from familiar organizational settings.

The need for these publicly accessible surfaces has been further highlighted by a number of researchers focusing on the development of small mobile devices such as the Personal Server [26]. These devices transport large amounts of state and connect to large displays for further interactive capabilities. Other more commercial devices that fall into a similar category include removable USB disks, MP3 players and digital cameras. These devices are small, lightweight, (increasingly cheaper to purchase and run) and can be easily connected to more powerful machines to rapidly exchange data. The emergence of such technologies has resulted in users carrying a large amount of digital media when they travel.

We aim to provide interactive capabilities that are sensitive to the needs of this class of device, while also supporting more powerful devices such as laptops and PDAs. We are particularly interested in the scenarios where users may wish to share and exchange the media they are carrying on such devices. Our aim is to exploit the advantages provided by large screen systems in facilitating sharing between groups of users, while also exploiting the ubiquitous nature of these media storage devices.

Providing public interactive surfaces for users to achieve this form of sharing and exchange requires us to consider what interactive features are needed for such a surface. The main requirements are that:

- ***The surface is communal*** and available to an open-ended community of users. The surface needs to support multiple users (working concurrently and asynchronously) and provide facilities to manage its shared use.
- ***The surface offers lightweight and familiar interactions*** that do not detract from the spontaneity of the collaboration. This is particularly important in supporting impromptu meetings where the surface is exploited in an ad-hoc (or opportunistic) manner.
- ***The surface offers a place of display and exchange*** that allows media to be left for a period of time and for users to exploit the surface as a place to coordinate the exchange of media with others.
- ***Users of the surface are remote from their normal network infrastructures***. The combined effect of corporate network infrastructures, firewalls and bandwidth issues may result in users being unable to remotely access their resources, and so we need to allow users to bring information to the surface rather than presume remote access. Broader network access becomes a useful facility for users rather than a prerequisite for interaction.

Dynamo: A communal resource for public interaction

The Dynamo system has been designed as a large publicly accessible interactive surface that allows people to gather around, share, display and exchange media with others. The interactive surface is composed of one or more displays that can be tiled both horizontally and vertically. Two common arrangements for the surface are shown in figure 1. On the left a dual projected horizontally tiled arrangement is shown and on the right a vertically tiled wall and tabletop configuration.

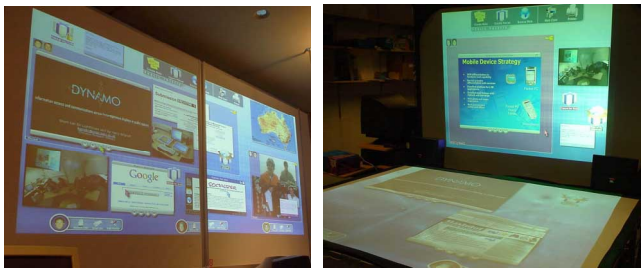

Figure 1. Two Dynamo surface arrangements

Dynamo promotes shoulder-to-shoulder collaboration by allowing multiple users to interact simultaneously on the same surface. Users can attach multiple USB mice and keyboards to the surface and also connect remotely via laptops and desktops. Once connected, the Dynamo surface allows users to:

- Manage the surface as a communal resource by claiming areas of the surfaces for use.
- Easily place information on the surface and take information from the surface.
- Display information for extended periods of time and leave items for others.

Each user interacts with the surface through an *interaction point*. An interaction point comprises of input devices capable of delivering mouse, text and media input to the system. Two broad forms of interaction points are provided:

- *Base interaction points* normally consist of a wireless keyboard, mouse and USB slots for attaching media

Figure 2. The main Dynamo interaction surface with a selection of media, a public palette (located at the top of the display), personal palettes (located at bottom) and two carve regions

sources such as removable USB disks, digital cameras, MP3 players and web cameras.

- *Mobile interaction points* can allow laptops and PDAs to act as interaction points as each of these has the capabilities to provide mouse input (through stylus or touch pads) and text input (through soft or hard keyboards) and deliver media from their internal disks.

The system is generally deployed with a number of base interaction points that can be extended as users attach new input devices or connect remotely to the surface.

