Organisation and Exportation of Media between Tabletop and External Storage Devices

ALEXANDER STEVENSON
SID: 307135306

Supervisor: Associate Professor Judy Kay
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School of Information Technologies
The University of Sydney
Australia

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Abstract

This research will be in focusing on how to manage and export digital artifacts from tabletop systems. Tabletop computing is designed for multi-user collocated collaborative work and we wish to build tools to further support this interaction paradigm. When using a tabletop it is critical that you have the ability to organise your digital media in ways which best suit your working conditions. This organisation scheme should also be collaborative and allow other people to interact with the digital artifact in a collaborative manner. We wish to also further explore the value that the simple process of exportation can be done to work at the tabletop. If you are unable to save or keep a copy of something you have been working on this diminishes the value it has as it is only accessible at that location. Hence in addition to organisation, we wish to study the impact and benefits which exporting digital artifacts from the table can supply.
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Chapter 1

Introduction

This thesis explores the organisation of media and methods for exporting media from the tabletop environment to an external storage device. We wish to enable users to quickly and effectively organise their files on the tabletop. Enabling users to export files from the tabletop will increase the potential power of the tabletop opening up a variety of new applications it could be used for. In this thesis we aim to explore these concepts and demonstrate their effectiveness at empowering the users of tabletops.

1.1 Motivation

Tabletop interfaces offer new ways to support collocated collaboration. While there has been considerable research into the ways that tabletops can provide new ways to collaborate, it is only recently that the price of the required technology has reduced to the point that tabletop systems are becoming increasingly available. Many applications have been developed for tabletop systems, for example digital photo sharing (Apter et al., 2006), 3D modelling (Maher and Kim, 2006) and browsing the internet (Morris et al., 2010).

1.1.1 Organisation

While there has been considerable research into many aspects of tabletop interaction, there has been little dealing with the organisation of information once it is actually on the tabletop system. Various forms of digital information are typically dumped on the tabletop in a haphazard manner, leaving the user to manually sort through the media. This thesis aims to develop automated tools which make the
1.2 Challenges

Chapter 1. Introduction

task of organising and managing media quicker and easier, so enabling the user to focus on their core task more effectively.

Existing tabletop organisation research generally involves the use of some sort of container which can be used to explicitly group media. In the case of [Scott et al., 2005], files have to dragged into the storage bin one at a time. We wish to provide a way this can be automated in such a way that users can organise very large collections in a few simple gestures.

1.1.2 Exportation

We believe that giving the user the power to export media from the tabletop system will dramatically increase the potential of tabletop systems. When users complete a task on the tabletop often the task they perform can be quite meaningless unless they have a way to take the end result of their task away with them. For example, if you were creating a postcard at a tabletop, you would obviously wish to be able to take the postcard away with you. Without the ability to take the postcard away the value of making it in the first place is extremely diminished. There has been minimal research published which addresses the issue of exportation and we wish to explore the field further and construct a solid conceptual framework.

1.1.3 Example Scenario

The following is an example scenario which we wish to be able to support by the end of this thesis:

Alice and Bob are planning a trip to Paris and each have brought along a mobile device to their tabletop display. Alice and Bob have to decide upon their itinerary for the trip by using the information contained in their mobile devices. Once Alice and Bob have transferred their files to the tabletop how should they be visually organised? And how can Bob take a copy of Alice’s photos away with him?

This thesis will explore ways to support activities similar to this one between Alice and Bob and answer the questions raised.

1.2 Challenges

There are many challenges and design considerations to be taken into account when designing on the tabletop platform. A main limitation of the tabletop interface is the limited screen real estate, which means large numbers of objects will clutter the screen to a large extent. Tabletop system input is typically performed solely through touches and gestures on the display; this is quite different from the standard
desktop paradigm of mouse and keyboard. While our proposed organisation tools will be designed to help reduce the problem of clutter we have to be careful we do not inadvertently create clutter ourselves when designing the tools.

Given that tabletop devices are embedded devices there is a range of challenges that need to be addressed. Tabletop devices can be used in a number of ways as a kiosk, enhanced kiosk or as a small group workplace device. As a kiosk people are able to freely walk up to the tabletop and interact with it. In this case no personal information or exportation preferences about users are known, we have to provide a flexible interface which users can use to export to various locations. An enhanced kiosk is similar to a kiosk, except that people are required to log into the system such as through a phone. Through this login we are able to fetch information about the user and are able to personalise the exportation interface. Finally we have the small group workplace device, where the tabletop is used by a small distinct group of people who use the tabletop often. In this type of environment we know exactly the people who would be using the system and should provide an interface which reflects this. Throughout this thesis we will further explore the design implications of each of these contexts.

1.3 Thesis Goals

The goals of this thesis are to:

1. Create conceptual framework, defining core operation and interface elements for the nature of organisation and exportation

2. Explore new interface primitives enabling small groups of people to organise files on a tabletop environment

3. Explore ways to enable exportation of files to external locations

1.4 Contributions

In this work I have created a conceptual model of organising and exporting digital artifacts from the tabletop, detailed in Chapter 3. We explore the variety of contexts in which tabletops can be used and the key user tasks which are critical to support on them. We then see how the concepts of organising
and exporting relate to these tasks. We also discuss interface primitives for the design of our tabletop applications.

In addition to the conceptual model, I have created two interfaces called MyCloud and Emailer. These applications are plugins to the Cruiser framework developed by the CHAI Research Group at University of Sydney. Eventually the tools I have created will be incorporated into the core functionality of Cruiser.

1.5 Thesis Structure

This thesis details the work and motivation performed in achieving the above mentioned contributions. It describes our motivations about performing work into the areas of organisation and exportation and describes the challenges we face when undertaking the research.

Chapter 2 discusses previous research in the fields of tabletop interaction, media organisation and file exportation fields that is relevant to our research. This chapter provides background about what existing research as a foundation for our work of tabletop organisation and exportation. We review work not just specific to tabletop but to organisation and exportation in general.

Chapter 3 will present a conceptual model of the system, including what is involved in organising and exporting media at a tabletop in terms of user interface primitives. We will describe different approaches that could be used to achieve our goals of organisation and exportation.

Chapter 4 will present our UI design & implementation of both the MyCloud and Emailer systems. We explore both the technology behind the applications and the design of the interfaces.

Chapter 5 details our evaluation design which we have used to evaluate our applications. We present all the questionnaires and tasks presented to the participants and our reasons behind each of them.

Chapter 6 summarises the entire project that has been completed. It links together the background, conceptual model and evaluation results into the key ideas which this research has revealed.

Chapter 7 outlines possible future work which could be performed to extend this research into a more mature state.
Chapter 2

Literature Review

This chapter outlines previous work in the fields of human computer interaction, tabletop interface design, organisation of files and the exportation of files from tabletop that is relevant to the design of our interface. We will identify sections of previous work to establish the groundwork for which this thesis will build upon. Problems and gaps in this research area of organisation and exportation of files on tabletop displays will be highlighted in order to clearly establish the outstanding questions.

2.1 Tabletop Interfaces

As a form of Single Display Group-ware, tabletop interfaces are designed to promote multi-user collocated collaboration and have been constructed in many different configurations. In terms of display, various techniques have been used including projection (Shen et al., 2003a) and self-illuminating screens (Collins et al., 2009). Various input devices have been explored with to interact with a tabletop including pen/styli (Shen et al., 2002), touch (Apted et al., 2006) and tangible interface elements (Ullmer and Ishii, 1997). As tabletop have evolved they are starting to gravitate towards a self-illuminating screen and multi-touch capabilities in order to accommodate multiple users at once.

2.1.1 SharePic

Typically applications when research is conducted in the tabletop area the result is a specialised application designed to perform specific tasks. Sharepic (Apted et al., 2006) is a good example of this, it aims to provide users with an interface to enable them to share and manipulate a collection of digital
2.1. Tabletop Interfaces

Figure 2.1: The Sharepic interface with users browsing some images.

photographs with other users. Using Sharepic users are able to perform a variety of tasks with the digital photos including moving, resizing, rotating and annotation. Sharepic also uses the concept of personal spaces where users can keep a selection of their own images which other users cannot interact with. In Figure 2.1 we can see the Sharepic interface being used by a pair of elderly people. The personal spaces are clearly defined by the coloured areas on either side of the tabletop.

The key ideas we can take from this research is that people can categorise digital artifacts on the tabletop in terms of ownership. People sometimes feel hesitant with interacting with each other files or are afraid people will touch their files. By defining a clear separation between artifacts and categorising them between private and public spaces, we can support this interaction paradigm. However in a tabletop environment, we are trying to encourage collaboration and this paradigm is counter productive. We want people to share and interact with all the information on the table by segregating the digital artifacts into ones that you can use and ones which you can’t people may feel restricted as to what they can do.
Chapter 2. Literature Review 2.1. Tabletop Interfaces

(a) The tabletop layout.  (b) The private space on a user’s laptop.

Figure 2.2: Screenshots of the parts of the Ubitable system

2.1.2 UbiTable

The UbiTable system, as presented by [Shen et al., 2003a], explores the concepts of personal spaces on the tabletop and transfer of files to and from a mobile device. The UbiTable system is designed for impromptu face-to-face collaboration between users. Users bring a laptop (or other mobile device) to the table with their personal files and are able to transfer these to the tabletop. Shen et al. used the idea that there should exist three different types of space on the tabletop system. A public domain area on the tabletop which anybody can interact with, a personal area on the tabletop which only the owner can interact with and a personal space on each user’s laptop. Initially the laptop and tabletop connect to each other by handshaking using IR sensors, then connection is established across a wireless network. Documents are transferred between laptop and tabletop by dragging them into the Interaction Record Space on the laptop at which time the user can choose where the file will appear on the tabletop, either in the personal or public spaces. UbiTable helps protect user’s privacy when sharing their personal files in a group environment by allowing the user to choose how accessible they wish their files to be. In addition to these features UbiTable also provides support for document editing, mark-up, and copying file as well as digital ink for users to draw or make annotations to documents.

The technique shown to move artifacts between tabletop and connected laptop is quite a novel concept and provides one of the first ways we’ve seen to quickly and easily transfer digital artifacts between tabletop and an external device. The concept of a special area of the table which is designated for transfer of artifacts is a novel idea which we continue to explore in this thesis.
2.1.3 Storage Bins

Scott et al. (2005) introduce a novel concept for organising and managing digital artifacts at the tabletop. Scott et al introduce a tool called the storage bin in which digital artifacts can be placed. Storage bins can be expanded and collapsed for users to "dynamically customize their working area". Artifacts inside storage bin are scaled to 35 percent of the original size of the bin but never smaller than a minimum size, of 80x80 pixels, to maintain object recognition. Storage bins can also be easily snapped to the sides of the table in order to minimise clutter they may cause and to easily get them out of the way of the center of the screen. One drawback as highlighted by Scott et al in their usability study is the use of a menu to manipulate the size and location of storage bins. Users "repeatedly tried to move the storage bins by touching an empty area in a storage bin and dragging" which suggests direct manipulation of storage bins would have been a better choice in terms of usability.

The key idea that we have taken from this research is that visual organisation of digital artifacts can help increase tabletop collaboration. Being able to visually group items enables users to manage their workspace in a more organised fashion than without the ability to group items together. A main issue we will keep in mind for our research is that users expect to be able to directly manipulate items on touch surfaces, especially when the rest of the interface can be directly manipulated.

2.1.4 WeSearch

WeSearch is a collaborative Web search system designed for tabletop displays (Morris et al., 2010). It is designed so multiple people can browse and search the web at once on a single tabletop. Users can share search terms by dragging them out of the browser to make search term objects. Any user can take these objects and plug it into their browser to use it in their searches. In addition to this, "clips" of webpages can be dragged out of the browsers. These clips are small segments of webpages which can be expanded and viewed by other users. There are a number of tools available on the display, such as the marquee, to make collaborating with other users easier. The marquee is a scrolling bar which contains URLs, search terms, page titles and clips by other users are shown here. An interesting feature of WeSearch is its containers, users can put clips into these containers and it will generate new search terms based upon the clips. WeSearch also contains a feature to store the state of the system as a webpage. At any time the system state can be saved and any container content generated into a webpage which summarises the session and contains details on who found the content and what keywords were used.
Chapter 2. Literature Review

2.1. Tabletop Interfaces

The key ideas we have taken from WeSearch for our research are the containers and the ability to save system state. Container on a tabletop provide a quick and easy way to organise items together. Once they are in the container there is an inherent relationship between them which can be quickly seen visual when glancing at them. The container paradigm was explored previously by Scott et al. (2005) as outlined in 2.1.3. WeSearch’s containers are directly manipulable and hence were more intuitive to use when moving and resizing. Morris et al also made the conclusion that items in a container are somehow related and make use of this by giving containers the functionality to produce search terms for the clips inside of them.

Figure 2.3: The OnTop user interface.

2.1.5 OnTop/Focus

Collins (2007) “OnTop” interface, (later extended and renamed to “Focus” Collins and Kay (2008)) is a tabletop file system management system based on an associative structure. Using OnTop users can perform associative searches on digital artifacts to get any files which are relevant to the selected one. By performing a dwell gesture on a digital artifact users select the file to search upon, this target file is
called the "focus-file". Each file on the system has a certain number of tags associated with it. OnTop uses these tags to determine how relevant a file is to the focus-file. The relevance settings of the files can be changed, with different weights associated with different tags. These settings are changed on the computers which contain the file systems being searched. When the results of the search is displayed on the tabletop, files which are more relevant have a larger size than those less relevant.

OnTop is built upon the Cruiser Tabletop which contains more tools used to manage files and control clutter on the tabletop. The Black Hole allows users to remove items from the tabletop. As files are moved close to the Black Hole they start to shrink until they disappear into the hole. This provides users with a quick and easy way to remove unwanted items from the tabletop. Cruiser also uses storage bins to organise files similar to those described by [Scott et al. (2005)]. A storage bin is similar to a folder on a normal computer and can be arranged in a hierarchical structure. [Collins (2007)] conducted a user study with OnTop contrasting it with a classical hierarchical system. This showed that OnTop was more efficient and easier to use on larger file systems.

