The Iterative Design and Study of a Large Display for Shared and Sociable Spaces

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Abstract

We explore the design opportunities presented by situating large interactive displays outside of the workplace, within shared and sociable spaces such as common areas at universities and conferences, cafes, and hotel foyers. We seek to provide a better understanding of this design space by charting the iterative design of an interactive large display system called Dynamo.

Dynamo has been designed to enable the sharing and exchange of a wide variety of digital media. We report on how the interaction metaphors were designed and refined upon in-lab and in-situ studies. We also study how an existing community uses this technology within their own established setting. Qualitative and quantitative analysis shows that the system was used extensively in a variety of ways, including sharing of photos, video clips, and websites, and for facilitating social interaction and collaboration. We conclude with recommendations for designing large display systems for shared and social spaces.

Keywords

Large Displays, User Studies, Interactive Systems, Ubiquitous Computing, Human-Computer Interaction, User Experience, User Interface Design.

The ethnographic studies revealed that people increasingly carry personal devices with them, but often lack the mechanisms to share media in situ, in a sociable way. In this example, the small screen of the camera poses limitations to shared viewing. In the final still, the girl shows frustrations in attempting to send the image to her friend's device.

Project Statement

The Dynamo project explores ways of facilitating information sharing, social interaction and collaboration within informal shared spaces, such as common areas at universities, conferences and cafes. Preliminary ethnographic studies [1] conducted on the project, revealed that increasing numbers of personal technologies are being brought to these types of spaces, with the aim of sharing digital information. In particular, media stored on mobile devices such as digital cameras, mobile phones, MP3 Players, removable USB disks, and laptops. The studies also revealed the potential for this type of digital information to act as triggers for conversation initiation and cooperation within the space [1, 2].

One of the main findings from these studies was that the ways in which collocated people can share digital information and collaborate are limited by the affordances of personal devices. They have small single user displays, lack features for group interaction, and often suffer from technical problems when trying to "talk" to other devices in order to exchange media. These factors often result in missed opportunities for social interactions and encounters. Based on these studies, the project aimed to explore the use of more appropriate displays – in particular large situated displays – in supporting activities within a variety of shared spaces.

Background

The project team provided a mix of disciplines and backgrounds, bringing together a technologist, UX designer and graphic designer who collaboratively worked on the design of the system. Two ethnographers conducted preliminary studies, and fed results back to the design team. Ethnographers, cognitive psychologists and HCI experts helped the design team in lab and field deployments of the system. The project ran for three years, with the first looking at ethnographic studies, design probes and sketches. The second focused on rapid prototyping and user-centered studies conducted in the lab and in-situ. The final year looked at longer term real-world deployments, refinement of the interaction model and evaluation of the system in these settings.

The precursor to this work is a broad body of research looking at interaction with large displays. These displays have predominantly been leveraged to support a variety of structured collaborative activities inside formal spaces such as meeting rooms, classrooms and offices [3, 4]. More recently, researchers have begun to investigate the possibilities for placing these types of displays within more social and public settings. These have included systems for conferences centers [5], common rooms and foyers inside organizations [6], and outdoor and indoor public spaces [7]. The shift towards non-workplace use and activities for large displays is a relatively new trend, as yet the design requirements for these display affordances in these contexts is unclear.

Solution

Our key design goal was to construct an interactive display that would support a variety of display, sharing and exchange functions, in particular supporting sharing of digital information brought to the space, as a way of triggering collaboration and social interactions.

In designing, building and studying the system we aimed to: better understand the requirements for designing large displays for informal, social and shared

The project faced many challenges: We required a hardware configuration that would be easily replicated outside of the lab in the real world. This meant working with readily procurable off the shelf hardware such as plasmas, instead of building custom hardware closely coupled with our lab environment.

We also aimed to design the system without being too closely constrained by limitations in existing software technologies. Our designers sketched out UIs and interaction models that pushed the boundaries of standard desktop systems. These led to software challenges in terms of supporting multiple points of input, and creating non-standard UI windows. These challenges resulted in the development of a new multi-user UI toolkit [9].

Our user studies also brought out challenges in terms of how best to capture data, particularly of screen interactions. This led to a generic logging tool that could playback system use on demand.

settings; study the effects that such a technology would have on an established community; and reflect on the social and technical implications for designing large displays. Key questions were: What type of physical display affordances work for these settings? How do people initially adopt such a novel technology? What types of interactive features facilitate social interactions and sharing within these types of spaces?

The overall development process was broken down into a number of phases and milestones (key parts are expanded upon later in this paper). These included:

- Preliminary ethnographic studies provided a better understudying of the nature of the space and provided some grounding to the stated problem. These are described in detail in [1].
- Lab studies helped identify initial system features and narrow the design space before the first phase of development.
- Design sessions ran throughout the course of the project. These first elicited system features, and UI designs based on preliminary ethnographic and lab studies. These helped form an initial prototype, which were later refined through evaluation and design sessions.
- Formative evaluation sessions exposed intermediate prototypes to users as a means of validating emergent features and design, and outlining new interactive facilities.
- A real world deployment looked at a longer-term user study of the display and evaluation of the designs in an authentic setting.
- The final phase looked at both qualitative and quantitative analysis of the system in use. This revealed diverse and extensive system usage, and helped us reflect upon implications for future designs.

The preliminary ethnographic study revealed a fundamental problem in sharing media and collaborating around personal devices in communal spaces. Our design goal was to explore how new affordances of displays could facilitate this process. Large displays such as plasma screens, wall projections or digital whiteboards, are inherently more visible than the smaller displays of mobile devices, and allow information to be shared and disseminated to larger groups of people. Our central solution was to augment existing spaces with interactive large displays that anyone can walk up and use. Groups of people can gather around these displays, simultaneously transfer media from a variety of sources (both personal devices and the web) and interact on the surface.