An example of a Dynamo surface is shown in Figure 2. The surface provides a multi cursor environment with each interaction point being represented by a color-coded telepointer. Users take control of these telepointers to interact with the surface. Associated with each telepointer is a *personal palette* (each marked using the same color-coding as its related telepointer). A palette consists of a number of distinct items (represented by an icon to the user) that can act as media sources and media sinks. For example, the files on a removable USB disk would be represented as media sources. A media source can be dragged off the palette and displayed on the main surface. Similarly, the user can drop media onto a media sink icon within the palette for processing. For example, dropping a video clip onto the USB disk icon located upon the palette results in the media being copied onto the associated removable USB storage device.

A *public palette* is also associated with the surface. This provides access to the key features of the system described in the next sections. This palette also provides access to publicly available devices (such as attached printers and webcams) that can be utilized through the surface.

Palettes facilitate the flow of information to and from the surface. They form the main point for exchange and sharing of media at the surface. As such, they utilize familiar drag and drop metaphors to rapidly pull media up onto the surface and transfer media over to other endpoints (such as a connected device).

The Dynamo system has been designed to work within public spaces where networking may be unavailable or limited. Therefore rather than relying on remote access to user configuration information, the system allows users to bring this information with them to the surface. This can be carried on small lightweight devices such as removable USB disks or on more powerful devices such as laptops. One typical example is for individuals to carry a profile on their USB disks, which identifies them and holds the various user-specific configurations such as name, email address, and on screen icon. Profiles are created and maintained either at the surface or (if a network is present) remotely via a web interface.

Users are not required to identify themselves before using the system. Unidentified users are given a guest profile that provides access to public services and areas of the screen.

However, identification provides users with additional features of the system including the ability to manage the surface as a communal resource.

Managing the surface as a communal resource

The Dynamo surface provides interactive mechanisms to allow users to manage the shared use of the surface. It does this by allowing identified users to "carve off" part of the large public surface providing them with a workspace that they can use to arrange and share media and where they can manage access to the region. Users mark an area of the screen by holding down the mouse and dragging to indicate the extent of a workspace. On release, interaction with the marked portion of the overall surface is restricted to the creator of the carved off region. Figure 3 shows two carved regions on a portion of the surface. On the right we see a green telepointer passing through a carve region that it cannot interact with - this is indicated to the user by the semi-transparent circle surrounding the telepointer.

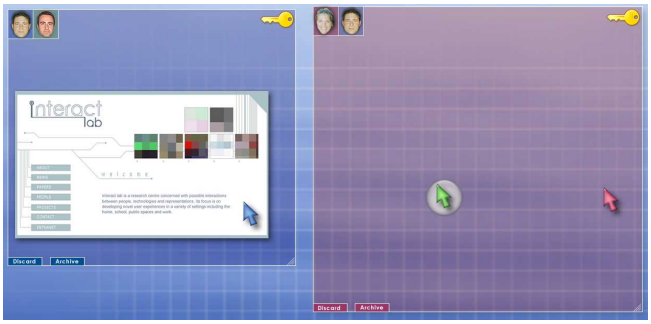

Figure 3. Two carved regions on the surface

The creator of a carved region can invite others into the space by dragging a key icon (located at the top right hand corner of the region) onto the palette of the desired user. Access is indicated by displaying an icon associated with the user in the top left corner of the region. Region creators can drag these icons outside of the region to revoke access for the associated user. Figure 4 shows an example of controlling access to a carve region. Access may also be granted to users who are not currently available by leaving the key within a media parcel that can be opened at a later date. The notion of media parcels is described in detail later in this paper.

Figure 4. Controlling access to carve regions

Regions may be short lived for informal ad-hoc meetings or long lived, so that they can be archived and referred to in the future. Archived regions are shown in an iconified form and may be moved off the surface or stored on the surface for use later. Once opened, the archived region restores all media contained within it and arranges them according to the previous spatial arrangement. This ability to persist an entire region with its associated media and access permissions allows structured longer-term collaboration to occur between users. For example, the outcomes of a monthly meeting could be stored in a carve region, archived on the surface and revisited or amended in future meetings.

Bringing media to the surface and taking it away

Users may bring media to the surface from a variety of sources using the interaction points offered by the Dynamo system. In the case of base interaction points users can exploit the USB connections available to access media on their personal devices. Users can drag this media onto the surface (through their associated palette) to interact with it or make it available to others.