2.1.6 Personal Digital Historian

Another system which has focused on interfaces for exploration of large, heterogeneous media collections is the Personal Digital Historian (PDH) by [Shen et al. (2003b)]. The PDH system aims to support for multi-user interactive story telling. It aims to help people construct, organise and navigate digital media collections in a collaborative manner around a tabletop. [Shen et al. (2003b)] used a model of organising the collections using the four questions essential to storytelling; who, when, where and what (The four W’s). These questions are encoded in the form of metadata onto each photo, and this metadata is in turn used to group media together. Similar to OnTop by [Collins (2007)], media on the tabletop is no longer "defined by their physical location in the file system" but rather by their context. Four principles were used to guide the development of PDH being: to allow natural, face-to-face conversation, afford easy-to-learn interactions, flexible organisation of content and simple content browsing and retrieval. In the evaluation user study performed one user commented "I am totally forgetting that I’m interacting with a computer!" meaning that if an interface is easy, quick, and intuitive to use users will feel comfortable using it.
2.1.7 Photohelix

Photohelix (Hilliges et al., 2007) is a tabletop photo sharing application that utilises tangible objects for browsing through a set of time-ordered photos. The set of photos are sorted in a spiral timeline which can be moved by a physical turning knob. When a photo album falls within the selected time range a dedicated window shows the album and its contents. These albums can then be dragged out onto the main surface of the table for users to interact with. Photohelix also supports the creation of new albums by performing a loop gesture around albums on the table. Once the gesture is completed the photos are put into a pile, from which individual photos can be selected and taken out. Upon evaluating the system, users commented that they “liked the chronological sorting of pictures”, implying that they like to be presented with organised photos rather than a disorganised pile.

2.2 File Systems

Hierarchical file systems have been around since the 1970s (Marsden and Cairns, 2003) and are widely used in computer systems today. The benefit of hierarchical systems is that they are simple and easy to implement and are easily understood by users. The UNIX file system as described by Ritchie and Thompson (1974) contains three different types of files: directories, ordinary files and special files. Directories are UNIX’s containers and are able to contain other files. Ordinary files are simple files such as text files and executables. Each I/O device in the UNIX system is linked with a special file. Whenever
2.2. File Systems

2.2. File Systems

(a) Pool Current. (b) Stream Current.

Figure 2.5: Two types of Currents

2.2. File Systems

(a) Pool Current. (b) Stream Current.

Figure 2.5: Two types of Currents

a read or write is requested on a special file the associated device is activated.

Directories have become commonplace in nearly all file systems being developed today. The ability to group files together has been invaluable for the organisation of files. Without the uses of directories files would be stored in a flat structure with seemingly no order between them. Directories also add a certain extent of human readability to the file system. Listing files in directories makes it much easier for users to remember and locate information even if they forget where exactly they put it. By giving directories descriptive names users can follow the granularity of the file path in order to find their target file.

2.2.1 Usability of Hierarchical Systems

Marsden and Cairns (2003) highlight some issues with classical hierarchical systems and attempt to improve their usability, especially for novice users. They highlight two main concerns with the use of hierarchical systems. Firstly, when file systems get large and store large amounts of files it is easy for users to become confused as to the exact location of each file. Secondly, hierarchical systems do not explicitly allow for multiple classification of files. Marsden and Cairns (2003) propose ideas similar to those employed in a relational database to find files which are similar to each other. They treat files as
tuples in a single relation with data such as Name, Date created and Size as its attributes.

### 2.2.2 Interface Currents

Hinrichs et al. (2006) have developed a unique file browsing system, Interface Currents, for the tabletop. The interface uses a fluid interface with stream of files floating around the edges of the table. This stream is called the "Peripheral Current" and can be resized as desired by the user. The size of files is determined by the thickness of the section of the current it is currently flowing through. Users can also "pull" the stream to the left and right to move the stream around the table for access to files which are too far away to reach. Users can take objects out of the current by simply dragging them out.

Users can also create their own currents to help organise files once they have been removed from the stream. These user created currents are called "Internal Currents". Users can create two kinds of Internal Currents, "streams" and "pools". Stream currents react in the same way as the Peripheral Current around the edge of the table, pools on the other hand are simply circles which users can store files in similar to the work shown by Scott et al. (2005).

Throughout the qualitative user study performed by Hinrichs et al, five out of six user groups created new streams to organise their files on the tabletop. At the conclusion of the user study, the authors concluded that Interface Currents supported the following interactions: exploration and discovery of visual information, equal access to information, casual and structured information organisation, both individual and collaborative work, and smooth and fluid transitions between individual and collaborative activities.
Chapter 3

Conceptual Foundations

This chapter details a conceptual framework based upon the research gathered from literature studied in Chapter 2. The background chapter explored and highlighted design features of the tabletop, implementations of various tabletop systems, and the needs for organisation and exportation. Using the concepts highlighted in Chapter 2, this chapter will present a conceptual framework and discuss various design considerations which will be taken into account during this research. We will also discuss various contexts in which tabletops are used and Key User tasks which need to be performed on them.

3.1 Tabletop Contexts

As briefly mentioned in Chapter 1 tabletops can be used in a variety of contexts which we will clearly establish and define in this section. Tabletops can be used in public places (e.g. museums), restricted places (e.g. small offices) or for private uses (e.g. personal computer), and in each case are used differently by varying numbers of people. We will refer to public tabletops as kiosks, restricted tabletops as embedded collaboration devices and private tabletops as personal devices.

3.1.1 Kiosks

Kiosks are machines that are typically used for a very specific purpose in a public location. They are designed so members of the public can simply walk up to the kiosk and start interaction. We designate kiosks in two different ways; kiosks which a user can use without identification and ones which require identification (personalised kiosks). For example, a kiosk which is used as a simple directory in a
shopping centre does not require users to identify themselves. If we extended this directory concept to one which displayed personalised information for users, such as showing them shops relevant to their interests, there would need to be some way for users to easily be able to let the directory know who they are.

A key distinction between both types of kiosk and other tabletop contexts is the size of the known users. Kiosks are designed to be in public places, therefore the amount of users of the system is very large and there is no way to effectively keep track of them all. In other more restrictive contexts we know the exact number and identities of all the users of the system. What this means for kiosks is we need some way to input information into the system which can help for exportation, whether by manual input or identification.

The power of identification can dramatically change the way kiosks are used, instead of providing the same interface to every user we can tailor the interface to individuals and potentially have access to details such as email. If a user wishes to export some digital artifacts from a kiosk they need to input information about how they wish to send it and where. At a personalised kiosk on the other hand since the user is already identified it is a relatively simple matter of finding locations the user wishes to send the digital artifacts to and presenting the choices to the user. We establish this difference as it greatly affects the way we have to design the interface in different contexts.

### 3.1.2 Embedded Collaboration Device

Embedded collaboration devices are tabletops which are used with a designated number of users in a restricted environment. For example, a small office could use an embedded collaboration device as a tool to facilitate their meetings and brainstorming sessions. This device is for the expressed use of the office workers and hence we know all the users who will use the table. Knowing the users gives us some options when designing the interface in this context.

Primarily, in knowing the list of users we can provide an interface from which users can quickly and effectively identify themselves on the tabletop. This gives us an advantage in terms of exportation as we can store all the personal data we need for exporting on the tabletop. We can store emails, computer names and network storage details against each user which can then be used quickly as links to quickly export digital artefacts to that location.

Being a restricted device also means the tabletop will probably have distinct times where it is used. For the small office example we can separate usage of the tabletop up into times where meetings were
conducted using the table. In doing so we can use these times to organise our files on the tabletop into distinct time periods.

### 3.1.3 Personal Device

A personal device is a tabletop which is just used by a single person for their personal use. This context is quite radically different to the other contexts as there is only a single user of the tabletop. Persistent storage is a high priority on a personal tabletop, as people expect their files and screen to be as they left them. Hence it is very important to have a solution that enables quick organisation and retrieval of their files.

A personal tabletop can be treated similarly to a personal computer. Resources and information that you access often should be readily available. On the PC we have options such as recent documents and auto-fill to make using the PC easier. This same level of personalisation should be prevalent in a personal tabletop. Files and folder which the user uses most often should be quickly and easily accessible. As there is only one user for the tabletop we do not have to worry about personalising it for every single person who uses it, we can just focus on the one.

### 3.2 Key User Tasks

This section outlines tasks that may need to be performed in the various tabletop contexts detailed above. Key user tasks are those which are core functions of a tabletop in various contexts. We endeavour to describe each of them and their importance in the aforementioned contexts. A brief summary of the following is shown in Table [3.2.5](#).

#### 3.2.1 Identification

When a user first walks up to a tabletop we know nothing about the user and hence cannot personalise or change the display to better suit this user’s needs. Identification is the ability for users to register themselves at the tabletop. By adding the ability to identify themselves we are able to customise the tabletop in ways to maximise its ease of use for the user. This can include measures such as automatically filling in email addresses, automatically syncing with file systems, tabletop usage history or even the change of appearance of interface elements. Identification can dramatically change the ways users interact with tabletops in various contexts.
For non-personalised kiosk devices identification isn’t required as they are designed for a very specific activity. During the activity there is generally very little need for the access or exportation of user’s files hence there is little need for users to identify themselves with the kiosk. In contrast, personalised kiosks by nature require users to identify themselves. Personalised kiosks tailor themselves to an individual by analysing their interests and needs. These kiosks could use information such as users’ email addresses, to eliminate the need for manual entry of details for exportation purposes.

Embedded collaboration devices are used by a small collection of users and hence while most personalisation option might be applicable to most people small changes such as emails and where to retrieve digital artifacts on will differ. For example, in a small office environment users may want to retrieve files from their personal office computers and since everyone has a different computer users have to specify a specific computer. With identification users would simply have to identify themselves with the tabletop and their computer location can easily be looked up automatically.

In personal tabletop devices there is no need for identification of the user as there will only ever be one. We can assume whenever the tabletop is used it is by the owner of the system and hence there is no need for personalisation.

3.2.2 Authentication

When users use a tabletop system there is sometimes the need to authenticate themselves if they are accessing any restricted or private information. Authentication is the act of establishing the identity of the user is who they claim to be. Either upon identification or access of restricted information users should provide credentials before access rights are granted.

For kiosks, both non-personalised and personalised, there should be nothing private accessible that needs authentication to access. Kiosks are public tabletops utilised by a very large number of users in a public area. Private information should never be displayed in such a public environment and hence there is no need for authentication if there is no need to access it.

Embedded collaboration devices need the security support that authentication provides. As there are multiple users of the tabletop and multiple personal file systems that can be accessed, it is important to first authenticate before access is allowed to the personal file systems.

It is not completely clear whether authentication is necessary for private devices. A lot of people leave their desktop computers without a password when it is the privacy of their own home. If a private device is located in an area accessible by other people authentication is necessary otherwise it may not
be much of an issue.

### 3.2.3 Saving Results

When performing work on any sort of device, whether electronic or otherwise it is important to have some sort of means to save work. With the ability to save and keep results which we have worked for it adds more value to the final product. Instead of just throwing the end result away at the end of a task, we can save it and have tangible result for our efforts. Saving results can come under 3 different categories, electronically sending, physically saving and persistence. We have defined each of these categories and what types of technologies they include.

**Electronically sending** is the method of saving results by sending them to an external location or device where it is stored. This can include technologies such as email, USB drives, bluetooth and network storage. This is the most useful form of saving results if you expect to continue working on them. While relevant to all contexts this is particularly useful at both types of kiosks. As users are not likely to return to the kiosk it is handy to be able to send information by a channel such as email so they can view the results later.

**Physically saving** is the ability for a tabletop to record results as a tangible item, generally printing. This form of saving is particularly useful if users wish to use the results without access to a computer. Physically saving, like electronically sending, is relevant to all contexts but kiosks get the most benefit out of it. Kiosks are often one time use system for users and to be able to instantly get results by a method such as printing ensures that the user does not have to return.

**Persistence** is the process of saving files on the tabletop so they can be accessed and reused at a later state. This is particularly useful in the embedded collaboration device and private contexts where there is repeated usage of the tabletop on a frequent basis.

### 3.2.4 Versioning

We define versioning as the ability to save the current state of the tabletop display and its files. Users can then go back to any previous state the tabletop was in and continue working from there. This has the advantage of supporting return usage. For example, Alice and Bob are planning a holiday and are interrupted while they are trying to choose between two hotels and have to arrange to meet at another time. With versioning, when Alice and Bob have another meeting they can load the state of the tabletop...
from when they were last using it and finish choosing their hotel. On a tabletop without versioning, Alice and Bob would have to find and put the files they were using back onto the tabletop. Versioning is not particularly useful on kiosks as the typically have a short one time use. There is little need to go back to previous states in a kiosk as most users would use it very little.

This function is most particularly useful at the embedded collaboration device. These devices have frequent use by a small number of users. For example, an embedded collaboration device in an office for a small software development company could be used to track and manage tickets and workloads for the developers. However, sometimes general meetings are performed at the tabletop. Without versioning, each time a meeting is held the tabletop display would have to be freed of any extraneous files, which would all have to be put back once the meeting is concluded. With versioning the, state of the tabletop display can be quickly reloaded.

Versioning is also useful in the private context. A user may be doing some work A but has to switch to work B temporarily. They could save the state of the tabletop so when work B is finished they can quickly go back to work A.

### 3.2.5 Organising

A key user task that is critical to all tabletop contexts is organisation of digital artifacts. It is critical that files remain or can be placed in an organised structure. Tabletops can quickly become cluttered and unorganised when too many files are being utilised at once. We covered techniques such as storage bins (Scott et al., 2005) and interface currents (Hinrichs et al., 2006) in Chapter 2. These helped users group files together to assist with organisation.

