Designing Multi-touch Tabletop Interaction Techniques to Support Co-located Group Information Management

By

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Declaration

I, Mohammed Ali Ditta (s208047126), hereby declare that the dissertation titled, "Designing Multi-touch Tabletop Interaction Techniques to Support Co-located Group Information Management", for the degree of Magister Scientiae is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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Mohammed Ali Ditta   Date

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Summary

Co-located group information management (GIM) is a form of groupware with the aim of enabling users to collaboratively find, store, maintain, organise and share personal and/or group information in support of a group activity. Existing systems aimed at partially supporting GIM activities have been implemented on single user devices. These systems make use of asynchronous communication that may hinder collaboration by misinterpretation, information leaks, etc. Few systems exist, with limited functionality, that support co-located GIM. Multi-touch tabletop interaction has given rise to a new approach for supporting Computer Supported Cooperative Work (CSCW). Multi-touch tabletops allow multiple users to naturally interact with a computer device using a shared display and gesture interaction. The tabletop environment also enables users to sit in a natural environment and synchronously communicate without bulky desktops or laptops. Multi-touch tabletops provide the hardware necessary to support co-located GIM.

Existing multi-touch interaction techniques were analysed and proved insufficient to support the advanced functional requirements of GIM. The goal of this research was therefore to support co-located GIM by designing new multi-touch tabletop interaction techniques. An architecture was proposed to support co-located GIM with new multi-touch interaction techniques. A software prototype was developed based on the proposed architecture to facilitate the main activities of GIM and to collaboratively compile documents. The prototype was named CollaGIM (Colla – collaborative, GIM – group information management). CollaGIM supports the main activities of GIM using natural gesture interaction on a multi-touch tabletop.

An evaluation of the software was conducted by means of a user study where 15 teams of two people participated. High task success rates and user satisfaction results were achieved, which showed that CollaGIM was capable of supporting co-located GIM using the new multi-touch tabletop interaction techniques. CollaGIM also positively supported collaboration between users.

Keywords: Computer-supported collaborative work (CSCW), compound gestures, Group Information Management (GIM), multi-touch tabletop, interaction techniques, natural interaction, Personal Information Management (PIM).

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Full Form
3D	Three Dimensional
API	Application Programming Interface
CDB	Collaborative Document Builder
CIF	Common-Industry Format
CL	Control Layer
CoE	Centre of Excellence
Co-IMBRA	Collaborative Information Manipulation, Browsing, Retrieval, and Annotation
CollaGIM	Collaborative Group Information Management (prototype)
CSCW	Computer Supported Cooperative Work
GIM	Group Information Management
HTML	Hypertext Markup Language
IBM	International Business Machines
IDE	Integrated Development Environment
MB	Megabyte
ML	Model Layer
MT-CollabUML	Multi-touch Collaborative UML
MTM-Tool	Multi-touch Modelling Tool
MVC	Model-View-Control
NMMU	Nelson Mandela Metropolitan University
OSK	On-screen Keyboard
PC	Personal Computer
PDF	Portable Document Format
PI	Personal Information
PIM	Personal Information Management
QUIS	Questionnaire for User Interface Satisfaction
SDK	Software Development Kit
UI	User Interface
UML	Unified Modelling Language
URI	Universal Resource Identifier
USB	Universal Serial Bus
WPF	Windows Presentation Foundation
XML	eXtended Mark-up Language
XPS	Open XML Paper Specification

Chapter 1: Introduction

1.1 Background

People are dealing with personal data on various platforms and devices on a daily basis. Cellular phones, tablet computers, notebooks, desktops and other devices all contain personal information about their users. Maintaining a central location for the management and retrieval of personal files and information is becoming increasingly difficult due to information fragmentation. Information fragmentation occurs when there is a need to access and manage related information in separate physical locations with little support from the tools that individuals use (Collins and Kay, 2008). Information fragmentation is the result of an individual's information being stored on different devices using different storage and organisation methods. Personal Information Management (PIM) is the process of managing personal information by implementing the activities of keeping, finding, organising and maintaining (Kljun, 2012). Emails, contacts, messages, media, and calendar information are some of the types of personal information that people may carry on their personal devices. In recent years, there has been an increase in interest in PIM due to the emergence of new technologies which have resulted in greater information fragmentation. Information fragmentation has caused increased complexity in managing an individual's personal information. Effective measures to manage information fragmentation are considered a key goal of PIM.

Group Information Management (GIM) extends the functionality of PIM to support information sharing among group members. GIM is the process of managing personal information in group contexts by supporting the four activities of PIM (keeping, finding, organising and maintaining) as well as the aspect of sharing information. The activities of GIM are used to support group tasks, such as collaborative document creation. Erickson (2006) views GIM as PIM in more public domains. An individual may keep, find, organise and maintain information to increase productivity on a daily basis, but these PIM activities are quite often embedded in group or organisational contexts (Lutters, Ackerman & Zhou, 2007), with sharing playing an important part (Erickson, 2006). As soon as personal information is shared, the information becomes group information. The study of GIM focuses on the interaction between personal information and group contexts.

GIM can occur in a co-located environment, where group members are in the same room, or close to each other. It is possible for GIM to take place in a synchronous (at the same time) or asynchronous manner. Individuals belonging to a group in a synchronous, co-located environment may refer either to hard copies of documents or to shared electronic copies. Although desktop computers can be used by groups participating in GIM, desktop computers do not effectively support collaboration because they were designed for single user, single input environments (Sams, Wesson and Vogts, 2011).

A study by Whalen and Toms (2008) identified the most widespread file sharing methods such as email attachments, physical device transfers (universal serial bus) and network file sharing etc. These file sharing methods were found to have specific advantages and limitations. Three key limitations are the lack of collaboration support, the inability to share and the inconvenience of sharing multiple files, and access control or security features. The sharing methods all take place in an asynchronous communication environment. Asynchronous communication is prone to several problems such as misinterpretation, missing data or information due to file corruption and reduced work quality (Weng and Gennari, 2004). Current GIM systems employ asynchronous communication mechanisms, which implies that current GIM systems have several shortcomings.

Innovations in multi-touch technology have given rise to new ways of interaction on multi-touch user interfaces. Multi-user, multi-touch user interfaces allow multiple users to collaboratively manipulate graphical visualisations with more than one pointing device or finger simultaneously per user on different types of surfaces and devices. A team can work together around a tabletop display, facing each other, rather than looking at a screen. A table setting encourages collaboration and coordination among groups of people (Hunter & Maes, 2008). A horizontal interactive surface is appropriate for activities involving collaboration, but with the emphasis on natural interaction, innovative software interface design is required in order to explore various solutions (Apted and Kay, 2006). Multi-touch user interfaces provide a medium for new, intuitive interaction techniques because of the move away from single user input devices and systems. Multi-touch user interfaces allow for multiple simultaneous inputs from different users and objects. An interaction technique is a combination of hardware and software elements that enable a user to interact with a computer. Multi-touch tabletops provide support for multi-touch gesture interaction. There are, however, currently no interaction techniques that specifically support GIM on a tabletop.

There has been limited research in the field of co-located GIM and more research is needed to investigate collaborative GIM in a co-located environment (Collins and Kay, 2008). A tabletop environment offers a medium for natural interaction techniques in a co-located environment. The tabletop environment also inherently supports collaboration among team members using the device.

1.2 Problem Statement

The problem statement for this research is:

> *GIM is currently not effectively supported by co-located, multi-touch interaction techniques on a tabletop.*

1.3 Thesis Statement

The thesis statement for this research is:

> *Co-located, multi-touch interaction techniques can be designed to effectively support GIM on a tabletop.*

1.4 Research Questions

The main research question for this research is:

> *How can co-located, multi-touch interaction techniques be designed to effectively support GIM on a tabletop?*

The secondary research questions for the main research question are:

1. *What are the shortcomings of existing GIM tools?*
2. *What co-located, multi-touch interaction techniques need to be designed to effectively support GIM on a tabletop?*
3. *How can a prototype supporting co-located, multi-touch, interaction techniques be implemented to address the shortcomings of existing GIM tools?*
4. *What are the benefits of using co-located, multi-touch, interaction techniques to support GIM on a tabletop?*
5. *What additional research should be undertaken to improve multi-touch interaction techniques for GIM?*

1.5 Research Objectives

The main research objective of this research is:

To investigate how to design co-located, multi-touch interaction techniques to effectively support GIM on a tabletop.

The secondary research objectives derived from the secondary research questions are:

1. *To identify the shortcomings of existing GIM tools.*
2. *To determine what co-located, multi-touch interaction techniques need to be designed to effectively support GIM on a tabletop.*
3. *To design and develop a GIM prototype using co-located, multi-touch interaction techniques to address the shortcomings of existing GIM tools.*
4. *To evaluate the benefits of using co-located, multi-touch, interaction techniques to support GIM on a tabletop.*
5. *To make recommendations for additional research to improve the proposed multi-touch interaction techniques for GIM.*

1.6 Scope and Constraints

The scope of this research is limited to collaboration in a synchronous, co-located environment. Multi-touch tabletop technologies and techniques will be used as the only form of input technique. No other source of input technologies such as physical keyboard, mouse, facial recognition, motion sensing, or voice recognition will be used in this research. Limited co-located, multi-touch interaction techniques have been used to support some basic functionalities of a GIM system; these existing interaction techniques will be modified and applied to the GIM domain (Collins and Kay, 2008). This research will also investigate the development of new interaction techniques that can improve the efficiency and effectiveness of GIM in a co-located environment.

1.7 Ethical Considerations and Resources

This research project involves a user study in which participants will be required to interact with the prototype and complete a post-task questionnaire. Ethical clearance was required for the user study and was obtained from the Nelson Mandela Metropolitan University's (NMMU) Human Ethics Research Committee (REC-H No: H13-SCI-CS-002).

1.8 Research Design

An appropriate research philosophy, research approach and research strategy are required for research. A research methodology will be identified and used throughout the duration of this research. The research scope and limitations, as well as the ethical considerations and resources will be discussed and a brief overview of how each research question will be answered is presented in Table 1-1.

1.8.1 Research Philosophy

A research philosophy refers to the systematic search for existence, knowledge, values, reason, mind and language. This type of research requires an open mind in order to discover beneficial findings to the world body of knowledge. A positivist approach is when a study is carried out in a manner where the researcher views everything from an objective point of view without interfering with any phenomena being studied (Levin, 1988). A positivist approach will be followed to demonstrate how co-located, multi-user, multi-touch interaction techniques can be designed to effectively support collaborative GIM on a tabletop.

1.8.2 Research Approach

The need to identify an appropriate research approach is important. The research approach needs to be selected in combination with the research philosophy to support the methodological process. Choosing the appropriate research approach can lead to improved research efficiency.

In combination with the research philosophy identified in Section 1.8.1, a deductive research approach will be employed (Schadewitz and Jachna, 2007). This approach will allow the research to establish a hypothesis (thesis statement) by using theory, conduct an observation to gather data and information (questionnaires, interviews, user studies), and finally confirm the hypothesis. Qualitative data will be analysed using thematic analysis whereby the results will be divided into positive and negative themes, rated and then interpreted.

A deductive approach will support determining how co-located, multi-user, multi-touch, interaction techniques can be designed to effectively support collaborative GIM on a tabletop.

1.8.3 Research Strategy

Two types of strategies will be used during this research: prototyping and the experimental strategy. Prototyping will be used to develop a software prototype using the multi-touch tabletop. The prototype will implement a co-located group information tool, using multi-touch interaction techniques, so that multiple people can effectively manage group information. This prototype will be used during experimentation. The experiments will be conducted to obtain data and to evaluate the data to see if co-located multi-touch tabletop interaction techniques can be designed to effectively support collaborative GIM. The experimental process will comprise user studies in which users will be immersed in a particular situation and required to perform certain activities in order to determine the effectiveness of incorporating co-located, multi-touch, interaction techniques with GIM on an interactive tabletop.

1.8.4 Research Methodology

A literature study will be the main methodology used to define the requirements of the co-located GIM application. The literature study will help identify issues with existing tools that can be addressed using co-located, multi-touch, interaction techniques, any positive aspects that should be included in the prototype and the positive aspects that a multi-touch interactive tabletop can provide to the way GIM can be supported.

Quantitative data, through questionnaires and logging, will be collected and analysed using the prototype and will be used to determine the effectiveness of using co-located, multi-touch, interaction techniques to support GIM on a tabletop. An empirical evaluation will be used to obtain results by allowing the participants in the user study to complete questionnaires relating to the prototype. Qualitative data will also be obtained from observations and interviews. Table 1-1 illustrates the secondary research questions and the research methods which will be used to answer these questions.

1.9 Structure of Dissertation

This dissertation will follow the research design identified in Section 1.8. The structure of the dissertation presented below is in accordance with the research methods and research questions presented in Table 1-1.

1.9.1 Chapter 1: Introduction

Chapter 1 serves as an introductory chapter to the research to be conducted. The goal of this chapter is to review existing research into the context of collaborative PIM and GIM, by providing a brief background of the study and the reasons for the research. This chapter presents the problem domain, the problem statement and the thesis statement, which proposes a possible solution to the problem identified in the problem statement. The research design is discussed, together with the project objectives and scope, in order to create a clear direction for the research.

Table 1-1: Research Methods used to Answer Secondary Research Questions.

Research Questions		Research Method
1	What are the shortcomings of existing collaborative PIM and GIM tools?	Literature Review, Analysis
2	What co-located, multi-touch interaction techniques need to be designed to effectively support GIM on a tabletop?	Literature Review, Analysis and Synthesis
3	How can co-located, multi-touch, interaction techniques be designed and implemented to address the shortcomings of existing collaborative GIM tools?	Modelling, Prototyping
4	What are the benefits of using co-located, multi-touch, interaction techniques to support GIM on a tabletop?	Experiments (user studies), Evaluation
5.	What research should be undertaken to improve multi-touch interaction techniques for GIM?	Critical reflection

1.9.2 Chapter 2: Personal and Group Information Management

Chapter 2 will discuss collaborative PIM and GIM using a large, multi-touch surface in further detail. Little research has been conducted on co-located GIM tools and the definition of GIM will be investigated in terms of its simplest components – keeping, finding, organising, maintaining and sharing of information in support of a task. This is due to the fact that few co-located systems have been implemented that are aimed at addressing only certain aspects of GIM and not all of the aspects (keeping, finding, maintaining, organising and sharing). Research will be conducted into these components, which will then be analysed to understand the particular features and contributions to GIM. This chapter will provide a clear understanding of the application domain. This chapter will answer the first research question of identifying the shortcomings of existing GIM tools by means of a literature study.

1.9.3 Chapter 3: Multi-touch Interaction

Chapter 3 will focus on the use of large, multi-touch tabletop (interactive tabletop) technologies. A literature study of the advantages and disadvantages of interactive tabletops will be conducted to identify how interactive tabletops can possibly support GIM. An investigation into how collaboration is enhanced using an interactive tabletop will be conducted. Finally the advantages, disadvantages and collaborative features of large, multi-touch tabletops will be discussed in relation to the shortcomings of existing GIM tools. An understanding into what multi-touch interaction techniques are and which techniques are currently supported will be discussed. The interaction techniques will be mapped to the functional requirements of a co-located GIM tool to identify which co-located, multi-user, multi-touch, interaction techniques need be designed to address the shortcomings of GIM tools. This chapter will answer the second research question by identifying what co-located, multi-touch interaction techniques need to be designed to effectively support GIM on a tabletop.

1.9.4 Chapter 4: Design and Implementation

Chapter 4 will discuss the design and implementation for the proposed co-located, multi-user, multi-touch interaction techniques of a GIM tool. This will be achieved by considering what type of personal information can be shared and communicated in a public domain and how the personal information will be shared among a group using a multi-touch tabletop. The software requirements of multi-touch tabletops will also be analysed. This chapter will also investigate how multi-touch tabletop interaction techniques can be designed to support a GIM system. Various user interface designs will be suggested to achieve maximum usability from the system. Chapter 4 will answer the third research question of how multi-touch interaction techniques could be designed and implemented to address the shortcomings of existing GIM tools.

1.9.5 Chapter 5: Evaluation

An empirical evaluation will be conducted to determine how effectively multi-touch tabletops can support GIM in a co-located environment. The benefits of using co-located multi-user, multi-touch and interaction techniques to support GIM will be identified and discussed. This will be the focus of Chapter 5, where user evaluations will be conducted in the form of user studies with the prototype and questionnaires will be used to collect quantitative and qualitative data. Chapter 5 will answer the fourth research question of identifying the benefits of using co-located, multi-touch interaction techniques to support GIM on a tabletop.

1.9.6 Chapter 6: Conclusion and Recommendations

Chapter 6 will conclude the research by summarising the findings identified from the study. The question of whether using co-located, multi-user, multi-touch interaction techniques on a tabletop can effectively support GIM will be answered. The chapter will conclude by discussing the achievements of the research, and providing suggestions for future research. Chapter 6 will answer the fifth research question by discussing what research should be undertaken to improve multi-touch interaction techniques for GIM.

Chapter 2: Group Information Management

2.1 Introduction

This chapter answers the first research question by identifying the shortcomings of existing Group Information management systems (GIM). This chapter defines GIM and examines the components that comprise GIM. An investigation into the typical tasks of GIM will be carried out, which will help establish the objectives and requirements of GIM. An examination of existing tools and techniques supporting GIM is conducted and the shortcomings of the existing tools and techniques identified. Lastly, a conclusion on the findings of this chapter is presented.

2.2 Overview

This section will discuss the main research focus terms and concepts relating to collaborative work and GIM. The discussion will include the concepts of groupware and Computer Supported Cooperative work (CSCW), GIM and the main components of GIM.

2.2.1 Groupware and Computer Supported Cooperative Work (CSCW)

Groupware is software and hardware that is designed to specifically support group work activities. Groupware is not merely a tool used to support communication between users, but a tool that can be used to support one or more group tasks. Groupware can be classified by means of a time-space matrix; time – when group members are working; and space – where the group members are working (Hansen and Järvelin, 2005). The classification of groupware is illustrated in Table 2-1 by means of time and space.

CSCW is the study of the use of computer technology to enable collaboration. Koch and Gross (2006) explains CSCW as a generic term, which combines the understanding of the way people work in groups with the enabling technologies of computer networking and associated hardware, software, services and techniques. This definition shows that CSCW involves an actual study and investigation, whereas groupware is a classification of software programs that support CSCW.

Table 2-1: Classification of Groupware Systems by Location and Time (Hansen & Järvelin 2005)

		Space	
		Group members working in same place	Group members working in different places
Time	Group members working at the same time	Synchronous, co-located groupware (E.g. Face-to-face conversation)	Synchronous, remote groupware (E.g. Telephone, video conferencing)
	Group members working at different times	Asynchronous, co-located groupware (E.g. Notes, post-it note)	Asynchronous, remote groupware (E.g. Letters, email)

2.2.2 Personal Information Management

People have always had to manage their personal information. Before the age of computers, paper documents were normally filed away in a particular order, photographs were placed in photo albums, and important dates were noted in paper calendars or diaries. The need for PIM has always existed and the same can be said of GIM. Individuals working in a team have to work on their individual tasks and then come together to collectively summarise the outcome of each of their tasks. Since the dawn of computers, new devices and software have continuously been used to improve the manner in which people conduct personal and information management. The invention of digital diaries allowed people to store contact details; computer programs such as Microsoft Outlook allow people to send email messages and attachments to others and manage all their calendar events. SharePoint servers were created to allow groups of varying sizes to manage and organise various types of shared documents.

Smart phones, tablet computers, notebooks, and other devices have made handling personal information much easier. However because each technology is manufactured by different companies and has its own operating system, the different devices that people own may not be able to share information with each other because of (for example) different file formats. Keeping a central location format management and retrieval of personal files and information has become increasingly difficult because of information fragmentation (Collins and Kay, 2008).

This brings us to the definition of PIM, which is the practice and study of the activities people perform on a daily basis. These activities include keeping, finding, organising and maintaining information (Kljun, 2012). An important goal in the study of PIM is to address the problem of information fragmentation making a person's personal information available at the right time, in the right place, in the right format.

There are various types of personal information in the field of PIM. Research in PIM and GIM has focused on the managing and/or sharing of emails, web pages, links (uniform resource identifiers -URIs), media (photographs), calendar data, attachments, references, and other general files (.pdf, word, excel, etc.) (Fourie, 2012; Jones, Whittaker & Anderson, 2010; Kljun, 2012).

The activities of PIM form part of the basic activities of GIM. GIM is discussed in further detail in Section 2.2.3.

2.2.3 Group Information Management

GIM builds upon PIM where individuals will continue to find, keep, organise and manage their personal information, but may eventually have to bring that information, or a subset of it, into a public space (Erickson, 2006). Once personal information has been shared, it becomes group information, since it is no longer solely restricted to particular individuals. The key aspect of GIM is the sharing of information between groups of users. Information sharing, or file sharing, is the process of making specific file(s) accessible to a specified entity or group, governing certain rights (read/write) over the file(s) (Whalen and Toms, 2008). Whalen and Toms (2008) stated that managing shared access to files can become a complex task in a sense that sufficient access is required to allow collaboration, but at the same time, too much access may cause unwanted exposure of the shared information. Any issues with the file sharing mechanism decrease security and hinder collaboration among the group (Whalen and Toms, 2008). Sharing by means of attachments in emails and the use of physical devices to transfer information were the two most commonly used sharing methods identified in the study by Whalen and Toms. A list of the most common file sharing methods is shown in Table 2-2.

Table 2-2: Most Widespread File Sharing Methods, n=69 (Whalen & Toms, 2008)

Most Commonly-used Sharing Method	% of People that used this Method
Email attachments	99%
Physical devices (e.g. universal serial bus stick - USB)	97%
Network file share	81%
Instant messenger	77%
Web server	71%
Peer-to-peer program (e.g. KaZaa)	70%
File copy protocol	67%
iTunes, proprietary systems, other (e.g. cables)	17% or less

All of the above file sharing methods either utilise asynchronous communication, or have no form of communication medium at all. This poses various implications for the quality of collaboration that can take place between teams. Asynchronous communication can lead to information leaks and reduce the quality of work produced. Collaboration efforts may be unsuccessful because individuals are not able to effectively communicate their ideas (Weng and Gennari, 2004). Whalen and Toms (2008) also identify the drawbacks or negative features of these file-sharing methods. A limitation of using emails to share information was that the total attachments of an email could not exceed 10 megabytes. Other limitations of the sharing methods included the loss of access to information, little or no information security and the lack of collaborative support. The list of disadvantages is illustrated in Table 2-3.

Table 2-3: Drawbacks of File Sharing Methods (Whalen & Toms, 2008)

Negative Features (Drawbacks & Limitations)
Limits on file size or file space
Lack of access control or security features
Inconvenient for multiple files
Cannot reach all recipients (e.g., across organizational boundaries)
Need specialized application (e.g., file copy software)
Poorly suited to collaboration
Slow

2.2.3.1 Group Information Storage

Group information storage refers to the techniques and hardware used to store group information. Group information storage can become complex, especially when there are no standard procedures for storing information. Individuals working in a group, store their personal information in their own customised fashion. If individuals in a group store group information in their own way, it will be very difficult for individuals viewing shared data to find and understand the information. The hardware used by a group needs to be negotiated as well. The group information needs to be made accessible to all group members at any time. Therefore, the manner in which group information is stored needs to be standardised (i.e. what hardware or software is used to store the information, what naming conventions and what formats are used).

2.2.3.2 Group Information Retrieval

Group information retrieval refers to the techniques used to retrieve information from a particular source or various sources. Information retrieval is a process that involves searching documents for information and extracting it. Group information retrieval would be a similar process except for it taking place in a group, and identifying what information will be relevant to other group members. Collaborative systems have been developed in which groups can collaboratively retrieve information.

2.2.3.3 Group Information Organisation

Group information organisation refers to the process in which stored data is organised to allow for efficient information retrieval. The different ways of organising data range from a simple naming convention, to metadata or tagging systems. Collaborative systems have been developed in which groups can collaboratively organise information.

2.2.3.4 Group Information Maintenance

Group information maintenance refers to the process in which group members carry out maintenance on stored information to identify which information is relevant and which is no longer relevant. Typical tasks of maintaining information may include searching, viewing, editing and deleting information.

2.2.3.5 Group Information Sharing

Group information sharing refers to the process of identifying information that appears relevant to another group member, or to the entire group, and sharing it in such a manner that allows easy access to the group or particular members. Typical tasks of sharing include searching for the information, selecting, and sharing the information over a known medium.

2.3 Example Application Domains

Erickson (2006) describes the typical applications of GIM. Such applications include the use of emails, web pages and wikis. Any group that engages in group activities and interacts with the internet through emails, web pages and wikis are in fact directly, or indirectly, performing some form of group information management. An example Erickson (2006) provides is that of an online calendaring system, where users may coordinate and schedule meetings within the group.

More recent examples of where GIM is used are in the field of social networking. Users of social networks are able to create personal profiles and share links to different sources of information. The privacy of shared information may also be controlled by restricting access and granting privileges to intended members. Erickson (2006) found GIM useful in the medical field where patient medical records are compiled from information obtained from several entities and devices, and are accessed by entities from different institutions for purposes ranging from healthcare coordination to medical insurance billing. Kljun (2012) investigated collaborative practices within personal information spaces with six PhD students specialising in different fields. These fields were identified as possible application domains for GIM and included the fields of languages, environmental studies, statistical studies, sociology and computer studies.

Military institutions, which rely on critical understanding between colleagues, need to ensure that the correct information is retrieved and shared amongst each other. Foster (2006) found that within military teams, team goals were supported by dense social networks and a shared situational awareness, which support regular, duplex information flow between members.

Foster's findings show that a variety of application domains exist that practice certain aspects of collaborative work and GIM. An academic institute practices collaboration and GIM on a daily basis amongst students and lecturers. The tasks carried out within an academic institution often result in collaborative documents being produced. This research project is being conducted at the Nelson Mandela Metropolitan University (NMMU) and will therefore be the chosen domain of this research. The output of a collaborative document is regarded as a typical task supported by GIM activities.

2.4 Features of GIM

Erickson (2006) established a simple GIM model that can be used to highlight certain features and issues that face GIM. Erickson describes the model of GIM as when a person generates information that is shared with a group in support of a task (Erickson, 2006). Table 2-4 takes Erickson's model and breaks it into three parts, where certain issues are highlighted, and what features should be included to address the issues.

Studies have shown that in order for GIM systems to be effective, the systems need to cater for certain requirements, both software and hardware. Group information may need to be classified to allow for efficient retrieval. This is a possible software requirement to allow information to be classified. Information can be classified by using standardised naming conventions, or tagging systems. A naming convention could be that of "Group_information_XY.docx", where XY would be a specific version of the group information (Voit, Andrews and Slany, 2009).

Tagging could be an effective way to classify information. Tagging is accomplished by adding a few descriptive keywords, or tags, to a piece of information. Tagged information could easily be found by searching for a particular tag. An issue arises when users over tag. Over-tagging occurs when users use different words or tags to describe the same characteristic (Voit *et al.*, 2009).

Table 2-4: GIM Model Illustrating Issues Faced and Possible Features to Address the Issue (Erickson, 2006)

Component of Model	Issues Faced	Possible Features to Address Issue
A person generates information	How to create the information to be shared?	Create and compile information
	What information do people choose to share and why?	Categorise sharable information
	How do they structure it?	Sort information
That is shared with a group	With whom is the information shared?	Specify sharing audience
	How is the target audience for the shared information specified?	
	How is the shared information structured so the group can use it?	Define standard structure
	Through what process is shared information negotiated?	Specify sharing medium
	What are the consequences of leaked information?	Specify security levels
In support of a task (document creation)	What happens when shared information turns out to be useful for other tasks or group members that are not in the user's best interest?	Information transfer
	To what extent is it possible to give users control over usage of their personal information?	Privacy
	What type of control (awareness of usage, correction of errors, retraction upon completion of task) is it feasible to provide the information owner?	Information Control

Faceted classification could be used to address the shortfall in normal tagging systems. Similar to tagging systems, faceted classification uses words to classify information. However, instead of allowing the users to use their own words or tags as in tagging systems, faceted classification makes use of a predefined set of words that are available for use in each set of facets to describe the information (Voit *et al.*, 2009).

Other research shows that users of a particular system tend to categorise information using location-based spatial layouts (Barreau and Nardi, 1995). An example is when users of an operating system group icons on a desktop to allow for quick access to the information and also to reduce memory overload. The benefit of using location-based spatial layout can be limited due to the screen resolution of the display. This requirement may be fulfilled by using the appropriate hardware (i.e. a larger display). The larger the display, the more spatial categories can be created.

Systems should be compatible with current user habits in such a way that it does not require the users to have to relearn an entire systems methodology. A tool, which only covers a certain set of applications, may fail to satisfy the majority of the user population (Gemmell, Bell and Lueder, 2006), because of unnecessary limitations. Different file browsers (Chau, Myers and Faulring, 2008; Marsden and Cairns, 2003) and other systems sometimes require a complicated user interface which plays an important part in the acceptance of a system. Existing PIM tools are developed based on a database centric architecture (Gemmell *et al.*, 2006). In most cases, people do not want to have to acquire specialised information storage software. People also want the ability to easily make backups of their information, which can be a lengthy procedure when using a database system. In this case, a GIM system needs to adapt to the user's needs as much as possible, without the user having to change established habits.

Searching is an important requirement of GIM. Group members may have to search through large repositories for their stored information. Searching is a valuable function, when looking for information when you do not know the storage location. It should also be noted that people tend to remember where a document or piece of information is stored, and in these circumstances, people prefer to browse instead of using the search function. Studies have also shown that people working in a group associate shared files with the member that shared the file, and not the title or content. People tend to remember who actually shared the information (Voit *et al.*, 2009).