Charting the Design Space

To identify key system features and narrow the design space further, first a number of lab studies were conducted with a series of low-fidelity prototypes. These studies were designed to answer key design questions regarding the affordances of the display: whether it would provide multi-user or single-user interaction, what types of input device it would support and what the physical orientation of the display would be. These studies involved various problem-solving tasks, requiring individuals to coordinate, discuss and make decisions as a group. The tasks were deliberately designed to be open-ended (in the sense that there are no right answers), allowing for different media to be accessed, interacted with, arranged and ordered.

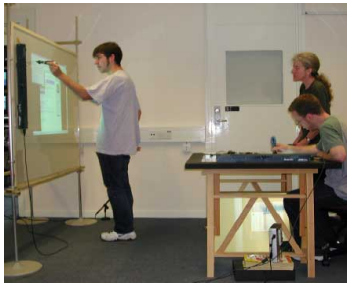

Figure 1: Large Interactive displays created for the lab studies.

For the studies two interactive displays were built. Back projection was used for both to prevent body shadows occluding the display. The vertical display surface used an SXGA projector, a semi-transparent plastic surface and a chassis frame (above left). The horizontal table surface used an SXGA projector, and a same sized glass surface embedded in a wooden frame (above right). Interaction with both displays was supported through pointing (using a Mimio device) or mouse and keyboard. Data was captured using observational notes, two video cameras (one focusing on subjects the other on the display) and post-study interviews.

A key aspect was to observe how different kinds of display affordances affect group collaboration, and, in particular, the way information is accessed, viewed and interacted with by collocated people working together. Some of the more salient findings from these studies are described in this section as they provide rationale for the interactive features discussed later. More details are provided in [1, 8, 9].

Multi-user or Single-user?

The first study explored the impact of single-user or multi-user displays on collaboration. The group task involved collaboratively designing an interactive poster. For the study a large vertical display (Figure 1 left) was connected to a Windows XP box, running the poster application (Figure 2). Two conditions were studied. In the first, the application allowed a single-user to drive the interaction. In the second, multi-user input was captured by the application to allow users to interact simultaneously. Groups of four were sat at two tables in front of the display (Figure 3), with either one or two input points comprising of keyboard and mouse. A total of 8 groups were studied – 4 on the single user display and 4 on the multi-user.

We found under the single-user condition, often role-based forms of collaboration emerged, where one user becomes the *interactor* or the *proxy* for the others. In the former, one person would often take charge immediately and dominate the interaction onscreen and within the group. In the latter, the user would become a proxy for the audience, who would call out for various actions to be performed on the display on their behalf. A number of subjects complained about not having had the chance to directly interact, and a number of participants appeared disengaged during the study. We also observed some “social embarrassment” associated with using the system in this condition. For example, some of the more quiet or shy participants clearly did not want to take the driving seat and control the interaction in front of others.

The multi-user arrangement provided more flexibility in the way people chose to interact with the display and each other, for example concurrently working on separate (but related) tasks, under roles where certain users act as the drivers, and showing and manipulating artifacts for an audience. Fluid floor control policies emerged in this condition, where people would easily coordinate their actions on the display – for example waiting for a colleague to resize media before repositioning it. In the single-user instance, the passing of floor control was less fluid, requiring people to interrupt the interactor to take control directly, and often change their own physical location or the position of the input device.

The time taken to build the interactive poster was also significantly different between the two conditions – the single-user arrangement averaged 34.4 minutes, while the multi-user 21.6. Of course, the tasks were open-ended in nature, so one would expect some variation between the groups. However we did observe the groups formulated various divide and conquer strategies for building the poster in the multi-user condition, which greatly reduced times for sorting through and arranging the media. For example, one person browsing and selecting the media while the other arranged the media on the display, or breaking the screen into two sections and arranging media simultaneously. The multi-user condition also allowed people to explore and learn the system features side by

Figure 2. The interactive poster application allows various media files to be selected and arranged on screen, including images, video, Web pages, text notes and drawings. The application can run in single user mode – where a user interacts in the same way as a standard desktop – or multi-user mode where input is captured from mice and keyboards (using RawInput) and used to control multiple cursors simultaneously.

Figure 3. Study observing multi-user input at the display. In this example two users are interacting with mice and keyboards, while one sources media from a laptop.

side. They would gesture with the cursor or carry out actions on each others behalf to get both parties up to speed with the interaction model. This complemented the "over the shoulder" learning model that was afforded by the large display, and could in part be attributed to the increased collaboration and task completion times for the multi-user condition.

Pen or Mouse Input?

The second set of experiments looked at different input techniques for interacting with the display. The display setup, task, number and grouping of subjects, and data capture was the same as the first series of studies. Two conditions were observed: one using the Mimio (a pen based input device) to interact with the display (Figure 4), the other using standard wireless mice and keyboards. A single user version of the interactive poster application was deployed.

We found that the pen input condition exacerbated the social embarrassment that subjects felt in the first study. With the pen, the user had to be positioned in front of the display and others rather than sitting side by side. Some users commented that they felt "on stage" or under the spotlight. Over half of the users interviewed reported that they experienced embarrassment and did not feel relaxed. Some commented that they felt under pressure not to make mistakes, not to be hesitant while interacting, because of onlookers. This level of self-consciousness and awkwardness was also noticed by onlookers. Those participants who were interviewed who did not interact with the system all indicated social awkwardness as the core reason. Out of the 16 participants that sat in on the pen based session only 5 interacted with the system. This contrasts with the mouse and keyboard case where 10 directly interacted.

Another reason for this apprehension could have been that the pen provided a paradigm shift for the users in terms of model of interaction, whereas the keyboard and mouse provided a more familiar model, in keeping with the desktop machines that they had already used. Subjects clearly struggled with certain aspects of pen input – for example right clicking or dragging across large areas of the screen. While other aspects of pen appeared more fluid than the mouse, particularly when arranging media or annotating on the screen.