### 3.3 Interface Elements

This section describes four interface elements for touch screens and evaluate their advantages and disadvantages. There are a number of ways interactions can be designed for tabletops. We have defined these as gestures, special objects, visible menus and invisible menus. We evaluate these interaction elements by studying various aspects of them. Table 3.3 summarises the findings of this section.
Chapter 3. Conceptual Foundations

3.3. Interface Elements

<table>
<thead>
<tr>
<th>Context</th>
<th>Kiosk</th>
<th>Personalised Kiosk</th>
<th>Embedded Collaboration Device</th>
<th>Personal Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Authentication</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>M</td>
</tr>
<tr>
<td>Save Results</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Electronic sending</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Physically saving</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Persistence</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Versioning</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Organising</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Accessing Information</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Key:** Y = Yes; N = No; M = Maybe

Table 3.1: Overview of tabletop contexts in relation to Key User Tasks.

<table>
<thead>
<tr>
<th>Element</th>
<th>Gesture</th>
<th>Special Object</th>
<th>Menu (Visible)</th>
<th>Menu (Invisible)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clutter</td>
<td>None</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Visibility</td>
<td>Zero</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Limited Gestures</td>
<td>Impacted</td>
<td>N/A</td>
<td>Slight Impact</td>
<td>Moderate Impact</td>
</tr>
<tr>
<td>Learnability</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Discoverability</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Memorability</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 3.2: Overview of tabletop contexts in relation to Key User Tasks.
3.3.1 Gestures

Gestures are interaction primitives which involve specific ways to touch the screen in order to activate various functions. An example of a gesture, is the "pinch" gesture on the iPhone in order to zoom out. The pinch gesture is performed by placing two fingers on the screen and moving them together. Using gestures to access functionality is useful as they do not take up any screen space thus not causing any clutter. However, at the cost of not causing clutter there are some drawbacks to gestures.

Firstly, they do not have any visibility as it is not on the screen. Secondly, there is a limited range of gestures that could possibly be performed. Complex gestures can be made up but then users would be required to remember a very large selection of gestures in order to effectively use the interface. Leading from this, gestures are harder to remember how to perform compared to interacting with a visible object. Without any training it is hard to discover and hence learn what the gestures for an interface are. The only way to learn is by experimentation with the interface trying gestures which are commonly used for similar tasks.

3.3.2 Special Object

Special objects are tools on the screen which perform specific tasks. For example, in replacement of the pinch gesture detailed in the last paragraph we could have a special magnify glass object which could be placed over other objects in order to make them bigger. The main drawback of special objects is their ability to cause interface clutter. This however is offset by some excellent other characteristics.

As we can see the special object it is highly visible and users have a better chance to remember how to use it the next time they come along. With gestures there is no visual image which users and remember, however with special objects the sight of the object itself may help users to remember its use. As we can see special objects are obviously much more discoverable than gestures and are generally more learnable.

3.3.3 Visible Menus

Visible menus are attached to the front of other objects and are visible at all times. Users can use the menu to perform various functions on the object it is connected to. Even though it is visible at all times it does not cause as much clutter as special objects as the menus are always attached and move with their parent object. If the menus are placed on top of the object then is could cause it to be obscured. On the
other hand, if the menu is placed just to one side of the object it makes the object take up more space causing clutter.

Menus need some gestures to interact with them however menus should require only a few very basic gestures and hence should not need to make up any complex ones. Visible menus are generally attributed with high rates of memorability (assuming menu is of a small length) and learnability as it can be easy to remember the shape and layout of the menu. While visible at all times visible menus are not quite as discoverable as special objects as they can seem to be integrated into a part of another object.

### 3.3.4 Invisible Menus

Invisible menus are similar to visible menus except that they require some sort of action to make fully visible. This action could be a gesture such as a drag out, where the menu draws out under the finger like a curtain or flipping an object, where the menu is located on the back. Invisible menus tend to have low clutter as they can be hidden easily, they make take up some space while being used but otherwise they are hidden. This in turn causes low visibility and discoverability as the menu cannot be seen unless the user performs the required action to make it visible.

If the mechanism to make the menu visible can be located and is easily performed, invisible menus can provide a medium level of learnability. However they have low memorability as the user has to remember both how to use the menu and how to access it.

### 3.4 Chosen Context and Interface Element

Through our studies of both tabletop contexts in Section 3.1 and Section 3.3 we have decided our implementation will focus on Embedded Collaboration Devices and Personal Devices utilising special objects in our interface. These two contexts give us the biggest opportunity to explore the concepts of both organising and exporting at the tabletop. We have chosen the special object due to its high levels of learnability, memorability, discoverability and visibility. Our implementation as described in Chapter 4 will reflect these choices.
Chapter 4

System Architecture

In the previous chapters we have laid down ground work for our research by looking into previous research and defining a conceptual model. This chapter describes the Cruiser interface primitives, system architecture for our MyCloud and Eemailer interfaces and their technical implementations.

Figure 4.1: The Cruiser interface.
4.1 Cruiser Interface

*Cruiser* is a tabletop system been developed over the last several years by the CHAI research group. Figure 4.1 shows the Cruiser system in use with a number of images, documents and tools arranged on the surface. It is implemented in the C++ programming language and the OpenGL 3-D graphics. Since its inception, Cruiser has been carefully designed to be cross-platform and hardware independent (Apted et al., 2005). Cruiser currently runs on G³ Plus touch screen (PQ Labs, 2010) which is capable of up to 32 simultaneous touches. This multi touch capability means multiple users can interact with the tabletop at the same time which is great for collaboration. Previous versions of Cruiser, such as Sharepic, have used the DiamondTouch table (Dietz and Leigh, 2001) while OnTop utilised the Mimio Capture whiteboard input device MimioCapture.

The interfaces we have developed, namely Emailer and MyCloud, are built as plugins to Cruiser. Here we will give an overview of Cruiser’s interface interaction and features.

### 4.1.1 Interface Interaction

Users interact with Cruiser through touch input with their fingers on the tabletop display surface. Using their fingers users can interact with objects on the table. Cruiser features a direct manipulation model for interaction, users are able directly manipulate object on the table through touch gestures.

Simply touching an object and dragging allows users to move objects around the table. When moved objects have momentum and "flicks" can be performed by quickly moving the object then letting go. This is an important feature as it allows users to put files in places they would not otherwise be able to reach. Users are able to rotate and resize using touch points located on the corners of objects. By pulling away from the object once a corner is selected an object can be resized. Touching and moving the corner in a circular fashion around the object will cause it to rotate.

Some objects have the ability to be flipped for extra functionality. Flipping objects is performed by touching the center of any side of an object and dragging across to the opposite edge. When files are flipped the name of the file is displayed on the back. While files are flipped other files may be attached to the back of them, when the main file moves or gets resized these other ones follow suit. When the parent file is flipped back over the objects on the back are hidden. This is a quick and easy way to group related files together.
4.1.2 Features

There are a number of tools which, over time, have been built into the core part of Cruiser these include the Blackhole, toolbox, storage bin, copier and the frame.

**Blackhole.** The Blackhole enables users to quickly and easily remove items from the tabletop display area. The Blackhole has a gravity well and if a file is moved close enough it will get pulled into the middle and disappear. The Blackhole does not remove files from the tabletop completely it just hides them, by performing a flip gesture any items which are in the Blackhole can be seen. These can be hidden again by flipping the Blackhole back over. Performing a dwell function on the Blackhole will slowly suck every object on the table towards it, this is a good way to quickly clear the tabletop.

**Toolbox.** The toolbox is a interface widget which is always present on the screen and cannot be pulled into the Blackhole. It contains a variety of tools which can be pulled out of it and used for various purposes. The remaining features that will be described in this section are located in this toolbox. To create a new instance of a tool the user simply touches and drags the tool out of the toolbox.

**Storage Bin.** The storage bin is similar in concept to the one described by [Scott et al. (2005)](2.1.3) as covered in Storage bins are containers which can hold files in them and arranges them in a grid layout. Files inside a storage bin are moved, resized and rotated with the parent. They provide an excellent way to group files together.

**Copier.** The copier is a tool which can create copies of files. Users simply drag a file onto the copier which puts a thumbnail of the object inside the copy object. By dragging this thumbnail outside of the perimeter of the copier users can create copies. This tool is especially useful if multiple people need to view the same file.

**Frame.** The frame has the ability to take screenshots of the interface. By positioning the frame over a section of the interface and dwelling on the frame a new file containing the screenshot loads onto the table. Alternatively, users can double tap a frame to take a screenshot of the entire tabletop display area. The screenshot is treated like any other regular file.
4.2 Interface Architecture

4.2.1 Emailer

Emailer is a plugin for Cruiser which allows users to create and send emails from the tabletop. Users are able to add any type of file displayable on Cruiser to the email as an attachment. The architecture for Emailer is not very complex, it uses traditional SMTP protocol (see figure 4.1.2). Once the email is created and sent the tabletop uses the standard SMTP protocol to send the mail via an SMTP server which forwards the mail on the its destination. Users may then access their mail server through a POP3 or IMAP protocol to download their emails.

Emailer allows users to drag files onto the email to add them as attachments. Figure 4.2 shows the
Emailer interface with several attachments. To remove attachments from the email users simply drag them out back onto the tabletop. The email object behaves similarly to the storage bin as described in 4.1 in that attachments moved, rotated and resized with the parent email. This keeps the interface consistent with the Cruiser framework.

Once the desired attachments have been added to the email users perform the flip gesture to view the back. As shown in figure 4.2.1, the back has a number of contacts. When contacts are selected by performing a tap gesture on them they light up and gain a white border to signify that they have been selected. Another tap will deselect the participant and darken back to its original state. This feedback is very useful in determining at a glance who an email is going to send to. Once the recipients are selected users simply perform the tap gesture on the send button in order to send the email. The status text "Select Participants” changes to "Sending..." to provide feedback to the user than their tap gesture on the send button was successful.

### 4.2.2 MyCloud

MyCloud is a cloud storage interface plugin for the tabletop. We use a product called Dropbox in order to facilitate the cloud storage aspect of the system. Dropbox allows users to sync their files to an online server across all your computers automatically. When the Dropbox client is installed on a computer users choose a folder to designate as their Dropbox. Any files placed into this folder will be
automatically uploaded to the Dropbox server. When the upload is finished, any computer connected to the internet will download the file and, if necessary, update the local version with the new one. If a computer is not online for the update it will download all the updates the next time it receives and internet connection. User’s can access their Dropbox in a number of ways including:

- **PC**
- Mobile devices, including iPhone, iPad, BlackBerry and Android
- Web access

Dropbox also has the functionality to share folders with other users. The owner of a folder can enable sharing and invite other users to share a folder. Changes made to this shared folder will sync with all the attached accounts. By installing and creating a Dropbox for the tabletop and sharing folders with users we can use Dropbox as a channel to export files from the tabletop. Figure 4.2.2 shows how the architecture of the system would work. In order to facilitate this we have created the MyCloud interface.

MyCloud, as shown in Figure 4.2.2 shows users the contents of a folder with the ability to drag out subfolders and files onto the tabletop. Using MyCloud users can browse through the file system...
and look at various files. We call objects showing the root directory "Clouds" and subfolders are called "subClouds". These names originated because it is a Cloud based solution. We concluded that the name Cloud would help portray the functionality of the interface. When subClouds and files are dragged out of their parent they create a copy of themselves while the original remains in the parent.

We also have added the functionality to be able to add files to Clouds and subClouds. Users simply drag files across Clouds and subClouds to copy them into the folder. The original image will remain on the table why a copy of it is added to the Cloud or subCloud. If a file is already in a Cloud or subCloud and an attempt is made to copy another one in a copy will not be created. To avoid accidental adding to Clouds we have implemented a locking mechanism. When the Cloud or subCloud is locked a red closed padlock is displayed and users are unable to add images. By tapping the lock, thus turning it green and open, users can add files to the subCloud or Cloud.

By combining the power of Dropbox and MyCloud together we can use MyCloud to access the Dropbox folder. Thus any files which are added to the MyCloud are automatically synced with Dropbox. Any user which has shared a folder with the tabletop account is able to deposit files into their shared folder on the tabletop and have it available when they return to their computers.
Chapter 5

Evaluation Design

The primary goal of this thesis was to explore new ways to organise and export files from tabletop systems. These concepts of organisation and exportation were explored as a basis for creating the tabletop interfaces MyCloud and Emailer. The MyCloud interface allows the organisation and export of digital artefacts from the tabletop through the use of cloud storage. The Emailer interface allows users to construct, add attachments and send emails from the tabletop. This chapter describes the evaluation design of a qualitative evaluation of both Emailer and MyCloud based on naturalised think-aloud. The purpose of this evaluation was to determine the usability of these interfaces and to determine their effectiveness when used at tabletop surfaces. This evaluation will only test the usability of the interface at the tabletop and will not test the participants using their Dropbox or email. The outcomes of this evaluation should produce ideas for future work in the areas of tabletop organisation and export.

5.1 Evaluation Goals

The primary goal of this evaluation is to determine the usability of MyCloud and Emailer on a tabletop. Nielsen (1993) defines usability as have five components, namely learnability, efficiency, memorability and satisfaction. We have divided these aspects of usability amongst our following sub-goals of this evaluation.

- Success in task completion
- User Satisfaction
- Elicit possible improvements
5.1. Evaluation Goals

5.1.1 Goal: Success in Task Completion

Under the goal of establishing how successful users were in completing their tasks we have placed Nielsen’s usability components of learnability, efficiency, memorability and errors. When evaluating the effectiveness of the interface the most important aspect to analyse is whether users are able to successfully complete all the tasks which they set out to achieve. Users could fail or find tasks hard to complete for a variety of reasons while using the interface, these can be categorised under Nielsen’s components of usability.

Learnability

Learnability of an interface can be described as the ability for a software product to enable the user to learn how to use it. When designing the interfaces one of our primary concerns was learnability. When a user first interacts with an interface they will feel more hesitant about using it if it is confusing and hard to understand. This will heavily impact their ability to successfully complete their tasks. Hence during our evaluation we wish to study how long and how many interface steps users need to expend to succeed in their first use of the interfaces. We measure learnability by how long first time users take to perform tasks with MyCloud and Emailer and if they require any hints or help while using them.