Figure 5. Displaying and controlling a presentation

The Dynamo surface allows a wide range of media to be displayed and exchanged, including web documents (such as HTML and PDF), MS Office documents (Word, PowerPoint and Excel), common image, video and audio formats, and streaming video and audio. Each of these files formats can be displayed and shared using the system. The system also provides simple control over each of these media formats once they are displayed (for example, controls to navigate forwards and backwards through a document or fill in a web form).

Figure 5 shows a PowerPoint presentation that has been dragged onto the surface from a personal USB disk. In this example, the surface allows users to view each slide and

navigate through the presentation. Each accessible media item on the surface can be downloaded and taken away by the user. In order to download a media item the user carries out a drag and drop action from the window displaying the media down to the device icon on the desired palette. For example, dragging the PowerPoint slides on display onto the USB icon (of a palette) will result in the slides being copied onto the associated USB disk. Users can also use this metaphor to give copies of their own media to others.

Users can display and share media directly on the publicly accessible areas of the surface or inside carve regions that they have access to – once placed on screen, the media window inherits the access permissions associated with the region surrounding it. These alternative modes of display and sharing can be used interchangeably dependent upon the collaborative task at hand. For example, one scenario could be an impromptu meeting at the surface where users have not first registered with the system. In this case, the overhead of user registration can have an adverse effect on the spontaneity of the collaboration, and so users may choose to share the media directly on the publicly accessible areas of the surface rather than first carving a region. If this scenario did evolve into a more structured meeting (for example, if the participants agreed to return to the space at a later date and revisit the work) then they can register with the system, create a shared carved workspace, and move the media (and other outcomes of the meeting) over for archiving.

Users can also transfer media to the surface through mobile interaction points. These interaction points allow more powerful devices such as laptops to connect to a shared Dynamo surface. Once connected, the surface is treated as a secondary peripheral display. This allows media to be dragged from the mobile device's desktop onto the shared Dynamo surface (see figure 6). Similarly media may be dragged from the Dynamo surface onto the mobile display. This feature allows users to quickly download media items, such as word documents, from the surface for editing on a more personal device (using familiar desktop applications), which they can later transfer back over to the large surface for sharing.

Figure 6 Moving media between a laptop and the surface

Leaving things for others

The Dynamo system also allows media to be packaged up into media parcels that can be left for others. Media parcels can be thought of as containers that can encapsulate multiple media items. Parcels can be directed to one or more users of the system. This allows parcels to be posted up on the Dynamo surface and picked up and opened up in the future by recipients. Parcels provide a mechanism for asynchronous sharing of media rich information between users. After being created, a parcel can be sealed on the surface so that it is not publicly viewable. The user can specify different permissions for opening up and accessing the contents of a parcel. An example of a user opening a media parcel is shown in figure 7.

In addition, to providing wrappers for a wide range of standard media, the Dynamo surface introduces a *Note* media type. A note is a simple XML based document containing an author, an optional title, and a message body. Notes can be edited (as well as viewed) on the surface. They provide a quick and easy way to allow users to annotate the media items on the surface. Users can also choose to reply to notes that are on surface. This allows for simple messaging between users of the surface, in a similar way to a notice board. Figure 8 shows a number of notes and parcels left on a Dynamo surface.

Figure 7. Opening a media parcel for a user called Mia (left); a sealed parcel for a user called Bob (right)

Users wishing to open a parcel need to identify themselves to the system before the information is displayed to them. In the case of users who access the surface through the base interaction points, the contents of the parcel are displayed on the screen. If users have access through a mobile interaction point, then the parcel can also be opened up on the display associated with the mobile device.

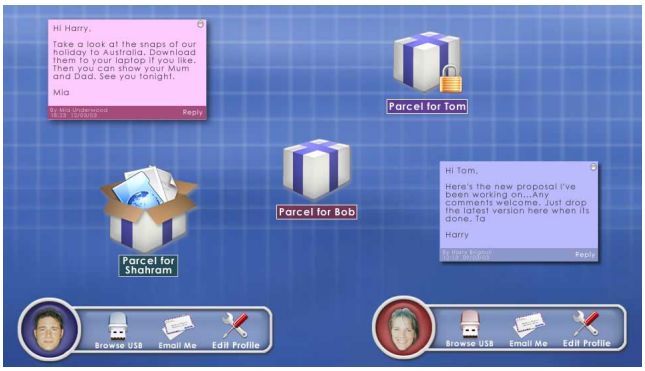

Figure 8. Notes and packages left on the surface

This section has described some of the main features of the Dynamo system. In the next section, we describe the

underpinning system architecture and discuss our implementation strategies.