GIM systems should also not face any unnecessary limitations (Voit *et al.*, 2009). The system should scale well to large amounts of information and not be subject to slow processing and lag. The system should be able to cater to the user's needs as effectively and efficiently as possible. A GIM system should also be transparent in a sense that the users know where the information is stored, what is happing to the information, how to easily create backups, how to copy and share the files as well as granting sufficient access to their information.

A useful feature for group information maintenance is the ability to assign expiry dates to information. The growing availability of storage at increasingly cheaper rates have led to people keeping information for longer periods of time (Barreau, 2008). The information contained within a document may become less useful as time progresses. The objective for which that information was stored may have passed its useful date, and thus render the information useless. The expiry data feature would allow users to specify an expiry date and once the date passes, that particular piece of information appears in a lower level of a search result, is moved to an archive folder, or is completely removed from storage. This feature helps to maintain the group information and keeps relevant information at the group members' fingertips.

This section discussed some necessary features for a GIM system to be successful and well utilised. Section 2.5 will clarify the functional and non-functional requirements for GIM, as well as provide a motivation for GIM systems.

2.5 Motivation and Requirements of GIM

This section motivates the need for a system to support GIM. The motivation will also comprise the benefits that GIM systems can provide to a team. Functional and non-functional requirements of a GIM system will then be derived from the possible features of a GIM system identified in Section 2.4.

2.5.1 Motivation for GIM

A key aspect of GIM is the ability to collaborate within the group. Effective collaboration between group members can increase work efficiency by effectively coordinating activities between group members to ensure that no work performed is redundant between the group members. A study by Shah (2010) identified three major reasons why individuals choose to collaborate:

1. Requirement – If we look at the work environment, quite often teams are formed in which the team is required to deliver one solution or objective. Each member within the team must collaborate with each other to ensure collective success in an effective and efficient manner.
2. Division of labour – A choice may be made by an individual to divide the workload of a particular task to ensure greater productivity. The key reason is synergy, where it is believed that two heads may be better than one. An example of synergy is where 1+1=3, meaning the marginal benefit of adding one more resource is greater and more productive.
3. Diversity of skills – A task given to an individual may be far too complex and require more than one skill set. In this case, the individual may have to collaborate with people with different skill sets and experiences to ensure that an expert opinion is obtained in order to complete the task.

The effectiveness of a GIM system depends on how well a collaboration medium is established. An effective collaborative setting can improve problem solving and motivate people because goals and plans are effectively communicated (Wilson, Hoskin and Nosek, 1993). Peer interaction can motivate the team to tackle problems that may seem unmanageable to an individual and thus lead to a solution of superior quality to that of an individual (Brown and Palincsar, 1989).

GIM can provide a medium for groups to effectively collaborate and share information to ensure greater productivity. It also provides a platform in which group members can have a common place for finding, keeping, maintaining, organising and sharing group information. GIM may also allow group members to effectively delegate tasks to ensure no overlapping occurs. The system may also provide a history of which member is responsible for what task, and also provide a query function to view historical information.

2.5.2 Functional Requirements of GIM

The possible features for a GIM system were discussed in Section 2.4. The features, which are based on Erickson's (2006) GIM model, allowed for six categories of functional requirements to be identified and are summarised in Table 2-5. Each requirement is also mapped to typical tasks that would be involved with fulfilling the GIM requirement.

A GIM system would first and foremost require a common information space in which users belonging to the space are able to access a location that has been predefined. The information space could be stored on a local drive (restrictive accessibility), cloud server (increased accessibility), or database. The information space will form the backbone of a GIM system which, if successfully implemented, could make group information readily available.

Communication is an important feature in GIM. A GIM system needs to allow for effective communication medium in which group members can communicate their individual thoughts to other members efficiently and effectively. The medium should limit misinterpretations and errors. Communication is also an important factor when it comes to division of labour. The process of dividing work between group members needs to be performed very carefully to ensure that each group member understands what is required of them. The division can be aided by splitting up tasks, keywords or concepts between group members (Amershi and Morris, 2008).

Collaborative systems are required to support numerous functions that are facilitated by awareness and communication (Morris and Horvitz, 2007). The main benefit of a collaborative system is that group members know what each other is doing to reduce the amount of repeated effort and increase efficiency.

Table 2-5: Derived Requirements of a GIM System

Requirement		Interaction Task
1.General		
1.1	Allow for the provision of shared access to an information space for all users	Allow login/logout functionality. View and browse information within information space.
1.2	Allow for communication between group members	Face-to-face communication. Store and view communications.
1.3	Allow for the workload to be divided and delegated to group members	Verbally assign responsibility. Pass information.
1.4	Keep a history of delegated tasks	Store tasks. Allow for tasks to be set as complete or incomplete.
1.5	Keep a history of searches and communication	Store and view logs. Store and view notes.
1.6	Allow for the information to be re-found and easily reusable	Store recently used files. Re-open recently used files.
2.GIM Aspect - Keeping		
2.1	Store documents and information in the shared information space	Save information
3.GIM Aspect – Finding		
3.1	Allow for searching by collaboratively querying or filtering the information space	Use of OSK. Select folders. Use criteria to find information.
3.2	Allow for search results or shared information to be visualised	View information.
3.3	Allow for collaborative navigation through search results	Browse results.
3.4	Allow for the information files to be opened from the personal information space	Open files.
3.5	Allow for manipulation of the search results or shared information	Share results.

Table 2-5: Derived Requirements of a GIM System (continued)

Requirement		Interaction Task
4. GIM Aspect - Maintaining		
4.1	Allow for editing and updating all information	Use of on-screen keyboard (OSK) to input text (e.g. annotate). Modify other values (e.g. ratings).
5. GIM Aspect - Organising		
5.1	Allow for the workspace to be organised in an effective manner	Sort workspace based on criteria.
5.2	Allow for a classification mechanism to help organise the information space	Modify values.
5.3	Allow for sorting of the information space	Select sort criteria.
6. GIM Aspect - Sharing		
6.1	Allow for information of the information space to be easily shared amongst the users	Visually share information.
6.2	Allow for a sharing mechanism to be used to transfer shared information into a user's personal information space.	Physically share a copy of information with other users.
6.3	Allow for a collaborative document to be created and shared amongst the users	Create a document by adding, deleting and moving information from other documents.

2.5.3 Non-functional requirements of GIM

The usability requirements of a GIM system will identify important requirements for user satisfaction. Shah (2010) identified three primary goals for the development of a collaborative system. The three goals include simplicity, integration and flexibility. Sams *et al.* (2011) employed these three goals in the development of Co-IMBRA, a collaborative information retrieval system, with positive results. Since Co-IMBRA, achieved positive results, it was decided that these three goals would be identified as non-functional requirements for a GIM system. Table 2-6 summarises the primary goals of Shah (2010). These requirements map onto the features that a GIM system should have, as discussed in Section 2.4.

Table 2-6: Primary Goals for Successful Collaborative Systems (Shah, 2010)

Non-functional Requirement	Description
Simplicity	Systems should be simple to learn, memorise and interact with.
Integration	The different elements of a system should be effectively integrated into a single user interface.
Flexibility	Systems should be designed to fit the preferences of the user.

2.6 Tools Supporting GIM

Research has shown that there is a need for co-located GIM systems (Collins and Kay, 2008). Various PIM systems have been developed to help increase an individual's productivity. GIM systems have been developed, but predominantly for large scale agencies, such as pharmaceutical companies.

This section introduces five existing software tools that either support PIM, GIM, or a component thereof. Section 2.7 analyses the existing software tools that satisfy the location-time requirement of co-located and synchronous communication.

2.6.1 Focus – A Collaborative PIM Prototype

Focus (Collins and Kay, 2008) was developed to present techniques for navigating and sorting multiple sets of personal information - mainly digital files and email - on an interactive tabletop. The tabletop setting was adopted due to particular advantages which were envisioned: workers would be able to share personal information (such as emails) to coordinate activities to ensure effective decision making; work being conducted by a team can be divided amongst team members and can later be combined using an interactive tabletop. The term GIM was not used to describe Focus because the focus of GIM is to share information with groups and institutions, rather than people in a co-located context. Focus is defined as a collaborative personal information management tool (Collins and

Kay, 2008). Using the classification of groupware discussed in Section 2.3.1, Focus is a synchronous and co-located groupware application. Figure 2-1 shows users interacting with the Focus prototype and Figure 2-2 shows a screenshot of the workspace.

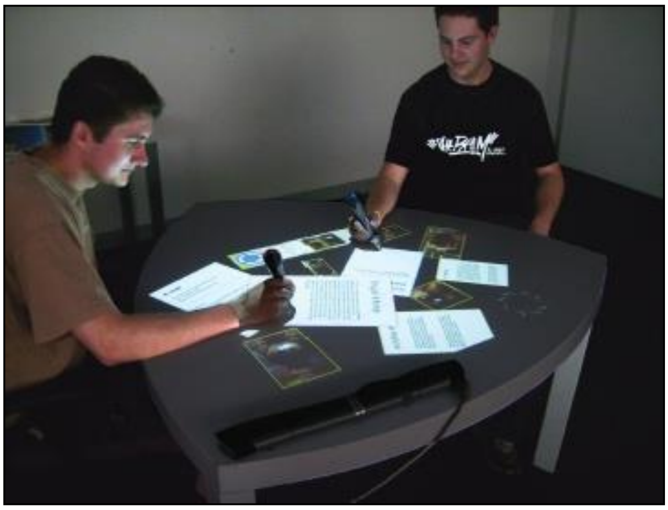


Figure 2-1: People using Focus to Collaboratively Access and Organise Personal Information (Collins and Kay, 2008)

Collins and Kay (2008) agree that there is a lack of research conducted on PIM and GIM using multi-user interactive tabletop displays. They support the need to implement PIM in a co-located tabletop environment in order to assist individuals to share personal information and collaborate in an effective manner.

Figure 2-2: The Focus interface showing a collection of e-mails, photos, documents and stored web-pages, which have been rearranged by users after two focus item selections (Collins and Kay, 2008)

The results of the evaluation of the Focus prototype showed that there is still much work to be done on collaborative PIM on the tabletop. Issues that were highlighted were:

1. Personal information privacy:

   How will individuals be able to control privacy so that they have complete control over the information accessible on the tabletop, and specify who can access it?

2. Clutter:

   Personal information consists of a lot of data, and with tabletops, what you see is what you get. How can clutter be reduced?

3. Overlapping objects:

   How to deal with object groupings such that when groups of objects are created they conflict with groupings made for other items, and

4. Storage scheme of the different types of personal information:

   Different types of personal information are stored in different ways by different users.

2.6.2 Chandler

Chandler is a PIM software application that is designed for personal and small-group task management (Chandler, 2013). Chandler is a desktop application and limited to one user per application. Chandler aims to create a workflow that is mainly focused on creating a unified representation for the storage of tasks and information so that they can be classified in a homogeneous way, refining that information through an iterative workflow, and allowing easy collaboration on the defined items. Features include flexible organisation whereby information can be organised into multiple contexts, and integrated calendaring where an individual can schedule tasks and set reminders. Chandler also allows for group calendar sharing, collaboration on drafts, maintenance of checklists, and sending and receiving emails with others. Using the classification of groupware discussed in Section 2.3.1, Chandler is an asynchronous, remote located groupware application. Chandler is also a desktop application and was designed for a single user. Chandler is not suitable for GIM in a co-located environment. A screenshot of the Chandler workspace is shown in Figure 2-3.

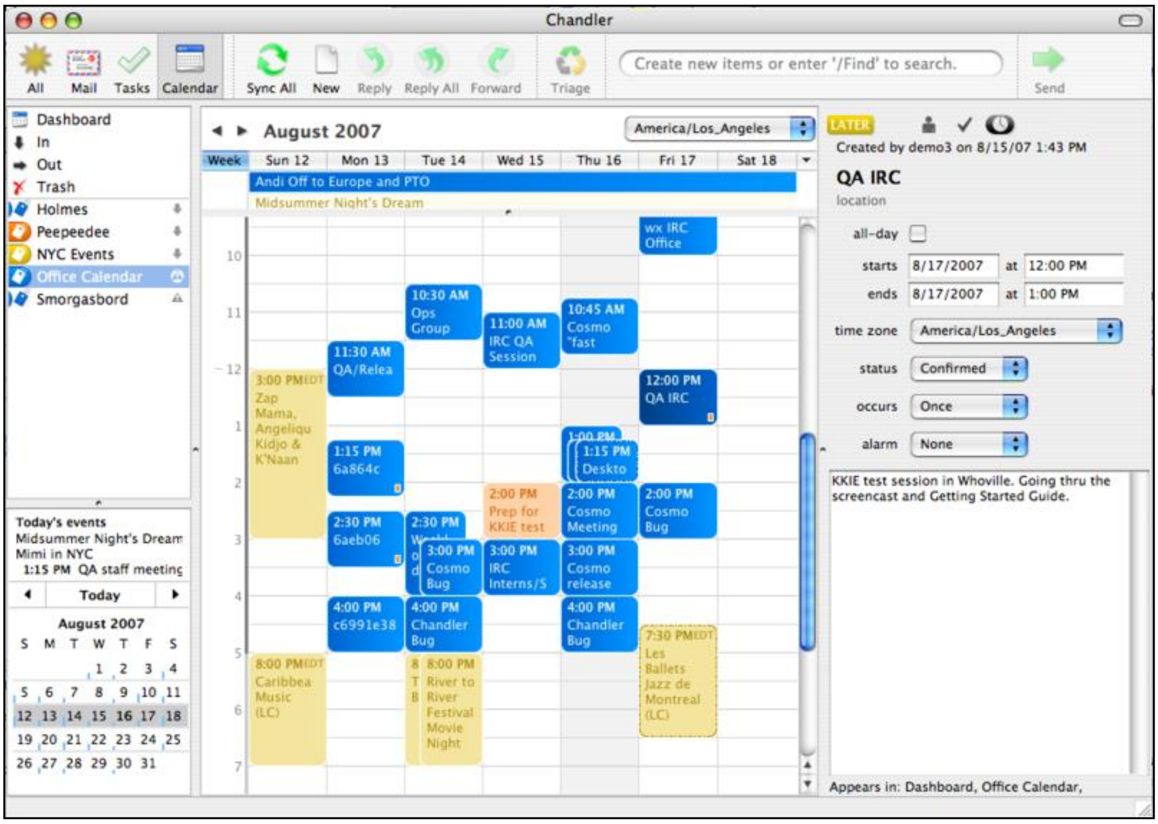


Figure 2-3: Snapshot of Chandler Dashboard (Chandler, 2013)

2.6.3 Evernote

Evernote is a software application that provides services for note taking and archiving (Evernote-Corporation, 2013). The note can be of many types such as formatted text, photographs, voice memos and web pages. A note may also contain attachments. Evernote makes use of tagging, annotating, editing and commenting on a note. The notes are stored in a folder structure. Evernote stores the information on a server and makes it available to the user on other devices that have the software installed by synchronisation. Once synchronised, the information is readily available on the device even without an Internet connection. Using the classification of groupware discussed in Section 2.3.1, Evernote is an asynchronous, remote located groupware application. A screenshot of the Evernote workspace is shown in Figure 2-4.

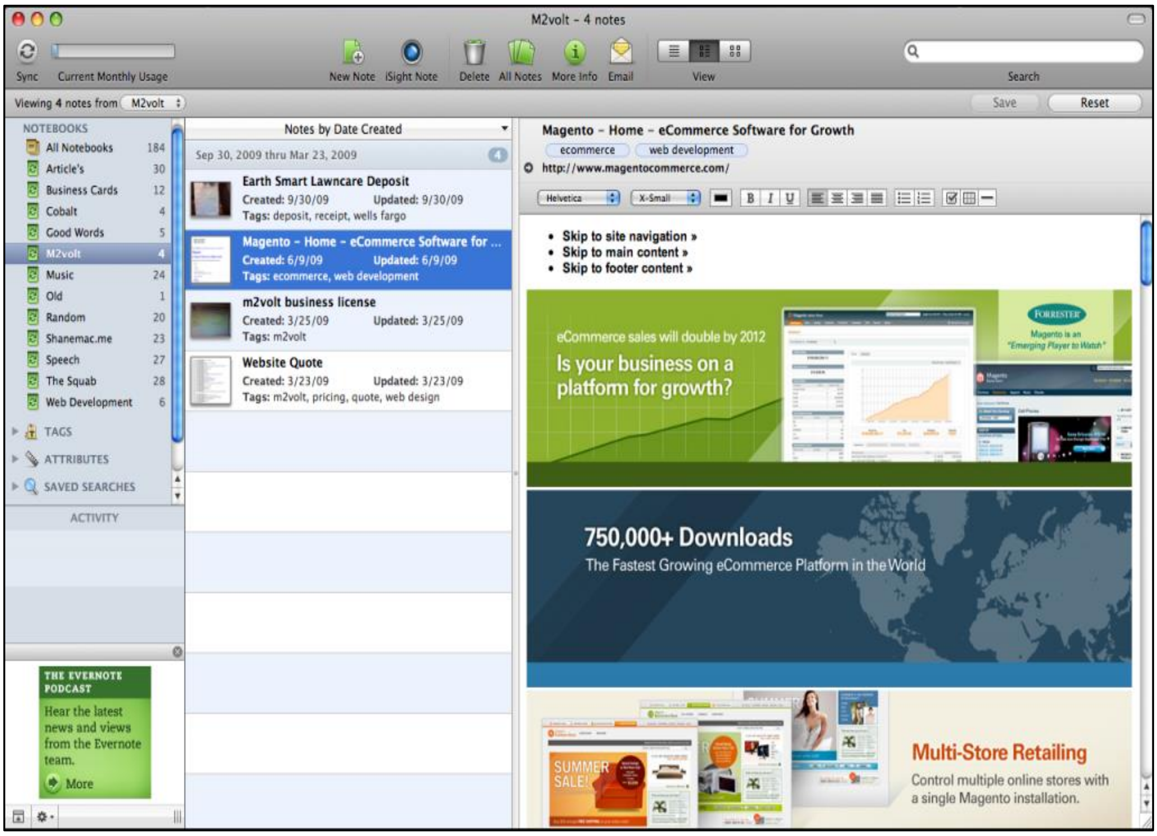


Figure 2-4: Screenshot from Evernote Software (Evernote-Corporation, 2013)

2.6.4 Cyn.in

Cyn.in is a collaborative software application that seamlessly inter-connects people with each other and their collective knowledge (Cynapse, 2013). This application is aimed at helping teams communicate faster and building collaborative knowledge by sharing and discussing different types of digital content. It makes use of collaborative tools such as wikis, social networks, blogs, file-sharing repositories, micro blogs and discussion boards to link a group of people. Using the classification of groupware discussed in Section 2.3.1, Cyn.in is an asynchronous, remote located groupware application. A screenshot of the Cyn.in workspace is shown in Figure 2-5.

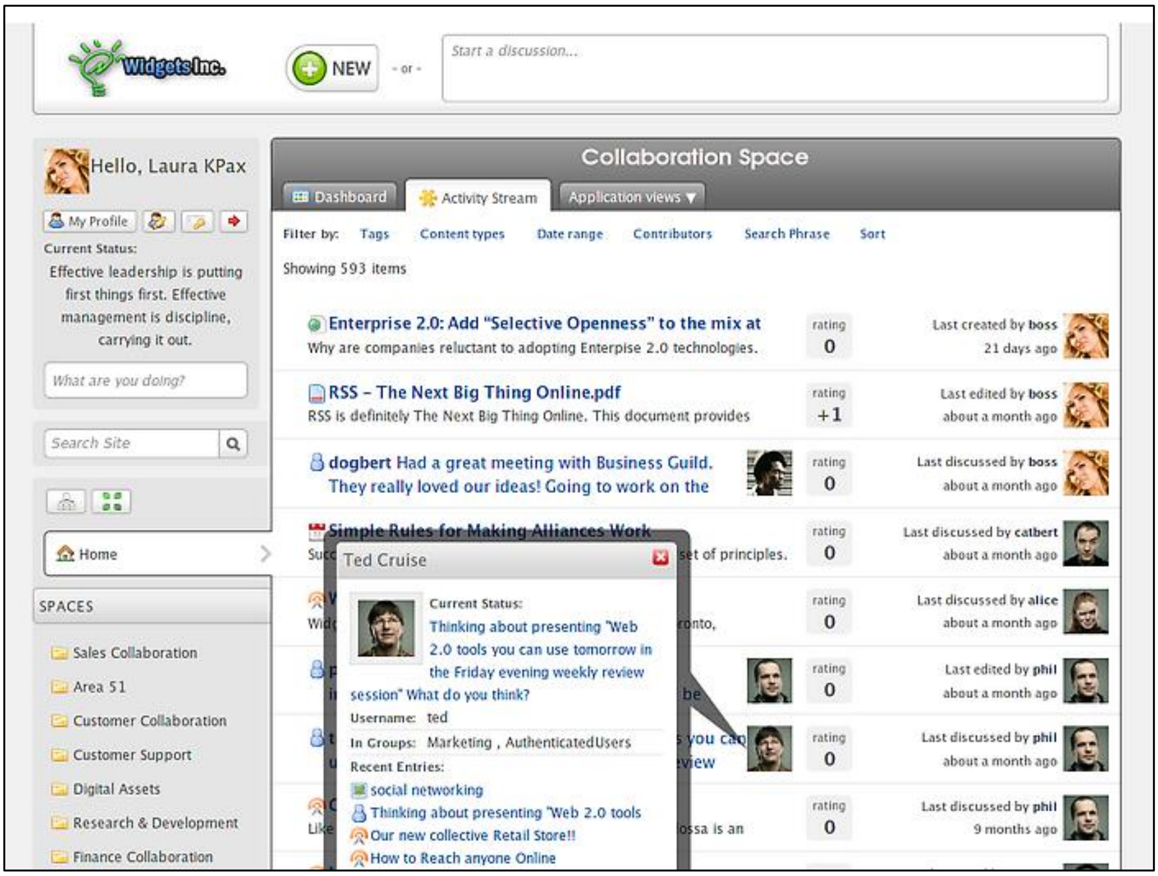


Figure 2-5: Screenshot of Cyn.in Dashboard (Cynapse, 2013)

2.6.5 International Business Machines (IBM) Lotus Notes

IBM Lotus Notes is the client side of a collaborative client-server platform (IBM, 2013). The application server side is Lotus Domino. Lotus Notes caters for integrated collaboration functionality, including email, contact management, to-do lists, instant messaging and calendaring. Additional collaborative activities such as video conferencing, file sharing and blogging can be integrated if necessary. Using the classification of groupware discussed in Section 2.3.1, IBM Lotus Notes is an asynchronous, synchronous and remote located groupware application. Synchronous communication is accomplished through video conferencing. However, the system is not suitable for co-located activities. A screenshot of the IBM Lotus Notes workspace is shown in Figure 2-6.

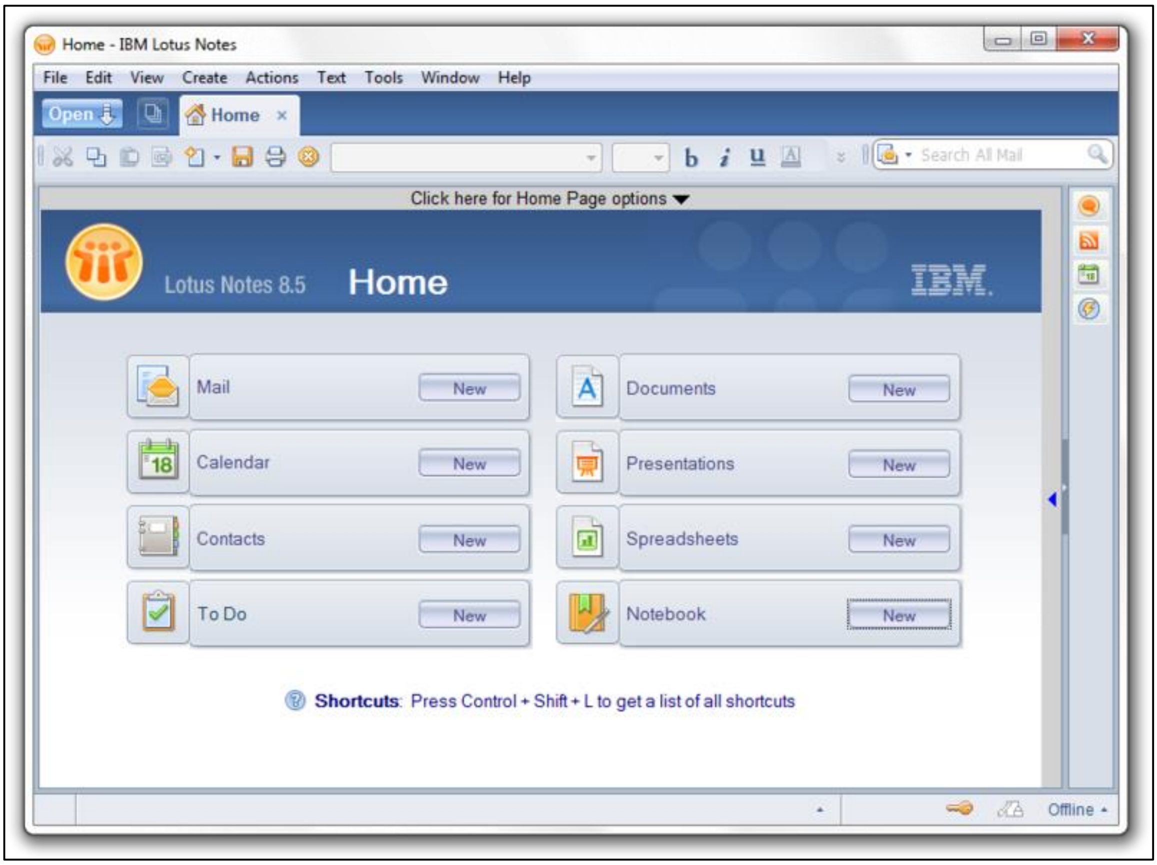


Figure 2-6: Screenshot of IBM Lotus Notes (IBM, 2013)

2.7 Comparison of Existing Systems

The existing systems identified in Section 2.6 were developed for different target audiences, but have evolved to support similar requirements. The classification of groupware matrix described in Section 2.2.1 will be used to identify into what class the existing systems fall. Having identified the requirements for a GIM system in Section 2.5, the existing systems that fit the location-time requirements of synchronous communication and co-located group interaction will be compared to see how well they fulfil the requirements.

Table 2-7 compares the existing systems by time and location and shows that Focus is the only system that satisfies the co-located and synchronous requirements. Table 2-8 maps the requirements of a GIM tool identified in Section 2.5 with the requirements of Focus. Table 2-8 shows that Focus only supports nine out of the nineteen GIM requirements identified in Table 2-5. Focus has no support for creating collaborative documents. The sorting of information on the workspace is user dependent and there is no system functionality to support the user. The sharing of information is also not supported by Focus as no actual transfer of data occurs. The idea of sharing using Focus only occurs by allowing users to see a piece of information. Focus, although a co-located, synchronous collaborative PIM tool, does not satisfy the requirements of a typical GIM system.

Table 2-7: Comparison of GIM system by Groupware Classification

	Focus	Chandler	Evernote	Cyn.in	IBM Lotus Notes
Location	Co-located	Remote	Remote	Remote	Remote
Time	Synchronous	Asynchronous	Asynchronous	Asynchronous	Synchronous or Asynchronous

Table 2-8: Mapping of GIM requirements to functionality of Focus

Requirement	Focus Functionality
1. General	
Allow for the provision of shared access to an information space for all users	Information space is hosted locally
Allow for communication between group members	Verbal communication
Allow for the workload to be divided and delegated to group members	Not supported
Keep a history of delegated tasks	Not supported
Keep a history of searches and communication	Not supported
Allow for the information to be re-found and easily reusable	Not supported
2. GIM Aspect – Keeping	
Store documents and information in the shared information space	Yes
3. GIM Aspect – Finding	
Allow for searching by collaboratively querying or filtering the information space	Not supported
Allow for search results or shared information to be visualised	Not supported
Allow for collaborative navigation through search results	Not supported
Allow for the information files to be opened from the personal information space	Yes
Allow for manipulation of the search results or shared information	Yes
4. GIM Aspect – Maintaining	
Allow for editing and updating all information	Yes (annotating)
5. GIM Aspect – Organising	
Allow for the workspace to be organised in an effective manner	User dependent
Allow for a classification mechanism to help organise the information space	Not supported
Allow for sorting of the personal information space	User dependent

Table 2-8: Mapping of GIM requirements to functionality of Focus (continued)

Requirement	**Focus Functionality**
6. GIM Aspect – Sharing	
Allow for information of the information space to be easily shared amongst the users	Visual sharing, no transfer of data.
Allow for a sharing mechanism to be used to transfer shared information into a user's personal information space.	Not supported
Allow for a collaborative artefact (document) to be created and shared amongst the users	Not supported

2.9 Conclusion

This chapter introduced GIM and the components of GIM, and compared GIM with groupware and CSCW. The classification of groupware or collaborative systems was defined by means of time and location. A time-location requirement was established in that only systems which are co-located and synchronous were evaluated. The chapter highlighted that GIM can be applied in the area of medicine, the military and universities. The number of application domains showed that there is a need for GIM when group work is being carried out. The possible features that a GIM system should have were identified and illustrated in Table 2-4 using Erickson's GIM model and prior results from collaborative PIM and other related tools.

Three primary goals were identified for a successful GIM system, namely simplicity, integration and flexibility. These goals will be adhered to carefully to ensure user satisfaction.