Both MyCloud and Emailer are developed and designed to integrate well into the Cruiser environment. They have common gestures and interaction paradigms as other elements of Cruiser. In order to successfully complete tasks using these interfaces users must already have a good understanding of Cruiser and its elements as described in Chapter 4. Users may find it hard to even discover the functionality provided by the interfaces if they have never used Cruiser before. This is particularly an issue with the Emailer interface as the ability to flip an object to see the back is not readily apparent to users. In order to evaluate the learnability of our own interfaces it is critical that users understand the basic primitives of Cruiser first.

To help create fair evaluation tasks that are a fair measurement of the learnability of the interfaces it is important that the users receive a good preliminary introduction to Cruiser. By giving an introduction before completing any evaluation tasks, users can learn and understand the fundamentals of Cruiser and we can then focus on evaluating the learnability of MyCloud and Emailer.

Efficiency

Nielsen defines efficiency as the expert user’s level of performance at the time when the learning curve flattens out. One problem with evaluating our system is first time users may require large amounts
of time spent using our interfaces in order to reach the maximum levels of their learning curve. It is not enough when evaluating to simply discover whether users are able to complete a task but also their efficiency.

Clutter will be a large concern as users will be presented with a very large collection of information within MyCloud that could very easily clutter the display and hinder performance at completing tasks. Due to the limited screen real estate clutter has always been a critical issue in effect tabletop interaction design. With more clutter on the tabletop it will become increasingly more difficult and hence less efficient for users to complete their tasks. When users drag subClouds out of a Cloud object it creates a new object on the tabletop and it is the responsibility of the user to remove the subCloud from the display when they are finished with it. Neglect to remove subClouds will very rapidly cause clutter and make it extremely difficult for users to finish their task.

In order to reduce large amounts of clutter when using the interfaces we should provide users with a shallow and small number of files and subClouds to interact with inside MyCloud. This will help prevent clutter which would hinder the completion of tasks. However, we do not wish to provide users with a data set that is so small as to be trivial. We attempted to strike a balance between these. This is covered more thoroughly in Section 5.2.5.

Memorability

In addition to testing whether users are able to complete tasks with our system we must also ensure that our system is memorable. Tabletop systems are something which you would typically use everyday hence it is important users are able to remember how to use the system next time they use it. Once they understand how the system works, it should be easy for them to build a mental model of it for their next use. We tested this to some extent in our think aloud by asking users to perform a series of evaluation tasks, having a break for a five minutes then completing a realistic task. This gives us some indication to the memorability of the interface by observing if users performed as well in the realistic tasks as they did in the others.
5.2. Experimental Design

**Errors**

It is important to minimise errors that can be made by users when using the interfaces. Each error which is made reduces the efficiency of the user and increase time of task completion. We defined errors in our system to be any time a user accidentally adds an object to a Cloud or subCloud or when users sent email with the incorrect attachments. For each participant pair we count the number of error in for later comparison and analysis.

5.1.2 **Goal: User Satisfaction**

We must also consider the psychological and emotional aspects of tabletop interaction while using our interfaces. Our reason for evaluating affect is to establish what people felt and perceived when using an organisation and exportation tabletop interface. The evaluation will focus on the attitudes and behaviours users displayed while using our interfaces. We will be studying the users’ reactions and comments during their interaction with the tabletop. In this way we can gather their perceptions on ease of use and efficiency of the design.

5.1.3 **Goal: Elicit Possible Improvements**

A highly desired goal of this evaluation is to elicit possible improvement from users. After using Emailer and MyCloud we wish to give participants the opportunity to give suggestions of possible improvements and new features to implement. After the conclusion of the tasks participants

5.2 **Experimental Design**

This section explains our procedure of evaluation, design of questionnaires, user task and how we recorded the results. Our evaluation aimed to assess success of our questions about our design goals mentioned above. Our experiment had the following main stages:

1. a questionnaire about participants’ background;
2. an introduction to Cruiser
3. evaluation tasks using Emailer
4. evaluation tasks using MyCloud
5. a realistic evaluation task requiring both Emailer and MyCloud; and

6. a post-experiment questionnaire regarding their perceptions after completing the tasks & eliciting suggestions for improvement.

5.2.1 Background Questionnaire

Users were required to fill out a background questionnaire about their experiences with tabletops, computer literacy and their ability to manage and export files. It is important for us to establish the experiences our users already have in the areas we are testing. We were especially interested in the users past experience and expertise in collaboration, managing file collections and sending files from one computer to another. If users do not collaborate with other people very often or don’t send many emails they may not fully understand the type of functionality we are trying to provide at the tabletop. Hence it is important that we understand the technical capabilities of each person in order to more effectively understand the recorded results.

The questionnaire supplied to participants is available in the Appendix A collected the following information:

• Age
• Occupation
• Gender
• Left/right handed
• Computer hours each week
• Previous tabletop experience
• Skill at managing files and emails
• Frequency of collaboration in same room
• Tools and procedures used for collaboration
• Frequency of sending files
We believe these questions enabled us to determine the expertise of users in the tasks we wish them to perform. We can make special note of the users who rated themselves highly and poorly in the skills at managing files and emails section and compare them to each other. We detail our observations of this questionnaire in Section [6.1] and detail our user demographic.

5.2.2 Introduction to Cruiser

Users were given a short introduction to the Cruiser interface. The experimenter will demonstrate the basic gestures and interaction primitives that are required for competent use. These interaction techniques (previously outlined in Chapter [4]) were as follows:

- Moving objects
- Rotating objects
- Resizing objects
- Flipping objects
- Putting objects into Blackhole
- Removing objects from Blackhole
- The use of various tools including storage bins, copier and the frame

Once the users had been shown these basic functions they are asked to interact with the Cruiser interface for five minutes to practice. In doing so they can build their mental model of Cruiser. This ensures that our evaluations of efficiency is assessed so they will have a better ability to interact with our interfaces. We did not record any results from this part of the study as it was simply designed to build the users’ fundamental skills in Cruiser before the evaluation of our interfaces.

5.2.3 Evaluation tasks

After being inducted to the Cruiser interface users are given are series of evaluation tasks to complete using Emailer and MyCloud. Each evaluation task tested a different piece of functionality. Users were asked to complete these tasks three times in order to ensure that they were fully competent in using the interface. A different mark was given to each task depending on how successful the user was at completing it. The four different marks in order from least to most successful were:
• Could not complete task
• Required a small bit of help to complete
• Completed the task by themselves but with a small bit of difficulty
• Completed the task easily and fluidly

**Emailer**

Users were asked to perform a series of tasks involving creating and sending an email. Users were presented with a fresh instance of Cruiser with 3 images as material for them to complete the tasks. Here we will detail each task, what signifies the task has been completed and the reason for the task.

Firstly, participants were asked to create an email object. This requires users expanding the toolbox and dragging the email icon onto the table. This task is completed when there is a new email object placed onto the table. Completing this task establishes the ease which users can create new email objects. If a participant can do this quickly it shows our interface lends itself to be learnable.

Participants are then asked to add an attachment to an email. To add an image to an email a user simply has to drag an image on top of the email and it will automatically add. On the completion of this task there will be one image in the email. Completing this tasks tells us the adding to email gesture is intuitive.

Next participants are asked to add multiple attachments to an email. This simply requires participants to perform the previous task multiple times. Upon completion of the task there will be more than one image in the email. This task should show the participant that more than one image is able to be added to emails.

Then participants were required to add attachments in a storage bin to an email. A storage bin had to be created from the toolbox, one or more images placed in the bin and then the bin placed inside the email. Upon completion of the task there should be a storage bin containing one or more images inside an email. This task is designed to show participants files can be grouped together and added all at one to the email object.

Similar to the previous task, participants were now required to add attachments on the back of other attachments and add them to an email. To complete this task, users must flip over an image, add one or more images to it then add the parent image to the email. It is up to the user whether they flip the parent image back over before adding it to the email. Upon task completion there should be an image on
the back of another image which is in an email. This shows participants another method to group files together which can be used to add multiple things at a time to an email.

Participants are then asked to remove an attachment from the email. Simply, users just have to drag an image out of the email. One less image in the email signifies the success of the task. This task measures the learnability of the remove attachment gesture.

Next, participants are asked to flip the email over in preparation for sending it. Users must perform a flipping gesture by selecting the center of an edge and dragging it towards the opposite edge. The task is completed once the back of the email is showing. This tests the learnability of the flipping gesture.

Participants are then required to perform two tasks where they have to select single then multiple recipients. Recipients are selected by simply tapping their picture on the back of the email. Completion of these tasks is signified by multiple recipients being lit up on. This tests both the gesture which is required to select recipients and the feedback given once recipients are selected.

All these tasks combine together to give us a clear picture of the usability of Emailer. By performing the above tasks 3 times we can track the progress of attempts and see how quickly participants learn the interface.

**MyCloud**

Users were asked to perform a series of tasks involving browsing and adding items to MyCloud. Users were presented with a fresh instance of Cruiser with 3 images as material for them to complete the tasks. Here we will detail each task, what signifies the task has been completed and the reason for the task.

Firstly, similar to the Emailer task, participants were asked to create a Cloud object. This involved enlarging the tool box and dragging out a Cloud object. Task completion is signified by a Cloud object on the tabletop. Completing this task establishes the ease which users can create new Cloud objects. If a participant can do this quickly it shows our interface lends itself to be learnable.

Next we ask users to remove images and subClouds from Clouds and subClouds. Participants should have dragged out an image from a Cloud, a subCloud from a Cloud and a subCloud from a subCloud. Task completion is signified by the aforementioned elements being created. This tests the intuitiveness of browsing and accessing files using the MyCloud interface.

Users were then asked to add an image to both a Cloud and subCloud. To accomplish this users first needed to unlock the subCloud/Cloud by tapping the padlock. Next users had to drag the image to the edge of the subCloud or Cloud to copy the image into the Cloud. This tests the learnability of the
padlock metaphor. If users found it hard to intuit that the padlock needs to be pressed for files to be able to be added, this tends to indicate a lower level of learnability.

Finally, users were asked to lock a Cloud. To complete this task the participants simply have to tap the padlock of an unlocked Cloud. This further tests the usability of the padlock metaphor.

### 5.2.4 Realistic evaluation task

In order to test our interfaces, Emailer and MyCloud, in an authentic environment we have constructed a naturalised think aloud activity. The goal of this part of the evaluation is to test our interfaces in a real-world situation. Previous tasks have been testing the usability of specific functions of the interfaces but this will determine how effective the interfaces are as a whole with multiple components being used in conjunction with each other. Participants were expected to stand around the tabletop and collaboratively interact with the supplied file system in order to complete a group task. We give the participants a detailed scenario in order to make the task authentic and as natural as possible. By choosing a realistic task which participants could actually relate to, it makes the interaction more authentic. The experiment was conducted with the following scenario:

*You are taking a subject in Ancient History at school and are required to make a poster about Achilles and the Battle of Troy from Ancient Greece. You are making this poster in a group of 5 people, 2 of whom are present today. In this poster you are required to have images and text of the subject material. Before making the poster Mr Smith (your teacher) has asked that you send him the resources you are planning to use to build the poster.*

*The 3 group members, (Alice, Bob and Charlie), not currently with you have performed some research about Ancient Greece and have put all of the material they have found in their Clouds. Your task is to find all the relevant material about Achilles and the Battle of Troy and send them to your teacher. In addition, you must also put all the material you have deemed relevant in the SubClouds called "Achilles" and "Battle of Troy".*

Participants will be supplied with a data set about Ancient Greece. The data set has been prepared ahead of time by the participants other fictional group members. The role of the participants is to sift through the information and extract any information relevant about Achilles and the Battle of Troy in order to complete a poster. It was necessary to browse through every folder in the file system in order to locate all the relevant files. Any information which they find they place into the initially empty
subClouds marked "Achilles" or "Battle of Troy". Participants must also email their fictional teacher with the materials they plan to use to build the poster. The data contained in the file system is outlined in more detail in subsection 5.2.5.

The initial layout presented to the user was a blank interface with only the Blackhole and the toolbox shown. In the toolbox participants were provided with the MyCloud, Eemailer, storage bin, copier and frame. Participants were free to use any available tool to complete the task.

In summary, this task was designed so that participants should be able to understand the goal and realise that it involves:

- accessing of materials others had created and made available at the table via the Cloud mechanism,
- discussing them them at the table, selecting relevant ones
- placing the relevant set into the relevant Clouds
- mailing the set to the teach

This ensures that observing participants will give insights into whether they can readily determine that these subtasks, supported by Eemailer and MyCloud, should be used and they could then determine how to do these subtasks.

5.2.5 Test Data

While performing the task presented in the previous section participants needed a set of data to work with. In the experiment scenario the users group members have placed a large volume of information about Ancient Greece into the MyCloud on the tabletop. Participants would then need to explore this set of data to find any about Achilles and Battle of Troy. This scenario assumed that users were unfamiliar with the file system provided to them and needed to conduct extensive searching to gather all the relevant information. We utilised a single file set for all participants; this ensured the trials were comparable.

A variety of information was included in the test data such as photos and fact sheets related to historical figures from Ancient Greece (including Achilles, Hector and Zues), and important cities (including Athens and Troy). The test data also included generic pictures of weapons and armour without any descriptive detail.

In total there are 96 files located in 16 directories. The depth of the file system has been kept quite shallow with a maximum depth of 3, that is files are never more than two steps away from the
root directory. A complete list of all the files is available in Appendix C. The files are split up into various folders based upon the type of information it shows. For example, all the fact sheets about historical people were kept in the folder "People/" and images of Trojan Horses were kept in the folder "Images/Trojan Horse".

There were two main reasons for the choice of this number of files for the test data.

- A large enough number of files to be representative of the numbers of files that might be considered for this class of task and for many interesting and useful tasks that might be undertaken at a tabletop
- Enough to possibly flood the interface with images and information causing clutter.