The supporting architecture

The overall system architecture is shown in figure 9. The main functionality for the Dynamo System is made available through a number of *managers*. The *Input manager* captures local mouse and keyboard data and also receives input data relayed over the network. The *Telepointer manager* controls creating, destroying and moving telepointers. The *Window manager* takes care of creating the various window types on screen and destroying and freeing resources associated with these windows. It also maintains windows information such as Z-ordering and ownership. The *Palette manager* handles the creation and placement of system palettes. It allows new user-specific personal palettes to be created, and allows existing palettes to be populated with data.

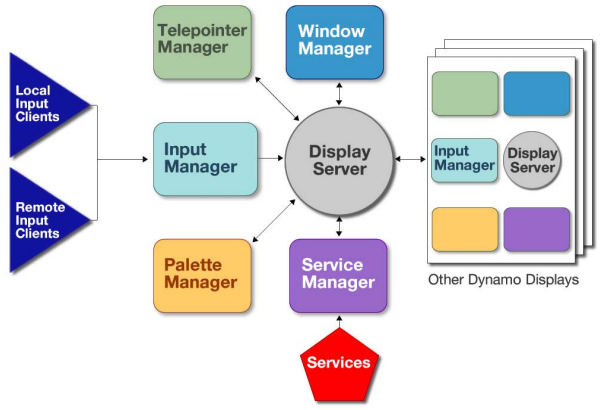

Figure 9. The overall system architecture

Finally, a *Service manager* locates new *services* that can be utilized by the system. The term service is used to describe a software component that can deliver media to the system, receive media from the system or both. Examples include wrappers for hardware devices such as web cams or printers, as well as, files on a file system such as those found on a USB disk. In the current implementation the Service manager listens for notifications when local devices are connected to the surface, which are in turn relayed to the main Dynamo application. Our plan is to extend this model in the future so that networked services can also be located and utilized by the system.

At the heart of the system lies the *Display Server*. The server acts as the main point of the control within the system. Its main job is to receive incoming data from the input clients and services (via the respective managers), process this data and render the output on screen.

The majority of the Dynamo system has been written in Java and C++. The core rendering and Input APIs have been written in C++ for win32 platforms. We use Microsoft's drawing library GDI+ for rendering, the Raw Input API (Windows XP only) for local multiple mouse and keyboard capture, DirectShow for audio and video rendering. Viewing of MS Office, Web, and PDF content is supported through ActiveX, OLE and COM technologies. For performance reasons, network communication is handled through raw TCP and UDP connections.

INFORMING THE DESIGN OF DYNAMO

The Dynamo system has been developed in a highly iterative manner with a series of ongoing evaluation sessions informing system development. During each of these sessions intermediate versions of the system were exposed to users as a means of checking emergent features and in outlining new facilities. The previous sections described the current features of the Dynamo system. In this section we wish to provide a very brief overview of the studies that shaped these features and also discuss some initial results from our recent assessments of these facilities.

Our initial formative evaluations focused on the placement of the surface in public spaces. In one instance, people congregating at a workshop held in a hotel were asked to use the system and provide feedback on its functionality. In particular, we were interested in how they took to the novel interaction techniques for sharing information across the public surface. These initial studies were significant in forming many of the mechanisms presented in this paper.

Our ongoing studies look more specifically at how the developed features may be used in practice. The study illustrated here focuses on the cooperative activities that enable the group to share, exchange and build information together using the surface. For this study, small groups of participants brought information to the public surface and worked together to create a poster assembled from a range of sources.

Obviously, space restrictions in this paper mean that we have to be illustrative rather than exhaustive in describing these studies. We therefore focus on the emergence of the carving and access control features associated with managing the surface as a communal resource.