The functional requirements and interaction tasks to support the requirements of a GIM system were established in Table 2-5, based on the possible features of a GIM system shown in Table 2-4. Five existing systems were identified, of which only one system, called Focus, satisfied the location-time requirement. The system was then compared to the requirements of a GIM system. The outcome of the comparison revealed shortcomings in Focus as well as a lack of systems that fall into the groupware category of co-located and synchronous.

The next chapter will review multi-touch interaction techniques to determine the possibility of implementing this form of interaction technique to support co-located GIM. The benefits of potential co-located, multi-user GIM user interfaces will also be discussed.

Chapter 3: Multi-touch Interaction

3.1 Introduction

This chapter will answer the second research question of what co-located, multi-touch interaction techniques can be used to effectively support Group Information Management (GIM) on a tabletop. This chapter will discuss multi-touch interaction with respect to supporting GIM. The chapter begins by providing a brief background on multi-touch technologies, the advantages, limitations, and also an investigation into the available multi-touch devices. Various systems that have been implemented using multi-touch devices will be analysed to gain insight into the benefits and shortcomings of these systems. Existing interaction techniques will also be identified and critically reviewed. The chapter concludes by considering the potential for multi-touch interaction techniques to support co-located GIM and maps the potential tasks of GIM to multi-touch interaction techniques.

3.2 Multi-touch Technology

This section provides a brief background on multi-touch interaction and related technologies. The general advantages and limitations of multi-touch interaction and related technologies are identified. Multi-touch technologies are also described in terms of display size and capacity of supporting simultaneous multi-touch points.

3.2.1 Background

Touch screen technology has been in existence since the late 1960's. The University of Toronto's Input Research Group invented the first multi-touch system in 1982 (Buxton, 2007). A multi-touch system is a device capable of supporting two or more simultaneous touch points. The multi-touch system employed a frosted-glass panel with a camera placed behind the glass. The glass panel was pressure sensitive. When interacting with the system, the camera would register touch points as black dots on a white background. The size of the dots would depend on how much pressure was being applied.

Several companies made use of multi-touch technologies to develop touch-sensitive keyboards and touch gesture pads. The first large multi-touch display was the DiamondTouch, developed in 2001 (Dietz and Leigh, 2001). The DiamondTouch allowed for simultaneous touch points on a large surface. Mobile phones also made use of touch technology, but it was not until Apple released the iPhone in 2007 that it became widespread. Today, multi-touch interaction is used in desktop computers, tablet personal computers (PCs), cellular phones and other devices.

3.2.2 Advantages and Limitations

Multi-touch interaction and technologies have paved the way for adaptable, more natural user interfaces. Instead of having limited input from physical input devices, the interface of a touch interactive system can be modified based on the content currently displayed. Physical input devices can also be virtually displayed on the touch screen to allow for the same input logic, but without the extra devices. Other virtual devices can be mimicked on a touch screen and therefore eliminate the need for extra devices. Figure 3-1 shows a virtual keyboard open on an iPad device. The virtual keypad is only opened when required and thereby eliminates the need for a physical keyboard. Multi-touch interaction has proven more natural and intuitive than existing input devices such as the keyboard and mouse (Anslow, 2010).

Several limitations of touch interfaces exist. The most obvious is occlusion, where the user's view of the display is compromised due to fingers and hands blocking vision (Moscovich and Hughes, 2008; Vogel, 2012). A simple method of reducing this problem is to employ well thought-out interface approaches, which allow for objects to be scalable (Benko, Wilson and Baudisch, 2006; Wu and Balakrishnan, 2003). Another concern is the size of the users' fingers described as the fat finger problem (Wigdor, Leigh and Forlines, 2006; Benko *et al.*, 2006). Often, a user's finger may be too large to easily interact with the interface and therefore the interface needs to be carefully developed to minimise this problem (e.g. larger buttons). Lastly, the taking of notes and high resolution image drawing on a touch screen cannot be easily performed on small touch screens.

Figure 3-1: iPad UI showing virtual keyboard for text input

3.2.3 Multi-touch Devices

Today, there are various multi-touch devices available to the public. Apple's iPhone introduced the concept of multi-touch to the mobile phone device. The multi-touch capabilities of a mobile phone allow users to manipulate photographs and other content in a flexible and convenient way. Due to the size of the screen, the number of simultaneous touch points and the device being a mobile phone, the device is only suitable for a single user.

The tablet PC was released soon after the introduction of multi-touch to mobile phones. Physically larger than a cellular phone, the tablet PC allows for a higher screen resolution and wider range of gesture interaction due to an increase in the number of recognisable simultaneous touch points. The tablet is still, however, a personalised device, which a user will not readily want to share and because of the limit of simultaneous touch points, it is still very much a single user device.

Multi-touch has also been integrated into desktop computers. Users may now interact with the desktop using touch monitors as well as the conventional mouse and keyboard. The desktop is still, however, a single user technology that has become more engaging for a user.

Lastly, multi-touch tabletops have become a popular device to enable effective collaboration between multiple people. The tabletop brings together the world of desktop PCs in the form of performance specifications and the world of multi-touch interaction as seen on tablets, but on a larger scale. Multi-touch tabletops are capable of supporting 32 or more simultaneous touch points, which enable multiple people to interact with a system at a given point. The tabletop platform opened up a new gateway for innovative software design to enable co-located collaborative work. Tabletops allow for a more natural way of interaction, because not only can users interact with software using their hands, but they can also capitalise on face-to-face communication with other users (Schubert *et al.*, 2012). Figure 3-2 shows a typical meeting around an interactive tabletop.

Figure 3-2: A Typical Meeting Around an Interactive Tabletop (Chowdhry, 2011)

The multi-touch tabletop appears to be the most supportive platform for co-located group work and will be the focus throughout the rest of this research project. The next section identifies the advantages that multi-touch interactive tabletops offer.

3.3 Advantages of Multi-touch Interactive Tabletops

The development of multi-touch tabletop technologies has allowed collaborative activities to be conducted in a more practical manner. Instead of groups of individuals working on separate desktop computers, tabletop environments can allow the group to sit down in an intuitive setting and collaborate face-to-face (Schubert *et al.*, 2012).

Brown and Palincsar (1989) suggest that peer interaction motivates the problem solver to amend claims that are not manageable; resulting in a solution of superior quality to solutions that collaborating individuals could manage separately. Wilson *et al.* (1993) demonstrated the benefits of collaboration for student programmers. Collaboration and communication of goals and plans improved problem solving skills and motivation in children. The benefits that students gain from collaboration can also be applicable to adults (Wilson *et al.*, 1993).

Existing desktop systems do not allow for people to collaborate and communicate effectively and efficiently in a co-located environment. Software applications developed for desktop computers are bound to the desktop and are built for individual use and not multiple users. Anslow (2010) confirms this in his investigation of whether multi-touch interaction techniques are more effective for co-located collaborative software visualisation than existing single user desktop interaction techniques (Anslow, 2010).

Balakrishnan *et al.*(2010) found that a visualisation was more effective when team members had full access to the shared visualisation and could synchronously interact with it. Furthermore, team members were more effective when they each had control of parts of the visualisation (Balakrishnan *et al.*, 2010).

Isenberg, Fisher, Morris, Inkpen, & Czerwinski (2010) stated that collaboration can be very useful during complex visual analytics tasks and that many visual analytical problems can be solved by groups working together, face-to-face. Team members have different ways of sharing and collaborating at different times. (Isenberg *et al.*, 2010)

The research by Isenberg *et al* (2010) revealed two key benefits of using a multi-touch tabletop. Sharing and face-to-face work improved collaboration because team members were able to point to and manipulate documents or conduct searches that they felt were relevant, and point to documents that their team members could see.

The advantages that multi-touch interaction provide can be useful when creating a co-located GIM system. GIM is involved in several domains and involves activities to support various tasks. The core fundamentals of a multi-touch tabletop are that it provides an effective medium for synchronous communication that can improve synergy between team members and allows for an effective collaborative environment. These fundamentals provide the basic requirements of a GIM system. This implies that multi-touch interaction techniques can possibly support co-located GIM. The next section describes the existing multi-touch interaction techniques.

3.4 Multi-touch Interaction Technique

An interaction technique is a combination of hardware and software elements that provides a way for computer users to complete a single task (Hinckley, Jacob and Ware, 2004). An example of an interaction technique is using a mouse to click the “Back” button in a web browser. Multi-touch interaction uses interaction techniques that provide a more natural way of interacting with a computer device. An example of a multi-touch interaction technique is when users use their fingers to resize a picture using a pinch gesture. With multi-touch interaction, users are able to manipulate and interact with the computer using their hands instead of using another hardware device (e.g. mouse, keyboard or joystick). Performing tasks on computers has been simplified with the advent of gesture recognition. A gesture is used to increase efficiency in performing a particular task. Multi-touch gestures have allowed for a more intuitive way of interacting with objects. On multi-touch devices, gestures are used to drag or move, rotate, resize, tap, sweep, flick and hold (as shown in Table 3-1) objects displayed on a computer (Hinrichs, 2011). A gesture is therefore a method of input used to complete an interaction technique in support of a task and hence, each task that can be performed using a gesture on a co-located multi-touch GIM system is a multi-touch interaction technique.

These gestures have been implemented on objects such as images, video players, web browsers and simple shapes (squares, triangles, etc.), but there are no interaction techniques that have been designed specifically for GIM. The information dealt with in GIM is complex because of the different types and methods of sharing information. There are also no established interaction techniques for collaboratively creating documents on a multi-touch tabletop. Possibilities of creating compound gestures, which are a combination of the standard gestures with other controls, could be used to support the advanced tasks of a GIM system. Therefore, new multi-touch interaction techniques will need to be designed to support all the tasks related to the requirements of a co-located GIM system.

Table 3-1: Visual Representation of Different Types of Gestures ((Hinrichs, 2011)*)*

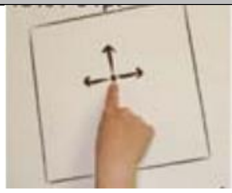
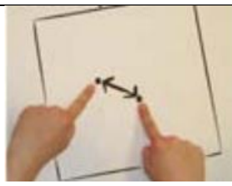
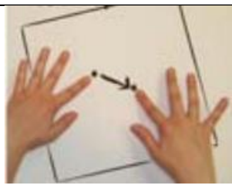
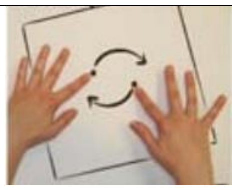
Gesture	Visual Representation
Drag or move	
Resize (zoom in/enlarge)	
Resize (zoom out/ shrink)	
Rotate	
Tap	
Sweep	
Flick	
Hold	

Figure 3-3 presents a generic interaction technique. Figure 3-3 shows that a multi-touch interaction technique consists of three components, namely, a gesture, an object and a task. When a gesture is invoked on an object in support of a task, an interaction technique is formed. This definition of an interaction technique can be used to identify existing interaction techniques as well as providing a model to design new interaction techniques.

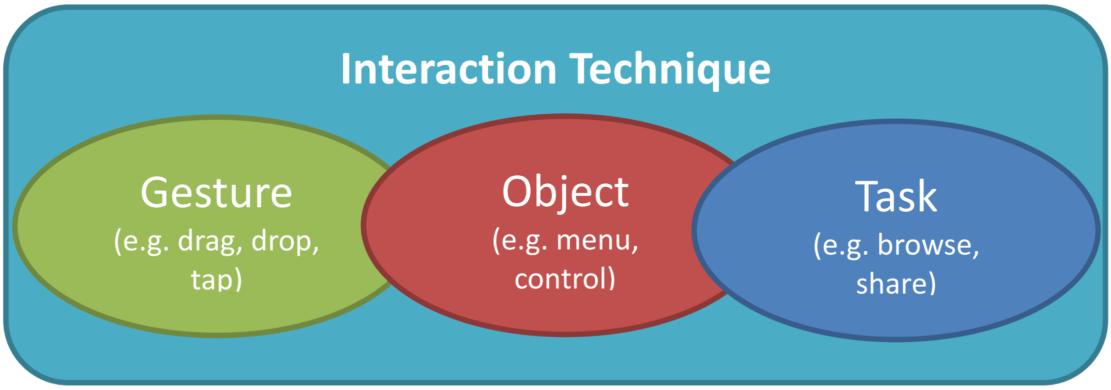


Figure 3-3: A Derived Generic Multi-touch Interaction Technique

3.5 Applications using Multi-touch Interaction Techniques

This section provides an insight into applications developed using multi-touch tabletops. The aim of this section is to identify each application's purpose and the advantages and disadvantages of each application.

3.5.1 Existing Applications

3.5.1.1 Collabee (Multi-touch Collaborative Diagramming Tool)

Collabee (Totolici, Malan, Silk, Sarenac and Kiarostam, 2010) is a multi-touch collaborative diagramming tool developed by students from the University of British Columbia in Vancouver. The prototype was used in an experiment to test the levels of collaboration on different interfaces. The three interfaces used were computer software, prototype and whiteboard. Participants in the experiment were required to create a unified modelling language (UML) diagram representing a provided software system.

Results showed that there were no substantial differences in the number of corrections made on each interface. There was also no substantial difference between the whiteboard and Collabee, but the whiteboard was considerably better than the desktop computer. Whilst there was no difference between the whiteboard and Collabee, the whiteboard and Collabee were considerably better than the computer software, based on the number of questions asked during the evaluation.

The evaluation showed that Collabee was at least no worse than other interfaces and at times, was better than the desktop computer. Questionnaires and follow-up interviews revealed that users enjoyed using Collabee more than the desktop computer and whiteboard.

3.5.1.2 Co-IMBRA (Collaborative Information Manipulation, Browsing, Retrieval and Annotation)

Co-IMBRA (Wesson, Vogts and Sams, 2012) is a system for collaborative information manipulation, browsing, retrieval and annotation. The system runs on a large 42" multi-touch tabletop and is capable of supporting multiple users simultaneously. The multi-touch interactive capabilities of the system enable the users to interact with the system using an intuitive and natural gesture interface. The functionality of the system caters for multiple users to simultaneously retrieve information from the web or other document collections and store the relevant information on a local hard disk drive. Evaluation of Co-IMBRA was conducted in the form of user studies to determine the effectiveness of the system as a multi-touch collaborative information retrieval tool. Overall results showed that Co-IMBRA was a highly effective in supporting collaborative information retrieval. Shortcomings identified were text entry and gestures for zooming as participants found difficulty in typing and resizing objects.

3.5.1.3 MTM-Tool (Multi-touch Modelling Tool)

MTM-Tool (Ditta, Cowley and Van der Post, 2011) is a collaborative multi-touch modelling tool aimed at enabling group members working on the same project to collectively create UML diagrams. The system runs on a large 42" multi-touch tabletop and is capable of supporting multiple users simultaneously. The theory behind a collaborative modelling tool is that group members are better able to create solutions that are of better quality to those solutions that a single individual creates. The tool was able to support up to four simultaneous users in which the users were able to create diagrams using customised gestures and userpads. The userpad concept was conceptualised to provide each user their own private space in which they could edit certain parts of a diagram, whether it be text, or relationship data. MTM-Tool underwent evaluation in which two users were required to complete a set of tasks. Overall results proved positive and the tool was deemed potentially useful to support collaborative diagramming. Text entry and the sensitivity of the touch gestures were identified as shortcomings of the study. Typing on an on-screen keyboard provided no feedback to the user and gestures were too sensitive.

3.5.2 Comparison of Existing Applications

This section compares the existing applications based on the user interface, workspace, controls, information input and user identification implemented in the system. The user interface is defined based on the type of standards and components used (e.g. Windows user interface (UI) layout with drop boxes). The workspace is the main UI element that provides the environment in which users conduct the system functions (e.g. Microsoft Outlook workspace environment). The controls of the system are defined as the objects that contain information and can be manipulated in the workspace. Information input is the mechanism that enables a user to input information into a control. User identification is the method of defining which piece of information belongs to whom.

Only Co-IMBRA and the MTM-Tool will be compared as the systems both used the same type of hardware during implementation and evaluation. Collabee was developed on a much smaller display where only text visualisations were used. Table 3-2 summarises the comparison between Co-IMBRA and the MTM-Tool.

3.5.2.1 User Interface (UI)

Co-IMBRA avoided conventional Windows UI design by keeping the use of windows controls such as menus, combo boxes, etc. to a minimum. Dialog boxes and sub-windows were substituted for multi-touch pop-up widgets. The aim was to create an interface that allows for natural interaction with a tangible look and feel of the interface.

The MTM-Tool initially employed combo boxes to select information, but this proved unsuccessful due to the inability to support multiple users. The UI design therefore deviated from standard Windows UI components. Custom controls were created to provide a natural and intuitive interface.

3.5.2.2 Workspace

Co-IMBRA has a workspace consisting of a large canvas that spans across the entire display. The canvas is painted with a dark background which helps reduce eye strain and fatigue. The initial workspace is kept simple where users invoke a long hold on the screen to access more functionality.

MTM-Tool also has a workspace consisting of a large canvas to allow for the maximum space available for users to engage with the workspace. The initial workspace is kept simple to limit the possibilities of clutter. Similarly the workspace background was kept dark due to bright colours resulting in eye strain.

3.5.2.3 Controls

In Co-IMBRA, controls are used to contain the information, called information controls. Each information control has a title bar and a canvas on which four different types of information can be displayed (Text, Images, Media, Hypertext Mark-up Language - HTML). The controls contain minimal UI content due to gestures providing the majority of the functionality.

In the MTM-Tool, custom UI controls were developed to portray the UI elements. The main control is similar to a dashboard in which every control needs to be linked to it in order for “ownership” to be established. The controls allow for interaction in both a gestural and step wise method.

Table 3-2: Comparison of Co-IMBRA with MTM-Tool

	Co-IMBRA	MTM-Tool	Design Recommendations
User interface	• Deviation from conventional Windows UI. • Promotes gesture interaction.	• Initial windows components proved unable to support multiple users. Later version deviated from conventional Windows UI. • Promotes gesture interaction.	• Should deviate from conventional Windows UI • Should promote gesture interaction
Workspace	• Workspace spans entire screen. • Dark background.	• Workspace spans entire screen. • Dark background.	• Workspace should span entire screen • Should contain a dark background
Controls	• Custom information controls containing text, image, media or HTML.	• Custom dashboard and controls.	• Should utilise custom controls
Information input	• On-screen keyboard, which spans the duration that a text field has focus. This limits clutter on the workspace.	• Virtual keyboard is constantly displayed on the dashboard, which becomes enabled when editing or adding new text fields. The virtual keyboard takes up the majority of the dashboard.	• Should utilise a temporary on-screen keyboard
User Identification	• Colour coded user identification. One colour belongs to one user.	• Colour coded dashboard for each user.	• Should use colour coded controls for user identification

3.5.2.4 Information Input

When editing information or annotating in Co-IMBRA, a virtual on-screen keyboard (OSK) appears, which enables users to input information. The OSK has a lifespan equal to the time that a textbox has focus. This is to avoid excess clutter on the tabletop.

MTM-Tool has a keyboard section on the main UI control. The keyboard is accessible as soon as a field is selected to edit. The virtual OSK allowed the users to input information. Unlike Co-IMBRA, the keyboard was built into the dashboard and was constantly displayed although only enabled when a field was selected to edit.

It was identified that text input was a shortcoming of both studies, and this therefore motivates that text input should be kept to a minimum for a multi-touch tabletop system.

3.5.2.5 User Identification

Co-IMBRA left it up to the users in order to identify themselves. The system allowed for different colours to be used for different users. All information controls opened by a particular user would be displayed in that user's selected colour.

MTM-Tool made use of colour co-ordinated dashboards in which users select a coloured dashboard and that dashboard remains the user's for the duration of the session. The dashboard is able to be locked so that no other individual can move the dashboard away from the owner.

3.5.3 Advantages and Limitations Experienced

Similar results were found in both systems using multi-touch tabletops. It is important to highlight that the multi-touch systems were determined to be the preferred platform for conducting group work. These systems enhanced group work and allowed for tasks to be completed in an effective, collaborative, manner. The systems were also said to be fun and enjoyable to use, whilst also being intuitive and easy to learn. The results also showed that individuals prefer using an interactive tabletop as opposed to a desktop computer. Sharing of information is also easily accomplished as information can easily be passed to other users and explained in a face-to-face environment. The use of gestures to increase efficiency of particular activities also proved beneficial to the application's success.

Some key limitations experienced by two of the existing systems were the data input mechanism. Both Co-IMBRA and MTM-Tool made use of on-screen keyboards in which users can enter data into fields. The problem with on-screen keyboards lies with the fact that there is no tactile feedback. In other words, there is no sense of notification to the user that a particular virtual button has been pressed. This can sometimes distract the user from the main task at hand. An observation was made during the evaluation of Co-IMBRA where users would often look between the on-screen keyboard and the text field to see which character to press and then look at the text field to see if the character was successfully entered.

Other issues faced by the systems were those of developmental weaknesses, such as, slow processing, sensitivity of gestures and UI layout.

3.6 Potential for Co-located GIM

Multi-touch tabletops have been shown to be effective in the development of co-located, collaborative systems. The tabletop allows multiple users to simultaneously interact with the device and allows for live, face-to-face communication to take place. Theory has suggested that individuals working as a team can achieve improved results than if they worked separately; this shows the benefits of collaboration.

Chapter 2 showed the need for a co-located GIM system. The multi-touch tabletop platform may prove beneficial for supporting the five GIM aspects of keeping, finding, maintaining, organising and sharing information. The need for new multi-touch interaction techniques to support some of the tasks related to the requirements of a co-located multi-touch GIM system was identified. New interaction techniques using simple and compound gestures will need to be designed to support collaborative document creation and sorting the workspace. Gestures may be conceptualised and implemented to improve the efficiency of invoking different system tasks. Since GIM focuses on group activities, the multi-touch tabletop combined with its inherent collaborative capabilities, has the potential to show that multi-touch interaction techniques on a tabletop can support co-located GIM.

3.7 Mapping of GIM Tasks to Multi-touch Interaction Techniques

Existing systems have implemented several interaction techniques on a tabletop to address tasks similar to those identified in Table 2-5. Co-IMBRA makes use of information controls to visualise different forms of information (text, images and html). The information control may also be flipped to apply ratings to the content as well as annotations (Wesson *et al.*, 2012). The multi-touch interaction techniques used in existing systems (Sams *et al.*, 2011; Ditta *et al.*, 2011; Collins and Kay, 2008) to support similar tasks are described in Table 3-3

Table 3-3: Existing Multi-touch Interaction Techniques

Existing Interaction Techniques		
Gesture	Control	Task
Tap	Login pad	Login
Tap	Scroll panel of control	View and browse information within information space
Language	Human element (mouth, hands, etc.)	Face-to-face communication
Tap	Information annotations	Store and view communications
Language	Human element (mouth, hands, etc.)	Verbally assign responsibility
Drag	Information controls	Visually share information
Pan	System log Control	Store and view logs.
Tap	Information control (flipped)	Store and view notes.
Tap	Information control	Save information
Tap	All controls with text fields	Use of OSK
Tap	Explorer control	Select folders
Tap	OSK and search control	Use criteria to find information

Table 3-3: Existing Multi-touch Interaction Techniques (continued)

Existing Interaction Techniques		
Gesture	Control	Task
Drag, resize, rotate and flip	Information Control	View information
Tap	Scroll panel of results control	Browse results
Double tap	File in explorer control	Open files
Drag	Any control	Share results
Tap	Any text field or slider	Modify values

Although the interaction techniques described in Table 3-3 do exist, they will need to be adapted to the GIM domain. Some interaction techniques will also need to be modified due to the fact that the existing interaction techniques do not meet the design recommendations made in Table 3-2. According to the definition of an interaction technique, any modification to the process in which a user completes a task using the system, will result in a new interaction technique. Therefore all modified interaction techniques are, in fact, new interaction techniques. A task mapped to a modified technique implies that the existing multi-touch interaction technique identified in Table 3-3 will be modified to support the same task.

Table 3-4: Typical Tasks of GIM Mapped to Interaction Techniques

Typical tasks required to meet GIM requirements	Interaction Technique
View and browse information within information space.	Modified technique required
Store tasks.	New technique required
Allow for tasks to be set complete or incomplete.	New technique required
Store recently used files.	New technique required
Re-open recently used files.	New technique required
Save information	Modified technique required
Use of OSK.	Modified technique required
Select folders.	Modified technique required
Use criteria to find information.	Modified technique required

Table 3-4: Typical Tasks of GIM Mapped to Interaction Techniques (continued)

Typical tasks required to meet GIM requirements	Interaction Technique
Browse results.	Modified technique required
Open files	Modified technique required
Sort workspace based on criteria	New technique required
Physically share a copy of information to other users	New technique required
Create document by adding, deleting and moving information from document.	New technique required

Important GIM tasks such as document creation, workspace sorting and physical copy-paste of information are not yet supported by multi-touch interaction techniques. New interaction techniques will have to be designed to support these tasks. Table 3-4 summarises the typical tasks for each requirement of GIM identified in Table 2-5, as well as those tasks that require existing interaction techniques to be modified. The tasks requiring modified interaction techniques typically used tap gestures step-by-step to perform the task. The tap interaction technique will be modified using more natural gesture interaction such as drag and drop.

3.8 Conclusion

This chapter introduced multi-touch technology and the potential benefits of utilising multi-touch technology. A brief background on the history of multi-touch interaction was provided, which served to highlight the advantages and disadvantages that multi-touch devices possess. It was noted that multi-touch user interfaces are flexible such that the user interface can adapt itself and still take input from the user. The multi-touch tabletop also eliminates the need for extra input devices such as the conventional keyboard and mouse. A limitation of multi-touch interfaces is occlusion, whereby the screen can become obscured by fingers. This limitation can, however, be solved by using scalable controls.

The different types of multi-touch devices such as smart phones, tablets, desktops and tabletops were discussed. A comparison of the devices showed that multi-touch tabletops were best suited for group work. Multi-touch tabletops were identified to inherently support collaboration due to the natural table environment in which people can communicate face-to-face. The tabletop setting also encourages group work and has an overall synergetic effect. The advantages that a tabletop offers are aligned to the basic requirements of a co-located GIM system, namely, to allow a group to synchronously communicate, collaborate and share information.

An interaction technique was identified as the interaction between a user and the system to complete a task. The task could be as simple as clicking Back on a web browser. A generic interaction technique was described as a gesture invoked on an object to support a task. A list of standard gestures was identified that users can employ to accomplish tasks in an efficient manner. These gestures including resize, tap, flick and rotate were implemented in the three systems discussed in this chapter. It was identified that compound gestures, which combine simple gestures to perform a task, could be used to support certain GIM tasks. Three existing multi-touch systems were reviewed to gain insight into the advantages and limitations that each system presents. Results showed that the multi-touch tabletop systems supported collaboration and allowed for effective group work to be conducted. A limitation was the on-screen keyboard, which allowed users to input data. The problem with the on-screen keyboard was that there was no tactile feedback, which notified the user that a button has been pressed.

The potential for multi-touch interaction to support co-located GIM was confirmed by identifying the advantages that multi-touch interactive tabletops can provide, especially in a co-located environment.

The components of generic interaction technique allowed for existing interaction techniques to be identified. The existing interaction techniques that support tasks similar to GIM tasks are described in Table 3-3. Several existing interaction techniques are required to be modified as they do not follow the design recommendations identified in Table 3-2. New interaction techniques are required to support tasks such as collaborative document creation, workspace sorting and sharing a physical copy of information. Table 3-4 showed the GIM tasks that require new or modified interaction techniques.

The findings of this chapter imply that although multi-touch interaction can support co-located GIM, existing interaction techniques must be modified as well as new interaction techniques developed.

The following chapter will discuss the design and implementation of a co-located GIM prototype system to test the proposed multi-touch interaction techniques to support co-located GIM.

Chapter 4: Design and Implementation

4.1 Introduction

The previous two chapters reviewed research conducted in the fields of Group Information Management (GIM) and multi-touch interaction. Chapter 2 identified the components that comprise GIM. Tasks relating to the components of GIM were identified and used to determine the functional requirements of a GIM system. Chapter 3 explained how multi-touch interaction techniques can be used to support the tasks of GIM. The tasks relating to each GIM requirement were mapped to existing interaction techniques, where possible, and the need for modified or new interaction techniques was identified.

This chapter introduces CollaGIM, a co-located Collaborative Group Information Management tool that utilises natural interaction techniques on an interactive tabletop. The design of CollaGIM is discussed in detail with regards to the proposed data design, user interface design and architecture. CollaGIM was implemented using the design requirements and a detailed discussion of the process is given.

The chapter concludes with a discussion on the overall design and implementation process. Changes to the design of CollaGIM made during implementation are identified and justified.

4.2 Application Domain

Within the Department of Computing Sciences at Nelson Mandela Metropolitan University (NMMU), a typical group activity was identified as creating collaborative group documents. Students are often required to work in teams to complete assignments and projects where the artefact produced is a collaborative document. For this reason, the selected application domain was a group of individuals working towards a common goal to produce a collaborative document using information collected individually.

4.3 Design

The design of CollaGIM aimed at fulfilling the requirements identified in Table 2-5 of Section 2.5.2. The design is broken into two subsections, which defines how CollaGIM should be constructed. This section presents the data design, which identifies the controls required to support GIM tasks and the UI design, which shows how existing, new and modified multi-touch interaction techniques were implemented to support the GIM tasks. An architecture for CollaGIM is proposed using the new multi-touch interaction techniques and compound gestures.