Of the total 96 files, there were 28 that were relevant to either Achilles or the Battle of Troy. This was structured so participants would have to carefully study each file to determine its relevance to the targeted topics. There were also files that were included which could have been used as supporting materials (such as pictures of helmets or weapons) but did not indicate whether they had any relevance to Achilles or the Battle of Troy.

### 5.2.6 Participant Experiences

After the realistic scenario was completed, the experimented invited the participants to comment on their experience and discuss it with the experimenter. The experimenter particularly elicited comments on which aspects of the system really stood out as either being really easy to use or hard to use. This part of the study aimed to give an opportunity for free and relaxed comments about participants’ satisfaction with the system and their overall reaction to using it. These comments were taken down as notes by the experimenter.

### 5.2.7 Post-experiment Questionnaire

After all the tasks were completed users were required to complete a post experiment questionnaire. The full questionnaire is available in Appendix B. The questions detailed what they found most/least enjoyable about the system, what was easiest to use and what they think can be improved upon. Users were encouraged to interact with any aspect of the tabletop system while completing the questionnaire.

This questionnaire had 8 questions some of which overlap which provides the benefit of users are more likely to mention something. The first 3 questions had a Likert scale with a prompt to explain their
5.2. Experimental Design

The first question asks if the user was able to complete all the tasks and is designed to ask the user how well they think they did during the free form think aloud. This establishes a baseline where we can compare how well the user did to how well they think they did. The second question asks the participant if they found the interface hard or easy to complete and entices them to elaborate. Third, the users are asked if they were easily able to identify the purpose of the screen elements. This was necessary to ask in order to establish the users’ view of the learnability of the interfaces.

The next two questions ask users what they liked best and worst about the interfaces. This is designed to receive feedback where users thought the interfaces was particularly strong or weak. We then ask participants what feature they would most like to see which is not currently present. This serves two-fold by highlighting what users think is missing about the system and also to gather ideas for potential future modifications to the interface.

Users are then asked, on a Likert scale, how confident they would feel using a tabletop for a particular activity. This can indicate to us whether users would feel inclined to use this interface on a daily basis and how confident they are with using the tabletop.

Finally, we just ask for any general comments regarding tabletops. This serves as a question where users can put down answers which may not fit in any other questions.
Chapter 6

Evaluation Results and Analysis

This chapter presents the results of the naturalised think aloud usability study. It first presents analyses of the participants’ background, based on the initial questionnaire. It then presents the results of the three main components of user study: those based on the fine grained usability tasks for the Emailer; then those for MyCloud; and finally, those for the more realistic free form task. We then reports the qualitative analyses for the post-questionnaire. We then draw upon all of these to summarise the key conclusions.

6.1 Participant Demographic

Through the use of the background questionnaire we have gathered information about our participants in order to determine the demographic spread. We can clearly see from table 6.1 that the majority of our participants were mostly young university students between the ages of 18 and 22. We did however manage to secure equal number of male and female students, this is helpful as it is representative of the general population. As we mostly have young people, our findings in the following sections may not apply as well to older generations.

Students were from a range of backgrounds including 2 computer scientists, 1 civil engineer, 1 student teacher, 1 chemistry, 2 psychology, 1 biomedical engineer and 1 biotechnology scientist. In addition to our students we had 1 secretary/masseuse. Although we do have a large number of students, which may limit the ability for us to apply our results to a wider user group, they are from a wide variety of disciplines.
### 6.1. Participant Demographic

Chapter 6. Evaluation Results and Analysis

<table>
<thead>
<tr>
<th>User</th>
<th>Age</th>
<th>Gender</th>
<th>Occupation</th>
<th>Hours of computer use per week</th>
<th>Description of file and email management skill</th>
<th>Frequency of collaboration</th>
<th>Frequency of sending files</th>
<th>Previous tabletop experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>21</td>
<td>F</td>
<td>Student (civil eng)</td>
<td>41+</td>
<td>Ad</td>
<td>W</td>
<td>D</td>
<td>No</td>
</tr>
<tr>
<td>1B</td>
<td>22</td>
<td>M</td>
<td>Secretary/ Masseuse</td>
<td>31–40</td>
<td>Ad</td>
<td>D</td>
<td>D</td>
<td>No</td>
</tr>
<tr>
<td>2A</td>
<td>21</td>
<td>F</td>
<td>Student (biomedical)</td>
<td>41+</td>
<td>Co</td>
<td>N</td>
<td>W</td>
<td>No</td>
</tr>
<tr>
<td>2B</td>
<td>22</td>
<td>M</td>
<td>Student (biotech)</td>
<td>11–20</td>
<td>Ex</td>
<td>M</td>
<td>W</td>
<td>No</td>
</tr>
<tr>
<td>3A</td>
<td>21</td>
<td>F</td>
<td>Student Teacher</td>
<td>31–40</td>
<td>Co</td>
<td>Y</td>
<td>W</td>
<td>No</td>
</tr>
<tr>
<td>3B</td>
<td>21</td>
<td>M</td>
<td>Student (chemistry)</td>
<td>41+</td>
<td>Ex</td>
<td>W</td>
<td>W</td>
<td>No</td>
</tr>
<tr>
<td>4A</td>
<td>21</td>
<td>F</td>
<td>Student (psychology)</td>
<td>21–30</td>
<td>Co</td>
<td>W</td>
<td>W</td>
<td>No</td>
</tr>
<tr>
<td>4B</td>
<td>22</td>
<td>F</td>
<td>Student (psychology)</td>
<td>41+</td>
<td>Ex</td>
<td>W</td>
<td>W</td>
<td>No</td>
</tr>
<tr>
<td>5A</td>
<td>21</td>
<td>M</td>
<td>Student (IT)</td>
<td>41+</td>
<td>Ex</td>
<td>W</td>
<td>W</td>
<td>Yes (10 mins)</td>
</tr>
<tr>
<td>5B</td>
<td>18</td>
<td>M</td>
<td>Student (IT)</td>
<td>41+</td>
<td>Ex</td>
<td>W</td>
<td>W</td>
<td>Yes (10 mins)</td>
</tr>
</tbody>
</table>

**Key:** NA = None; Li = Limited; Co = Competent; Ad = Advanced; Exp = Expert; N = Never; D = Daily; W = Weekly; M = Monthly; Y = Yearly

Table 6.1: Overview of participant demographics.
Chapter 6. Evaluation Results and Analysis  

6.1. Participant Demographic

Our participants were predominately heavy computer users who spent 40+ hours at a computer a week. We had 6 participants who used computers 41+ hours a week, 2 who use them 31–40 hours a week, 1 who use them 21-30 hours a week and 1 who uses computers 11-20 hours per week. Every group had at least one member who uses a computer 40+ hours a week, except for group 3. Since every group has such heavy computer usage our final results may be less representative to the larger population.

In addition to the number of hours participants used a computer each week we also asked them to rate themselves on a few different computer skills. Firstly, we asked them how skilful they were at file and email management. Out of 10 participants 4 described themselves as experts, 2 as advanced and 4 as competent. When asked how often they sent files from a computer 8 participants answered daily and 2 weekly. These two measures point to our participants having good technical skills and should be able to understand all the concepts conveyed to them. Again, these measures show we have an above average technical skill level and this study may be less representative of the main population.

Since tabletops are designed for a collaborative environment we needed to gather information about how frequent participants collaborated with other people in the same location. We found that 6 out of 10 participants collaborated weekly, 1 daily, 1 monthly, 1 yearly and 1 never. For most of our participants, collaboration seems to be a regularly occurring activity. Interestingly our secretary (Participant P1B) had the highest amount of collaboration, likely due to being in an office environment and dealing with lots of paper documents. Participants P2A and P3A claimed they had very little to no experience in collaboration. In our analysis in Section 6.6 we will study the effect of how experience in collaboration affected users ability to complete the tasks.

In addition to collecting the frequency of collaboration, we also encouraged users to detail what technologies they use to support collaboration. These technologies are ranked in Table 6.1 from most to least mentioned.

A noticeable trend here is the high use of email for collaboration with 7 out of 10 users claiming they use it for collaboration. This shows that email is a useful technology to share files with other people leading to some validation of the use of our Emailer interface. USB drives were mentioned quite frequently by users, when asked by the examiner to elaborate why they ranked USB devices so highly participants P1A, P3A, P3B all stated that they were "cheap", "portable" and "easy to use". This leads us to the conclusion that users are looking for collaboration support which is quick, easy and able to be
6.2 Evaluation tasks: Emailer

As described in Section 5.2.3, users were asked to perform a number of evaluation tasks using Emailer. These tasks were designed to test the variety of functionality available. The results for these evaluation tasks are shown in Table 6.2.

Participants were asked to complete the entire set of tasks 3 times in a row. The first attempt affects learnability while the other two indicate whether a method was memorable. Out of 5 groups, 2 completed

<table>
<thead>
<tr>
<th>Technology</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>7</td>
</tr>
<tr>
<td>USB drives</td>
<td>6</td>
</tr>
<tr>
<td>Multiple computers/laptops</td>
<td>3</td>
</tr>
<tr>
<td>Google docs</td>
<td>2</td>
</tr>
<tr>
<td>Dropbox</td>
<td>1</td>
</tr>
<tr>
<td>Printer</td>
<td>1</td>
</tr>
<tr>
<td>Manila folders</td>
<td>1</td>
</tr>
<tr>
<td>Filing cabinets</td>
<td>1</td>
</tr>
<tr>
<td>Network access</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 6.2: Technologies Participants used to collaborate.

easily moved between locations. Only one participant (P5B) mentioned the use of Dropbox to support collaboration. However, it is worth noting that P5B is an IT student and would be more informed about the latest technologies and hence would be more likely to be exposed to Dropbox. We cannot determine the reason for the low usage of Dropbox as users may simply have never heard of the technology before.

None of our users have had any tabletop experience before, except participant P5B who claims "someone once gave me a quick 10 minute introduction to the basics of Cruiser, just moving things around and rotating". P5B most likely had this experience at an Open Day demonstration for the University of Sydney’s School of Information Technologies. This minimal use is unlikely to affect our study. However, we did take it into account when studying the results.

One relevant piece of information that was not covered by this questionnaire is that participant P1B suffers from vision impairment and is partially blind. This may have affected his use of the tabletop and may give some insight for other people with visual impairments.

All the data mentioned above including the questions and participant answers are in Appendix A.
Table 6.3: Table shows how successful the 5 Groups were at completing a set of Emailer tasks. Each task had to be completed 3 times.

<table>
<thead>
<tr>
<th>Group:</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attempt</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Create an email object</td>
<td>○</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Add an attachment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Add multiple single attachments</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Add attachments in a storage bin</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Add attachments on the back of attachments</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>○</td>
</tr>
<tr>
<td>Remove attachments</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Flip email over</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Select recipient</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Select multiple recipients</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Deselect a recipient</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Send email</td>
<td>✓</td>
<td>✓</td>
<td>○</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Key:** ✓ = Completed Task fluidly/easily; ○ = Completed task only after exploration; ● = Completed task but Observer had to intervene
the tasks the first time, without difficulty and by the 3rd attempt at the tasks every user could complete them in a fluid and easy manner. This result indicates that our interface rates highly for our learnability goal.

Further, the observer of the experiment only had to intervene twice during the entire set of tasks of any group. G2 and G4 both had problems, while they knew they had to open the toolbox in order to create a Cloud, they simply could not remember how to enlarge it. Both groups tried a double tap gesture and a 2 finger zoom gesture (which is common to iPhone, iTouch and iPad devices) in order to open the toolbox. In each case the observer merely prompted "Do you remember how to enlarge objects?" which then caused them to remember to use the corners to enlarge. On their second attempt, G2 was able to perform this correctly but had a some difficulty correctly selecting the corner touch point while G4 completed the task fluidly. G1 and G3 had a similar problems with the touch target on the first attempt but performed it fluidly on their next 2 attempts. Overall, this points to a problem that is related to the underlying Cruiser framework and its interface for enlarging objects.

Only on two other tasks did a group have any difficulties. G3 had a problem with adding attachments on the back of another attachment to send. They flipped over an image, then attempted to add another image of a very similar size onto the back of it. Since the image on the back was almost the same size as the original image, it overlapped the touch targets to flip the image back over. Participants P3A eventually fixed this problem by making the added image smaller to reach the touch targets. G3 did not make this mistake again. Nor did any other group. Then again, the problem is due to following the interface convention of Cruiser. This points to the need for avoiding the problem of attached images being too large for flipping to be possible. G2 encountered a problem where they pressed the send button multiple times in quick succession because the first touch did not give any immediate feedback. This problem could be addressed by adding feedback on a successful send action. In their subsequent attempts they were more patient and only pressed the send button once.

Due to the small number of problems encountered by participants and the speed with which groups learnt from their mistakes, we can claim that we have created a highly learnable interface. Participants needed no more than 3 attempts to perfect any task the Emailer is capable of. But it indicates that feedback on the mail action could improve usability. However, it points to two areas of improvements to consider for the Cruiser framework:

- Attached objects on the back of objects should be scaled to avoid covering controls
Chapter 6. Evaluation Results and Analysis

6.3 Evaluation tasks: MyCloud

As described in Section [5.2.3] users were required to perform a number of evaluation tasks using MyCloud. These tasks were designed to test the variety of functionality available. The results for these evaluation tasks are shown in Table 6.3. In comparison with the Emailer, participants had a lot more difficulty using the MyCloud interface. Every group encountered at least one problem while completing the tasks.

When creating a Cloud every group performed this fluidly except for G5 who became confused between the icon for the storage bin and the Cloud as they look the same. Initially participant P5A dragged the storage bin out before realising he had the wrong tool and dragged out a Cloud instead. This confusion is understandable as it is not possible to distinguish between the storage bin and the Cloud. However, G5 was the only group with any hesitation. The others used a process of elimination, as they

Table 6.4: Table shows how successful the 5 Groups were at completing a set of MyCloud tasks. Each task had to be completed 3 times.