With pen input the user also had to be situated within reach of the display to interact, which limited their orientation and spatial arrangement. During the studies we observed that people would often use their own mobility and the mobility of artifacts to coordinate their collaboration with others. These types of mobility were restricted during the pen study. The person at the display found it much more difficult to keep aware of what the others were doing at the table. In contrast, wireless input devices allowed collaborators to quickly work side by side at the table, move around more freely, and largely maintain their orientation with others. We also found that people interacting with pen often occluded other members, who would have to reposition or glance around the user to see the actions occurring on the display.

Horizontal or Vertical?

The final study looked at how the physical orientation of the large display impacts on collaboration. Both vertical (Figure 4) and horizontal (Figure 5) conditions were tested. 16 groups, each made up of three participants,

Figure 4. Study observing participants interacting with a large back projected display using pen input.

Figure 5. Study observing participants interacting with a tabletop arrangement.

took part in the study. 8 groups took part in the vertical and 8 groups in the horizontal condition. The problem-solving task involved developing an itinerary for a day trip to London for a particular group of tourists, with a specified budget.

Both arrangements had specific benefits. Situating a large interactive display as a horizontal surface encouraged group members to work around it in a socially cohesive and conducive way. The way the horizontal condition was configured meant that it was possible for all seated members of a group to see the information on the display. The close coupling between the work surface and the display made it easier for the members to switch roles, via putting down and picking up the input device. Group members maintained a high level of awareness of what each other was doing even though they were sat side by side. However, sometimes it was difficult to establish eye contact, especially between the two members sitting at either end. The close physical proximity also came at a cost – eliciting some levels of discomfort and social awkwardness between members and limiting mobility during the task.

Clearly the number of people that can sit alongside or round a table and have the same viewpoint is limited. Any more than a small group of three or four is likely to make it difficult for group members to talk to each other while also interacting with the display. One obvious advantage of the vertical displays is that they can accommodate groups that are likely to change in size, and where information needs to be shown and discussed with an audience of people.

Another key contrast was that vertical displays inherently afford more varying levels of engagement than horizontal tabletop displays. Participants could indeed interact directly with the display or they can interact indirectly with it. For example, they can be remote drivers by asking direct interactors to do something on their behalf. They can be casual observers, attending to the display occasionally. They can be closely engaged with what is going on or from a distance as part of an audience. This allowed less comfortable users to first take a back seat, learn the system and later engage at their own pace.

Dynamo

Based on the findings reported in the previous section, a prototype of the Dynamo system was developed composed of three key parts:

- A large shared vertical display which is typically composed of a plasma or projected screen.
- *Interaction points* comprising wireless keyboard and mouse or laptops for multi-user interaction on the display.
- The *device hub* where users' mobile devices can be connected and media accessed and transferred.

The overall function of Dynamo is to provide a large visual surface which supports a range of display, sharing and exchange functions, and allows the interconnection of a variety of personal devices and media types. Dynamo may be used in many ways, for example as a noticeboard, a presentation screen, a surface for group "show and tell" activities, for exchanging files, for browsing the web and multimedia in groups, and generally, providing a shared point of reference for conversational support. A full report of the interactive features of Dynamo is provided in [9]. A screenshot of the system is shown in Appendix 1a.

Dynamo acts as a hub for:

- *Displaying* media from a variety sources (mobile devices, network drives, the Internet) for people gathered around to view and discuss.
- *Interacting* with media. For example, navigating through a slideshow, browsing web pages, and controlling video.
- *Arranging*, positioning and resizing media according to the activities and physical arrangement of users.
- *Transferring* media to other endpoints, such as connected devices, allowing people to download content and *exchange* information between their personal devices.
- *Grouping* media together for organizing and storage.
- *Persisting* media for asynchronous use, so that content is available even when the source disconnects.
- *Mediating access* to owned media in order to grant or deny access to others.
- *Duplicating* media directly on the surface, so that people can work on copies side by side. For example, concurrently analyzing different parts of the same video clip on the display.

Dynamo is a multi-user system, allowing simultaneous interaction from multiple users, via interaction points. Each interaction point controls a color-coded cursor on the display. In the first version of Dynamo, multi-user access is optimistic and relies on social negotiation between the co-present users. For example, all windows can be manipulated by any user, regardless of who created them. Dynamo supports most common media types, such as MS Office documents, Web pages, and common image, video and audio formats. Media types can be scaled on screen – i.e. stretched to larger or smaller sizes – arranged, and interacted with e.g. navigating through web pages or PowerPoint, editing text, and playing video and audio.

Interaction points are the means by which users interact with Dynamo. “Base” interaction points (typically wireless mouse and keyboard pairs) are deployed as standard so people can walkup and interact. Users with laptops or tablets can utilize these as “mobile” interaction points, connecting over the network and redirecting input to the display. In a normal set up, three base interaction points are provided. Any combination of base and mobile interaction points can be used. Additional interaction points can be added (or taken away) during usage.

The device hub allows mobile devices to be connected to the display either physically using USB or over the wireless network. Once connected, media can be selected, transferred to the surface and displayed, arranged, annotated, copied and controlled. Alternatively, existing media on the display can be downloaded to connected personal devices and taken away by the user. Middleware is leveraged to make the types of devices and data formats the display supports extensible at runtime [10].

Information is moved onto and off of the display using *palettes* (see Appendix 1b). A palette consists of a number of distinct items, represented by icons, which can act as ‘sources’ and ‘sinks’ of media. A media source can be dragged off the palette and displayed on the Dynamo display. For example, a source wrapping a video file can be dragged onto an accessible region of the display whereupon the file is opened, rendered on screen, and interacted with. Similarly, the user can drop media onto a media sink item within the palette for processing. For example, dropping an image file on a removable USB drive icon downloads that particular image to the related disk. Palettes provide the main mechanism by which users can transfer information between the display and connected personal devices.