4.3.1 Data Design

CollaGIM is a collaborative GIM tool. The system allows multiple users to simultaneously access and interact with different forms of information (documents, images, videos, etc.). The system also enables users to share the information as well as construct an artefact, such as a document, in a collaborative manner. Due to CollaGIM being a multi-user application, important data needed to be correctly tracked and managed by the different dashboards, information controls, document builders and other controls. Table 4-1 maps the controls to the tasks supported by each control.

A dashboard is a control which provides a user with access to his/her own information. Once a user logs into CollaGIM using a login control, the system pulls all the group information from the content management system. All information such as documents, images and videos are displayed within the user's dashboard. The dashboard is also used to visualise the on-screen keyboard for text input. The dashboard is capable of supporting specific interaction techniques such as zoom-in, zoom-out, rotate, drag, flick and share items. A feature of snap-to-minimise was introduced to limit clutter on the workspace. The snap-to-minimise feature was added so that unnecessary clutter is avoided and enough information is displayed to identify what the object is, as suggested in *WeSearch* (Morris, Lombardo and Wigdor, 2010). The dashboard control makes use of existing, modified and new interaction techniques to support the typical tasks of GIM. These interaction techniques are further discussed in Section 4.3.2.3

An information control is a custom made UserControl which is used to visualise an information type. The information control is able to visualise text, images and videos. The information control can be flipped to add a rating or annotations. The annotation could be used as a tagging scheme. Ratings and annotations also provide meaning to information. The metaphor of flipping an object is a mechanism to reduce clutter on a tabletop display (Collins, 2007). The control can be closed as well as shared with other users by means of an intuitive drag and drop gesture. The information controls are capable of supporting specific interaction techniques such as zoom-in, zoom-out, rotate, drag, flick, flip and share. The information control makes use of existing and new interaction techniques. These interaction techniques are further discussed in Section 4.3.2.4.

The document builder is a custom made UserControl that enables users of CollaGIM to collaboratively construct documents by dragging and dropping information from a dashboard or information control into the document builder. Information within the document may be rearranged to the team's specification. The document builder required new interaction techniques to be developed and uses compound gestures to perform several functions. The collaborative document builder uses new interaction techniques to support the GIM task of document creation. Further details on the interaction techniques for the collaborative document builder are discussed in Section 4.3.2.6.

The main widget is a control that allows for all other controls to be opened. The login control allows users to login and access their personal information. The workspace sorter is a control that enables users to collaboratively sort the entire workspace using new interaction techniques. The system log stores all communication between the users and the system. The recently used control allows for all the information from all active users to be easily re-found and re-opened. The task list control stores a list of tasks that can be set as complete or incomplete. The keyboard control provides the text input to all text fields from any control. Further details on the interaction techniques used to support the GIM tasks are discussed in Section 4.3.2.

The different controls, whilst supporting different functional requirements, all need to be under constant synchronisation with regards to certain data fields. The data fields are listed in Table 4-2, and are identified by means of the attribute type and a description. Table 4-2 also specifies which controls contained the specified data field.

Table 4-1: Controls of CollaGIM mapped to Tasks Supported

Control	Tasks Supported
Main Widget Control	• Provides a menu to open controls such as the Login, collaborative document builder, task list, workspace sorter, system log and recently used controls.
Login Control	• Allow login/logout functionality (existing)
Dashboard Control	• View and browse information within information space (modified) • Use of on-screen keyboard (OSK) (modified) • Select folders (modified) • Use criteria to find information (modified) • Browse results (modified) • Open files (modified) • Share results (existing) • Physically share a copy of information to other users (new) • Create document by adding information (new)
Information Control (text, image or videos)	• Visually share information (existing) • Store and view communications (existing) • Store and view notes (existing) • View information(existing) • Modify values (existing) • Transfer information to other users (new) • Create document by adding (new) • Save information (modified)
Document Builder Control	• Create document by adding, deleting and moving information from document (new)
Workspace Sorter Control	• Sort workspace based on criteria (new)
System Log Control	• Store and view logs (existing)
Recently Used Control	• Store recently used files (modified) • Re-open recently used files (modified)
Keyboard Control	• Modify values (existing)
Task List Control	• Store tasks (new) • Allow for tasks to be set as complete or incomplete (new)

The controls of CollaGIM shared some similar data fields. When users interact with the different controls, the user may change some parameters in a control that will need to be filtered to other related controls. The data fields are kept synchronised by checking each field when an action is performed against the particular control.

Table 4-2: Key Data Fields mapped to Controls

Data field	Type	Description	Control
Owner	dashboard	The owner of the dashboard	Information control
OtherOwners	dashboard[]	List of other active users	Dashboard
colour	Brush	Selected colour of the user. Used for user identification.	Dashboard, Information control, Document builder and System log
items	itemInfo[]	List of all the files accessed from group folder. Displayed on the dashboard.	Dashboard
documentItems	itemInfo[]	List of all information objects dropped into the document builder.	Document builder
recentItems	itemInfo[]	List of all recently used items from all users.	Recently used control
author	String	Information objects original owner	Information control and Document builder
rating	int	Rating of an information object	Dashboard and Information control
itemInfoURI	URI	Uniform Resource Identifier (URI) of a files source	Dashboard, Information control, Document builder
isEngaged	Boolean	Checks whether an information control is ready to receive text input	Information control
isSharable	Boolean	Checks whether a file is sharable based on duplications and file state	Dashboard, Information control

4.3.2 User Interface Design

The user interface is an important part of the application as it acts as the bridge between a user and the application's functionality. A well-designed interface will fit the user's needs and support the functions in an easy and intuitive manner. In Table 3-2 of Chapter 3, the following guidelines were identified:

- The overall user interface should deviate from the conventional desktop Windows user interface (UI);
- The workspace should span the entire display area and should contain a dark background;
- Controls should be custom designed;
- Avoid clutter by utilising a temporary on-screen keyboard; and
- Object ownership should be indicated by means of colour.

The objective was to make GIM more collaborative and effective in a co-located environment. This was achieved by creating a natural interface that invoked efficient, easy-to-use touch interaction techniques and allowed users to effectively and efficiently communicate with each other.

CollaGIM was designed using the Surface 2.0 software development kit (SDK) (Microsoft, 2013). This SDK provided some useful controls, but additional custom controls were also needed. For example, the SDK did not provide multiple instances of on-screen keyboards and also did not have controls that were able to be easily flipped. Although a mono-functional control, such as the library container was useful, its overall functionality was limited. More dynamic controls that have integrated functionality such as the collaborative document builder, workspace sorter and dashboard, were required to support the different aspects and tasks of GIM. This sub-section identifies in detail how each component of CollaGIM was designed to meet the requirements and guidelines identified in Chapter 3.

4.3.2.1 Workspace and Main Widget

The workspace was implemented with a typical dark wood background. The idea was to simulate a typical tabletop. The dark wood background reduced eye strain and provided a contrast to all other controls that could be opened. The main widget is the gateway to the functionality of CollaGIM. Widgets are an important graphical control that can provide functionality to multi-touch applications (Benko *et al.*, 2006). The main widget was designed to be compact and robust, which allowed users to access it from anywhere around the table as well as positioning and locking it to a place deemed suitable. Figure 4-1 shows the expanded main widget, which allowed the addition of users, opening of the collaborative document builder, task list, workspace sorter, recently used, system log as well as providing the ability to be locked such that it cannot be dragged or rotated, but is still accessible. The main widget makes use of the menuItem control from the Surface 2.0 SDK.

Figure 4-1: Main Widget on CollaGIM Workspace

4.3.2.2 Login Pad

The login pad control is opened once the “Add user” menu item is selected from the main widget. The login pad was standardised such that it only requires a username and password to access personal information. User identification was mentioned in the guidelines for developing multi-touch tabletop applications. It therefore seemed logical that whilst a user is logging in, the user should be able to select a colour that identifies his/her objects on the tabletop. Figure 4-2 shows the login pad where users may use the menuItem to select a colour for identification. Once the correct login details have been entered, the user may tap on submit to access his/her dashboard or personal information space. The login pad supports gestures for rotation, drag, pass, flick and tap. The login pad is the only control to contain a fixed keyboard for text input. The process of logging in uses existing interaction techniques.

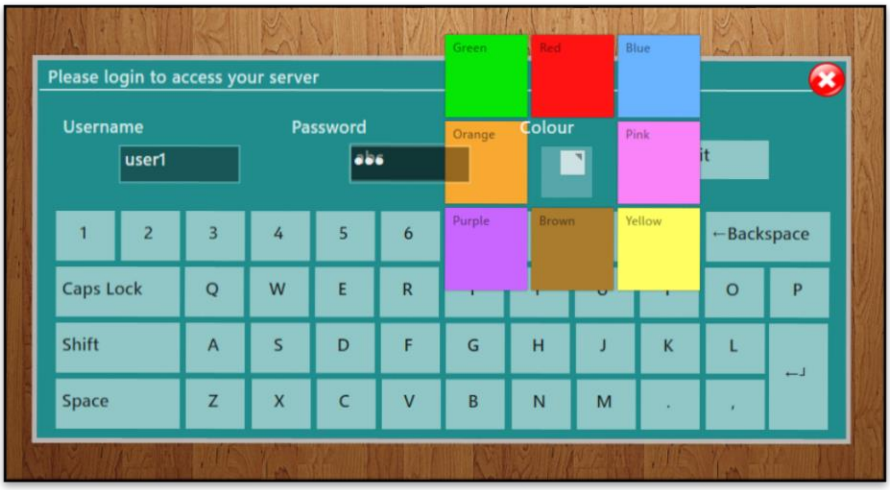


Figure 4-2: Screenshot of a User Selecting a Colour Identifier on the Login Pad

4.3.2.3 Dashboard (Personal Information Space) and On-screen Keyboard

Upon successful login to the system, the system pulls all the files from the user's group folder hosted externally to CollaGIM and visualises it in a dashboard. The dashboard was designed using a libraryContainer (Microsoft, 2013), which allows for the files to be grouped, placed and visualised with titles, ratings and large thumbnails. The combination of text titles and thumbnails was used because it allows users to recognise the file effective and efficiently (Woodruff, Faulring and Rosenholtz, 2001). Figure 4-3 provides a view of a user's dashboard. This is a modified interaction technique that uses a libraryContainer to visualise files.

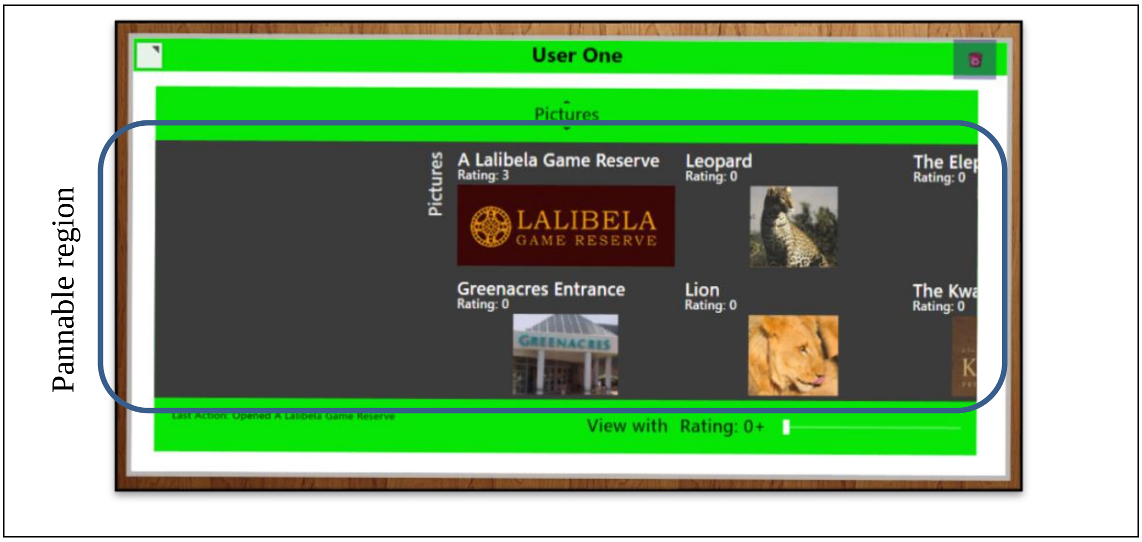


Figure 4-3: Full View of a User's Dashboard

The dashboard contains a menu with facilities to either logout or lock the dashboard, as seen in Figure 4-4-1a. The lock dashboard action disables all motion gestures of the dashboard itself, but the user is still able to interact with the contents of the dashboard. The ability to lock controls prevents unintentional gestures and can also give the user a sense of territoriality (Pinelle *et al.*, 2009). The interaction technique to lock controls does exist.

All the files that have been pulled from a content repository are visualised in the pannable region. The user is able to pan left or right to search for relevant files or folders. The panning feature is a modification to existing interaction techniques whereby users can browse files in a libraryContainer using the pan gesture instead of tapping down or up on a typical windows explorer. A feature for directly searching for folders can be seen in Figure 4-4-2a where by simply touching the folder name opens the list of all available folders (Figure 4-4-2b). The desired folder may then be selected. Once chosen, a panning animation will occur, which will result in the visualisation of the desired folders contents. This feature was integrated with the libraryContainer control available in the Surface SDK but is also considered a new interaction technique for selecting folders.

Files will be allowed to have ratings based on the quality of the content of the file. The rating feature adds relevance to the information and allows for the information to be categorised for retrieval. The rating is also displayed beneath the title of the file. The dashboard allows for all the files to be filtered based on rating. The sliding bar in Figure 4-4-3a can be dragged left or right to increase or decrease the filter criteria. For example, “View with Rating 3+” will only show those files with a rating specified 3 and above. All other files will be hidden until the criteria matching the rating or a 0+ rating is specified. This process of filtering the dashboard is a modified interaction technique that uses a slider bar to filter files, which allows for files to be easily found. Results of the filter process are displayed in the same libraryContainer and can be shared by moving the libraryContainer to an area where other users can see it.

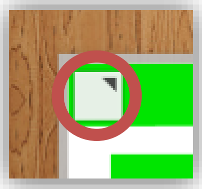
The dashboard contains an action bar that updates based on major actions performed. For example, if a file called “Lalibela Game Reserve” is opened, the action bar will update to meet the description seen in Figure 4-4-4a. This bar provides the user with recent events that have occurred relating to the user. Other actions that are noted in the action bar are when a file is shared between users, added to the document builder or deleted. The action bar forms an important part in providing users with feedback.

Files can be opened from the dashboard by dragging and dropping the thumbnail from the dashboard to the workspace. An information control opens containing the information. (The information control is further discussed in Section 4.3.2.4.) The process of dragging and dropping to visualise a file is a modified interaction technique.

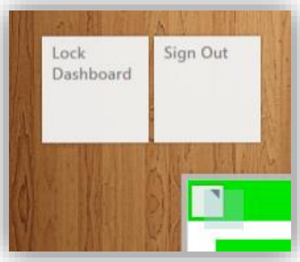
Information can also be transferred to other users by dragging and dropping the thumbnail in the information control into the user's dashboard. The process of using a thumbnail from the information control to share information is a new interaction technique. Further information about the information control and using the thumbnail to share information is discussed in Section 4.3.2.4.

Information can also be added to the collaborative document builder by dragging and dropping a file from the dashboard to the document builder. The process of dragging and dropping between the dashboard and document builder to add information is a new interaction technique. The collaborative document builder is discussed in further detail in Section 4.3.2.6.

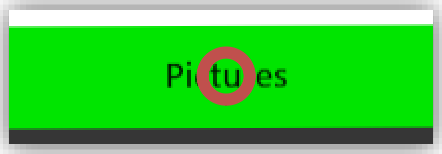
The deletion of a file from the dashboard can be accomplished by touching and dragging a file within the dashboard to the recycle bin as seen in Figure 4-4-5a. The file may be recovered by dragging the file from the recycle bin back to the pannable region. The process of deleting and recovering files uses modified interaction techniques by allowing users to drag and drop information to either delete or recover it. A user can invoke the snap-to-minimise gesture, which converts the large dashboard into a small convenient icon (Figure 4-4-6a). This feature helps reduce the issue of clutter on the tabletop. The icon is colour-coded and contains the user's name for user identification. The snap-to-minimise is a new interaction technique that alleviates the effects of clutter.



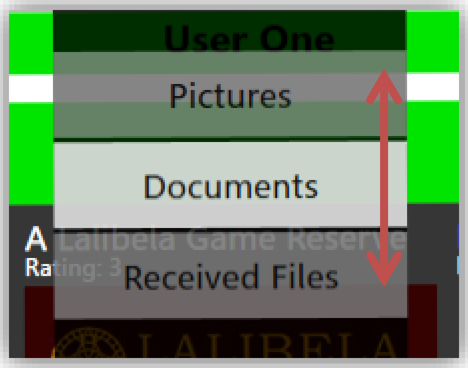
(1a) menu of dashboard – initial state



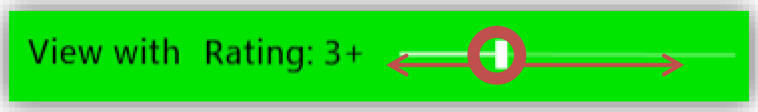
(1b) menu of dashboard – active state



(2a) Folder selection – initial state



(2b) Folder selection – active state



(3a) Personal information space filter

(4a) Action bar

(5a) Delete a file by dragging and dropping into recycle bin

(6a) Dashboard – Minimised version

Figure 4-4: Components of Dashboard Control

The keyboard control of CollaGIM was implemented with the goal to reduce clutter and appear only when needed. An approach of having one dedicated keyboard per user was followed and since there would be only one dashboard per user, the keyboard control was integrated with the dashboard (Figure 4-5). The keyboard is linked to the information controls in such a way that if an information control is ready to receive input, the keyboard will automatically appear in the owner's dashboard. The keyboard may be closed by tapping on the "Close" button. All text input is saved automatically. Due to the fact that a control receiving input can be placed relatively far away from the keyboard, a mirrored text block was integrated into the keyboard control. This mirrored text block is a duplicate of the text that will appear in the desired object's text block. This integration should reduce eye strain and fatigue as the user will not have to continuously switch focus between two objects to ensure correct text input is achieved. The use of an integrated keyboard and dashboard control is a modified interaction technique whereby each control does not have a dedicated keyboard and is instead linked to a single keyboard within the dashboard. In the case when the dashboard is in a minimised state and the keyboard has been opened, a keyboard opened notification is displayed. This implies that the dashboard must be in a maximised state in order for a user to input text.

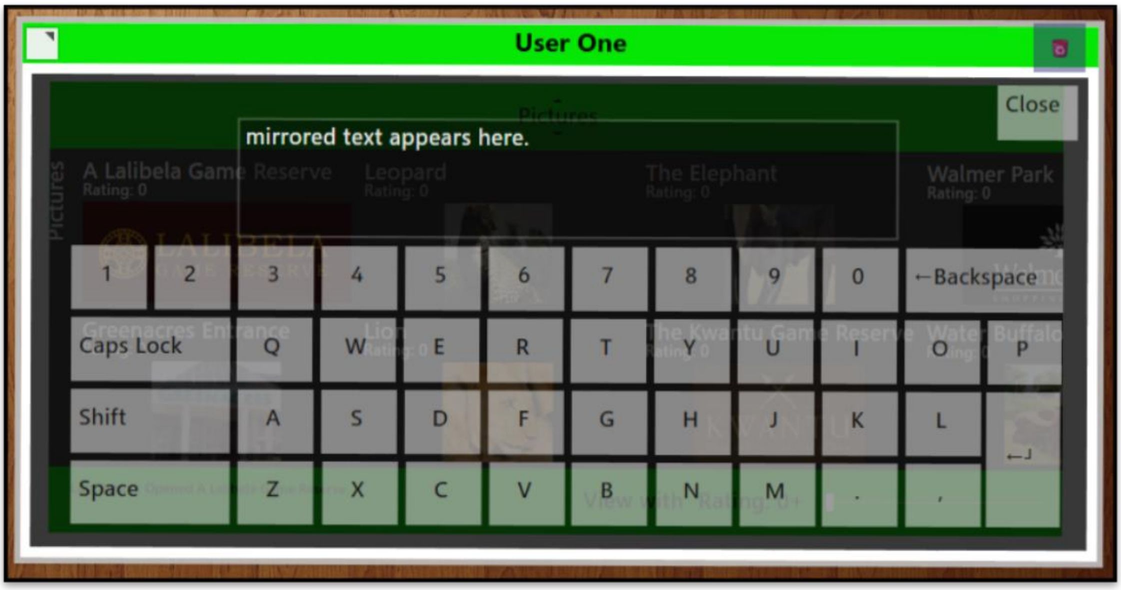


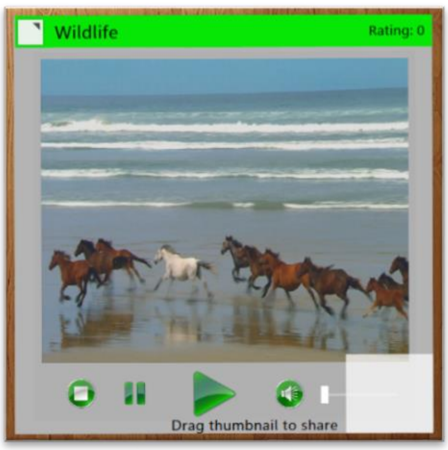
Figure 4-5: Dashboard with Keyboard control opened

4.3.2.4 Information Control

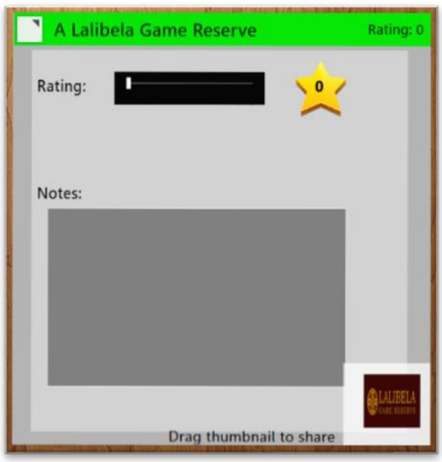
The user is able to open a file from the dashboard by dragging and dropping the file's thumbnail onto the workspace. The file is opened in an information control with the same orientation as the source dashboard. The information control may view text, images or videos. The text information control supports text panning and the video information control provides the basic media player functions. An information control may be flipped over to add useful ratings or annotations for tagging purposes. Figure 4-6 shows the three different types of information controls as well as the flipped side. Using an information control to visualise information and flipping it over uses existing interaction techniques. The information control may also be passed to other users to view the information. The pass gesture is an existing interaction technique.

(a) Text Information Control (front)

(b) Image Information Control (front)



(c) Video Information Control (front)



(d) Information Control (flipped)

Figure 4-6: Different Information Controls

The information control supports gestures such as tap, rotate, drag, drop, share and snap-to-minimise. The minimised information control is a small icon displaying the thumbnail of the file. The snap-to-minimise gesture is a new interaction technique to prevent clutter.

The information controls have a menu through which basic actions may be completed. These actions include close (closes the open file), flip (flips the information control over) and save (saves all changes made to the information control). The information control also shows the current rating of the file in the top right corner. Changes made to an information control are automatically saved when it is flipped over.

The flipped side of the information control allows for the rating to be changed by using the slider. As the rating changes, the value in the gold star and top right hand corner are updated. The rating value in the dashboard is also updated. Annotations are made by touching the text block under notes, which then opens the keyboard control in the dashboard. Modifying values within the information control uses existing interaction techniques for text input and adjusting ratings.

The sharing of files needed to be accomplished in a natural and intuitive manner. The bottom right corner of each information control contains a thumbnail of the opened file. This thumbnail can be dragged and dropped from the information control to another user's dashboard (Figure 4-7). When the item is dropped on the dashboard, the file has been successfully shared. This is a new interaction technique as mentioned in Section 4.3.2.3. The action bar on the dashboard also updates accordingly to notify the user that a file has been received. This feature of dragging and dropping the thumbnail to share information is also extended to compiling a document using the document builder. The thumbnail allows information to be added to the document builder, which is a new interaction technique. A thumbnail was used to share the file because moving the physical object would displace the object completely and if shared, the object would have to be moved back to its original place.

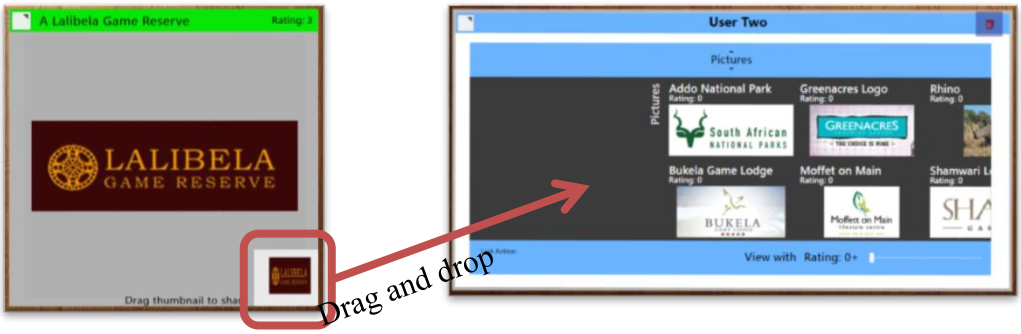
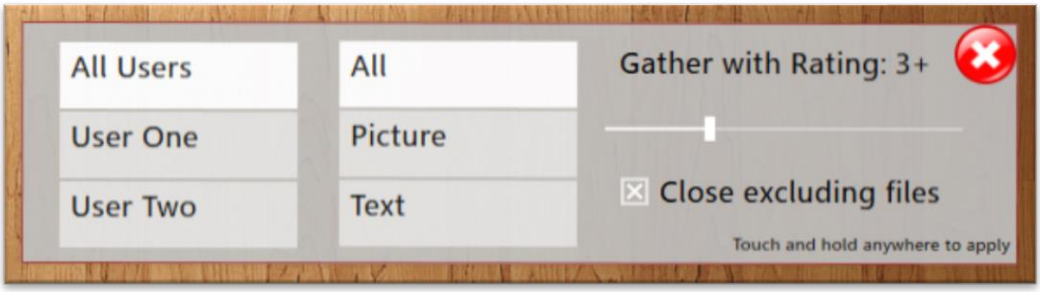


Figure 4-7: Process of Drag and Drop to Share

4.3.2.5 Workspace Sorter

The workspace sorter control was designed to sort all open information controls on the workspace. There can only be one instance of a workspace sorter as the workspace is a shared environment. The workspace sorter can be opened from the main widget. The workspace can be sorted based on users, file type and ratings, as seen in Figure 4-8-a.



(a) Workspace sorter – Sorting for all file types with rating 3+ from all users. All files that do not match must be closed.

(b) Results from sorting the workspace.

Figure 4-8: Workspace Sorter and Sort Result

There is an option to close all open information controls that do not match the sort criteria. Once the sort criterion has been selected, a long touch or hold gesture anywhere on the workspace will invoke the sort algorithm. The sort algorithm groups all the matching information controls to the location where the hold gesture was invoked. The results appear as in Figure 4-8-b, where all the matching information is grouped into piles. Using the metaphor of piles is an effective and efficient method to sort information (Henderson, 2009). The steps involved with completing a workspace sort represent a new compound gesture. The entire process of sorting the workspace is a new interaction technique.

4.3.2.6 Collaborative Document Builder

The Collaborative Document Builder is a custom control designed to enable group members to collate high level documents. The purpose of the collaborative document builder was to enable users to generate a collaborative document by conducting the typical activities of GIM. This document builder fulfils the requirements of GIM where it provides the functionality to create an artefact (i.e. a collaborative document). The document builder control can be accessed from the main widget.
Initial designs of the document builder yielded unsatisfactory results as the design was still very much Windows-based (Figure 4-9). The initial design allowed users to add files through a menu option. The file would then be added to a list which could be shifted up or down by touching a button. Files added to the document were populated into a Word document and converted to an open extended mark-up language paper specification (XPS) file type for visualisation in the control. The population and conversion process would occur each time information was added or removed from the document. Magnifying in and out of the document also made use of buttons. This design proved inefficient and did not follow the design recommendations identified in Table 3-2, which recommended that the UI deviate from conventional Windows UI and promote gesture interaction.

A more natural and intuitive design was required. The document builder needed to accept information quickly and easily. Information within the document should be easily movable with gesture interaction. The result of redesigning the initial prototype resulted in the design shown in Figure 4-10.