Study 1: Public Feedback

This initial study sought to collect feedback from a group of people from different locations attending a workshop held at hotel conference center. The setting was akin to an ad-hoc meeting, where small groups might get together to share ideas. About 65 people were at the meeting. The Dynamo system was placed in the foyer, which was used for group breakouts and coffee breaks. We were interested in finding out what passers-by's perceptions were of the system; whether they found it easy to understand and use, and whether the physical configuration could support ad-hoc collaborative activities involving showing media to each other, and exchanging information.

The system was configured using a single SXGA projector providing a vertical public surface (approx 2.5m wide by 2m tall, positioned approx 1 meter above ground), with two interaction points supporting wireless keyboards, mice, and slots for USB disks. Laptops providing a mobile interaction point were placed on a couple of tables. Helpers were on

hand to give instructions and explain how the system worked.

The study was based on an early version of the system. The surface did not support an access control model, and users were free to carry out any interactions. The metaphor of carving was also used differently. Users would first need to carve an area of the surface and then display media within this area. In the next sections, we describe the key findings associated with carving and access control, and discuss how these initial metaphors were evolved to provide an effective means of managing the communal surface.

Findings

In total, 40 of the 65 delegates showed an interest in the system, of which about 30 interacted with it, some as individuals and others as small groups. The others watched on. Participants were observed interacting with the system, and then interviewed afterwards.

• Carve and drag interaction needs explicit instruction

When initially using the Dynamo surface, most of the participants clicked and double clicked on the icons in the palettes to try and activate them. This is a well-known user interface technique, thus for them to interact with the surface required us to explain and demonstrate the carve and drag concepts. When the reason for placing media onto the surface in this manner was explained it was readily understood. After a short while all the participants were able to master the new interaction technique.

• Simultaneous interaction and the problem of overlap

Participants all considered the ability to simultaneously interact on the public surface as being beneficial for collaboration. For example, one participant said *"it's much more sociable than using laptops around a table"*. Another said*"... you can just give something to someone by just dragging"*. However, others voiced concerns that the freedom for any user to manipulate any window could invite malpractice, like stealing copies of other people's work without their permission, or closing their windows.

Refining carving and access control

This initial study suggested that a communal surface to support the display and transfer of different media enabled information to be readily shared and exchanged. Different media (for example, video, images, web pages, PowerPoint slideshows) were rapidly selected from an individual's palette and placed on the Dynamo surface. Once opened the media was then available to be moved, controlled and copied to others.

However, this first study also showed providing a completely free-for-all surface can have its downside. In particular, users can metaphorically tread on each other's toes, by intruding or taking over someone's use of the space – especially when there is a multitude of concurrent activity on the surface.

This problem of *overlaps*, where one user's interactions interferes with another's, is a common problem in most groupware systems. We could implement a strict policy of control for the surface (possibly reducing the level of sharing and exchange) or, we could let the users decide their own social protocols for how to coordinate with one another. We did not see these options as the antithesis of each other. Rather, the issue for us was seeking a midway point between removing overlaps entirely and providing the flexibility needed for fluid coordination. The aim is not to provide a mechanism that restricts interaction but rather one that reduces overlaps to a manageable level and allows social protocols to be used between people (known to each other) to coordinate the sharing.

This lead us to develop our hybrid approach whereby users may mark areas of the surface as regions and then open these to others. Within regions overlaps may still occur but they do so at a more manageable level that can be mitigated by the surrounding coordination activities. The following study illustrates some of the social protocols that emerged within the groups, enabling them to work out for themselves how to share media within regions and handle these overlaps.

Study 2: Group working using the surface

A collaborative task was designed requiring shared usage of the surface. The task was open-ended, requiring group discussion. It involved creating an interactive poster on the Dynamo surface, by browsing and choosing media from a mixed selection of sources, which included USB disks and web sites. Three groups of four people were asked to select and spatially arrange the content from USB disks (slides, documents, images, and video) on the Dynamo surface to create a poster, with the option of creating text in notes and displaying web pages if they wished. The surface set up included two interaction points supporting wireless keyboards, mice, and slots for USB disks. A laptop providing a mobile interaction point was also available to the group. Two tables arranged in a wide 'V' shape in front of the surface were provided with chairs to sit on. This was to allow users to both easily look at each other and at the surface (see figure 10).