<table>
<thead>
<tr>
<th>Group:</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attempt</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Create a Cloud object</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Drag a single image out of Cloud</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Drag subCloud out of Cloud</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Drag subCloud out of subCloud</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Add an image to a subCloud</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>Add an image to a Cloud</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>Lock a Cloud</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Key: ✓ = Completed Task fluidly/easily; ○ = Completed task only after exploration; ● = Completed task but Observer had to intervene

- There should be a review of the enlargement gestures, perhaps to support finger pinch and spread as has become standard
6.4 Realistic Free form Task Results

had already used every other tool in the toolbox. This poses a problem for memorability as return users may have forgotten the position of MyCloud since the last time they used the tabletop. In subsequent uses of the system, G5 had no difficulties. While we see results and our reflections point to the merit of a different icon for MyCloud, in practice, this did not seem to pose serious problems for learnability.

The only other tasks that groups, except G5, had trouble completing are adding images to Clouds and subClouds. G1, G2 and G4 all completed the tasks after a little experimentation. G3, however, needed direction from the observer in order to add an image to a subCloud. The observer gave the hint "what do you think the locks mean?". Consequently, the participants were successfully able to complete the tasks. G3 showed a bit of hesitation on the second attempt at the adding but by the 3rd attempt was able to fluidly add images.

There are two core parts of MyCloud, the ability to drag subClouds and images out and to be able to add images. Participants did not encounter any problems with taking images out and browsing through subClouds on any of their attempts. However, for adding images, our participants had some difficulty.

6.4 Realistic Free form Task Results

For our free form task, participants had to gather material for a poster about Achilles and the Battle of Troy. We used video recording to capture the experiment. We then reviewed the video to assess how well participants used each main part of the interface and other key aspect that were described and are important for interpreting the other results. Table 6.4 summarises the analysis. As explained in 5.2.4 we have recorded a variety of information including time till completion, abilities to access, mail, and store media, errors and unique number of relevant files collected.

We measured time till completion in order to determine how long people took to complete the task compared to the number of files collected. Groups took an average of 12:54 minutes. G2 and G5 were much faster, this appeared because they were impatient to finish. "Files gathered" is the number of unique files relevant to either Achilles or the Battle of Troy which users collected into the relevant subClouds. The total number of unique relevant files is 28. One measurement of the efficiency our our participants is the number of unique relevant files found per minute. These have been calculated in Table 6.4. These should be interpreted with caution as participants were told to work quickly and it was natural for them to discard files as they viewed them. Even so, we observe that G3 was the most efficient group.
## Chapter 6. Evaluation Results and Analysis

### 6.4. Realistic Free form Task Results

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>Access</th>
<th>Mail</th>
<th>Store</th>
<th>Errors</th>
<th>Files Gathered</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17:58</td>
<td>✔️</td>
<td>✔️</td>
<td>○</td>
<td>4</td>
<td>16</td>
<td>P2 is partially blind and has vision problems. Realised it wasn’t possible to delete. Spammed send button.</td>
</tr>
<tr>
<td>2</td>
<td>8:30</td>
<td>✔️</td>
<td>✔️</td>
<td>○</td>
<td>3</td>
<td>10</td>
<td>Unlocked Cloud to remove items. Moved files to storage bin before sending. Confused why there were two copies when adding.</td>
</tr>
<tr>
<td>3</td>
<td>17:17</td>
<td>✔️</td>
<td>✔️</td>
<td>○</td>
<td>2</td>
<td>27</td>
<td>Confused why there were two copies when adding. P5 learnt to lock subClouds to reduce accidental adding.</td>
</tr>
<tr>
<td>4</td>
<td>14:05</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>4</td>
<td>16</td>
<td>Tried to flip Clouds on 2 separate occasions. Unlocked Cloud to remove items. Trouble flipping mail. Spammed send button.</td>
</tr>
<tr>
<td>5</td>
<td>6:39</td>
<td>✔️</td>
<td>○</td>
<td>○</td>
<td>5</td>
<td>8</td>
<td>Pulled lots of subClouds out at once. Tried to flip cloud to delete objects. Confused why there were two copies when adding. Spammed send button.</td>
</tr>
</tbody>
</table>

**Key:** ✔️ = Completed Task fluidly/easily; ○ = Completed task only after exploration;

Table 6.5: Results of Realistic Evaluation.
6.4. Realistic Free form Task Results

Chapter 6. Evaluation Results and Analysis

<table>
<thead>
<tr>
<th>Group</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.89</td>
</tr>
<tr>
<td>2</td>
<td>1.18</td>
</tr>
<tr>
<td>3</td>
<td>1.56</td>
</tr>
<tr>
<td>4</td>
<td>1.14</td>
</tr>
<tr>
<td>5</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Table 6.6: Efficiency at finding relevant files

by a very wide margin.

now consider the "Access" column of Table 6.4. Although we have already tested the participants’ ability to access images and subClouds in our previous set of tasks, we also wish to rate their performance in the free form task. Every group except G4 were able to browse through the file system fluidly and easily. G4 were able to browse the interface without problems. However, they developed an odd misconception. These participants started unlocking Clouds in order to be able to interact with their contents.

We now consider the "Mail" column. When sending mail G1, G2 and G3 had no trouble sending their files. However, G4 and G5 pressed the send button many times when they did not instantly get feedback to say the email was being sent. This confirms our earlier observation that the interface would be improved if there is immediate feedback on this action and that a series of touches does not send repeats email. Participants were sending a much larger collection of files than they had in previous tasks. This meant the email took a much longer time to send items. This lengthy delay between the action of sending and the feedback confused both groups.

The "Store" column of Table 6.4 shows that groups had problems with storing images into Clouds. However, this was not due to the same reasons as highlighted in Section 6.2. Many files being used by users were accidentally copied to locations not intended by the participants. The cause of this was leaving locks open, either intentionally, or unwittingly opening them and then dragging images across the open Clouds. The next column of Table 6.4 shows the error frequency, which was recorded for each group. An error is an accidental addition to a Cloud. Surprisingly, G5, even though they have the shortest time for completion, were the most error prone. A reason for this may be that 5A and 5B were anxious or impatient to finish the task and hence made more mistakes.
6.5 Post-Questionnaire

Our post-experiment questionnaire had open ended questions to give users freedom to give feedback in their own words. The main goals for this thesis relate to MyCloud and Emailer. Inevitably, we also received a range of comments specifically about functionality in Cruiser. We analysed answers, grouping into common themes. In table 6.5.1 we summarise these putting them into groups for MyCloud and Emailer, Cruiser, improvements to interfaces and confidence in using the system.

6.5.1 Emailer and MyCloud Comments

As can be seen from Table 6.4 we received both positive and negative comments about different parts of the interfaces and Cruiser. We put all the positive answers in the "positive comment" group but have listed more specific groups for negative comments. Since these provide critical information for the future interface improvements.

Five participants stated that the system "requires some practise time" to gain skills to be able to use it efficiently. We can conclude from this that our system is unfamiliar and requires time and practise to use it easily. It is significant because 5 participants each made nearly the same comment with P3B even saying it in two different questions.

Another key issue which appeared repeatedly was "problems with clutter due to the operations of clouds". Four separate participants felt that the extra copy created when adding images to Clouds was unnecessary and led to clutter of the interface. When adding images to subClouds during the free form task, 4 out of 5 groups noted annoyance at this extra copy. With this repetition of the same remark among many participants, this indicates a need to improve this behaviour of MyCloud.

We noticed throughout the free form task that every group tried to place the Cloud with their files inside the Emailer. However, during the questionnaire only 3 participants commented on this behaviour. As participants learnt from the evaluation tasks that you are able to group images together through the use of storage bins or putting them on the back of each other, it was logical to assume the same rules applied to the Cloud. We can conclude from this that our system is not internally consistent. Users expected this behaviour since they had already seen it with other very similar tools.

Two comments with very similar themes were "problems with images added to cloud and not coming out" and "could not delete from clouds". These may seem identical in meaning but the former suggests the act of not coming out is the issue while the second indicates the lack of a delete function. Three
participants mentioned these problems, with P3A mentioning both for a total of 5 coded comments in the table. During the task users quite often accidentally added images to subCloud which they had left unlocked or accidentally unlocked. This was an irreversible and irritating error. When this occurred, there was no way to remove items from the Cloud. We have determined from these comments that it is critical to add a delete function is.

Two participants had problems with the locks on the clouds. These locks were designed to prevent accidental storing of images into Clouds. P1A had difficulties where "dragging items over to the 'black hole' other objects were used/unlocked". This resulted in several errors where the group accidentally added a number of files to a subCloud without intending to. P3B, on the other hand, merely found the locks "confusing" saying it took her a while to figure out how they work but they were easy once known. In the free form task, P3B had the misconception that you were required to unlock Clouds before pulling objects out of them. She eventually understood and was performing the function of locking and unlocking Clouds more fluidly by the end of the task. This points to the need to refine the design to avoid this problem.

Participants P5A and P5B did not initially understand the meaning of the word "Cloud" nor its purpose on the interface. After a small amount of experimentation they eventually understood. However, their confusion suggests that there should be exploration of a more intuitive name.

6.5.2 Cruiser

As previously stated we aimed to collect information specifically about our interfaces but we also collected some comments about Cruiser since our interfaces are built on top of it. The main concerns participants had about Cruiser were the flip gesture and clutter due to large items.

Participant P4B had problems with the actual flipping of the object while P1B did not like the gesture itself. During the free form task P4B constantly had trouble flipping items to use the functionality on the back. Her main problem was she constantly missed the touch targets. The problem lessened when she realised she could enlarge the objects to make them and their touch targets bigger before trying to perform a flip. P1B on the other hand, simply did not like the use of sides to flip as "it was a waste of time and energy when a simple double tap would have been faster and would have resulted in less errors getting the other side rather than the corners". Both these comments seem to point towards making the flipping touch targets bigger in order to more easily flip objects.
### Chapter 6. Evaluation Results and Analysis

#### 6.5. Post-Questionnaire

<table>
<thead>
<tr>
<th>Comments</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Related to Emailer or MyCloud interface</strong></td>
<td></td>
</tr>
<tr>
<td>Positive comment</td>
<td>Q1P1A, Q1P1B, Q1P3B, Q2P3B, Q2P5A, Q3P1A, Q4P1A, Q4P2A, Q4P3A, Q4P3B,</td>
</tr>
<tr>
<td>Problems with clutter due to operation of clouds</td>
<td>Q1P1B, Q5P1A, Q5P2B, Q5P4B</td>
</tr>
<tr>
<td>Problems in trying to add clouds to email</td>
<td>Q1P5A, Q1P5B, Q2P4A, Q5P4A</td>
</tr>
<tr>
<td>Problems with images added to cloud and not coming out</td>
<td>Q2P5B, Q5P3A, Q5P3B</td>
</tr>
<tr>
<td>Storage bin and Cloud look the same</td>
<td>Q3P1B</td>
</tr>
<tr>
<td>Did not initially understand purpose/meaning of &quot;a cloud&quot;</td>
<td>Q3P5A, Q3P5B</td>
</tr>
<tr>
<td>Cloud lock problems</td>
<td>Q2P1A, Q3P3B, Q5P1A</td>
</tr>
<tr>
<td>Could not delete from clouds</td>
<td>Q5P2A, Q5P2B, Q5P3A</td>
</tr>
<tr>
<td>Requires some practice time</td>
<td>Q1P4A, Q2P1A, Q2P2A, Q2P3A, Q2P3B, Q3P3B</td>
</tr>
<tr>
<td><strong>Related to Cruiser interface</strong></td>
<td></td>
</tr>
<tr>
<td>Positive comment</td>
<td>Q2P1B, Q4P1A, Q4P1B, Q4P2B, Q4P3A, Q4P3B, Q4P4A, Q4P4B, Q4P5A, Q4P5B</td>
</tr>
<tr>
<td>Could not identify what file contained</td>
<td>Q2P1B</td>
</tr>
<tr>
<td>Flip gesture</td>
<td>Q2P4B, Q5P1B, Q5P4B</td>
</tr>
<tr>
<td>Resize gesture</td>
<td>Q5P2A</td>
</tr>
<tr>
<td>Rotational inertia</td>
<td>Q5P5A</td>
</tr>
<tr>
<td>Clutter due to very large items</td>
<td>Q5P3B, Q5P5B</td>
</tr>
<tr>
<td><strong>Improvements to Interfaces</strong></td>
<td></td>
</tr>
<tr>
<td>Create subCloud</td>
<td>Q6P1A</td>
</tr>
<tr>
<td>Ability to change filenames</td>
<td>Q6P1B</td>
</tr>
<tr>
<td>Ability to flip Cloud and read filenames</td>
<td>Q6P1B</td>
</tr>
<tr>
<td>Delete image from Clouds</td>
<td>Q6P2A</td>
</tr>
<tr>
<td>More defineable touch areas</td>
<td>Q6P2B</td>
</tr>
<tr>
<td>Snap objects to grid option</td>
<td>Q6P2B</td>
</tr>
<tr>
<td>1 dimensional image expansion/contraction</td>
<td>Q6P3A</td>
</tr>
<tr>
<td>Ability to tie files together</td>
<td>Q6P3B</td>
</tr>
<tr>
<td>Written emails</td>
<td>Q6P4A, Q6P4B</td>
</tr>
<tr>
<td>Add Clouds to email</td>
<td>Q6P4B, Q6P5A</td>
</tr>
<tr>
<td>Image manipulation tools (drawing/adding/changing labels)</td>
<td>Q6P5B</td>
</tr>
<tr>
<td>Search</td>
<td>Q6P5B</td>
</tr>
</tbody>
</table>

#### Confidence in using System

<table>
<thead>
<tr>
<th>Comments</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairly easy and simple</td>
<td>Q7P1A, Q7P5B</td>
</tr>
<tr>
<td>No preference to use it</td>
<td>Q7P1B</td>
</tr>
<tr>
<td>Need more practise</td>
<td>Q7P3A</td>
</tr>
<tr>
<td>Easier for collaborative work</td>
<td>Q7P4A, Q7P5B</td>
</tr>
<tr>
<td>Don’t know how to personalise</td>
<td>Q7P5A</td>
</tr>
</tbody>
</table>

Table 6.7: Classifying answers to post-experiemnt questionnaire into common themes
The issue of oversized items on the tabletop taking up too much space was mentioned by participants P3B and P5B. P3B commented that ‘oversized’ files prevented effective use of screen space” while P5B claimed "the fact that there is no maximum size meant images and folders could take over the top of the table covering other items”. Sometimes, in order to read effectively, files were required to be opened to a very large size which is mainly where this problem originated. These participants occasionally became annoyed when their partner enlarged an image so much that it covered the objects they were currently using.