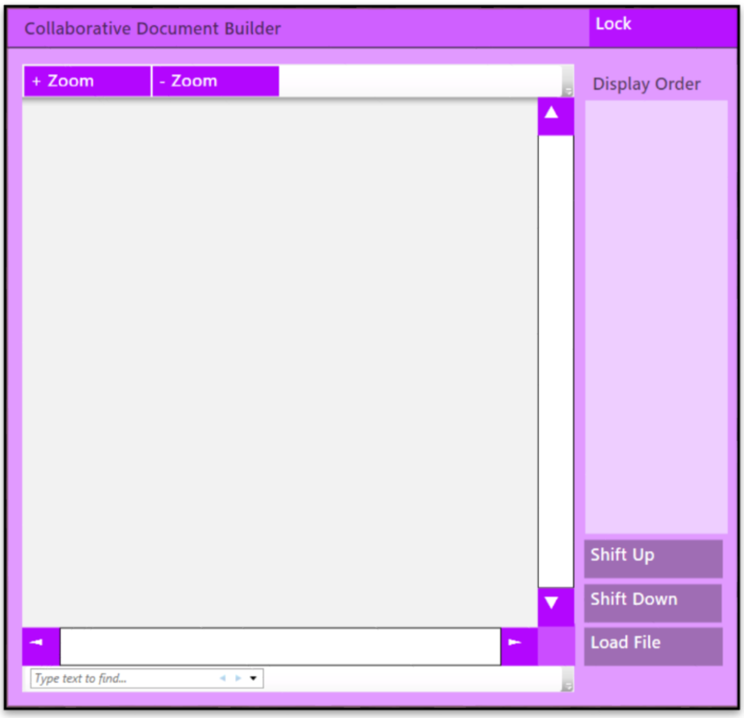
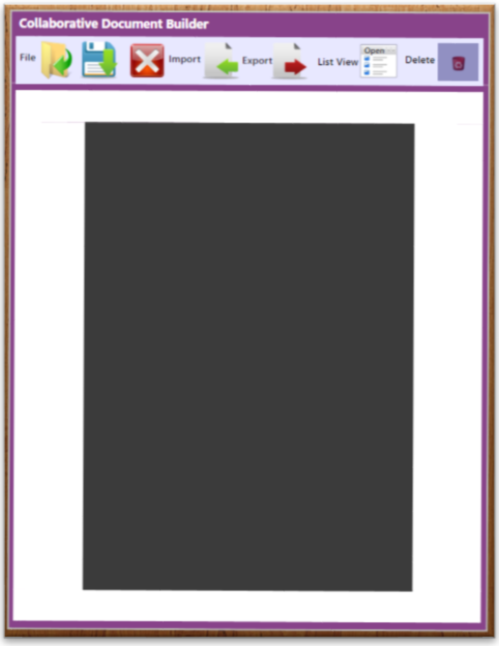


Figure 4-9: Initial Collaborative Document Builder design

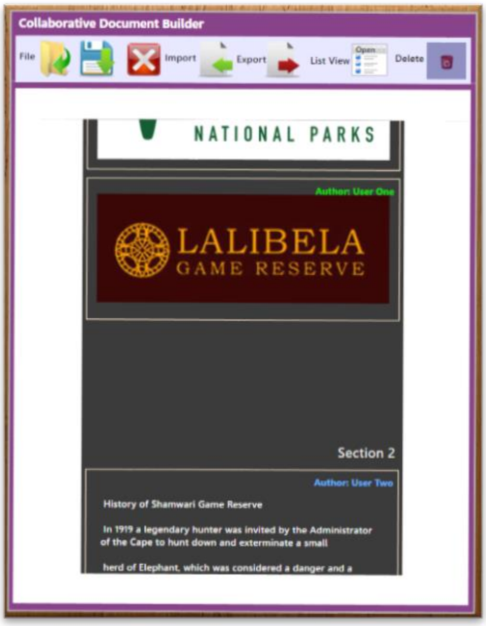
The design makes use of a vertical panning area in which information may be added. The vertical structure was selected to resemble the typical method of creating a document using Microsoft Word or Google Docs (Google, 2007). The manner in which information may be added to the document is similar to that of the sharing process. The thumbnail of a file in the information control can be dragged over the collaborative document builder. Upon drag over, a list view of the contents contained within the document is shown (Figure 4-10-b). Whilst the list view is open, a green bar illustrates where the information will be dropped. Upon dropping, the information is added to the document in the specified location. The information that is dropped into the document contains information on the source author. This is identifiable by the colour-coded username that appears on the top right corner of each dropped piece of information.

If a piece of information is dropped erroneously into the incorrect position, the information can be reordered by simply dragging the information, which reopens the list view, and dropping it into the right position. Alternatively, information may be dragged and dropped into the recycle bin of the collaborative document builder for deletion. The list view can be toggled open and closed to view the overall structure of the document.



(a) Initial state of collaborative document builder

(b) State while information is being dropped into the document



(c) State after information has been added to the collaborative document builder

Figure 4-10: Collaborative Document Builder Illustrating the Process of Adding Information to the Document

Other functions on the ribbon of the collaborative document builder includes opening, saving, closing, importing and exporting documents.

The use of all the simple gestures and controls that are integrated with each other into one fluid step per function, gave rise to newly designed compound gesture for creating collaborative documents. All the steps involved with adding, deleting and moving information uses new interaction techniques.

4.3.2.7 Other Controls

CollaGIM caters for recently used files to be accessed, system logs to be viewed and a predefined task list to guide users. These controls are all accessible from the main widget.

The Recently Used control keeps a record of all files that have been loaded in the workspace by all users. The files are stored in a libraryStack, which is a control from the Surface 2.0 SDK. The Recently Used control allows for the recent files to be dragged and dropped onto the workspace for visualisation. Figure 4-11 contains a snapshot of the Recently Used control. The user can pan through the recent files by slightly shifting the top file to the back. Using a control to store recently used files from all users and using a libraryStack to view the files is a new interaction technique. The ability to open the files by dragging and dropping it from the libraryStack to the workspace is also a new interaction technique.

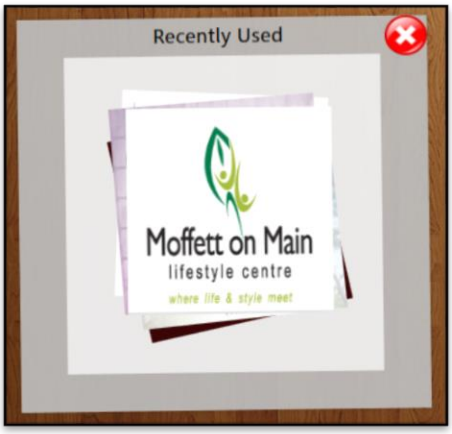


Figure 4-11: Recently Used Control

The system log was implemented to keep track of user interaction with the system. Each time a major action is performed, a colour coded entry is added to the system log. A timestamp is also applied to each entry. Figure 4-12 shows the system log of CollaGIM. The system log uses existing interaction techniques to store and view logs.

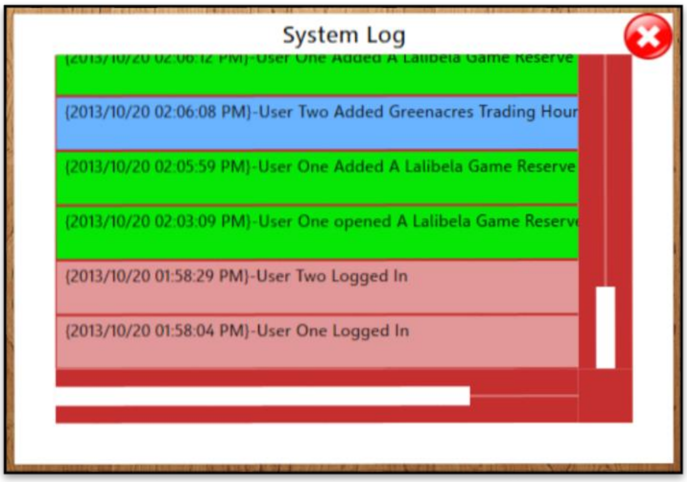


Figure 4-12: System Log of CollaGIM

The task list control was implemented to provide users with an on-screen version of tasks to complete. The idea is that users should not be required to switch between paper and the display during evaluation. The task list can display tasks as either marked complete or incomplete. Figure 4-13 depicts the task list used in CollaGIM. Using an on-screen task list is a new interaction technique, as well as providing a means to set a task as complete or incomplete.

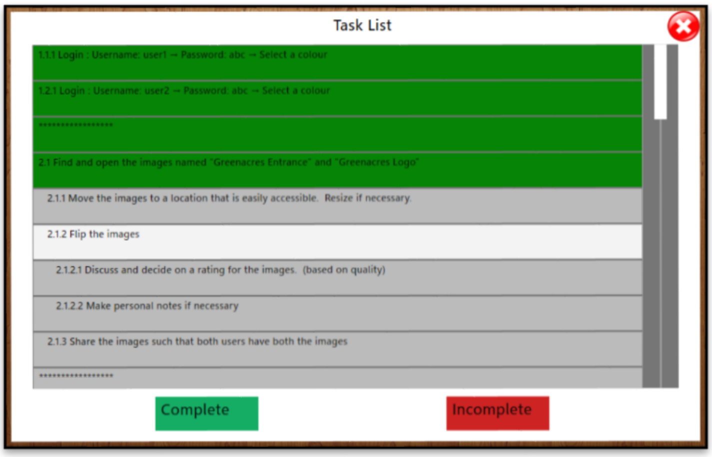


Figure 4-13: Task List Control of CollaGIM

4.3.3 Architecture

The purpose of designing an architecture is to provide a basis on which a system can be implemented. The architecture outlines the dependencies between each component of the system as well as how the information should flow within the system.

CollaGIM focused on integrating multi-touch interaction techniques with typical GIM activities. In Figure 4-14, the “client” represents CollaGIM, where the key requirement is creating the View Layer (UI) for the tabletop, accessing a user’s information in the information repository, providing the controls to manage that information, and providing a means for constructing a collaborative document using the accessed information.

The Control Layer consists of the multi-touch interaction component, which sends the interaction data to the control layer. The multi-touch component will recognise simple gestures and compound gestures for newly developed controls. A compound gesture is a gesture that makes use of various gestures built into one control.

4.3.3.1 Architecture Process Flow

The architecture can be explained using a bottom up approach. Touch interaction input is received from the tabletop device (Touch Device). The type of data registered from the touch device is the raw co-ordinates of the touches. This information is sent to the Touch application programming interface (API).

The Touch API makes use of gesture recognition to identify which gesture has been invoked, such as rotate, drag or resize based on the raw touch data provided. These components provide manipulation functionality to the Control Layer (CL). The control layer contains custom controls that are designed to support the functional requirements of a GIM system. The controls will be implemented to support gesture manipulation for the user interface. Compound gestures will be created and used for the Collaborative Document Builder, which will be discussed later in this chapter.

The Model Layer (ML) provides access to the information repository where the user's information is kept for visualisation. The information is obtained from a content management system that sends through information on request.

The View Layer utilises both the ML and CL by combining the information received from the ML with the custom made controls available in the CL. The visualised information will be available for interacting with by invoking any of the gestures applicable to the controls.

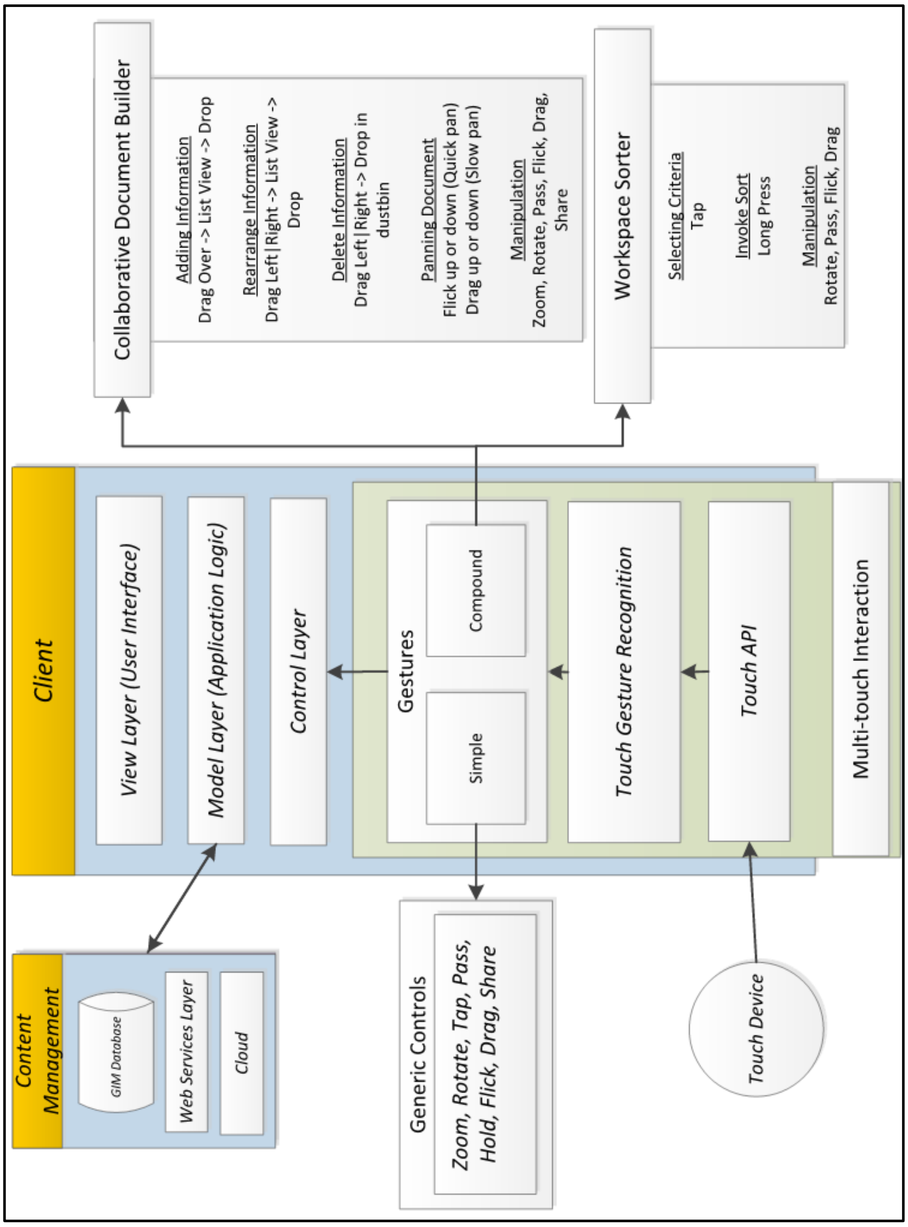


Figure 4-14: Proposed Architecture for GIM Applications using Multi-touch Interaction Techniques

4.4 Implementation

The previous section described how each control was designed to support the desired functional requirements. This section describes the implementation procedure in terms of the scenario, implementation tools, and achievement of functional requirements. A discussion on the issues encountered and how these issues were overcome is covered in this section.

4.4.1 Implementation Tools

This section identifies the environment in which CollaGIM was implemented. The environment consists of both hardware and software components. The hardware required for implementation is that of a large multi-touch display and a computer capable of handling quality graphics and continuous interaction. The software component requires a platform that is suitable for multi-touch application development. The amount of support available can help improve code quality and functionality. The development environment should be multi-touch supportive, which will allow for custom controls to be developed capable of supporting gesture interaction.

4.4.1.1 Hardware

CollaGIM was implemented on the Telkom/Nelson Mandela Metropolitan University (NMMU) Centre of Excellence Multi-touch tabletop. The tabletop was built using a custom designed wood structure that hosts a 42” LG Plasma television. A 42”, G3 multi-touch USB overlay developed by PQ Labs was fitted over the television, which recognises multi-touch interaction. The overlay is capable of recognising 32 simultaneous touch points. The television and multi-touch overlay was connected to a high-end computer running Microsoft Windows 7. The tabletop display was designed to be used in both a vertical and horizontal setting. Other stop positions were available to allow the display to be positioned between the horizontal and vertical setting.

4.4.1.2 Integrated Development Environment (IDE)

Microsoft Visual Studio 2010 was chosen as the IDE for implementation. Visual Studio offered a comprehensive package with the complete .NET framework and quality developer support. The .NET framework had a large online following of support, tutorials and SDKs. The framework also supported the Surface 2.0 SDK for multi-touch development (Microsoft, 2013). User interface design and programming was supported extensively by Visual Studio 2010.

4.4.1.3 Surface 2.0 SDK

The Surface 2.0 SDK is a software development kit for program development on Microsoft's custom build tabletop, Surface. The SDK is, however, not limited to the Surface device. Other computers with multi-touch capabilities can use the Surface 2.0 SDK. The SDK provides developers with limited, but useful controls designed for multi-touch interaction. It provides the basic blocks for building advanced controls.

The SDK is available to the Visual Studio environment and can be used in programs that use Windows Presentation Foundation (WPF). The SDK provided sample solutions implemented using WPF with a C# backbone.

4.4.1.4 Graphical User Interface Design

WPF was a graphical design component of the .NET framework. The custom user controls identified in Table 4-1 were developed using WPF within the Visual Studio environment. WPF provided standard events for touch input and were easily customised to support multi-touch gestures. Functionality was added to the designs as WPF is easily integrated with C#. Controls available in the Surface 2.0 SDK were also capable of being integrated with WPF.

4.4.1.5 Programming Development Language

Microsoft Visual Studio caters for various programming languages, one of which is C#. The Surface 2.0 provides sample solutions in C# with a WPF graphical interface. These factors provided the justification for CollaGIM to be implemented in Microsoft Visual Studio 2010 using WPF for front end graphics and C# as the backbone. The Surface 2.0 SDK was also used during implementation.

4.4.1.6 Thripple

Thripple is an open source library of three dimensional (3D) controls and panels available for WPF applications (JoshSmithOnWpf, 2009). CollaGIM required innovative design where controls were required to be flipped. Thripple provided the controls that could be animated in a natural manner. Thripple was readily available for WPF and was downloadable with free sample projects. The sample projects were developed in C#.

4.4.2 Functionality

This section discusses how the implementation of CollaGIM met the requirements identified in Chapter 3. Each requirement is listed and a discussion follows.

4.4.2.1 Allow for the provision of access to a user's personal information space

This requirement was fulfilled by enabling the user to login with the login pad control. Upon successful login, the user's information was pulled from a content repository and the files were loaded into the dashboard control. The files were visualised as thumbnails and grouped into folders. The dashboard was the control that allowed users access to their personal information.

4.4.2.2 Allow for communication between group members

The tabletop environment inherently supported communication between users. The benefit of this environment was that users could stand or sit down around a table and use synchronous communication when necessary. This reduced misinterpretations and increased work quality.

Communication of a user's individual and group interaction through the system was kept updated in the system log control. The system log kept colour coded entries with a coordinating time stamp.

Communication was also performed by adding annotations to any piece of information. The information control enabled users to flip over an open file and input any notes applicable to the specified piece of information. When a file was shared, the annotations were maintained and passed into the sharing destination.

4.4.2.3 Allow for the workload to be divided and delegated to group members

Workload could be divided and delegated verbally. It was up to the group to decide who was responsible for what task. All controls implemented in CollaGIM were able to be shared or passed to other users. In the case of working on a collaborative document, the group leader could verbally delegate a user to add a piece of information that did not belong to him/her into the document.

4.4.2.4 Keep a history of delegated tasks

The task list control enabled a list of predefined tasks to be loaded into CollaGIM. Each task on the list was able to set as complete or incomplete. Completed items appeared in green on the list and incomplete items appeared grey. The task list was accessible from the main widget.

4.4.2.5 Keep a history of communication

The communication between the user and system was maintained within the system log control as mention in Section 4.4.2.2. Communication based on a piece of information was stored on the flipped side of an information control as an annotation.

4.4.2.6 All for the information to be re-found and easily reusable

Visualised information on the workspace was tracked and stored in the recently used control, which was accessed from the main widget. This control contained information that had previously been opened by all active users. The user was able to filter through the list by panning, and reuse any piece of information by dragging and dropping it onto the workspace.

4.4.2.7 Store documents and information in a user's personal information space

The collaborative document builder enabled users to save documents into all the users' personal information space. This could be achieved by tapping on the save button on the ribbon of the document builder control.

Other files could be dragged and dropped into the relevant dashboard to save the information into the user's personal information space.

4.4.2.8 Allow for searching by querying and filtering the personal information space

The dashboard contained a folder selector which, when changed, automatically panned the personal information space to the files within the folder. The files could then be panned (browsed) further to find the desired files.

Each file within the dashboard was visualised with a title, thumbnail and rating. The rating value was the criterion that was used to filter the user's personal information space. On the dashboard was the label "View with Rating 0+" and a slider. The dashboard only displayed those files with the rating greater than the specified numeric value. The value could be adjusted by touching and dragging the slider left (-) or right (+). The slider's range was from zero to ten. The dashboard was automatically updated as the value changed.

4.4.2.9 Allow for the search results or shared information to be visualised

Results from filtering the dashboard were displayed consistently. All files were grouped by the parent folder and were ordered by rating within the folder. Results could be panned to view other files or folders.

4.4.2.10 Allow for collaborative navigation through search results

Results displayed within the dashboard could be passed to other users. These users could pan the results themselves and decide on the validity of the results. As mentioned, all controls were flexible in a sense that any user could use any control with verbal authority.

4.4.2.11 Allow for the information files to be opened from the personal information space

All information could be opened by dragging and dropping the file from the dashboard onto the workspace. Once dropped, the file opened within the information control. The information control was capable of visualising text, images and video files. Text information controls had a pannable text viewing area, whilst the video information control had the media player functions. Images were simply visualised statically.

4.4.2.12 Allow for manipulation of the search results or shared information

The dashboard containing the results as well as the opened information on the tabletop could be manipulated by means of rotation, zoom and move gestures. The snap-to-minimise gesture could also be invoked.

4.4.2.13 Allow for editing and updating all information

All opened information on the workspace could be flipped over for editing and updating the information's ratings or annotations. The rating value could be adjusted by touching and dragging the slider left (-) or right (+). Annotations could also be made by tapping the text block which opened the keyboard control in the dashboard for text input. Text input was saved once the keyboard was closed or the text block lost focus.

4.4.2.14 Allow for the workspace to be organised in an effective manner

The workspace could be organised by means of the workspace sorter control which was accessible from the main widget. All opened information controls could be sorted by criteria based on the information type, information owner and rating. The option to close all information that does not match the sort criteria was provided. Once the sort criterion had been decided, a long hold gesture on the workspace invoked the workspace sort algorithm. This gesture pulled all the information that matched the criteria to the position in which the long hold gesture was invoked.

4.4.2.15 Allow for a classification mechanism to help organise a user's personal information space

Each piece of information contained a rating. This rating value was viewable from the dashboard and information control itself. The value could be changed using the slider on the flipped side of the information control. This rating was the classification mechanism used to filter the personal information space and could be used to sort the workspace.

4.4.2.16 Allow for sorting of a user's personal information space

The sorting of a user's personal information space went hand in hand with the filtering feature. The dashboard could be sorted based on the ratings of each file. When the "View with Rating 0+" value was adjusted, the dashboard was sorted according to that value within the parent folder.

4.4.2.17 Allow for information on the workspace and personal information space to be easily shared and allow for a sharing mechanism to be used to transfer information into a user's personal information space

All information on the workspace can be passed to another user to visually share the information. Sharing was accomplished by invoking a drag and drop gesture. Sharing information contained within the user's personal information space was done by dragging and dropping the file directly from the owner's dashboard on top of the destination dashboard. Files that were already visualised in an information control on the workspace could be shared by dragging the thumbnail from the information control on top of the destination dashboard.

4.4.2.18 Allow for a collaborative artefact to be created and shared amongst the user's

CollaGIM was implemented with a collaborative document builder. This control allowed for documents to be created by simply dragging and dropping information into the document. Users were able to add information to the document by the same process to share information (dragging and dropping), but instead of dropping the thumbnail on top of the dashboard, the user dropped the thumbnail on top of the document builder. Users were able to move objects around within the document, as well as delete information. The document could be saved and distributed to all group members.

4.5 Discussion

CollaGIM was implemented using WPF, C# and the Surface 2.0 SDK within the Microsoft Visual Studio development environment. Thripple was used to provide 3D content for flipping information controls. The implementation matched the design in all areas and successfully integrated all of the proposed requirements.

A concern when developing for a group of users on a multi-touch tabletop was keeping track of which information belongs to whom and whether or not a control is ready to receive input from the user. One of the non-functional requirements was to keep clutter to a minimum, so an on-screen keyboard was required in a known location and appears only when needed. The on-screen keyboard was implemented within the dashboard since each dashboard belonged to one user at a time. This enabled the user to access the keyboard in a constant location.

Existing systems attached the keyboard directly to the component to which input was being provided (Wesson *et al.*, 2012; Ditta *et al.*, 2011). This eliminated concurrency issues, but either occupied a fixed space, or allowed for several keyboards to be opened at the same time. CollaGIM only allowed one keyboard per user in a constant location, so linking each information object to a keyboard posed a technical issue. Expert reviews confirmed this, as each user's keyboard was erroneously linked with other user's information rendering the keyboard useless. The expert review also showed that since the keyboard may in some cases be relatively far away from the text field, users had to frequently shift focus between the keyboard and the information object, causing fatigue and confusion.

This issue was addressed by creating a link between each keyboard and the controls it could access. This relationship passed information to the keyboard about when a control was ready to receive input or not and what text input a control already contains. An input window was also added to the keyboard, which displayed the text input that was already contained in the information object. All input was reflected accordingly in the keyboard window.

New and modified interaction techniques were required to support some of the tasks of GIM. The new and modified interaction techniques are summarised in Table 4-3 using the components of a generic interaction technique identified in Figure 3-3.

Table 4-3: Typical GIM Tasks mapped to New and Modified Interaction Techniques

Gesture	Object	Task
Pan	Dashboard control	View and browse information within information space [modified]
Tap and pan	Task list control	Store tasks [new]
Tap	Task list control	Allow for tasks to be set complete or incomplete [new]
Tap	Recently used control	Store recently used files [new]
Drag and drop	Recently used control	Re-open recently used files [new]
Auto-save and tap	Information control	Save information [modified]
Tap	Single OSK per dashboard control	Use of OSK [modified]
Tap and automatic pan animation	Dashboard control	Select folders [modified]
Drag	Slider on dashboard control	Use criteria to find information [modified]
Pan	Dashboard control	Browse results [modified]
Drag and drop	Thumbnail in dashboard control	Open files [modified]
Tap, drag and long press	Workspace sorter control	Sort workspace based on criteria [new]
Drag and drop	Thumbnail in dashboard and information controls	Physically share a copy of information to other users [new]
Drag and drop	Collaborative document builder control and the thumbnail in dashboard and information controls	Create document by adding, deleting and moving information from document. [new]

4.6 Conclusion

This chapter presented the design and implementation of CollaGIM, the co-located GIM prototype using multi-touch interaction techniques. The application domain was determined to be a group of individuals using GIM activities to compile a collaborative document. The user controls of CollaGIM were identified and important data fields identified to create consistency between each of the controls. The user controls were also mapped to the tasks required to support GIM. The user interface design of each control were discussed in terms of how each GIM task is supported. The user interface design focused on what functionality each control delivers as well as the type of interaction supported. Several tasks required a modified or new interaction technique, which were summarised in Table 4-3.

The dashboard control implemented a combination of existing, modified and new interaction techniques. Using a libraryContainter to view files as thumbnails and also browse the files with pan gestures used a modified interaction technique. Other modified techniques that were used was integrating the OSK within the dashboard for text input, sorting information in the libraryContainer with a slider, opening files by dragging and dropping, and selecting folders to view in the libraryContainer.

The information control made use of a thumbnail to transfer information to users and to add information to the collaborative document builder. The process of using the thumbnail to support these tasks used new interaction techniques.

The initial design of the collaborative document builder deviated from the guidelines established in Chapter 3. The second design of the document builder, which utilised combinations of simple gestures and controls, resulted in new compound gestures and interaction techniques. The workspace sorter was also designed using compound gestures, which led to new interaction techniques to sort all the information open on the entire workspace.

The recently used control used new interaction techniques by combining all the recently used files for all users into a libraryStack. The task list control was implemented using new interaction techniques to visualise tasks and set the task as complete or incomplete.

A generalised architecture to support co-located GIM using multi-touch interaction was proposed and provided a link from receiving raw touch input to manipulating the user interface layer with simple and compound gestures.

Section 4.4 discussed the actual implementation of CollaGIM. The manner in which CollaGIM was implemented to address the functional requirements identified in Chapter 3 was explained.

The next chapter, Chapter 5, describes the evaluation of CollaGIM. The evaluation will provide insight into the effectiveness of the design and implementation of CollaGIM and help determine whether multi-touch interaction techniques can support co-located GIM.

Chapter 5: Evaluation

5.1 Introduction

In Chapter 4, the design and implementation of a co-located group information management tool, called CollaGIM was discussed. CollaGIM was designed using new and modified multi-touch interaction techniques, which enable users to physically manipulate objects on a tabletop with touch gestures.

This chapter will address Research Question 4, to evaluate the benefits of using co-located, multi-touch interaction techniques to support Group Information Management (GIM) on a tabletop. The purpose of this chapter is to determine that co-located GIM can be supported using multi-touch interaction techniques. This will be confirmed by conducting an evaluation of CollaGIM to determine the effectiveness and efficiency of the prototype. A user study was conducted with 30 voluntary participants. The results of the user study are analysed and presented to validate the design and overall solution provided by CollaGIM.

This chapter begins by identifying the evaluation techniques, which were used for the evaluation of CollaGIM. The evaluation of CollaGIM is discussed, which includes the objectives, instruments, participant selection and task plan information. The results and discussion thereof are presented and the chapter concludes with design implications and recommendations.

5.2 Evaluation Techniques

The evaluation of CollaGIM is necessary, as it provides the answer to Research Question 4 identified in Chapter 1. An evaluation technique for interactive tabletop environments had to be identified as CollaGIM was implemented on an interactive tabletop.

The identified technique had to be aligned with evaluations carried out on similar multi-touch systems such as Co-IMBRA (Collaborative Information Manipulation, Browsing, Retrieval and Annotation), MT-CollabUML (Multi-touch Collaborative unified modelling language) and other systems (Basheri, Munro and Burd, 2013; Wesson *et al.*, 2012; Pinelle *et al.*, 2009). All experiments involved participants who were required to work in teams to achieve a goal by completing activities related to the system functionality. The types of activities were typically presented in the form of a task list, which when completed, would indicate that the goal had been met. Basheri *et al.* obtained results by conducting a comparative study, but this involved a comparison between a desktop and tabletop prototype (Basheri *et al.*, 2013). A comparative study was not feasible as there was no existing system to which CollaGIM could be compared. Other evaluations involved the participants completing a questionnaire based on their experiences once they had completed the evaluation (Buisine *et al.*, 2007; Wesson *et al.*, 2012; Ditta *et al.*, 2011). Qualitative and quantitative results were obtained from the questionnaire and performance results were obtained based on the time taken and number of tasks successfully completed. This type of evaluation technique was considered feasible for CollaGIM.