Figure 10. A photo of the set-up used for second study (taken from above the Dynamo surface)

As with the earlier evaluation, the participants had little problem learning the new interaction techniques, and readily understood the need to carve spaces and drag media from the palettes in order to be able to share them.

Over a period of time the groups developed their own social protocol of how to collaborate and coordinate their activities on the Dynamo surface. To begin, many participants had difficulties in knowing what the etiquette was of using the public surface. Most members of the group were very polite and asked out loud to the others in the group before they opened any media on the surface. Only one person went ahead and populated the surface with their media, without taking into account what the others were doing or wanted to do.

After a short while, the users began to look at the materials they were given. They did this by sifting through them and then selecting those they wanted to use in the poster. The surface provided a resource for organizing media across the group. Typically, the materials were organized on the surface in roughly ordered lists (ranging from 'definitely keep' to 'maybe'). Illustrated by the following excerpt:

> M carves a region and opens a history.doc
> C: *One for the parents there*
> R*: yes... might be interesting for some people*
> C: *Stick it down in the bottom corner somewhere*
> R: *Yeah.*

As the group members began to create the poster they often helped each other out by speaking aloud. For example:

> L: *Can anybody move this one?* (has trouble grabbing title bar) *I'm trying to get the old lady to the front.* (takes hand off mouse momentarily)
> P grabs an occluding window and moves it out of the way
> R then grabs another occluding window and moves it out of the way leaving L with space on the surface.

Other times they would ask each other to carve spaces to put media in:

> R: *Can someone else carve me a space and I'll put something in it*
> M very quickly carves a space: *there's a space*
> *C: I'll carve you the space and you can come and drop it in*

However, there were also times when users in the same carved region unwittingly got in each other's way:

> J makes some space for his new window by closing one in its way.
> *R: Oh, you closed my Events!*
> *J: Oh Sorry, Did I?*
> *R: That was mine that was!*
> *J: Oops! I do beg your pardon!*

Towards the end of the task, the various group members started to arrange the different shaped and sized media on the surface to construct the poster. A common strategy was for one of the users to propose a plan of action, which the others followed by creating various carve regions, placing media into them and positioning and resizing the items appropriately. For example:

> J: *I would like that, that box just to be the size of the picture, and then have that in the center, and then have all the things on the periphery.*
>
> R resizes a window to be smaller and positions it on the periphery of the region, and then does the same with another
>
> A also resizes a window small, and drags it next to Rs

Much coordination between the group members when working together was evident. At certain times, overlaps would occur but these were less frequent and therefore more manageable than the first study. When overlaps did occur people would often speak aloud to make others aware of the overlap or to apologize for their own actions. In general, we found that these social protocols were established quickly and allowed issues associated with overlaps to be resolved easily.

CONCLUSIONS AND FUTURE WORK

In this paper we presented the development and design of a multi-user public interactive surface. The Dynamo system exploits one or more large screens to allow a number of users to simultaneously interact. The surface is designed for the sharing and exchange of media carried by users on mobile devices. To support this we have developed a number of key interaction mechanisms:

- *Carve regions* allow users to appropriate portions of the surface and manage it as a communal resource.
- *Interaction points* and *palettes* are provided to allow users to easily transfer media to and from the surface.
- *Media parcels and notes* allow users to leave media on the display for extended periods of time, annotate media, and collaborate asynchronously with others.

These features have evolved from and been informed by a number of user studies – some of which have been described in this paper.

Our work is ongoing and we are currently looking at different ways of extending the Dynamo system to support other kinds of collaborative activities, especially those that happen away from the surface. One such feature is the provision for users to take copies of the media on the surface, disconnect from the system for a period of time and then reconnect to the surface remotely to maintain updates. We are also exploring mechanisms to allow remote Dynamo surfaces to be linked together, allowing carved regions on one Dynamo surface to be made remotely available to others. Our aim is to provide remote and co-located workspaces that support fluid access and sharing of information.

As in the case of the development of our current set of facilities, these new features will have a significant impact

on the way people collaborate. In particular, we are interested in the ways in which remote users (who are not shoulder with those at the Dynamo surface) will view their interactions, and share and exchange media with the remote group.

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