6.5.3 Improvements

Users suggested several improvements to the interface. These include creating subClouds, delete images from Clouds, more definable touch areas, snap to grid option, ability to tie files together and image manipulation tools. However, only two suggestions were made by more than 1 participant, these being written emails and adding Clouds to emails. P4A and P4B would have both liked to be able to add text to the emails which they sent in order to "further describe the contents of the email" (P4A when asked why they wanted text in emails by observer). Every group at one point tried to add a Cloud to an email but eventually discovered that this is not possible; P4B and P5A both suggested this functionality be implemented. As previously stated this part of the interface is inconsistent and adding this functionality would definitely serve to make the interface more consistent.

6.6 Analysis of Results

In the previous sections we have described the results we have collected. This section summarises the key strengths and problems of our interface designs.

6.6.1 Key Strengths

During our evaluations we have gathered several key strength of our system and highlighted where it has performed its best.

Emailer

Most of our strengths come from the Emailer interface which performed excellently across its broad range of elements. Participants were very quick to learn where to create an email object. G1, G2 and G4
had some difficulty in opening the toolbox but every group knew that the toolbox contained the email icons. Adding attachments to emails, in any form including storage bins and back of objects, was highly intuitive. Participants seemed to instinctively know how to add attachments to emails using the simple drag and stop gesture. Following from adding attachments, it was a short stretch for participants to figure out how to remove items from an email. Every group intuitively understood the gesture for removal of attachments. All participants acted fluidly when selecting recipients the first time during the evaluation tasks. The immediate feedback when a recipient was selected was easily understood by participants. Users also found it very easy to send emails once they had attachments and recipients selected.

**MyCloud**

Our MyCloud interface also had some strengths as well. Firstly, all participants knew where to create a MyCloud object from. Dragging files and subClouds out of Clouds and subClouds was performed really well by all users. During the evaluation tasks not one group had the slightest bit of difficulty with browsing through MyCloud. This browsing part of the interface was established to be highly learnable and users can understand it very quickly.

### 6.6.2 Key Problems

During our evaluation we have highlighted numerous problems with our design which caused difficult to use interfaces, errors and confusion.

**Emailer**

The main problem with Emailer was the feedback for when participants pressed the send button. During the evaluation tasks users only sent a small amount of files through Emailer and hence has quick to send and the feedback was almost instant. However, during the realistic evaluation users were sending a much bigger file collection. This cause the email to delay in sending and also delayed the time when the feedback appeared to indicate the file was sending. Due to the delayed response participants quite often pressed the send button multiple times, sending an email each time, until the feedback started playing.

Another problem discovered was the incompatibility with MyCloud. During the evaluation tasks users grouped files together in two different ways, in storage bins and on the back of objects. They then used this group of objects as attachments to an email. This set a mental model in every participants’
mind that groups of objects can be added to an email. However, with our implementation it was not possible to add a Cloud or subCloud to an email although every group tried to do this. This shows that Emailer has an internal inconsistency which impacts ease of use.

**MyCloud**

There were several key problems with MyCloud which were highlighted during the various usability tasks.

First problem arises when users add images to a Cloud or a subCloud. Users were quite often confused by the original file still being left on the table after it is copied into the Cloud. This superfluous file then had to be manually deleted by the user by putting it into the Blackhole. If the users neglected to Blackhole these files the interface soon became too cluttered to work with. This problem was highlighted by answers Q1P1B, Q5P1A, Q5P2B and Q5P4B of the post experiment questionnaire as well as by observation during the free form naturalised think aloud.

Another problem which arose was the accidental adding of files into Clouds. This was further impounded by the problem that users cannot remove images once they have been stored in subClouds or Clouds. This meant that any accidental addition was an irreversible error. Accidental addition usually happened when users purposefully or accidentally unlocked files then moved an image from one side of the tabletop to the other. On the way the files generally touched an unlocked subCloud and were copied into it. Comments outlining these problems are Q2P5B, Q5P3A, Q5P3B, Q2P1A, Q3P3B, Q5P1A, Q5P2A and Q5P2B.

The final problem discovered during our evaluations is that MyCloud takes some time to practise with. Users commented that the interface was quite unfamiliar and required time to understand how it functions (Q1P4A, Q2P1A, Q2P2A, Q2P3A, Q2P3B and Q3P3B). While participants quickly understood browsing and looking through subClouds and images, they had a hard time understanding the interaction mechanisms behind adding files into Clouds and subClouds.
Chapter 7

Conclusions

This thesis presented Emailer and MyCloud the first work to explore ways to support flexible export of files from tabletops. Emailer allows emailing attachments, and MyCloud, is a cloud based storage system for users to organise and send files to other locations. These tools were evaluated in a carefully designed qualitative evaluation of the usability of their interfaces. Through collecting and analysing multiple sources of evidence collected, these give insight into user interaction with a hierarchical file system and sending email from a tabletop environment. This chapter concludes the thesis by drawing conclusions from the analysis, relating these back to our initial thesis goals, identifying the key contributions of the thesis and how these provide foundations for further work.

7.1 Contributions

Contribution 1: Conceptual Framework

We initially set a goal for this thesis to create a conceptual framework detailing core operations and interface elements for the nature of both organisation and exportation. We have shown that it is useful to consider tabletops in terms of the context in which they are used. These contexts shape the core functionality which needs to be available to support the users in that environment. We defined the key user tasks that are should be supported in each context and found that, while the task of organisation is relevant to all contexts, exportation is particularly important on embedded collaboration devices and private devices. We built our applications MyCloud and Emailer in order to address the need for these types of devices.
In addition to defining the contexts, we also defined the interface elements which can be used to design touch screen interfaces. Upon reviewing the benefits of each, in terms of usability and taking account of the mental models supported by the Cruiser framework, we decided the special object should be our element of choice when designing our interfaces.

**Contribution 2: Interface Primitive for Organisation**

We have explored the use of a hierarchical browser interface with synchronised cloud storage to assist users with organising files at the tabletop. We combined our hierarchical file viewer with cloud storage technology *Dropbox* in order to achieve our final MyCloud interface. When evaluating this interface, we discovered that users found it easy to browse through files. However, adding files to the file system was difficult. Our interface design was shown to suffer from clutter, which impacted user efficiency. At the same time, MyCloud made significant progress towards our goal by providing an interface primitive to assist with the organisation of digital artifacts at the tabletop.

**Contribution 3: Exportation of Media**

Both of our interfaces MyCloud and Emailer had the ability to export files to other locations. MyCloud, through the use of the *Dropbox* backend can share folders with other *Dropbox* users. Any files placed in these shared folders are synced to all associated accounts. This is an effective interface and mechanism to quickly and easily save files for use on other devices. Emailer provides functionality to send email with attachments from the tabletop. Devices such as phones, pocket PCs and other computers have the ability to check and download email. Hence, through the use of Emailer we can export files to arbitrary people.

It can be seen that we have achieved our goal of exploring ways to enable exportation of files at the tabletop. With the ability to access cloud storage and send emails the tabletop now has several ways of choosing how to send documents to external locations.

**7.1.1 User Study**

During this thesis we performed a carefully planned user evaluation in order to test the usability of our interface designs. Our evaluation had several steps which were structured to gather as much information about our interfaces as possible. These steps were:
• a questionnaire about participants’ background;

• an introduction to Cruiser

• evaluation tasks using Emailer

• evaluation tasks using MyCloud

• a realistic evaluation task requiring both Emailer and MyCloud; and

• a post-experiment questionnaire regarding their perceptions after completing the tasks & eliciting suggestions for improvement.

We first established the demographic of our user group through a background questionnaire. Next users were given an introduction to Cruiser in order to build their mental model of its interaction primitives, such as moving, resizing, rotating and flipping objects. With their mental model of Cruiser established, participants were then asked to complete a series of tasks first using Emailer then MyCloud. These tasks were designed to test the learnability and memorability of the interfaces. They also served as practise using the interfaces in order to see how they performed in a realistic evaluation task. Users were asked to enact a scenario which was designed to be as authentic as possible. Finally, participants were asked to complete a questionnaire with questions designed to elicit as much information from them as possible.

Limitations

There were some limitations in our usability evaluation, primarily being the user demographic. Our users were mostly students between the ages of 18-22 who considered themselves between competent to expert computer users. The user group is not representative of the general population, hence our results may not apply as well to older or less technically skilled populations.

7.1.2 Further Work

There is further work which could be undertaken to further build upon this work. The first step would be to refine our UI using our results collected from our usability evaluation. This would include fixing any bugs which were found during the user study in addition to any improvements users have suggested. Secondly, we should conduct the usability study again with a demographic more representative of the
general population. This would enable us to apply our results more generally to the wider population. In addition to widening the participant demographic, it would be beneficial to get some results in a field trial in order to perform an even more authentic experiment, with new and improved versions of our interfaces, than the one already conducted.

### 7.1.3 Conclusion

In this thesis we have aimed to explore the concepts of organisation and exportation in the highly collaborative environment provided by tabletops. We have defined and presented a conceptual framework which highlights contexts in which tabletops are typically used, key user tasks performed in these contexts and an analysis of interface primitives for touch screen devices. As a result of the conceptual model we developed two interfaces MyCloud and Emailer which support the user tasks of organisation and exportation. These were evaluated in an extensive user study and we presented our findings.
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http://doi.acm.org/10.1145/1718918.1718987.


Appendix A

Background Questionnaire
Background Questionnaire

Please complete the following questions about your background:

Age: ______  Occupation: ________________________________

Gender:  
☐ Male  ☐ Female

1. Are you primarily right- or left-handed? (please tick one)
   ☐ Right-handed  ☐ Left-handed  ☐ Ambidextrous

2. How many hours do you typically use a computer each week? (please tick one)
   ☐ None  ☐ 1 to 10  ☐ 11 to 20  ☐ 21 to 30  ☐ 31 to 40  ☐ 41 or more

3. Have you ever used a tabletop interface before? (if yes, please give details)
   ____________________________________________________________
   __________________________________________________________________
   __________________________________________________________________

4. How would you rate your level of skill at managing files and e-mails with a computer? (tick 1)
   ☐ None  ☐ Limited  ☐ Competent  ☐ Advanced  ☐ Expert

5. How often do you need to collaborate with other people (in the same room) by sharing files/documents? (please tick one)
   ☐ Never  ☐ Daily  ☐ Weekly  ☐ Monthly  ☐ Yearly

   If yes, please describe the tools/procedures you use to support the collaboration:
   __________________________________________________________________
   __________________________________________________________________
   __________________________________________________________________

6. How often do you need to send a file on your computer to another location (e.g. another computer, email etc)?
   ☐ Never  ☐ Daily  ☐ Weekly  ☐ Monthly  ☐ Yearly

Please tell the experimenter when you have finished completing the questionnaire.
Thank you for your participation in this study.
Appendix B

Post-experiment Questionnaire
Post-Experiment Questionnaire

Please complete the following questions about your experiences using the touch-based interface. For each of the questions, please mark one box in each line to indicate your response, and explain in further detail (give feedback) when indicated.

1) I was able to complete all the tasks:

<table>
<thead>
<tr>
<th>strongly disagree</th>
<th>disagree</th>
<th>somewhat disagree</th>
<th>neutral</th>
<th>somewhat agree</th>
<th>agree</th>
<th>strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

Please explain:
______________________________________________________________________________
______________________________________________________________________________

2) How easy/difficult did you find the tasks to complete:

<table>
<thead>
<tr>
<th>very easy</th>
<th>easy</th>
<th>somewhat easy</th>
<th>neutral</th>
<th>somewhat difficult</th>
<th>difficult</th>
<th>extremely difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

Please explain:
______________________________________________________________________________
______________________________________________________________________________

3) I was able to easily identify the purpose of each object on the screen:

<table>
<thead>
<tr>
<th>strongly disagree</th>
<th>disagree</th>
<th>somewhat disagree</th>
<th>neutral</th>
<th>somewhat agree</th>
<th>agree</th>
<th>strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

Please explain:
______________________________________________________________________________
______________________________________________________________________________

______________________________________________________________________________
4) What did you like best about the application and its interface?

______________________________________________________________________________
______________________________________________________________________________

5) What aspect of the interface did you least like when completing the tasks?

______________________________________________________________________________
______________________________________________________________________________

6) What aspect or feature would you have liked the application or interface to contain that is not currently present?

______________________________________________________________________________
______________________________________________________________________________

7) After completing the tasks I feel confident in using such a system (the touch-based interface) to communicate with my family/friends:

<table>
<thead>
<tr>
<th>strongly disagree</th>
<th>disagree</th>
<th>somewhat disagree</th>
<th>neutral</th>
<th>somewhat agree</th>
<th>agree</th>
<th>strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

Please explain:
______________________________________________________________________________
______________________________________________________________________________

______________________________________________________________________________
8) Do you have any other general comments regarding touch-based interface?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________


Please tell the experimenter when you have finished completing the questionnaire.

Thank you for your participation in this study.
Appendix C

Evaluation Test Data

Each person in the experiment was given their own individual set of files to share at the tabletop. As a result, each file system listing contains two sets of files, corresponding to Person A and Person B. The listing of each person’s file system is divided into two separate file systems: a small file system and a large file system.