Gediga (2001) discussed several techniques of evaluating software systems. The techniques used for systems that were feasible for CollaGIM fell into the usability testing category. Gediga (2001) described this form of evaluation technique as a classical experiment for testing hypotheses. The identified technique could therefore produce results that could be used to support the thesis statement identified in Chapter 1. The usability study can involve participants answering questionnaires and being observed. The results that can be obtained from this study would be valuable based on a statement by Jakob Nielsen:

"User testing with real users is the most fundamental usability method and is in some sense irreplaceable, since it provides direct information about how people use computers and what their exact problems are with the concrete interface being tested"
– Nielsen (1993, page 165)

A usability study involving groups of participants was identified as the preferred evaluation technique.

5.3 Evaluation Objectives

The objective of this evaluation was to determine whether the thesis statement provided in Chapter 1 should be accepted or rejected. In essence, it was to determine how effectively the multi-touch interaction techniques built into the CollaGIM prototype supported the GIM activities of sharing, storing, finding, organising and maintaining group information. Positive results from the evaluation would suggest that the proposed design, multi-touch interaction techniques and architecture of CollaGIM can effectively support co-located GIM. Any negative results obtained from the evaluation were noted and addressed in Section 5.7.4.

5.4 Evaluation Design

The purpose of the evaluation was to obtain empirical data that could support the thesis statement. The experiment involved several teams of two participants interacting with CollaGIM to complete a set of provided tasks for a pre-defined scenario. Prior to the experiment, the participants were provided with some basic instructions for interacting with CollaGIM. There was no instruction on how the individual participants were meant to work or delegate tasks. The aim of the experiment was to obtain metrics that facilitate determining the efficiency, effectiveness and collaborative support provided by CollaGIM. Once the experiment was completed, participants were asked to complete a user satisfaction questionnaire to obtain subjective experience metrics.

5.4.1 Data Collection Methods

The data collection was carried out in the following ways:

- System measured – CollaGIM provided functionality to log participant interactions with the system. The data logged included the number of shared copies and shared updates.
- Task List – A task list was provided to the participants on which they were able to mark off all successfully completed tasks. The principal investigator also had a task list for the participant team on which completed tasks were marked off. After the test was completed, the three lists (two participants and one principal investigator) were compared to ensure correct results were captured.

- Observation – All participant experiments were recorded by an overhead camera (visual and voice). The principal investigator also took notes during the experiment.
- Subjective Evaluation – Participants were required to complete biographical, pre-test and post-test questionnaires.

5.4.2 Metrics

The metrics obtained from experiments allowed for the efficiency, effectiveness and collaborative ability of CollaGIM to be evaluated. The following metrics were therefore used:

- Efficiency – This was measured by ratings given by the participants to certain questions within the post-test questionnaire.
- Effectiveness – The measurement of the task completion rate, i.e. the proportion of tasks successfully completed by the participant.
- Collaboration – This was measured by ratings given by the participants to certain questions the post-test questionnaire.
- User satisfaction. This is measured by ratings given by the participant in the post-test questionnaire.

The above mentioned metrics were collected using the data collection methods identified in Section 5.4.1.

5.4.3 Location and Instruments

The location of the evaluation was in the Usability Lab of the Department of Computing Sciences at Nelson Mandela Metropolitan University (NMMU). CollaGIM was implemented using a large multi-touch tabletop belonging to the Telkom/NMMU Centre of Excellence (CoE). The evaluation was therefore conducted using this multi-touch tabletop device. The usability lab consists of two rooms separated by one-way glass. The participants were situated in the participant room in which they interacted with the prototype and hardware, whilst the principal investigator observed from the observer room. The participants were monitored by an overhead camera that was fed through to the observer room. The participants and the principle investigator communicated through an intercom system when necessary.

5.4.4 Task Plan

The participant teams were provided with a task list (Appendix E) that described the scenario, goal of the exercise and a list of tasks that had to be completed to achieve that goal. Each team member was provided with an identical copy of the task list. The task list comprised four sections that were aimed at accessing the system, finding relevant information, sorting information and collating information into a document. The tasks within each section were asked in a manner such that the participants were required to use all the functionalities available in CollaGIM to complete the task list. The teams were required to decide who was to perform which tasks or who had which role in the team. The task list was provided in the form of a paper document, but CollaGIM did also make provision for an on-screen task list.

5.4.5 Questionnaires

A pre-test questionnaire and a post-test questionnaire were provided to the participants, which they were required to complete. The pre-test questionnaire, which was based on the Common Industry Format (CIF) for usability testing, was used to collect anonymous biographical, demographical and experience information of each participant (NIST, 1999).

The post-test questionnaire was adapted from the Questionnaire for User Interface Satisfaction (QUIS) (Chin, Diehl and Norman, 1988). Additional questions were included to measure the support CollaGIM provided for collaboration. The breakdown of the post-test questionnaire was as follows:

- Cognitive Load
- Overall Satisfaction
- Usability
- Collaboration; and
- General comments

The post-test questionnaire was provided after the participants completed the task list.

5.4.6 Statistics

Statistical analysis was conducted on the raw data obtained from the experiments. Results for all participants were captured into a Microsoft Excel spreadsheet. Descriptive statistics were calculated such as mean and median. The collaborative metrics were also captured and compared to the results to ensure consistency.

5.5 Participants and Selection Criteria

Participants were selected based on their computer literacy (computer courses i.e. WRFC101) and level of computer experience (collected in the pre-test questionnaire). Selected participants were required to work in groups of two to complete a list of tasks based on a provided scenario. Only two participants per group were chosen due to the size limitation of the screens display. The target participant pool was 30 students that made up 15 groups. A convenience sample of students and staff was recruited from the Department of Computing Sciences and other Departments within the Faculty of Science of NMMU since CollaGIM could involve any form of group information.

5.6 Evaluation Procedure

The evaluation procedure of CollaGIM took place in the Usability Lab of the Department of Computing Sciences, NMMU. Participants interacted with the prototype implemented on the multi-touch tabletop. Participants were recorded by an overhead camera. Participants worked in groups of two to complete a set of common tasks (Appendix E). Prior to the actual experiment, the participants were briefed about the functionalities and other relevant details related to interaction and use of CollaGIM (Appendix A and B). The participants were also required to complete an informed consent form (Appendix C) and pre-test questionnaire (Appendix D). Once the formalities were completed, the principal investigator allowed the participants to interact with the prototype until they confirmed that they were ready to begin the test. At this stage the principal investigator left the participants and the experiment began. The participants were required to attempt to complete each task to the best of their abilities as a team. If the participants required assistance, they were allowed to ask for help, and the necessary notes were reflected against the task.

Once the experiment was concluded, the principal investigator re-joined the participants and presented them with the post-test questionnaire (Appendix F). Participants were dismissed once the questionnaire was completed.

5.7 Results and Analysis

This section provides feedback on the results obtained during the evaluation procedure of CollaGIM. The results of the biographical questionnaire are discussed in detail followed by the results of the post-test questionnaire. The post-test questionnaire results are divided and presented into performance results, user satisfaction results, collaboration results, qualitative results and observations.

The observations, collaboration and performance results are presented on a per team basis, whereas user satisfaction and qualitative results are presented on a per individual basis.

5.7.1 Demographics

The evaluation procedure saw fifteen teams of two take part in the experiment (n_{Team} = 15). The biographical questionnaire and post-test questionnaire, were, however completed as individuals (n=30). This section will present the participant and team biographical results obtained from the pre-test questionnaire.

5.7.1.1 Participant Demographics

The participants of the study were selected on a request basis; they were engaged in person within the public area of the Department of Computing Sciences and asked if they would like to participate in the study. The participant was asked to pair up with a colleague with whom they have had working experience. The participants were then asked to complete the biographical questionnaire.

The participant demographical results were split into two figures, one presenting personal results, the other presenting results relating to group work and multi-touch environments.

Figure 5-1 indicates that the majority of the participants were male. Eighty seven per cent of the participant selection had a right dominant hand. The majority of the participants were part of the 21-29 years age group which is expected due to the participants being selected within a university department. Only ten per cent of the participant selection was aged between 30 and 39 years. Ninety seven per cent of the participants were students and only three per cent were academic staff. Participants were asked whether they suffered from any form of colour blindness and the results showed that none of the participants had such a condition. The results showed that fifty seven per cent of the participants had a certified postgraduate degree, whereas only sixteen and twenty seven per cent of participants had a matriculation or bachelors certificate respectively. All participants were computer literate where sixty seven per cent of the participants had been exposed to computers for more than ten years, twenty seven per cent had been exposed between 6-9 years, and only 6% had been exposed for 3-5 years. This correlates with the results that eighty three per cent of participants felt they were experts in the use of computers.

Figure 5-2 shows that the participant selection had a good amount of exposure to teamwork. Over half the participants selected had daily exposure to information sharing as well as to multi-user, collaborative software. All participants had used a multi-touch device and were therefore familiar with touch interfaces, but only seventeen per cent had used large screen technologies.

5.7.1.2 Team Demographics

Figure 5-3 illustrates the team composition based on three different criteria. It was found that 73% of teams consisted of both male participants and only 20% had a mixture of both genders. Education between the team members was a relatively even split with 33% consisting of undergraduates and postgraduates, 40% postgraduates only and the remaining 27% made up of undergraduate only teams. Lastly, 73% of teams consisted of both expert users and only 20% had one expert and one intermediate participant. Seven per cent of the teams had both users with intermediate computer expertise.

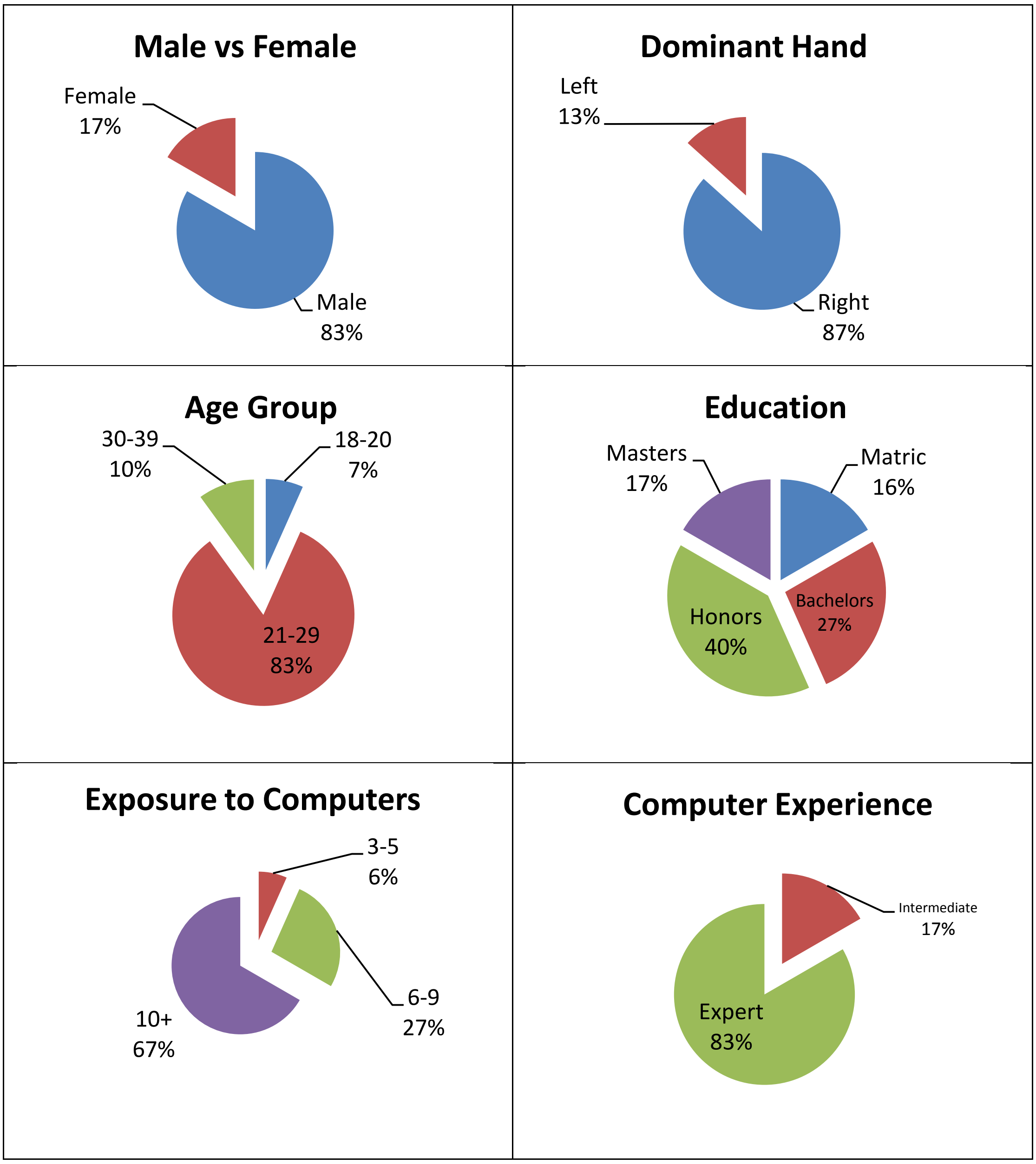


Figure 5-1: Participant Biographical Results - Part 1 (n=30)

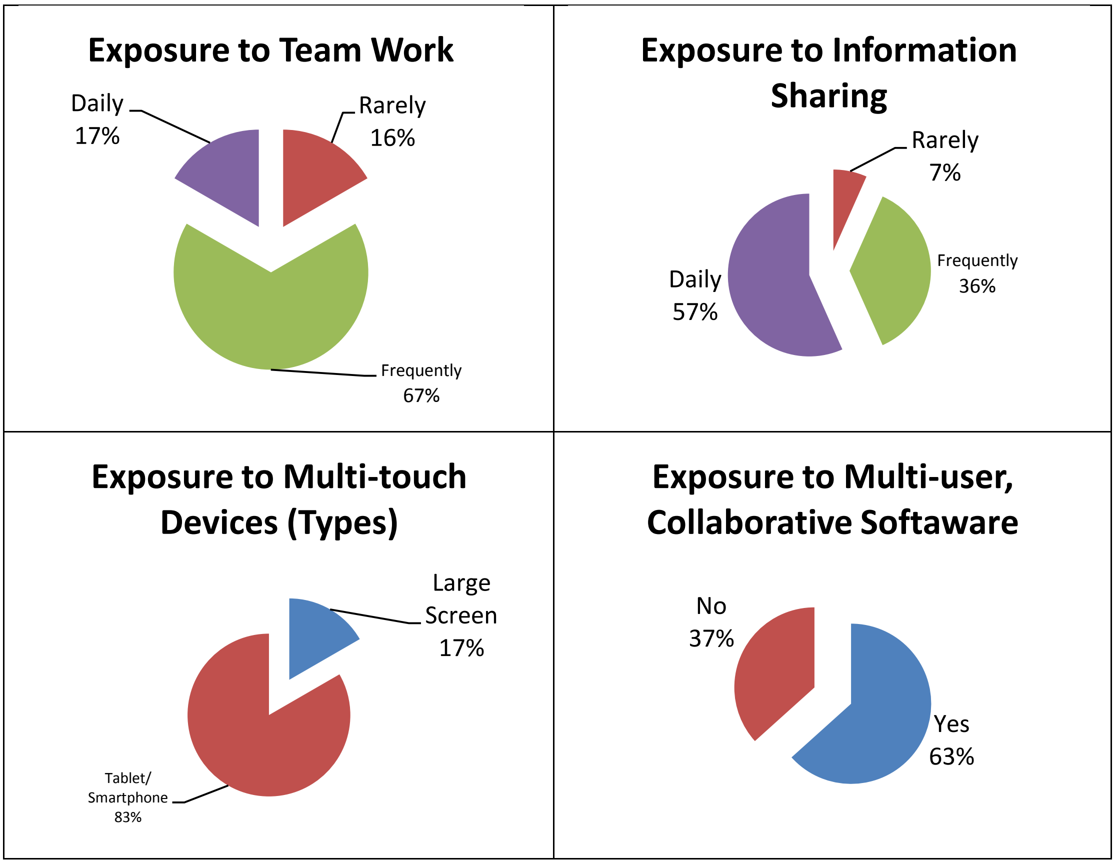


Figure 5-2: Participant Biographical Results - Part 2 (n=30)

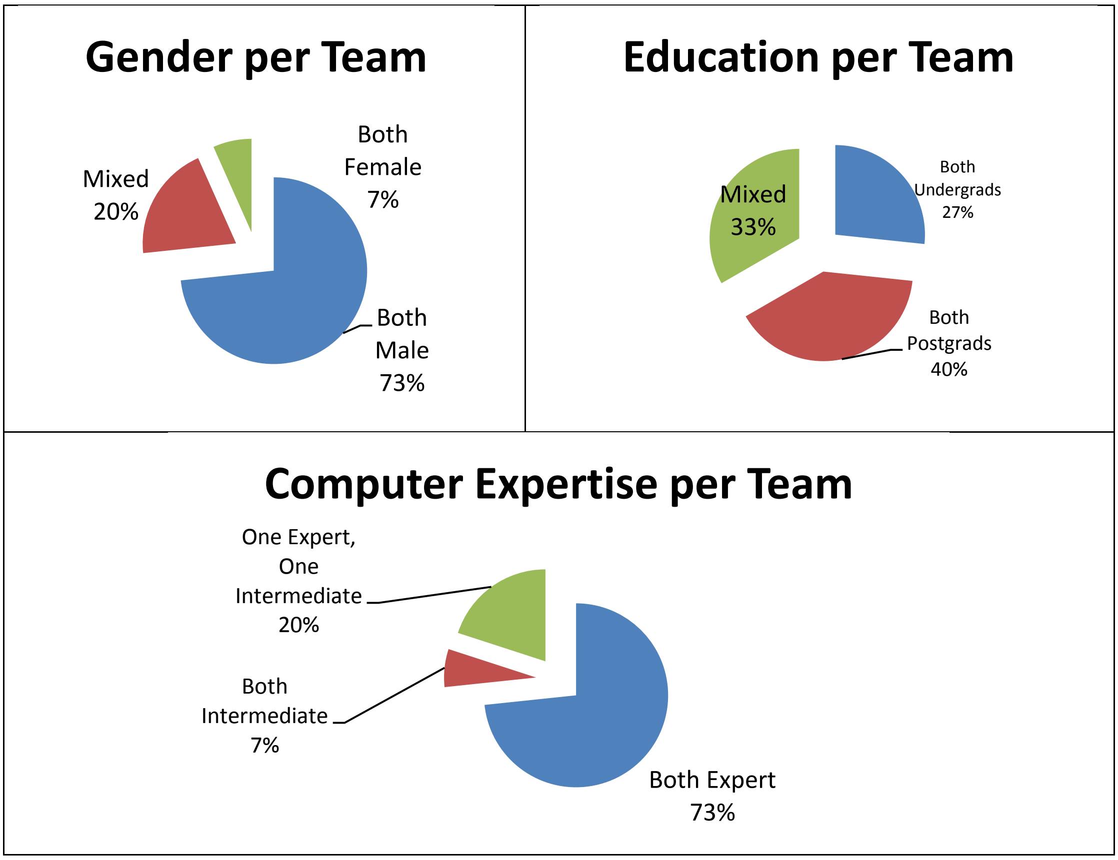


Figure 5-3: Team Biographical Results (n=15)

5.7.2 Performance Results

During the evaluation, it was noted that the time taken on a task is an inaccurate way of measuring performance as the scenario and task list required each team to communicate at will and collaboratively make decisions. Some teams had lengthy discussions about a task, whereas others reached a unanimous decision relatively quickly, therefore no time statistics were taken into account.

The performance results were therefore based on the number of tasks a team successfully completed (n=15). A task was marked as complete when both team members were satisfied and moved on to the next task, irrespective of whether the objective of the task was met or not. A completed task could either be successfully complete, partially complete or incomplete, in which case a value of 1, 0.5 and 0 was allocated to the task respectively. A successfully completed task indicates that the objective of the task was met. A partially complete task indicates that the task objective was met, but all steps were not followed. Lastly, an incomplete task indicates that the objective of the task was not met, and that the team had to move on without completion. Participants were required to indicate the level of completion on the task list by providing a complete tick, half tick or cross.

Figure 5-4 presents the success rate per task for each team that participated in the evaluation. Tasks one, two and three had a one hundred per cent success rate. These tasks included accessing the user’s personal information, finding relevant information and sorting the personal information space and workspace. Task four, relating to the collation of a collaborative document had a 96.67% success rate, where only one team partially completed the task. The overall success rate, taking the combined results of all tasks, was an encouraging 99.17%.

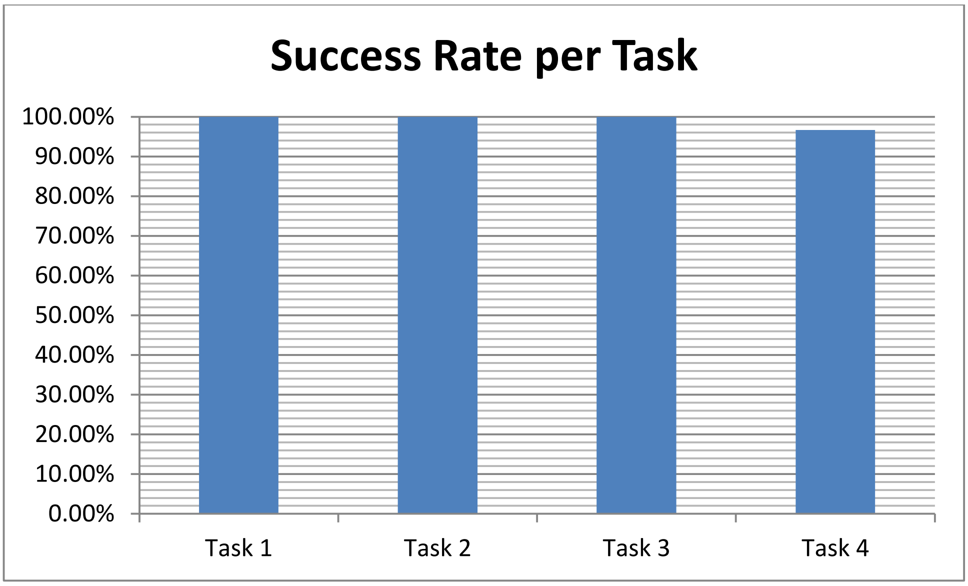


Figure 5-4: Total Success of each Team per Task (%) (n=15)

5.7.3 Satisfaction Results

User satisfaction results were collected using the post-test questionnaire. The questionnaire consisted of a total of 42 questions which were divided into four sections, A - cognitive load, B - overall satisfaction, C - usability and D - collaboration. The questions were answered by indicating a cross on a rating scale using a 7-point Likert scale. The cognitive load section of the questionnaire contained questions that were answered by indicating a value between 1, for very low and 7, for very high. The remaining sections were answered by indicating a value between 1, for "strongly disagree" and 7 for "strongly agree".

The results for questions in Section A were inverted with the exception of question 4, which related to performance. This was done to standardise the results for the entire questionnaire such that values close to 7 indicate positive results.

Cronbach's alpha, a measure of internal consistency, was calculated for each section of the post-test questionnaire to ensure reliability of the results. A common guideline for describing internal consistency using Cronbach's alpha can be seen in Table 5-1.

Table 5-1: Interpretation of Internal Consistency using Cronbach's Alpha (Kline, 1999)

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

The results of Cronbach's alpha are shown in Table 5-2 where Sections B and D both fall in the acceptable region. Section C had an alpha that indicates a good internal consistency. Section A, however, had a poor level of internal consistency and may need to be reassessed in future work. The combination of Sections B, C and D were considered as the overall usability of the system. The overall usability had a good level of internal consistency. The overall reliability of the quantitative results obtained from the questionnaire was calculated as a combination of Sections A, B, C and D. The overall qualitative results are shown to have an acceptable internal consistency.

Table 5-2: Cronbach's Alpha Results for Each Section (n=30)

Section	Cronbach's Alpha – Internal Consistency
A. Cognitive Load	0.57 – Poor
B. Overall Satisfaction	0.74 – Acceptable
C. Usability	0.87 – Good
D. Collaboration	0.79 – Acceptable
B + C + D	0.80 – Good
A + B + C + D	0.74 – Acceptable

Figure 5-5 presents an overview of the user satisfaction results in terms of the mean, median and standard deviation bars of each section of the questionnaire. The overall usability (B + C + D) and overall quantitative results (A + B + C + D) are also shown. The overall quantitative results of the questionnaire show that the mean was just below 6, whereas the median was 6. The standard deviation of the overall quantitative results was 1.01, but this relatively high value is mainly attributed to the results from Section A. The overall quantitative results were therefore very encouraging.

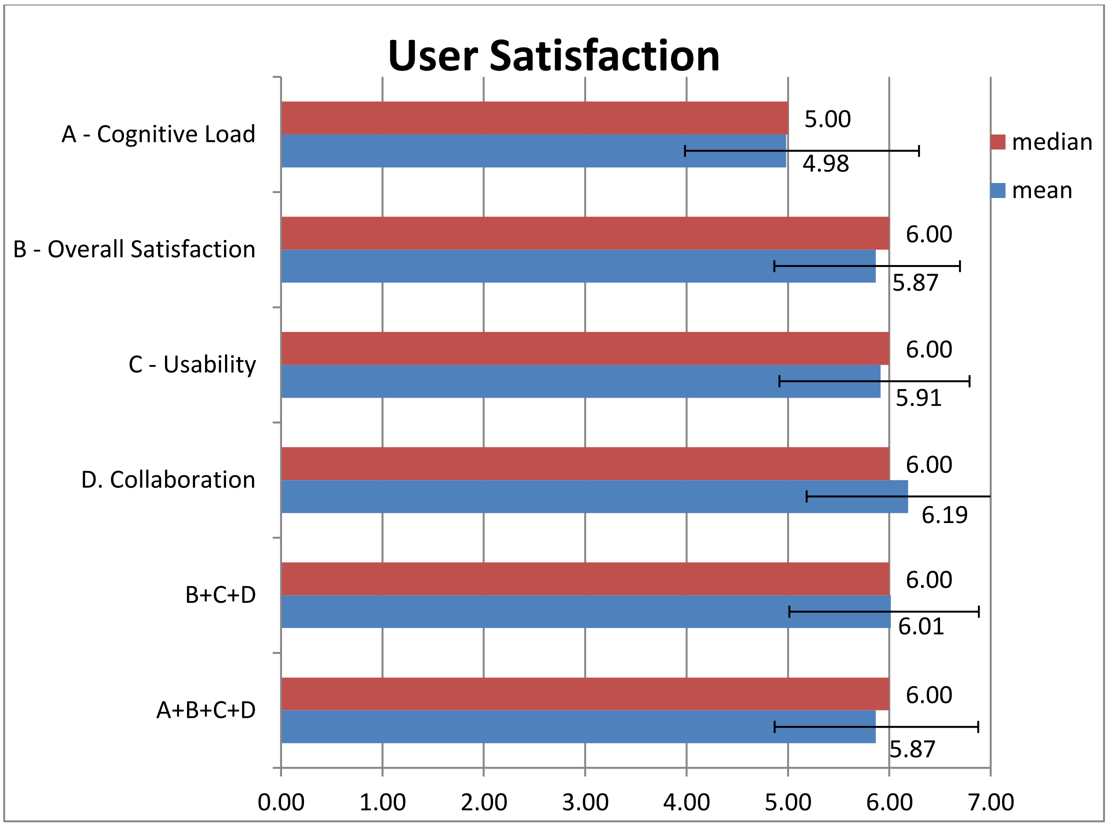


Figure 5-5: Overview of User Satisfaction Results (n=30)

Section A returned fairly positive results with a mean of 4.98. The standard deviation of 1.31 was the highest of all the sections; this indicates that the participants had mixed views on the questions relating to cognitive load. The median for Section A returned a result of 5.00.

The results for Section D indicate that this was the most highly ranked section of the questionnaire with a mean of 6.19. The standard deviation of 0.84 was the second lowest of all sections. The median for Section D returned a result of 6.00. The results for this section are encouraging as a key feature of CollaGIM was to provide collaboration between group members.

Section C was the second most highly rated section with a mean of 5.91. The standard deviation of 0.88 was placed third out of the four sections. The median for Section C was 6.00.

Section B followed very closely after Section C with a mean of 5.87. The standard deviation of 0.83 was the smallest of all the sections. The mode and median for Section B both returned results of 6.00.

The combination of Sections B, C and D, which indicate the overall usability of the system, delivered encouraging results with a mean rating of 6.01. The standard deviation was only 0.87 with the median returning a result of 6.00. The overall usability results were therefore very encouraging.

Figure 5-6 shows the mean results obtained for each question of Section A - cognitive load. The graph is presented with the standard deviation error bars.