Further Informing the Design

Dynamo has been developed in a highly iterative manner with a series of evaluation sessions informing the design of interactive facilities. During each of these sessions intermediate prototypes were exposed to users as a means of checking emergent features and outlining new facilities. The initial formative evaluations focused on the placement of the display in heterogeneous shared and social spaces for short periods of time. These included the foyer of a hotel which was used by workshop attendees during group breakouts and coffee breaks [9], and the communal bar area at a conference centre [2].

One in situ study was designed to support media sharing between delegates attending a two-day workshop at a hotel. The display was placed in the foyer, which was used for group breakouts and coffee breaks. About 65 people were at the workshop. In total, 40 of the 65 delegates showed an interest in the system, of which about 30 interacted directly, some as individuals and others as small groups.

The system was configured using a single SXGA projector providing a vertical display 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 devices. Laptops providing mobile interaction points were placed on a couple of tables. Two ethnographers studied the interactions occurring within the space and on Dynamo, and interviewed people afterwards.

The findings of these studies revealed that Dynamo had promise in enabling media sharing within such social gatherings. However, problems in ownership and access to media and devices also emerged. Much collaboration and coordination was observed during these studies. People often passed onscreen windows and media to each other, they helped each other out by gesturing with cursors and delegating control, and exchanged roles and interactive arrangements fluidly based upon the tasks at hand. For example, in several instances it was observed that a group would simultaneously search the web for content, and gather resources and arrange them on the surface, before having various discussions about the material. These would act as conversational triggers for others to join into the discussion.

A great deal of sharing and exchange of information between parties was also observed. In several instances, groups of people, with USB devices or laptops, would move material over to the display surface to start a group discussion, after which others often copied the on-screen material onto their devices. Often people would stand on the periphery of the "interaction zone", where others were directly interacting with the surface, and first observe others using the system. In some cases, these people merely remained observers, while on other occasions they were drawn into interacting with the system. People in these activity spaces engaged in socializing activities associated with the display - talking about, gesturing to and watching the display being used. Other people were more peripherally aware – typically eating, drinking and socializing elsewhere in the space and occasionally glancing over.

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.

The use of a single projection screen (giving a maximum resolution of 1280 pixels by 960) resulted in the surface often becoming cluttered and crowded with media. At particular times during quiet periods, certain users would "prune" the media on screen by closing active windows. This often led to frustrations as people returned to the surface and found their material had gone. One user commented: *"I didn't like the fact that other people kept closing my notices when I left"*. When interviewed users raised concerns about privacy and security, particularly given that anyone could take a copy of material on screen or browse items on their personal devices. In several instances users accidentally opened other peoples' connected USB drives, causing embarrassment and concern to the owners. Users were therefore hesitant in having their personal devices connected, in case someone would maliciously or accidentally open up sensitive material.

Refining the Interaction Metaphors Further

These preliminary studies showed that providing a completely free-for-all surface can have its downside. Users can metaphorically tread on each other's toes, by intruding or taking over someone's space – especially when there is a multitude of concurrent activity on the

Figure 6. The user palette provides access to user specific services, such as browsing a personal device or emailing content to the individual. The palette is password protected so that only the owner can logon. Only the associated cursor (that the user logs on with) can access the contained services and any windows opened using the palette.

display surface. There was also a notable lack of representation of ownership and access rights of devices within Dynamo's virtual space. In light of these and other issues, the Dynamo user interface was refined in several ways.

Device Ownership and Registration

Any user, who desires private access to their personal device, can optionally register it. Registration can be carried out away from the Dynamo display, via a web-based application. This creates a configuration folder on the user's device, which includes an XML document containing the specified name, password (encrypted), and personal icon of the user.

When an unregistered device is connected to Dynamo, it appears on the public palette, and is accessible by anyone. When a registered device is plugged into Dynamo, it appears on a separate, user palette (Figure 6). The owner can click on the palette and enter a password into a small dialogue box which appears adjacently. Upon login, the system associates the cursor to that particular user. If a user connects multiple registered devices, one user palette aggregating the services of each device is created. Unregistered users are able to use the system at any time as anonymous "guests". They have access to public areas of the surface and can interact with media and devices on the public palette.

Persisting and Aggregating Items

Another issued raised by this first study is the management of the surface real estate. The surface would often become cluttered with media, and the lack of persistence was problematic when "pruning" media from the surface. An initial solution could be to increase the resolution of the surface by adding support for multiple tiled displays. While this may be a useful facility for users, the surface is still likely to get congested with media, particularly when used for long periods of time. This is because the users do not have the means for effectively grouping and preserving the media on the shared surface in a "compact" form. They can either leave media open on display or close it permanently.

The interaction metaphor of *parcels* is introduced to provide users with a means of packaging media together on the Dynamo display for future access. Parcels allow for asynchronous sharing of media. They allow media to be posted up for others and left on the Dynamo display for extended periods of time in a

An example of creating a parcel: Users (shown by red and blue cursors), drag content into the parcel. These appear as icons in a tray at the bottom of the parcel window. Clicking each icon opens the associated media file in the parcel window. The user can select the recipients from a list. Finally, the *seal* button is pressed and the iconified parcel is labelled for access later.

A carve region on part of the shared display. On the right a cursor passing through a carve region is displayed encased in a bubble, indicating it cannot interact with the surrounding region or contained windows.

The creator of a carve region can invite other registered users into their space by placing a key icon (located at the top right hand corner of the region) onto the palette of the desired user.

private form. Parcels have two states – sealed and open. When sealed, a parcel is shown iconified with a text label. When open, the parcel allows users to browse the contained items and open specific content in the window. Parcels also offer facilities for setting access control, sealing, and deletion.

Partitioning the Space

The problem of *overlaps*, where one user's interactions interferes with another's, was another common finding of these studies. One approach could be to implement a strict policy of control for the surface and contained media (potentially reducing the level of sharing and exchange). On the other hand, it could be left to the users to decide their own social protocols for coordination on the display. The design challenge is seeking a midway point between removing overlaps entirely and providing the flexibility needed for fluid coordination between collocated people. 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 groups of people (known to each other) to coordinate the sharing.