C1  File System Listing

Achilles/
Articles/
Battle of Troy/
Cities/
Images/
People/
Plaques/
Signs/

./Achilles:
{empty}

./Articles:
Nicholson Museum Article 2.jpg
C1. File System Listing

Nicholson Museum Article 3.jpg
Nicholson Museum Article.jpg
Roman Sarcophagus Article.jpg

./Battle of Troy:
{empty}

./Cities:
Athens.png
Mycenae.png
Troy.png

./Images:
Achilles/
Armour/
Cities/
Masks/
Mummies/
Remains/
Statues/
Trojan Horse/
Vases/
Weapons/

./Images/Achilles:
Achilles Horses.jpg

./Images/Armour:
Armor Helmut.jpg
Body Armor.jpg
Helmut 1.jpg
Appendix C. Evaluation Test Data
C1. File System Listing

Helmut 2.jpg

./Images/Cities:
Acropolis Athens.jpg
Athens Theatre.jpg
Map of Troy.jpg

./Images/Masks:
Agamemnon Mask.jpg

./Images/Mummies:
Mummified Cat.jpg
Mummy Sign.jpg
Mummy Tomb.jpg
Mummy Foot.jpg
Mummy Hand 2.jpg
Mummy Hand.jpg
Boy Horus Mummy.jpg

./Images/Remains:
Painted Remains.jpg
Rocks of Troy.jpg
Romain Sarcophagus.jpg

./Images/Statues:
Statue 1.jpg
Statue 10.jpg
Statue 11.jpg
Statue 2.jpg
Statue 3.jpg
Statue 4.jpg
C1. File System Listing

Statue 5.jpg
Statue 6.jpg
Statue 7.jpg
Statue 8.jpg
Statue 9.jpg

./Images/Trojan Horse:
Trojan Horse Painting.jpeg
Wooden Trojan Horse.jpg
Wooden Trojan Horse 2.jpg

./Images/Vases:
Clay Pot 2.jpg
Clay Pot 3.jpg
Clay Pot.jpg
Psyche Vase.jpg
Rape of Cassandra Vase.jpg
Sarpedon Battle Vase.jpg
Trojan War Vase.jpg
Hector Vase.jpg
Achilles Horse Vase.jpg
Egyptian Vase.jpg
Plain Vase.jpg

./Images/Weapons:
Bronze Weapons.jpg
Spear 1.jpg
Spear 2.jpg
Spear 3.jpg
Spear 4.jpg
Spear 5.jpg
Appendix C. Evaluation Test Data

C1. File System Listing

Spear 6.jpg

./People
Achilles.png
Achilles Horses.png
Agamemnon.png
Ajax.png
Andromache.png
Apollo.png
Athena.png
Cassandra.png
Hector.png
Hekabe.png
Hypnos.png
King Priam.png
Lycia.png
Olieus.png
Patroklos.png
Psyche.png
Sarpedon.png
Thanatos.png
Trojan Horse.png
Trojan War.png
Zeus.png

./Plaques
Greek Plaque.jpg
Greek Plaque 2.jpg

./Signs
Aura Sign.jpg
Bronze Helmut Sign.jpg
Buried In Italy Sign.jpg
Chieftain Cup Sign.jpg
Gaius Sign.jpg
Human Remains Sign.jpg
Mummified Cats Sign.jpg
Rape of Cassandra Vase.png
Remains of Troy.png
Roman Emperors Sign.jpg
Sarpedon Battle Vase.png
Tail of Three Lives Sign.jpg
The Gods Sign.jpg
Appendix D

Post-experiment Questionnaire Answers
Appendix D. Post-experiment Questionnaire Answers

I was able to complete all the tasks:
1- Strongly Disagree 7 - Strongly Agree

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1P1A</td>
<td>6</td>
</tr>
<tr>
<td>Q1P1B</td>
<td>6</td>
</tr>
<tr>
<td>Q1P2A</td>
<td>6 –</td>
</tr>
<tr>
<td>Q1P2B</td>
<td>7 –</td>
</tr>
<tr>
<td>Q1P3A</td>
<td>7 –</td>
</tr>
<tr>
<td>Q1P3B</td>
<td>7</td>
</tr>
<tr>
<td>Q1P4A</td>
<td>5</td>
</tr>
<tr>
<td>Q1P4B</td>
<td>6 –</td>
</tr>
<tr>
<td>Q1P5A</td>
<td>6</td>
</tr>
<tr>
<td>Q1P5B</td>
<td>6</td>
</tr>
</tbody>
</table>

- Q1P1B: I could do everything but 2 things slowed me down, firstly the superfluous items that had to be thrown out everytime you moved a file between clouds, secondly the way clouds didn't display files appropriate to their size/shape seemed slow and cumbersome.
- Q1P3B: Interface was user friendly and simple.
- Q1P5A: I was confused by not being able to add Clouds to emails.

Table D.1: Q1 Post-experiment Questionnaire Results.

How easy/difficult did you find the tasks to complete:
1 - Extremely Difficult 7 - Very Easy

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2P1A</td>
<td>5</td>
</tr>
<tr>
<td>Q2P1B</td>
<td>4</td>
</tr>
<tr>
<td>Q2P2A</td>
<td>5</td>
</tr>
<tr>
<td>Q2P2B</td>
<td>6 –</td>
</tr>
<tr>
<td>Q2P3A</td>
<td>6</td>
</tr>
<tr>
<td>Q2P3B</td>
<td>6</td>
</tr>
<tr>
<td>Q2P4A</td>
<td>4</td>
</tr>
<tr>
<td>Q2P4B</td>
<td>5</td>
</tr>
<tr>
<td>Q2P5A</td>
<td>7</td>
</tr>
<tr>
<td>Q2P5B</td>
<td>6</td>
</tr>
</tbody>
</table>

- Q2P1A: To make it easier it requires some time to practise. Also as dragging items over to "black hole" other objects were used/unlocked, sometimes confused me.
- Q2P2A: I'm a bit un-co, it was hard to get some things to work but once I figured it out it was easier.
- Q2P4B: knew what had to be done and knew how to do it, but couldnt get it to work! e.g. flipping over an image
- Q2P5A: There was an issue of images accidentally being added into a cloud and not coming out otherwise intuitive.

Table D.2: Q2 Post-experiment Questionnaire Results.
Appendix D. Post-experiment Questionnaire Answers

I was able to easily identify the purpose of each object on the screen:
1- Strongly Disagree 7 - Strongly Agree

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3P1A</td>
<td>6</td>
</tr>
<tr>
<td>Q3P1B</td>
<td>5</td>
</tr>
<tr>
<td>Q3P2A</td>
<td>7 -</td>
</tr>
<tr>
<td>Q3P2B</td>
<td>6 -</td>
</tr>
<tr>
<td>Q3P3A</td>
<td>4 -</td>
</tr>
<tr>
<td>Q3P3B</td>
<td>6</td>
</tr>
<tr>
<td>Q3P4A</td>
<td>6 -</td>
</tr>
<tr>
<td>Q3P4B</td>
<td>6 -</td>
</tr>
<tr>
<td>Q3P5A</td>
<td>6</td>
</tr>
<tr>
<td>Q3P5B</td>
<td>7</td>
</tr>
</tbody>
</table>

Table D.3: Q3 Post-experiment Questionnaire Results.

What did you like best about the application and its interface?

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4P1A</td>
<td>Novelty of the blackhole. Drag ability from any folder into email attachment, without going through traditional subfolder search again.</td>
</tr>
<tr>
<td>Q4P1B</td>
<td>The black hole</td>
</tr>
<tr>
<td>Q4P2A</td>
<td>Easy and uncluttered</td>
</tr>
<tr>
<td>Q4P2B</td>
<td>It was swishy (Items had momentum)</td>
</tr>
<tr>
<td>Q4P3A</td>
<td>The speed with which we could complete the tasks, and the ability to interact with someone else’s work at all times.</td>
</tr>
<tr>
<td>Q4P3B</td>
<td>It was enjoyable to use, and very easy to run multiple ”documents” or folders concurrently.</td>
</tr>
<tr>
<td>Q4P4A</td>
<td>It’s cool. Handy that multiple windows can be opened on the one desktop. No use of a mouse click.</td>
</tr>
<tr>
<td>Q4P4B</td>
<td>Multi-touch, black hole, that you could rotate things, makes surface usable for more people</td>
</tr>
<tr>
<td>Q4P5A</td>
<td>The fact that you could have nested containers</td>
</tr>
<tr>
<td>Q4P5B</td>
<td>The images were easily manipulated and shared between participants</td>
</tr>
</tbody>
</table>

Table D.4: Q4 Post-experiment Questionnaire Results.
Appendix D. Post-experiment Questionnaire Answers

### What aspect of the interface did you least like when completing the tasks?

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5P1A</td>
<td>The ability to &quot;unlock&quot; accidentally while dragging over. Creation of duplicate when dragging image into separate subfolder</td>
</tr>
<tr>
<td>Q5P1B</td>
<td>Didn’t like the use of the sides to flip, was a waste of time and energy when a simple double tap would have been faster and would have resulted in less errors getting the side rather than the corners</td>
</tr>
<tr>
<td>Q5P2A</td>
<td>It goes against common multi-touch gestures currently used (2 fingers to zoom). you can’t delete out of subClouds.</td>
</tr>
<tr>
<td>Q5P2B</td>
<td>Files duplicating when copied to folders and also not being able to delete files in folders.</td>
</tr>
<tr>
<td>Q5P3A</td>
<td>Not being able to remove items from a subCloud once accidentally put in.</td>
</tr>
<tr>
<td>Q5P3B</td>
<td>Inability to remove files from Clouds and SubClouds. Some &quot;oversized&quot; files prevented effective use of screen space once expanded</td>
</tr>
<tr>
<td>Q5P4A</td>
<td>You couldn’t add a subcloud as an attachment. Had to add files one at a time.</td>
</tr>
<tr>
<td>Q5P4B</td>
<td>Hard to flip images. That things kept copying for no reason! e.g. when we put something into a subCloud it made 2 copies. If a subcloud os unlocked then stuff you copy into one subclouds also gets copied into the unlock subClouds.</td>
</tr>
<tr>
<td>Q5P5A</td>
<td>Lack of rotational inertia</td>
</tr>
<tr>
<td>Q5P5B</td>
<td>The fact that there was no maximum size meant images and folders could take over the top of the table covering other items.</td>
</tr>
</tbody>
</table>

Table D.5: Q5 Post-experiment Questionnaire Results.

### What aspect or feature would you have liked the application or interface to contain that is not currently present?

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q6P1A</td>
<td>Create subfolder option</td>
</tr>
<tr>
<td>Q6P1B</td>
<td>Word recognition and the ability to change file names. the ability to flip over a cloud and read file names</td>
</tr>
<tr>
<td>Q6P2A</td>
<td>Delete.</td>
</tr>
<tr>
<td>Q6P2B</td>
<td>More definable colours to see where to touch, snap to grid option</td>
</tr>
<tr>
<td>Q6P3A</td>
<td>1 dimensional image expansion/contraction</td>
</tr>
<tr>
<td>Q6P3B</td>
<td>Ability to tie files together so that they move/expand together - would be useful when dealing with related files</td>
</tr>
<tr>
<td>Q6P4A</td>
<td>Written email application. Little vibration to show when a letter has been typed.</td>
</tr>
<tr>
<td>Q6P4B</td>
<td>Attach folder/clouds to emails. Add text to emails</td>
</tr>
<tr>
<td>Q6P5A</td>
<td>Ability to add clouds to emails</td>
</tr>
<tr>
<td>Q6P5B</td>
<td>Further image manipulation tools such as drawing or adding/changing labels on images. A search functionality to find images quickly.</td>
</tr>
</tbody>
</table>

Table D.6: Q6 Post-experiment Questionnaire Results.
Appendix D. Post-experiment Questionnaire Answers

After completing the tasks I feel confident in using such a system (the touch-based interface) to communicate with my family/friends:
1- Strongly Disagree 7 - Strongly Agree

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q7P1A</td>
<td>5</td>
</tr>
<tr>
<td>Q7P1B</td>
<td>6</td>
</tr>
<tr>
<td>Q7P2A</td>
<td>6</td>
</tr>
<tr>
<td>Q7P2B</td>
<td>7</td>
</tr>
<tr>
<td>Q7P3A</td>
<td>6</td>
</tr>
<tr>
<td>Q7P3B</td>
<td>7</td>
</tr>
<tr>
<td>Q7P4A</td>
<td>5</td>
</tr>
<tr>
<td>Q7P4B</td>
<td>5</td>
</tr>
<tr>
<td>Q7P5A</td>
<td>6</td>
</tr>
<tr>
<td>Q7P5B</td>
<td>6</td>
</tr>
</tbody>
</table>

Table D.7: Q7 Post-experiment Questionnaire Results.

Do you have any other general comments regarding touch-based interfaces?

<table>
<thead>
<tr>
<th>Participant</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q8P1A</td>
<td>Grid overlay or &quot;auto sort&quot; system could be useful for the interesting group situations</td>
</tr>
<tr>
<td>Q8P1B</td>
<td>I had an issue where the perspective was slightly off - perhaps thinner glass is needed.</td>
</tr>
<tr>
<td>Q8P2A</td>
<td>It’s fun</td>
</tr>
<tr>
<td>Q8P2B</td>
<td>–</td>
</tr>
<tr>
<td>Q8P3A</td>
<td>–</td>
</tr>
<tr>
<td>Q8P3B</td>
<td>Ability to expand files with 2 fingers (like an Iphone) instead of being force to use corners would be good.</td>
</tr>
<tr>
<td>Q8P4A</td>
<td>The triangles within the templates are good to show where you should touch to flip the templates around.</td>
</tr>
<tr>
<td>Q8P4B</td>
<td>I like how you can resize/enlarge images and docs and clouds easily</td>
</tr>
<tr>
<td>Q8P5A</td>
<td>I think that the send button should be greyed out/locked etc. while sending as there is no indication whether or not an email is sending if the &quot;sending&quot; indicator is behind another object.</td>
</tr>
<tr>
<td>Q8P5B</td>
<td>The multitouch interface was intuitive and usable. The structure of the program was easily navigated.</td>
</tr>
</tbody>
</table>

Table D.8: Q8 Post-experiment Questionnaire Results.