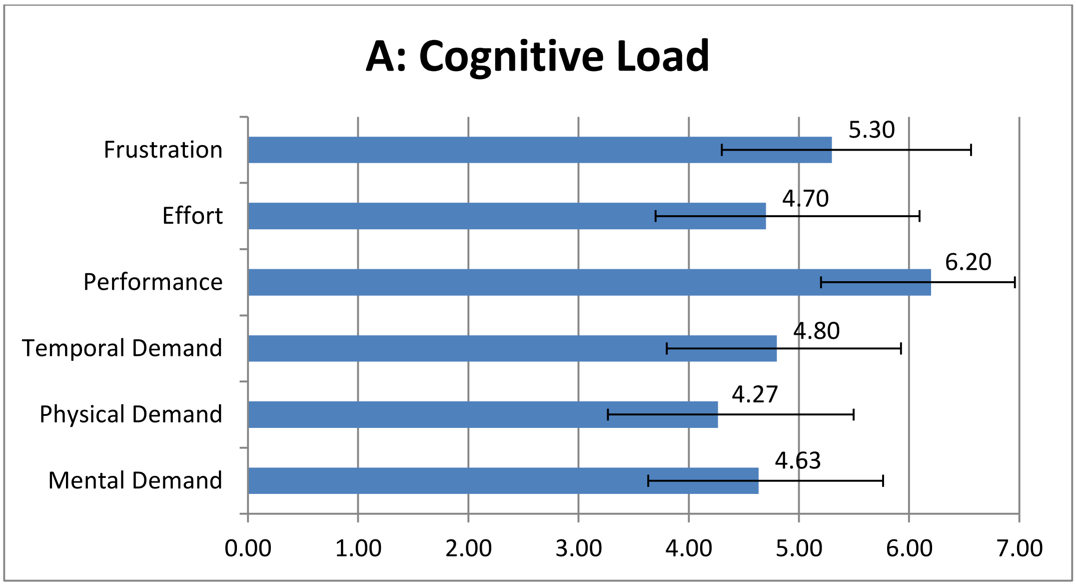


Figure 5-6: Mean 7-point Likert Scale Rating for Section A - Cognitive Load (n=30)

The graph indicates that participants gave the lowest rating to physical demand with a mean rating of 4.27. The question that was posed was:

- *"How physically demanding were the tasks?"*

The mean result is still good and implies that the tasks of CollaGIM were not physically demanding on the participants.

The questions relating to mental demand, effort and temporal demand had mean ratings of 4.63, 4.70 and 4.80 respectively. The following questions were posed to the participants:

- *Mental demand: "How mentally demanding were the tasks?*
- *Effort: "How hard did you have to work to accomplish your level of performance?"*
- *Temporal demand: "How hurried or rushed was the pace of the tasks?"*

These ratings imply that the tasks were understandable, but required the users to think carefully about each task. Participants also felt that whilst using the system, a fair amount of effort was required to achieve their level of performance. The participants were also not very rushed by the pace of the tasks. The results are also likely due to the users having to perform the tasks on a large multi-touch tabletop, which was new to them. The modified and new interaction techniques that the participants had to use may have also contributed to these results. The standard deviation of Section A was quite large compared to the other sections; this implies that although some users experienced a large cognitive load, others did not.

Frustration was the second most highly rated, with a mean rating of 5.30. This implies that users were not frustrated when the used CollaGIM. Performance results were most highly rated with a rating of 6.20. This shows that the participants felt they performed optimally when completing the tasks.

Figure 5-7 shows the mean results obtained for each question of Section B, overall satisfaction. The graph is presented with standard deviation error bars. The overall results obtained from this section are encouraging as the lowest rated question was only 5.67, relating to overall satisfaction with the system. The highest rating of 6.03 was given to learnability, that is, how easy was it to learn the system. The next highest result was for ease of use, 6.00. The results indicate that the participants were very satisfied with how easy it was to learn and use CollaGIM. The question relating to simplicity had the highest standard deviation, but the mean result of 5.77 shows that the design of CollaGIM was very simple. Overall results of satisfaction with the system were very high.

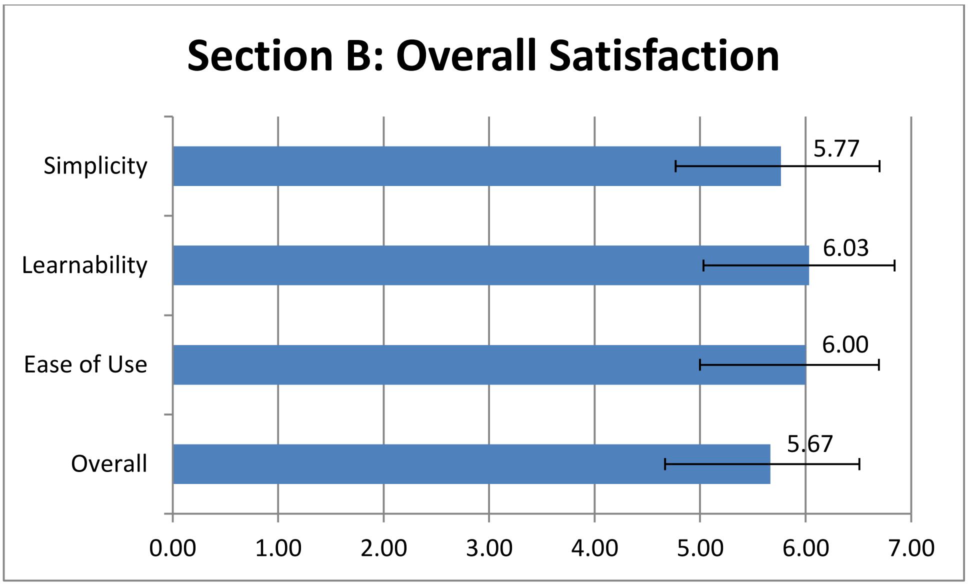


Figure 5-7: Mean 7-point Likert Scale Rating for Section B - Overall Satisfaction (n=30)

Figure 5-8 shows the mean results obtained for each question of Section C - usability. The graph is presented with standard deviation error bars.

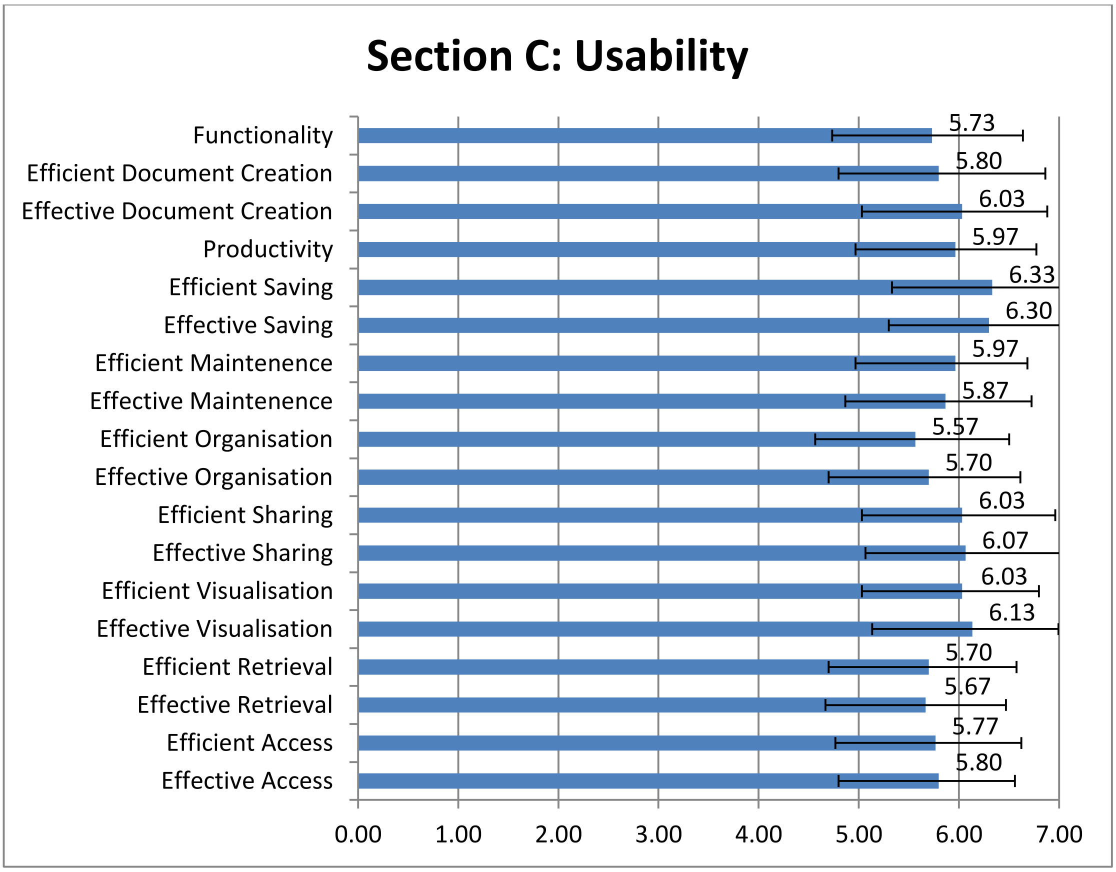


Figure 5-8: Mean 7-point Likert Scale Rating for Section C - Usability (n=30)

The usability section of the questionnaire was designed to gain participant feedback on each task supported by CollaGIM. Two questions based on effectiveness and efficiency of each aspect was asked. Further to the functional aspects of CollaGIM, another question based on the production of a collaborative document was asked. This question was related to the creation of a document. Overall questions based on functionality, productivity, access and visualisation of the system were asked.

Figure 5-8 indicates that no question within Section C had a mean rating of less than 5.50. This implies that CollaGIM had a very high level of usability. The results are explained in terms of the typical GIM tasks and creating the collaborative document followed by the remaining usability questions.

- **Keeping** (saving) – Participants found that they were both highly effective and highly efficient in saving information with a mean rating of 6.30 and 6.33 respectively. This aspect of CollaGIM was most highly rated of all questions and implies that CollaGIM supported the GIM task of keeping information.

- **Finding** (retrieval) – Participants found that they were both effective and efficient in finding information with a mean rating of 5.67 and 5.70 respectively. This aspect of CollaGIM was highly rated and implies that CollaGIM supported the GIM task of finding information.

- **Maintaining** (maintenance) – Participants found that they were both effective and efficient in maintaining information with a mean rating of 5.87 and 5.97 respectively. This aspect of CollaGIM was highly rated and implies that CollaGIM supported the GIM task of maintaining information.

- **Organising** (organisation) – Participants found that they were both effective and efficient in organising information with a mean rating of 5.70 and 5.57 respectively. This aspect of CollaGIM was highly rated and implies that CollaGIM supported the GIM task of organising information.

- **Sharing** – Participants found that they were both highly effective and highly efficient in sharing information between participants with a mean rating of 6.07 and 6.03 respectively. This aspect of CollaGIM was highly rated and implies that CollaGIM supported the GIM task of sharing information.

The results for the questions relating to the typical GIM tasks are encouraging as they show that the functionality developed in CollaGIM met the functionality requirements.

- **Document Creation** – Participants found that they were highly effective and efficient in creating an artefact with a mean rating of 6.03 and 5.80 respectively. The results from creating a collaborative document are very encouraging as it shows that CollaGIM can be used to create a collaborative document in an effective and efficient manner.

- **Accessibility** (access) – Participants found that they were both effective and efficient in accessing the information on the system with a mean rating of 5.80 and 5.77 respectively. This feature of CollaGIM was highly rated and implies that CollaGIM successfully provided access to all information.

- **Visualisation** – Participants found that they were both highly effective and highly efficient in visualising information with a mean rating of 6.13 and 6.03 respectively. This feature of CollaGIM was highly rated and implies that CollaGIM successfully visualised all controls and information.

- **Productivity** – Participants found that they were highly productive with a mean rating of 5.97. This feature of CollaGIM was highly rated and implies that CollaGIM was capable of enabling participants to be productive.

- **Functionality** – Participants found that the functions of CollaGIM met their expectations with a mean rating of 5.73. This feature of CollaGIM was highly rated and implies that CollaGIM successfully met the functional requirements of a GIM system.

The combined results of usability and functionality imply that the functions provided in CollaGIM were well catered for and that the functionality allowed the participants to become quickly productive when using the system. The overall results of the usability section are very encouraging and show that CollaGIM met its usability requirements.

Figure 5-9 shows the mean results obtained for each question of Section D - collaboration. The graph is presented with standard deviation error bars.

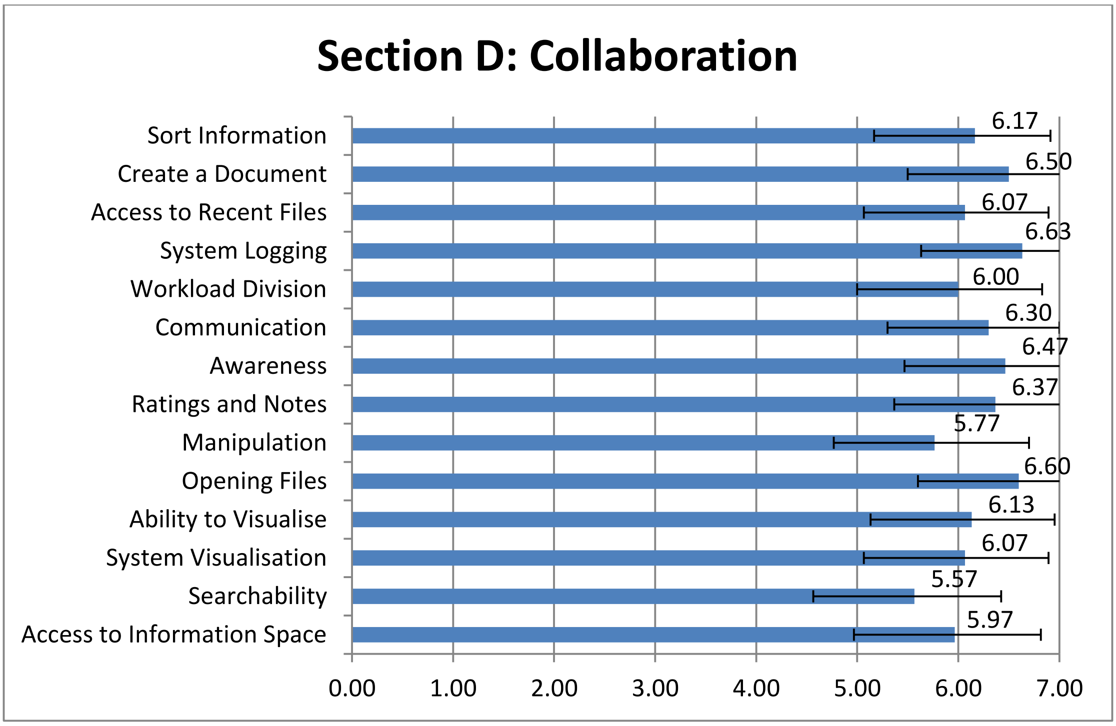


Figure 5-9: Mean 7-point Likert Scale Rating for Section D - Collaboration (n=30)

Some important results from Section D were that communication (6.30) and awareness (6.47) were effectively supported. This is an important result as CollaGIM needed to maintain an effective communication medium and ensure that users are made aware of actions. Being able to collaboratively create a document (6.50) was also highly rated. This is an achievement as the goal of CollaGIM was to support the aspects of keeping, finding, maintaining, organising and sharing information in support of an activity (i.e. creating a collaborative document). The task of creating a document was successfully met.

Participants found that sorting information was highly effective and efficient with a mean rating of 6.17. This provides evidence that the workspace sorter was an effective and efficient tool to sort open information on the workspace.

Participants also found opening and visualising information was highly effective and efficient with mean ratings of 6.60 and 6.13 respectively. This shows that the custom controls developed such as the dashboard, information control and the collaborative document builder were highly effective and efficient in fulfilling their functional requirements.

There were only three questions that obtained a mean rating of just below 6.00, which is highly encouraging. These questions were:

- *"The system effectively provides access to an information space."*
- *"The system enables us to search the information space effectively."*
- *"We could effectively manipulate the visualised objects."*

Although relatively lower than the other ratings, these ratings were still encouragingly high. The lowest rating was given to search ability with a rating of 5.57. This may have been due to the fact that there was no advanced in-depth field search functionality. Manipulation was the second lowest with a mean rating of 5.77. This rating may be relatively lower due to the hardware limitations of the implementation device. It was noted that the device sensors were not completely accurate and may have had a negative effect on this result. Finally, the mean result of 5.97 was given to the accessibility to the information space. This result indicates that the participants had sufficient access to the information space.

5.7.4 Qualitative Feedback, Observations and Implications

The qualitative results were recorded using two methods. The first method was allowing the participants to provide feedback through the questionnaire. The participants responded to four qualitative questions, which asked the participants to list the most positive aspect of the system, the most negative aspect of the system, any general comments or suggestions, and for any further remarks. This method highlights the qualitative feedback from the participant's point of view. The second method was by means of observing each team interact with the system during the study. The observer noted all issues while interacting with the system and misconceptions that the participants had. This method highlights the qualitative feedback from the observer's point of view.

The qualitative results were analysed using thematic analysis and are presented in two different subsections based on the two different collection methods.

5.7.4.1 Questionnaire Feedback

This section will present the qualitative results obtained from the questionnaire. The results were split into positive and negative themes. Suggestions for improvement received from the participants are also presented.

Table 5-3 presents the positive themes identified from the participants' feedback obtained from the questionnaire. The results are displayed in themes with a corresponding frequency of how many times this particular theme occurred. Examples of the comments are also shown.

The result shows that thirty per cent of participants mentioned that the system was of good quality. One participant went as far to say that the program is so brilliant, that it would be a good idea if people in industry tried out the system. The system visualisation also received positive feedback as thirty per cent of participants provided positive comments relating to this aspect. One participant mentioned that the system was an excellent visual representation for collaborative work.

Twenty seven per cent of participants commented that the system was very easy to use, with one user mentioning that it makes life much easier when working with documents and images. A further twenty seven per cent of participants appreciated the collaboration support that the system provides. Specific mention was made of the collaborative document builder being very useful and that the system encourages collaborative work. This result is particularly positive as it provides support that the collaborative document builder is an effective way to create a collaborative document using CollaGIM.

Table 5-3: Positive Themes Identified from Participant Feedback

Theme	Category	Freq. %	Examples of Comments
Good System	Usability	30%	*"It's a brilliant program and would be good if people in industries tried it out."* *"The system works great."*
Good Visualisation	Usability	30%	*"Item visualising was great and easy to find them on workplace."* *"Very great visual representation for collaborative work."*
Easy to use	Usability	27%	*"The system was easy to use."* *"Makes life much easier when working with documents and images."*
Supports Collaboration	Functionality	27%	*"The system provides collaboration and encourages us to work as a pair together."* *"Document builder is useful."* *"Good, simple, useful system for collaboration."*
Easy Sharing	Functionality	23%	*"Sharing of files between workspaces is quick and easy."*
Fun /enjoyable	Usability	23%	*"A very useful and powerful tool which can make working in teams easier and more fun."*
Intuitive	Usability	13%	*"The system is a touch based system, therefore interaction is through touch, this allowed for easy gesture based interaction."*
Learnability	Usability	13%	*"Easy to learn."*
Simplicity	Usability	13%	*"The system simplifies most aspects with regards to workspace, functioning and visual aspects. It is simple to use and hence its positivity."*
Efficiency	Usability	7%	*"Did not require much time to complete tasks."*
Good Feedback	Functionality	7%	*"Reflecting the last action (feedback)."*
Saving	Functionality	3%	*"Saving the ratings and notes automatically"*

Twenty three per cent of participants commented that sharing was made particularly easy by being able to simply drag and drop information between information spaces. This is encouraging as a key aspect of GIM is providing an effective and efficient mechanism to share information. The system was also rated fun and enjoyable with twenty seven per cent of participants mentioning this in their comments.

Other positive remarks included the intuitive nature of the system as well as how simple and easy it was to learn the system. The system was also mentioned to be efficient and provided good feedback. Automatic saving was also mentioned to be a positive aspect.

Table 5-4 presents the negative themes identified from the participants feedback obtained from the questionnaire. The results are displayed in themes with a corresponding frequency of how many times this particular theme occurred. Examples of the comments are also shown.

Half the participants commented on the limitations of the touch device itself. They were not impressed with the touch sensors as touch gestures were recognised when paper and clothing touched the display. This led to confusion as objects moved without the participant's awareness. The touch sensor also caused gestures such as dragging and dropping an object to be cancelled without the user intending to do so. A participant stated that the touch sensitivity is poor and that it negatively affects the performance of the system. It should be noted that the limitations of the touch sensor is not related to the design of the system. Perhaps a better touch device should be used for future work.

Twenty per cent of participants commented that feedback was not sufficient when performing a save and when sharing is complete. A participant indicated that the team was unsure whether a file was successfully shared or not. Feedback is provided to the participants through the "last action" notification available on the participant's dashboard. This notification may need to be emphasised more by providing some animation to the notification.

Table 5-4: Negative Themes Identified from Participant Feedback

Theme	Category	Freq. %	Examples of Comments
Touch Sensor/Device	Usability	50%	*"The sensitivity of the touch screen was a bit problematic."* *"The touch sensitivity is poor; it negatively affects the performance of the system."*
Feedback	Usability	20%	*"It would be good to provide feedback once a file has been shared to another workspace."* *"Better feedback for saving."*
Clutter	Usability	20%	*"Main widget is hidden if screen becomes cluttered."* *"Get cluttered and messy when more documents are open on the screen."*
Gestures	Usability	17%	*"When working with a text/document the window is hard to resize."* *"The system accidently selected items below the ones we dragged."*
Keyboard	Usability	10%	*"Typing was difficult."* *"The keyboard input wasn't friendly."*
Visualisation	Usability	10%	*"Document thumbnail has no text."* *"When opening options on top-left of item, moves off-screen if close to edge."*
Document Builder	Usability	10%	*"It was kind of hard to insert information into the document builder. Sometime information would go into the incorrect section."*
Deleting	Functionality	7%	*"Deleting was a bit problematic."*
Sharing	Functionality	7%	*"When sharing files, it wasn't instant."*
Learnability	Usability	3%	*"Needs time to get used to it."*
Annotation and Rating	Functionality	3%	*"Annotation and rating on text documents are not relevant."*

Clutter was mentioned as a concern by twenty per cent of the participants. Some participants experienced the main widget being lost when many files were open on the tabletop. Other participants mentioned that the workspace became messy when more files were open.

Concerns relating to certain gestures were made by seventeen per cent of the participants. A participant mentioned that the gesture to zoom-in and out of a document file was particularly difficult. This was due to the text of a document being pannable when selected. The participants were only able to zoom-in and out of a control along the border of the text information control. Other participants mentioned that dragging and dropping would sometimes select other objects whilst dragging. This was mainly due to the touch sensor not recognising gestures correctly.

Other negative themes identified were related to the keyboard used for text input. Three per cent of participants mentioned this as a negative aspect. Visualisation of a document in miniaturised mode was negatively commented on as a thumbnail with no relevance to the text was displayed. Three per cent of participants found it difficult to move information around within the document builder. Other minor comments related to sharing, learnability, annotating and rating.

Suggestions made by participants are seen as an important way to get ideas for future work. Several suggestions were made and grouped into relevant sections. Some design suggestions made by participants include the following:

1. *The rating slider handle should be enlarged to cater for touch.*

   Addressing this issue was deemed important as CollaGIM is a fully touch interactive system. This issue could be addressed by resizing the surfaceSlider control which should improve touch accuracy.

2. *The main widget should be in a fixed place (e.g. like a menu bar)*

   This was not seen as an appropriate suggestion. The reason being that the multi-touch tabletop caters for users sitting around the table and therefore viewing the system from different perspectives is required. The main widget was designed such that all users are able to move it to a convenient location and lock it in place.

3. *Improve on graphics*

   This suggestion was not regarded as important as the aim of CollaGIM was to serve as a prototype to prove the thesis statement identified in Chapter 1. The use of better graphics would improve the system aesthetically, but would not have any effect on usability and functionality.

4. *Colour identification scheme should cater for a wider variety of colours*

This suggestion was not considered as important as the evaluation procedure only involved two participants at a time. A variant of eight colours were available to the participants and were more than sufficient. This suggestion would have no impact on the overall usability and satisfaction results.

5. *When logging in to the system, a chosen colour should be disabled*

This suggestion was considered important as colour was used to indicate ownership of objects on the workspace. Without disabling currently selected colours, other users have a chance to select the same colour. This issue could be addressed by disabling a colour on all login controls when a user has successfully logged in with a colour. This ensures that all users have unique colour identifiers.

One participant suggested testing the system on a larger touch display. Suggestions were also made regarding the touch sensor with seventeen per cent of participants suggesting new hardware. A participant suggested keeping the participants aware by keeping an active log open on the tabletop. Two participants suggested the system cater for accessing the Internet which may be a viable suggestion for future work. A suggestion was made that shared files should appear in the received folder as well as the relevant destination folder. This suggestion can be implemented and tested in future work.

5.7.4.2 Observations

Observation notes were made by the observer whilst a team was participating in the study. There may be a correlation with the themes identified in Section 5.7.4.1. The observation notes present some issues, misconceptions made by the participants and other relevant observations.

The design of CollaGIM incorporated an on-screen task list with the aim of eliminating the use of a paper-based task list. The participant were allowed to decide what form of task list they wanted to use and the study showed that no participants opened the on-screen task list. Perhaps for future work, the availability of the on-screen task list should appear on the dashboard itself or not be included in the system at all.

Three misconceptions appeared when participants interacted with the information controls and its minimised form. The following list describes these misconceptions:

1. Participants initially attempted to drag the whole information control to share or add to the document builder and not the thumbnail.
2. Participants initially attempted to drag the miniaturised item to share or add to the document builder.
3. Participants expected a tap or double tap gesture to maximise a miniaturised item.

These observations have some validity and may be considered for future work. By implementing these expectations, the results might show an improvement in ease of use.

The document builder appeared to have some issues and misconceptions. One issue was that when participants were attempting to drop information into the builder, the list view did not correctly update the drop location. This issue was not widespread. The misconception was that participants thought that they should be able to move information within the document builder from the list view. This misconception should be implemented in future work and may have a positive impact on a user’s experiences.

The last action bar updated all information correctly, however, there was not enough feedback to notify the users to its latest update. Perhaps in future work, an animation may be used to better notify the users.

The workspace sorter makes use of a long press gesture to sort the entire workspace of open files. This gesture was accidently invoked several times during the study. This was due to users maintaining a hold gesture whilst looking at the task list. Perhaps the long press gesture should only be allowed to be invoked when the workspace sorter control is open on the workspace. This will reduce the chance of erroneously invoking the gesture. There was some confusion between the workspace sorter and personal space sorter, this confusion may be related to the learning curve of adapting to CollaGIM.

When the keyboard was enabled for text input, the participants expected it to close when the enter key was pressed. There were issues with deletion as mentioned under the negative themes of Section 5.7.4.1. The touch sensor also contributed to a lot of frustration from the participants. Clutter was also noted to be a concern as several participants did not make use of the snap-to-minimise gesture for clutter avoidance.

5.8 Conclusion

This chapter described the evaluation of CollaGIM with the aim of confirming the thesis statement identified in Chapter 1. The evaluation also assessed the usability and usefulness of the CollaGIM system. An investigation into the possible evaluation techniques was conducted and it was identified that a user study combined with pre and post-test questionnaires and observations should be employed. The evaluation of CollaGIM involved 30 participants being paired in groups of two, in which each team was provided with a pre-test questionnaire, scenario and task list. The teams were required to complete several tasks using CollaGIM. Once the tasks were completed, participants completed a post-test questionnaire. The results identified that CollaGIM obtained very high levels of performance, user satisfaction, efficiency and effectiveness.

Results showed a 99.17% overall task completion rate, which clearly indicates that participants were able to perform tasks efficiently and effectively. This also positively indicates that GIM activities can be supported on a multi-touch tabletop.

The overall user satisfaction of the questionnaire returned positive results with a mean rating of 5.87 across all sections of the questionnaire. This implies that an average of 5.87 was given to all questions in each section of the questionnaire and therefore, implying that the participants were highly satisfied with the system and its functionality.

The combined usability which only considers results from the user satisfaction, usability and collaboration sections of the questionnaire returned with a mean result of 6.01. This result is very positive as it implies that CollaGIM was both highly effective and efficient. The high mean usability rating suggests that the participants could perform all the aspects of GIM in support of creating a collaborative document.

Qualitative feedback highlighted some positive results where participants mentioned that the system was highly fun and easy to use. Participants also mentioned that CollaGIM supports collaboration in a positive way and that the collaborative document builder is an effective way to create documents.

The majority of the negative themes from the qualitative feedback were related to the touch device itself. The touch sensor was ineffective and caused frustration. Several of the participants mentioned that the device was problematic and negatively affected the prototype.

Observations were made that highlighted issues and misconceptions that participants had with CollaGIM. The most common misconception was that participants thought that they could share and add information to the document builder by dragging and dropping the entire object. This was not the case as the software only allowed sharing and adding to the document builder by dragging and dropping a thumbnail. The small thumbnail was used so that the entire object is not displaced, and the relatively large size of the object does not obscure other objects while adding to the document builder. These misconceptions could be addressed in future work, which may have a positive effect on intuitiveness.

Overall, results obtained from the evaluation determined that CollaGIM could effectively support GIM tasks using multi-touch interaction techniques on a tabletop.

The next chapter concludes this dissertation by identifying the contributions made by this research. In addition, several points are discussed and presented for possible future work.

Chapter 6: Conclusions and Recommendations

6.1 Introduction

The primary objective of this research was to design suitable interaction techniques to support co-located Group Information Management (GIM) on a co-located, multi-touch tabletop. This chapter addresses the fifth and final research question by discussing the research contributions and recommendations for future work.

This chapter begins by discussing the achievements of this research in relation to the research objectives identified in Chapter 1. Insight into the theoretical and practical contributions of this research are provided, followed by a discussion of the limitations and problems experienced while conducting this research. The chapter concludes by identifying suggestions for future work.