Carving is the interaction metaphor introduced to allow users to appropriate an area of the shared display for mediated access. The technique provides identified users with the capability to "carve off" an area of the large display providing them with a workspace that they can use to arrange and share media. Access to this area and any contained media is controlled by the creator of the carve region. Users mark an area of the surface (using an interaction point) by first indicating the starting location and then the size of the region. Once marked out, interaction with the carve region is restricted to the creator – referred to as the "owner" – of the carved region. Other users attempting to access this region will receive visual feedback identifying that interaction within the space will fail. The owner can then choose to open this area of the surface up to others in order to interact collectively. This is done by dropping a key icon onto the palette of the desired user, placing the key in parcel (for asynchronous access), or placing the key over the cursor of another collocated (but unregistered) user.

A Real-world Study of Dynamo

After this redesign, we sought a more thorough and longer-term study of Dynamo within an authentic real world setting. The aim was to find a communal setting that was used by a large group of people who interacted regularly with each other for a variety of purposes (and who were not members of a familiar research community). A main motivation was to explore how an existing community who move in and out of a shared physical space – that has its own cultural identity and existing configuration of technologies and artifacts - relate to, take up, and accommodate a new technology. Of particular interest was whether the community would use Dynamo to publicly exchange, show and share an assortment of digital media in social, fun and collaborative ways.

The focus of this study was to examine the initial adoption and social effects that arise when a new technology is introduced into an established communal setting. A key factor for the successful adoption of large surfaces, that involve voluntary use, is the way they are initially perceived by members of the targeted community with respect to how they can be used to their advantage and effect. In view of this, a two-week

Various deployment options where explored such as a student volunteer's room at a conference, and a common room for a student union newspaper team on campus. Access was finally negotiated to a high school common room used by a community of students. What was particularly appealing about this space was that it was used to support a peripatetic community of people and a broad range of social activities. Of particular interest for the study was the extent to which the students would use the Dynamo display, how frequently and for what purposes, as well as exploring the social conventions that arose when using the surface within their own setting.

The common room supported a variety of activities including reading, eating and socializing. Information was disseminated using noticeboards and flyers.

study was conducted that enabled an analysis of the evolving patterns of adoption and social interaction during the initial period of deployment [11].

The Setting

The Dynamo system was deployed in a common room provided to 17-19 year old (6th form) high school students as a place to socialize between classes. A number of different approaches were used to understand the setting and to collect information:

- A brief ethnographic study was undertaken prior to the deployment to understand the nature of the space and to consider its suitability as a place of deployment [1].
- System activity was logged throughout the study to capture users' direct interactions with Dynamo.
- Two researchers were present to study system use throughout the deployment. Two fixed video cameras captured interactions around the system, one focusing on the screen, the other capturing the room view. These were supplemented by the intermittent use of a hand-held camera.
- Pre and post questionnaires were distributed to the students to collect details and opinions.

There were 150 students at the college and there was considerable movement in and out of the common room during the course of any day. The students made use of the space for a variety of purposes. They would hang out with friends in free periods, sometimes doing schoolwork, but mostly socializing. A preliminary survey showed high levels of personal device ownership, with mobile phones being most popular, and digital still cameras, USB and ZIP disks and MP3 walkmans the next most commonly owned devices. Instances were observed of students passing around their digital cameras to show others photos they had recently taken, and sending each other photos via their MMS mobile phones. The students reported use of communication tools, including mobile phones, SMS and MMS, email and IM.

Direct Interactions with the Display

The system was deployed for a total of ten days from late Friday afternoon to Thursday evening (see Appendix 2 for further details). The room was available to students Monday to Friday from 8.30 to 5.30. During the two-week deployment, the use of Dynamo varied considerably: students displayed and exchanged photos, video and music, which they had created themselves or brought in from home, they contributed to a pool of public media and left parcels as private gifts for specific people, they gave entertaining shows to audiences, posted notices for others, played together on the surface, and engaged side-by-side in group discussions and interactions.

Figure 7 shows the types of media that were displayed on the surface. Internet connectivity was limited in the first week due to a number of networking issues, which explains the upsurge of HTML content displayed in the second week. Images and video were the most popular types of media displayed. The availability of digital cameras that could be easily connected via USB encouraged students to generate this form of content. Over half of the media uploaded to the surface came from digital stills or video cameras. Most of this media was created on the fly by students for their friends and tended to be more popular than displaying media from the web and other places (even when Internet connectivity was restored in the second week).

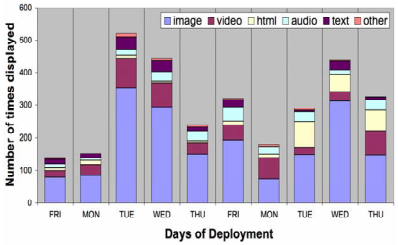

Figure 7. Different media formats displayed on the surface.

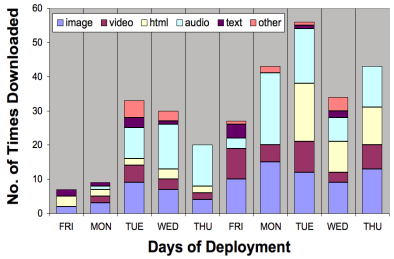

Figure 8. Different media formats downloaded from the surface.

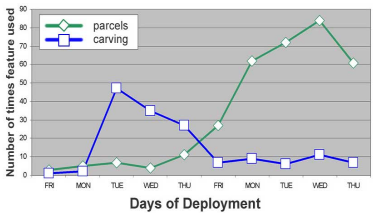

Figure 9. The use of parcels and carving during the study.

The creation of new media content such as photos of friends, videos of students performing, and music of school students, captured the imagination of the students – most of whom had an artistic background. More longitudinal data is required to draw deep conclusions as to why media created in this way by the students proved so popular. However it was observed that these types of media were more readily used as conversational props and drew in a greater audience within the common room, and therefore would have carried a greater social significance for the students.

Video files and other media files brought in from home by the students using removable USB drives also proved popular. Media sourced from removable USB drives makes up almost a quarter of all media uploaded onto the surface. A smaller percentage used laptops and MMS phones for sourcing media. Laptops were used in very specific cases, when students needed to edit and convert media before transferring it onto the shared surface, in particular, for photography students that required scanned versions of their photographs.

Audio (created by music students and various school bands) tended to be as popular as images and videos to download from Dynamo, as shown in Figure 8. Many of these downloads reflected a negotiated exchange where one student would either offer or request the media from another.

In addition to logging the movement of media types, the use of the interactive mechanisms provided by Dynamo were also logged. Figure 9 shows the number of times the system features of parcels and carving were used. For parcels this is the number of times a new parcel was created, or an existing sealed parcel was opened. For carving this was the number of times a user carved a region and added a window (or set of windows) to it. Carving was used more frequently in the first week than in the second, as users developed a better understanding of this feature. In the first week, carving was often used as a mechanism to play and socialize with others - by either carving over another user's active window or carving over the free space on screen to deny access to others. This unanticipated and playful usage helped users strengthen their familiarity with this feature. By the second week carve regions were used in more targeted ways, when users found a genuine need to control access to shared content such public notices and images.

In comparison, the adoption of parcels was much slower. As shown in Figure 9, parcels were used more in the second week, when users needed to persist items, avoid on-screen clutter, and leave gifts for one another. Parcels became increasingly popular as they allowed students to filter media, and persist items that they knew would engage and hold the attention of the recipients, such as funny photos of friends and acquaintances on the school trip.

Findings

The system was used throughout the study by a range of different users for a number of different activities. Relatively even distributions of male and female participants were observed. Post hoc feedback from the students regarding Dynamo was overwhelmingly positive (78% of survey respondents wrote positive comments), and many indicated disappointment when the system was dismantled at the end of the study. Although these interviews do not provide conclusive

Figure 10. Tidying up the virtual space by repositioning parcels and closing redundant media windows.

Figure 11. People interacting simultaneously on the display side by side. Here the user on the right takes on a tutoring role.

evidence, they provide a general feel for the perceived effect of Dynamo on community life in the common room. Headcounts before and during the study also indicated that the common room was considerably busier during the deployment.

Persistence and Display Space Management

When Dynamo was first introduced, media on the display was highly ephemeral. After an initial period, users began to see Dynamo as also a display for persisting media, in the form of public parcels and notices. Interestingly, other users learned not to close these items down, by judging whether they looked like they had been intentionally left up for public consumption. In doing this, they would also often close down windows that looked redundant (such as redundant file browser windows or out of date notices).

The ability for registered users to lock media windows, gave rise to the practice of "policing", i.e. keeping track of users who left locked windows, and reminding them to close them down. Parcel "tidying" was also an activity that people became increasingly engaged in as the study progressed. Users would gather up these parcels and tidy them into rows or groups, sometimes putting newer or personally favored items first, and older items last. Certain users took on these roles and would police or tidy the surface daily. Interestingly enough, these users who took on maintenance roles on Dynamo were also members of the student union: a small group of students who had a position of responsibility and were partially in charge of managing the upkeep of the common room. There were strong parallels between the practices and roles of responsibility, tidying and maintenance in the physical common room, and on the Dynamo display. For example, one user would routinely tidy up the common room and mirror these actions by tidying up parcels on the virtual surface (Figure 10).

Socializing and Concurrent Use

Individuals would often entice social interaction with others in the room using Dynamo as a *conversational prop*. For example, they would select media that they felt would trigger conversations with others gathered, or deliberately resize windows to engage people at the back of the room. These props had a "honey-pot" effect drawing larger and larger groups of people, which often lead to the cooperative use of Dynamo. Figure 11 shows a typical large group directly interacting with Dynamo. Here 6 people are sharing 3 interaction points, and are intertwined in conversation about the websites and media displayed.

Another emergent practice involved the *co-browsing* of media folders and web pages by two or three people together. For example, users would connect a digital camera, and share a file browser window, each pulling out images they personally found interesting, positioning them on the surface, and chatting together about them. Such media collages would often be left open on the surface for others to see, or users would collaboratively fill a parcel to store the content in. People would also browse the web together in a similar way, using it as a resource to spontaneously find and display media to socialize about.

The students quickly understood the sociable and open approach to the information sharing that Dynamo enabled. While students were already familiar with media sharing technologies, such as email, IM, MMS, they discovered it was more sociable using Dynamo.

Figure 12. Engaging from the back of the room, by occasionally glancing over at the display.

Figure 13. User decides to register a USB device, using an available laptop.

The extensibility of the model allowed students to use their own personal devices to interact with the Dynamo. Students frequently collated media from different sources to share with others. For example, people often brought in media sourced from digital cameras and emails and left these up visible on the surface as public resources, promoting discussions and allowing others to freely download them.

Levels of Engagement

People in the vicinity of Dynamo were able to "oversee" interactions while engaging in other activities away from the display. Low engagement included being present but engaged in an activity away from the display; occasionally re-orientating towards the screens; or shouting out intermittently to indicate peripheral awareness, for example "*make that photo bigger*" or "*turn it up*". The open nature of the space and the physical affordances of the display lend themselves to these levels of engagement. People would become more drawn into actions on screen and chat and discuss with direct interacts increasingly their level of engagement. This often led people to directly interact either individually or as a group with Dynamo, paying a great deal of attention to the system and conversational interactions relating to the media displayed.

Gradual Buy-in

These levels of engagement enabled "gradual buy-in", allowing users to move from typically low engagement or occasional use of Dynamo, to progressively higher levels. People learned about the system while going about their normal daily activities in the common room, gradually gaining enough knowledge to interact. The multi-user aspects of the display meant there was almost always an interaction point free for first time user to start experimenting with the system – manipulating public media, devices and services. At a further level of buy-in, students could register their devices so that they could log on to the system and have a degree of access control over their own media. This buy-in model made it easy for students to try out Dynamo with minimal effort and to choose when they wanted to increase their buy-in up to full registration.

Tutoring

It was observed that the community members themselves became tutors, demonstrating the system to others. This type of tutoring was often implicit rather than explicit. For example people would invite their friends (who were novice users) to join them and start using Dynamo together side by side. As well as, being a social activity, users were also introducing others to the system and transferring knowledge.

Dynamo's multi-user facilities enabled users to tutor and help each other in this way. For example, a user who does not know how to fill a parcel can be helped by a friend, as they can simultaneously fill the parcel together using different interaction points. This type of side by side tutoring was observed numerous other times during the study, and complemented the over the shoulder types of learning afforded by the large displays. The latter was important for those students who were not comfortable learning in front of their peers. Often back seat tutoring was observed, from people who never actually used the system directly but who had learnt from watching. Other students made use of known quiet times to try out the system when there wouldn't be many people around, thus also avoiding social embarrassment.

Future work will look at different ways of extending the model of interaction 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.

The ability to allow remote Dynamo displays to be linked together is also being explored, allowing carved regions on one display to be made remotely available to others. The aim is to provide remote and collocated workspaces that support fluid access and sharing of information. As in the case of the development of the current set of facilities, these new features will have a significant impact on the way people collaborate. Of particular interest is the ways in which remote users (who are not shoulder with those at the display) will view their interactions, and share and exchange media with the remote group.

Implications for Design

The iterative design, lab and in situ studies provide some initial insights and implications for the design of large interactive displays for shared and social settings. These include:

- *Interactive displays should be sympathetic to the shared nature of the space and the affordances of existing physical artifacts in order to closely fit the ecology of the space*. For example, Dynamo display mirrored and extended the shared nature of other physical surfaces within the space, such as walls and tables, and provided multi-user interaction that helped its adoption as a communal resource.
- *Provide flexibility both in terms of physical and digital arrangements*. These types of communal spaces are configurable. They contain different artifacts that can be moved around and rearranged to suit the community of people. When developing interactive display systems it is important to consider these properties of the physical space and allow the technology to also be rearranged and reconfigured by its users. For example, within the study, Dynamo was flexible in terms of the personal devices it supported, allowed users to choose the different interactive configurations that they required. Further, people were not physically constrained when interacting with the surface, and could freely position themselves within the space. This configurability allowed users to adopt and use the display in the ways they wanted to, without radically impacting on their existing use of the space and technologies.
- *Design interactive display applications that the community can adapt to their own activities*. When designing for such general-purpose and diverse social spaces it is important not to overly structure interactive applications for particular activities or use. For example, within the study, the attempts to promote use by placing seeding media based around student assignments and what were considered interesting images failed because students found them contrived. Rather the students used the generic facilities of the surface in the ways that closely fitted their existing practices and activities within the space, such as socialising, creating and sharing media.
- *Provide an initial set of display-based interactions that are intuitive and can be easily and comfortably followed*. Allowing users to engage with the display, without needing help or feeling self conscious, is a key concern when situating displays in communal spaces. For example, during the study, the support for graceful buy-in meant that students could gain confidence with the initial set of interactions and then move on to learn the novel mechanisms of the model of interaction such as carving and parcels to enable more controlled sharing and exchange of media.

Conclusions

This paper has presented the iterative design of a large display system for shared and sociable spaces. Preliminary studies have identified a need for better support for media sharing and collaboration within such spaces. The designs have explored the integration of personal devices and large displays for media sharing. In-house and short-term studies have helped refine and validate the designs and model of interaction. A longer-term study has explored the effects that such a system can have on a real-world community – augmenting the ways that people socialize, collaborate and

communicate with others in such spaces. Qualitative and quantitative analysis shows that throughout the study, Dynamo was used to display, share and exchange a wide variety of media. There was a high uptake of the various Dynamo features. The students accomplished familiar activities in novel ways and with different interactive arrangements. This took place within a communal context with the students integrating Dynamo as a shared resource into their communal space.

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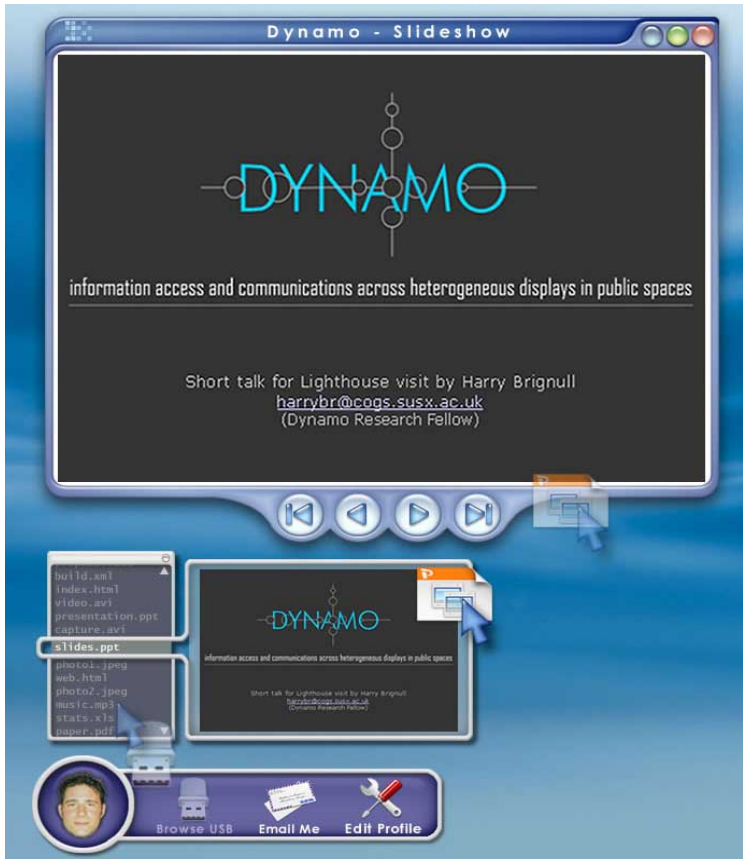
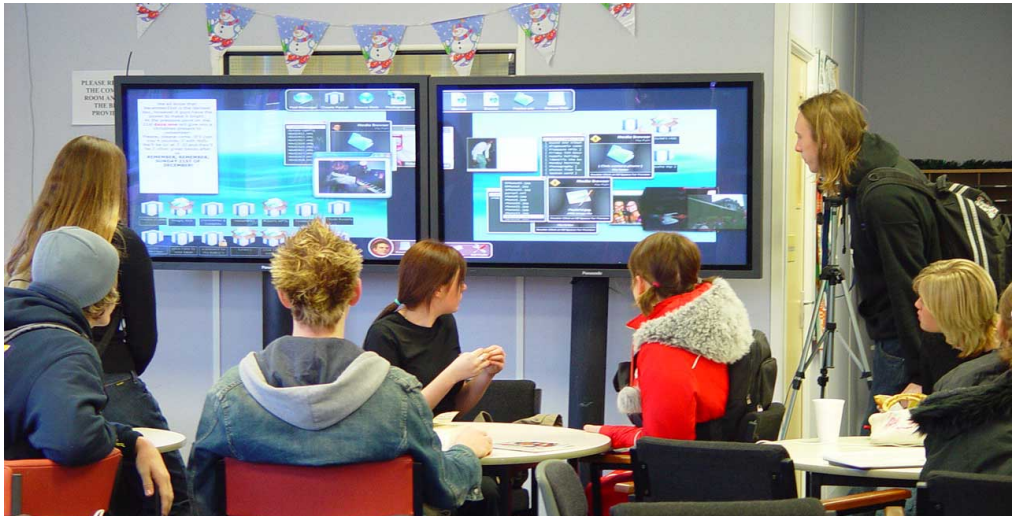
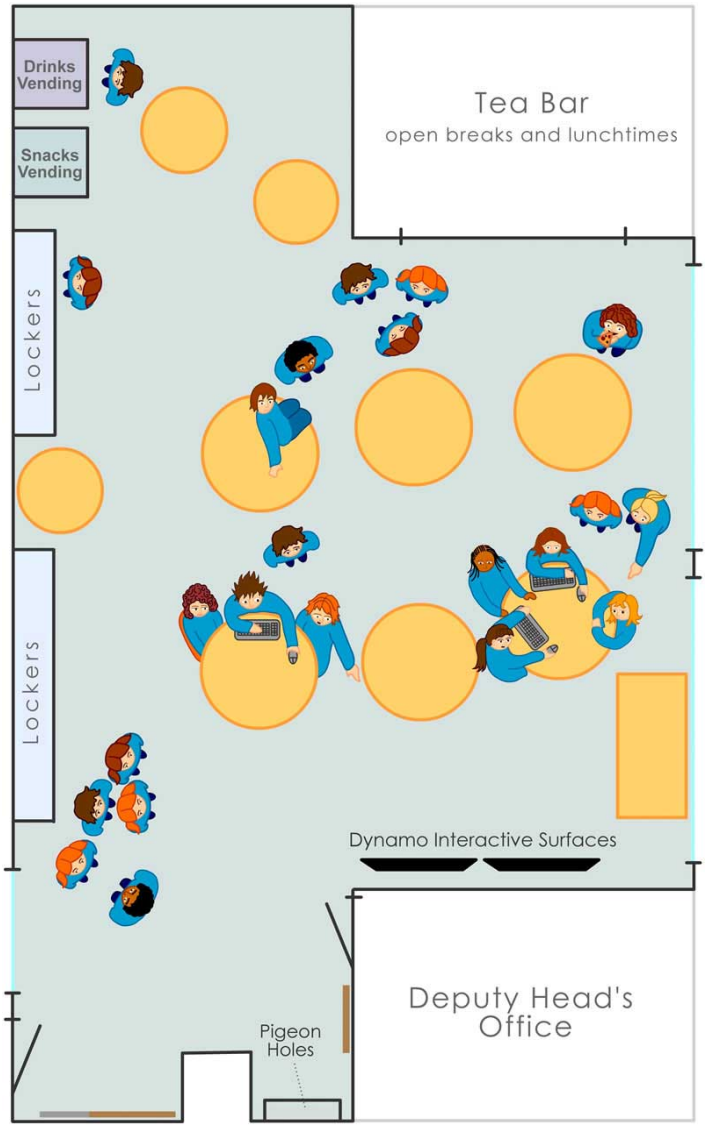
Appendix 1a. The Dynamo interactive display application. Color-coded cursors show multiple users interacting simultaneously on the display. The "palette" at the top provides access to public devices (storage devices, multimedia devices, printers) and public system services, such as browsing web, posting a message and creating a parcel to store media.



Appendix 1b. Interacting with palettes. Familiar direct manipulation and WIMP metaphors are used to interact with palettes. *Dragging* an item off the palette opens the content on the display – either rendering the media (with controls at the bottom), or providing a browser to navigate through multiple items to select or preview specific content. Media can also be dropped onto an icon on the palette for processing, for example copying a document onto removable USB drives. This is done by dragging the non-titlebar area of a window and dropping it onto the desired icon on the palette.





Appendix 2. For the deployment of Dynamo, two 50-inch plasma screens were positioned side-by-side against a previously unused wall, as shown left and depicted right. This particular arrangement was chosen over others (e.g. horizontal tabletop) to accommodate fairly large groups of people that were likely to change in size and also to afford vary levels of engagement with the displays. Three base interaction points, each comprising of wireless keyboards and mice, were provided for multi-user input. Removable USB drives were available to purchase allowing the students to bring in media for the display and take media away with them.