6.2 Achievements of Research Objectives

The literature study showed that GIM is currently not effectively supported in a co-located environment. The typical requirements and tasks of a GIM system were determined and mapped to multi-touch interaction techniques, because multi-touch interaction on a tabletop was identified as a possible means to address the limitations of remote GIM. Remote GIM systems face the issue of asynchronous communication whereby misinterpretations and data loss may occur. Another concern was limitations in how information was shared. Existing sharing mechanisms have limitations in terms of file size, security and accessibility. The primary research objective of this research was therefore to investigate how to design co-located, multi-touch interaction techniques to effectively support GIM on a tabletop. The following secondary research objectives were derived to fulfil the primary research objective:

1. *To identify the shortcomings of existing collaborative GIM tools (Chapter 2).*
2. *To determine what co-located, multi-touch interaction techniques need to be designed to effectively support GIM on a tabletop (Chapter 3).*

3. *To design and develop a GIM prototype using co-located, multi-touch interaction techniques to address the shortcomings of existing GIM tools (Chapter 4).*
4. *To evaluate the benefits of using co-located, multi-touch, interaction techniques to support GIM on a tabletop (Chapter 5).*
5. *To make recommendations for additional research to improve the proposed multi-touch interaction techniques for GIM (Chapter 6).*

A literature study was conducted to understand the field of GIM. GIM was found to be an extension of PIM where the core aspects are keeping, finding, maintaining, organising and sharing of information. Several types of application domains of GIM were identified and discussed in Section 2.3. An investigation into how groups share information was conducted and studies showed that all the methods either used an asynchronous means of communication or none at all. The disadvantages of these sharing methods were presented in Table 2-3.

The key features of GIM were identified using an existing model of GIM. These features helped identify typical issues faced by GIM applications and enabled possible suggestions to be made to address these issues (Section 2.4). The core aspects of GIM were used to identify functional requirements and interaction tasks for a typical GIM system. The non-functional requirements such as usability, simplicity and ease of use were identified as very important. An investigation into available tools that support co-located GIM revealed that only one system, called Focus, had the minimal functionality to support co-located GIM. The functionality that Focus provided was mapped to the identified functional requirements of GIM in Table 2-5. Focus was found to be lacking in functionality as it did not allow for a collaborative document to be produced, hence the rationale for further investigation into the research area. GIM is conducted in support of a collaborative task and Focus does not allow for any collaborative task to be achieved. The collaborative document builder will fulfil the requirements of a typical GIM system. These findings addressed the first research objective by identifying the shortcomings of existing GIM tools.

Multi-touch technologies were investigated in Chapter 3 as a possible means of supporting GIM in a co-located environment. A generic multi-touch interaction technique was described in Figure 3-1 as the combination of a gesture that is invoked on a control to support a task. It was established that multi-touch interaction techniques provide a more natural and intuitive way of interacting with computer technology. The multi-touch tabletop itself has benefits that naturally support group meetings as individuals can position themselves around a table and communicate face-to-face. The tabletop also eliminates the issue of asynchronous communication (data leaks and misinterpretations) discussed in Chapter 2.

Existing gestures such as drag, resize, rotate, tape, sweep and flick were identified in Table 3-1. These gestures could be combined into new compound gestures to support specific tasks of GIM. This was required as the simple gestures were not capable of supporting some of the advanced tasks of GIM, such as creating a collaborative document and sorting the workspace. An investigation into existing multi-touch applications was conducted and a set of design recommendations were identified: the user interface should not use existing Windows user interface (UI) metaphors, the workspace should span the entire display, custom controls to support specific GIM tasks were required, the use of an on-screen keyboard was necessary, and a means of user identification was important. These recommendations were summarised in Table 3-2.

Section 3.6 provided the potential benefits of using multi-touch interaction techniques to support co-located GIM. Section 3.6 also identified existing interaction techniques that were used in similar systems. These techniques were summarised in Table 3-3 using the three components of a generic interaction technique and mapped to the tasks of GIM that they can support. Several existing multi-touch interaction techniques did not conform to the design recommendations identified in Table 3-2 and therefore had to be modified. Several tasks of GIM also required new multi-touch interaction techniques. Table 3-4 summarises the tasks of GIM that require modified and new multi-touch interaction techniques.

New multi-touch interaction techniques were required to support collaborative document building and effective workspace sorting, to name but a few. This chapter identified the potential use of multi-touch interaction techniques to support co-located GIM, thereby achieving the second research objective of determining what multi-touch interaction techniques could be designed to effectively support co-located GIM on a tabletop.

An architecture to support co-located GIM using multi-touch interaction techniques was proposed in Chapter 4. The architecture was based on the model-view-controller pattern. The architecture illustrated how raw touch data is received and passed between layers to provide functionality. It showed how the touch data is recognised as gestures, which are used to manipulate controls. The controls were populated with information from the model layer and presented in the view layer. The different control classes were identified and mapped to functionality that would achieve the functional requirements of a GIM system as identified in Chapter 2 (Table 4-1). The proposed data design of the system was discussed which identified custom controls to support the tasks of GIM. The custom controls such as the dashboard, information control and collaborative document builder were mapped onto the tasks of GIM (Table 4-1). Critical data fields were identified that needed to be under constant synchronisation across the different control classes to ensure that consistent data is displayed (Table 4-2). The user interface design of each control was discussed in detail, illustrating the graphical interface, functionality and relevant gestures. The controls were designed using combinations of existing, modified and new multi-touch interaction techniques. The new and modified multi-touch interaction techniques that were used to support the tasks of GIM were identified in Table 4-3.

The dashboard was designed using a libraryContainer from the Surface 2.0 software development kit (SDK) to store and visualise files. The dashboard allowed users access to their personal information space and effectively and efficiently allowed them to browse, open and share files. The collaborative document builder was designed using the similar vertical page view as seen in Microsoft Word and Google Docs. The collaborative document builder allowed users to collaboratively compile documents with the support of GIM activities. The collaborative document builder made use of new compound interaction techniques to support several functions such as adding, moving and deleting information. The workspace sorter also made use of compound gestures to sort all the open files on the workspace. The workspace sorter allowed users to sort all open files on the workspace in an effective and efficient manner. The workspace sorter was built using touch controls to select the workspace sort criteria and a long press to invoke the sort operation. These compound gestures were specifically developed to support co-located GIM activities.

A prototype named CollaGIM (Collaborative Group Information Management) was developed using the proposed design guidelines. To allow for convenient evaluation, CollaGIM was developed to support GIM activities that would typically take place in an academic institution. The typical output from conducting GIM activities in an academic institution are collaborative documents or articles. The collaborative task that CollaGIM supports is therefore the construction of a collaborative document.

CollaGIM allows users to keep, find, maintain, organise and share personal and group information. The information can be sorted within the personal and group workspace. Information can be easily shared by dragging and dropping it into another user's dashboard, his/her personal information space.

Documents are created using the collaborative document builder. Users may add information to the document by dragging and dropping information within it. The document builder makes use of several steps to add information. These steps were aligned with the overall design and are as natural and intuitive as possible. In-depth information on how each component of CollaGIM was implemented to support the typical GIM functionalities was discussed in Section 4.4.2. The design and implementation of CollaGIM met the third research objective by using multi-touch interaction techniques to support the GIM activities of keeping, finding, maintaining, organising and sharing information as well as being able to combine these tasks to produce a collaborative document.

CollaGIM was evaluated to determine how well the multi-touch interaction techniques can support GIM in a co-located environment. The metrics used to evaluate CollaGIM were effectiveness, efficiency, collaboration and user satisfaction. A user study was used to conduct the evaluation. Participants in the study were required to complete a pre- and post-test questionnaire. The post-test questionnaire made use of a seven-point Likert scale to rate the system. There were also four questions for obtaining qualitative feedback from the participants. Observation notes relating to system issues and misconceptions were taken by the observer who conducted the study. Performance and user satisfaction metrics were calculated.

Thirty participants evaluated CollaGIM in groups of two due to the limitations of the size of the display. The participants were selected from a convenience sample of students and academic staff from the Faculty of Science at Nelson Mandela Metropolitan University (NMMU).

Results from the evaluation showed that CollaGIM was highly effective and efficient in supporting co-located GIM with multi-touch interaction techniques. The task success rate of the overall study was 99.17%. The post-test questionnaire yielded a mean rating of 5.87 (max = 7.00) for all sections of the questionnaire combined. The overall usability results, which included the sections for overall satisfaction, usability and collaboration, yielded strongly positive results with a mean rating of 6.01 (max = 7.00). Qualitative feedback from the participants showed that the usability of CollaGIM was high and that it effectively supported collaboration. Specific mention was made of the simplicity and usefulness of sharing and creating documents in the collaborative document builder. Some valuable suggestions were made by the participants, which related to upgrading the multi-touch hardware, but some software recommendations were also made. The evaluation process allowed for several suggestions and improvements to be made for future work. The evaluation and results obtained addressed the fourth research question by evaluating and identifying the benefits of using co-located, multi-touch interaction techniques to support GIM on a tabletop.

This chapter will address the fifth and final research question by discussing the research contributions and recommendations for future work in the following sections.

6.3 Research Contributions

The research contribution of this research project can be divided into both theoretical and practical contributions. These contributions are discussed separately in this section.

6.3.1 Theoretical Contributions

The main theoretical contribution of this research project was showing that multi-touch interaction techniques could be designed to support co-located GIM. The evaluation results provided empirical evidence that by using multi-touch interaction techniques for co-located GIM, a highly effective and efficient group working environment can be achieved. The results showed that a multi-touch GIM system can provide several benefits such as high levels of performance, user satisfaction, learnability and enjoyment in use. With the implementation of CollaGIM, it was established that integrating GIM with multi-touch interaction techniques is feasible and can form a basis for other developers to apply the new interaction techniques to similar tasks.

Existing multi-touch interaction techniques were identified and discussed in Chapter 3. The realisation that the current interaction techniques are too simple to perform some of the advanced tasks of GIM, led to the design of new multi-touch interaction techniques. The collaborative document builder was created to support collaborative document creation and editing by a group of individuals as GIM activities were required to support a task. This document builder is the first of its kind to be developed for a multi-touch surface and the evaluation results showed that it is an effective way to collate high level documents by adding, moving and deleting information.

The idea of simply dragging and dropping files from one user's personal information space to another's with a single gesture on a multi-touch tabletop proved to be a highly effective and efficient means of sharing information. The evaluation results confirmed this with mean results from the Usability Section for effectively and efficiently sharing information of more than 6.00 (out of a maximum of 7.0). The workspace sorter was also found to be an effective and efficient way of sorting open files on the workspace.

6.3.2 Practical Contributions

The main practical contribution of this research project was the design and implementation of CollaGIM, a co-located GIM prototype that is supported by multi-touch interaction techniques to meet the requirements identified in Table 2-5. This prototype could be used by any group of individuals to collaboratively keep, find, maintain, organise and share information in order to create collaborative documents. The evaluation, which tested CollaGIM, returned highly positive results and at the same time showed that CollaGIM is a productive system. CollaGIM is therefore the main practical contribution resulting from this research project.

CollaGIM was designed and implemented using a Model-View-Controller (MVC) pattern architecture. The design has basic controls that perform certain functions. These controls are not limited to a particular domain. The controls were designed and developed using Windows Presentation Foundation (WPF) with a C# code backbone. They provide a base library for other developers to use as a foundation to build other related applications. The library can be easily integrated with other multi-touch applications supporting WPF or C#. The controls can also be modified to improve functionality or ease of use. This library of controls is the second practical contribution resulting from this research project.

6.4 Limitations and Problems Encountered

A number of problems were encountered when conducting this research. Developing a multi-user, multi-touch application required several data fields to be kept constantly synchronised (Table 4-2). A constant link between user controls had to be established to allow for correct information to be displayed. Another issue arose when designing the collaborative document builder. Since there were no interaction techniques or guidelines for adding, moving or deleting information from a document on a multi-touch surface, the collaborative document builder had to be developed from scratch. The initial design deviated from the design guidelines identified in Table 3-2 by only allowing information to be added, moved and deleted using buttons. Thereafter, a more natural and intuitive design was created as shown in Figure 4.10. Results showed that this design was an effective and efficient way of collating high level documents. The lack of multi-touch controls also proved to be a problem, which resulted in custom controls (e.g. collaborative document builder, dashboard and workspace sorter) being designed.

The following two research limitations were identified:

1. The prototype was limited to being deployed on the only large, multi-touch device available in the research lab. This device occasionally proved to be problematic during the evaluation as the sensor had difficulty recognising touch points and gestures. The upgrade to a newer multi-touch device should have a positive impact on user experience and satisfaction.

2. The interaction techniques and architecture were only tried and tested in the CollaGIM prototype. More benefits may be identified if the proposed multi-touch interaction techniques are incorporated into other GIM or related systems.

6.5 Future Research

Several opportunities for future work were identified based on the results of this research. The immediate work that can be conducted is the improvement of CollaGIM based on the suggestions made in Section 5.7.4. Improving CollaGIM, and re-evaluating it with a wider selection of participants, could provide more insight and conclusive results.

The design of the CollaGIM system used colour identification to provide a sense of ownership to the users. Colour identification, however, does not prevent users from interacting with other user's controls. Future work may be conducted, which prevents users from interacting with other user's information. This could be achieved by using overhead cameras, together with facial recognition software, to detect and identify users. The cameras would track each user and communicate with the system as to whether a user is allowed to interact with a specific object (including controls) displayed on the tabletop. This could increase the privacy and security levels of CollaGIM and improve the usability of the system.

CollaGIM made use of direct manipulation multi-touch interaction techniques. Since the library of CollaGIM can be easily integrated into other applications, future work could include enabling users to conduct GIM proximally. This would allow users to be tracked within a certain proximity to the multi-touch tabletop and enable users to interact with group information using air gestures recognised by advanced sensors such as the Microsoft Kinect.

Groups within an international company might have to conduct group activities with groups from other locations. The goals of these groups will be aligned and could therefore provide an opportunity for future work. Utilising CollaGIM in distributed locations and creating a link between the two groups within CollaGIM might support new ways of group information management. This approach would incorporate both co-located and distributed environments. Future research in the field of co-located, distributed GIM could produce some interesting results.

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Appendix A: User Study Written Information Provided

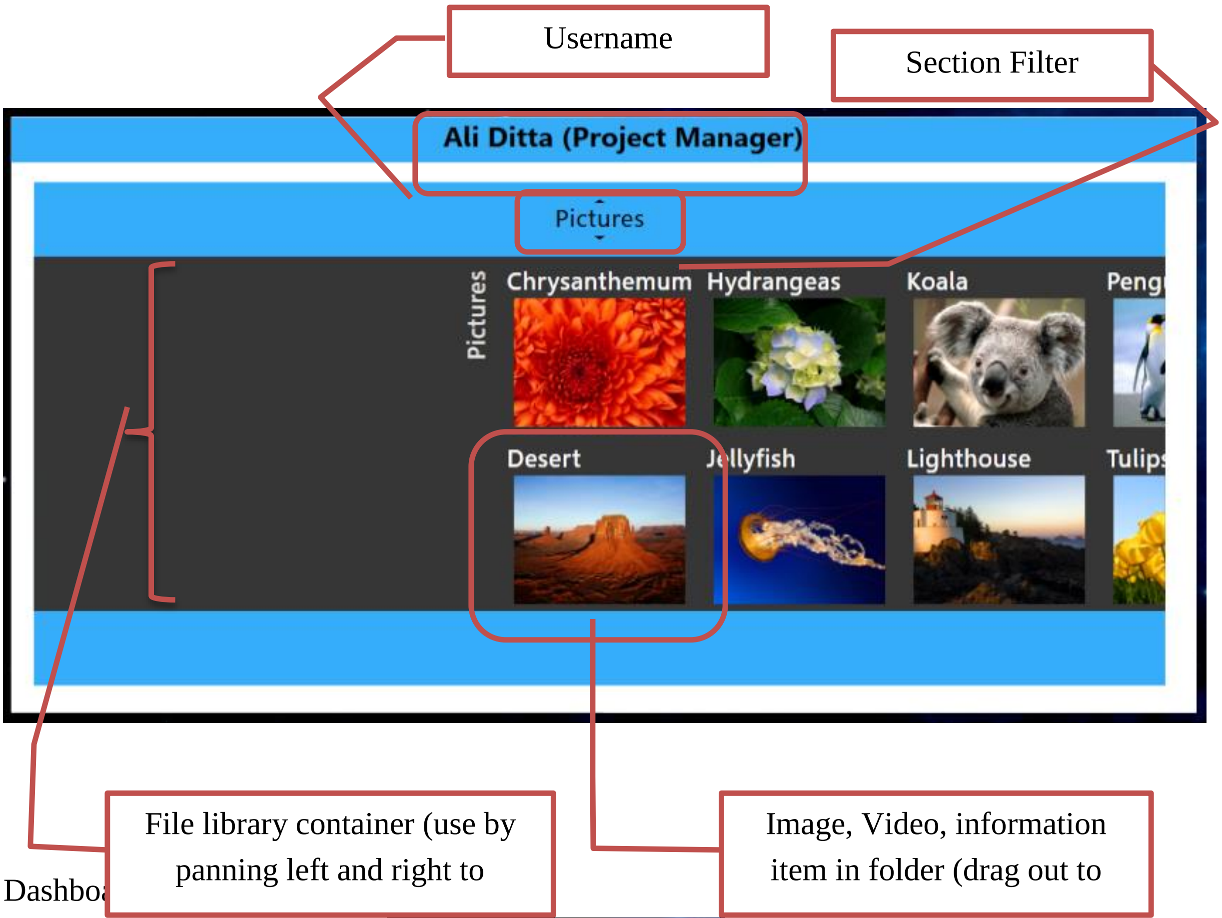
The evaluation procedure of CollaGIM will take place in the Usability Lab of the Department of Computing Sciences, NMMU. You are required to interact with the prototype implemented onto the multi-touch tabletop. You will be recorded by an overhead camera. You will work in groups of two to complete a set of common tasks. Prior to the actual experiment, you will be briefed about the functionalities and other relevant details relating to interacting and using CollaGIM. You will be required to complete a pre-test questionnaire. Once the formalities have been completed, the principle investigator will allow you to engage with the prototype until you confirm that you are ready to begin the test. At this stage the principal investigator will leave the you, and the experiment shall begin. You will be required to attempt and aim to complete each task to the best of your capabilities as a team. If you require assistance, you may ask for help, and the necessary notes will be reflected against the task.

Once the experiment has been concluded, the principle investigator will re-join you and present the post-test questionnaire. You will be dismissed once the questionnaire has been completed.

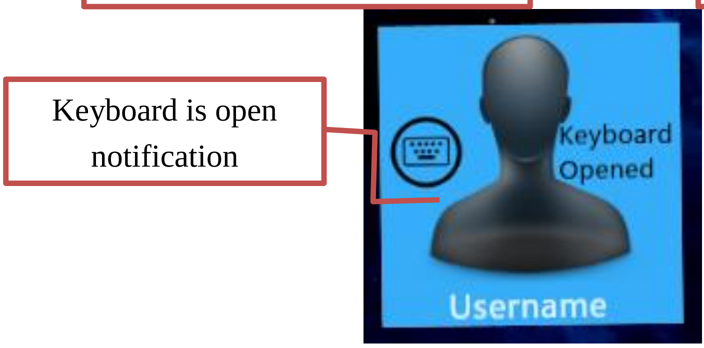
The overall evaluation process will take +-1 hour.

The following information is given to the teams by the researcher. It is intended to be used as a reference.

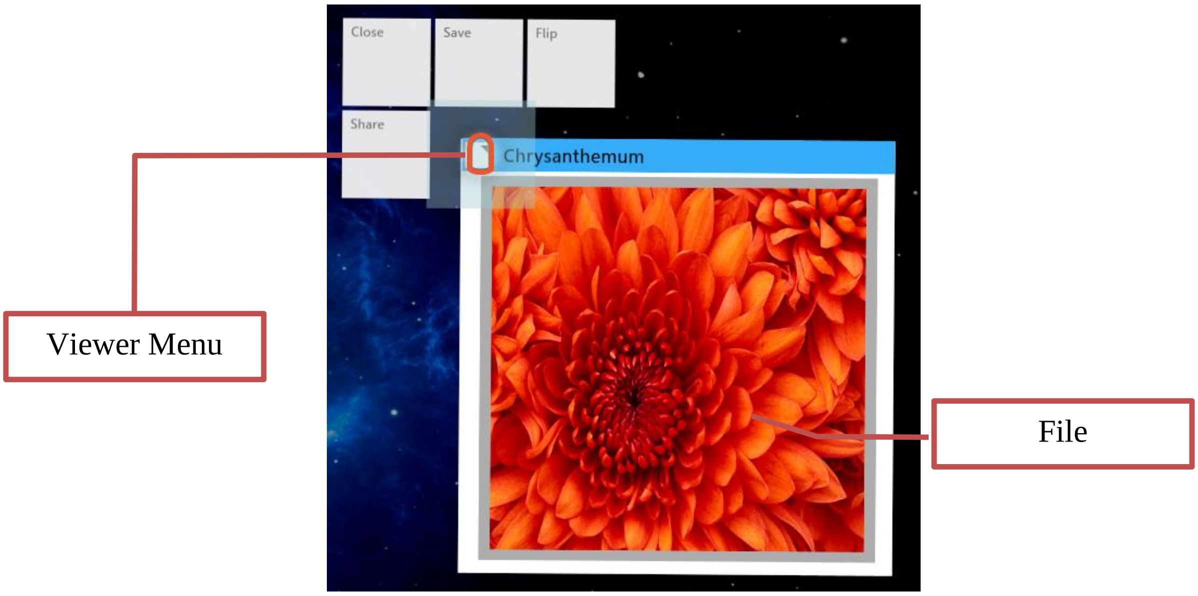
Dashboard Control



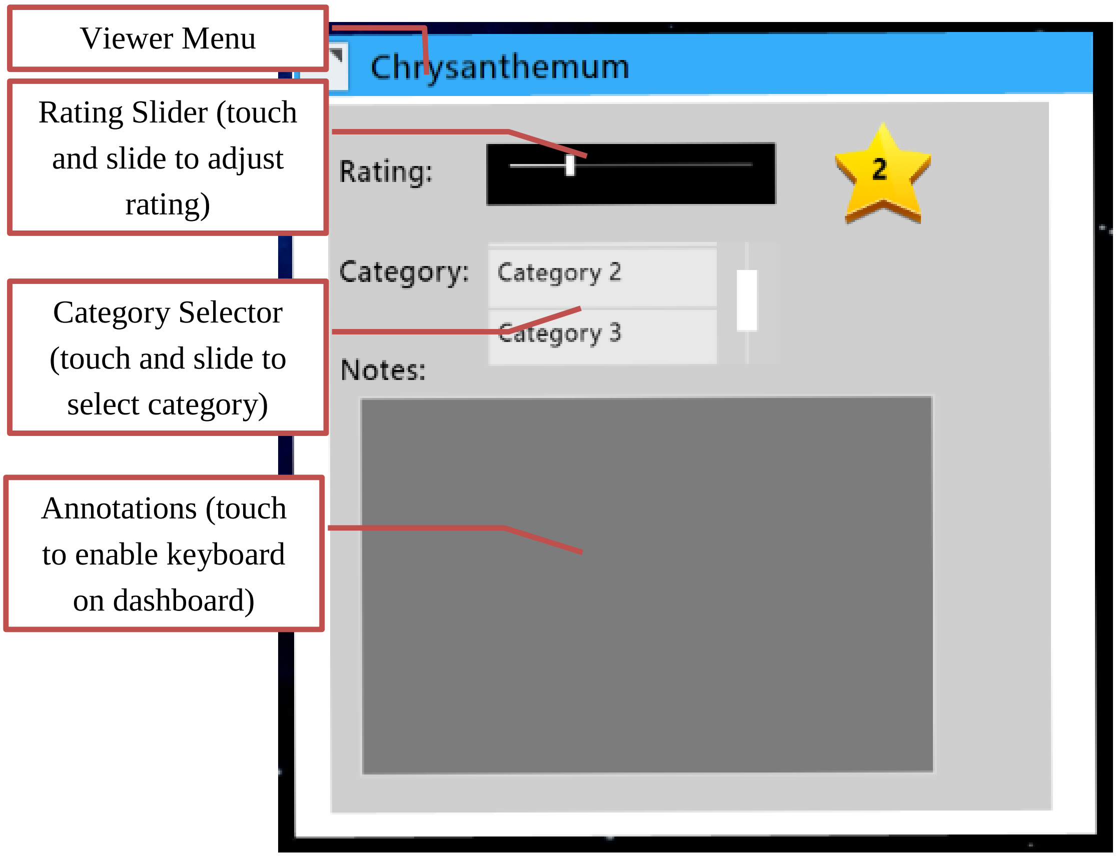
Dashbo



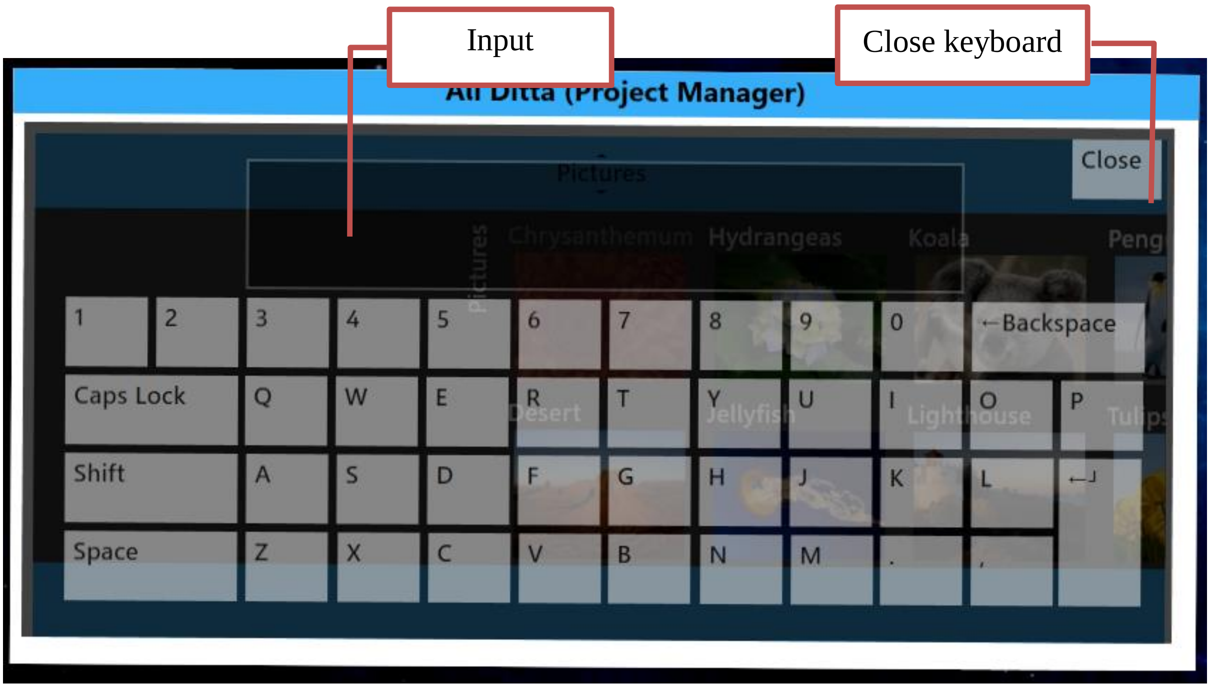
Item Viewer Control (Front)



Item Viewer Control (Flipped)



Keyboard Control



Appendix B: Verbal Information Provided

The following information is given to the participants by the principle investigator prior to the test. The purpose is to describe the basic functionality of CollaGIM in order to facilitate the initial meeting with the system. The system functionalities will be demonstrated whilst description is being given.

Disclaimer

Please note the following:

1. Participation is voluntary
2. You may withdraw from the study at any given time
3. Confidentiality/anonymity will be guaranteed
4. You will be recorded by an overhead camera
5. You are required to complete a pre and post task questionnaire
6. The duration of the evaluation is approximately one hour
7. Please ensure you have completed the consent form prior to evaluation.

Scenario

As members of the marketing team at Nelson Mandela Bay Tourism, you have been tasked to portray Port Elizabeth's best attractions in South African Airway's (SAA) Magazine, Sawubona. Sawubona Magazine is given out for free to all passengers that fly with SAA. It is a useful means of advertising Port Elizabeth's best attractions. The article should comprise of vibrant images and meaningful text.

As individuals, you had searched for multi-media and compiled text snippets for the article and have decided to utilise CollaGIM to present and discuss each other's findings as well as collate the article.

Instructions

CollaGIM is a co-located Group Information Management system that enables users to collaboratively share, store, find, manage and organise group information. You will be working as a team to complete a list of tasks relevant to the above scenario. How you choose to split the workload is up to you; you may choose to work on the same task together, to divide the tasks amongst yourselves, or have one member act as a project leader, who delegates subtasks.

CollaGIM makes use of a multi-touch interface to provide a natural and intuitive experience to the users. A member may select the number of users engaging with the system to load the correct number of dashboards to access their information. For this experiment, users are required to manually login to their file space to access their files. Once login is complete, each user's dashboard will be displayed containing their information. The dashboard is resizable, rotatable and movable by using pinch, rotation and dragging gestures respectively.

To visualise an object from the dashboard, simply drag out the required file vertically from the dashboard and drop it on the general work area. The visualised object is also resizable, rotatable and movable. The object can be flipped by holding the top left menu icon and dragging your finger to the flip label.

The flipped side of the visualised object allows for a rating and category to be applied. Notes may also be taken by touching the notes region, which in turn opens a keyboard on the owners dashboard. Please note that if the dashboard is in its minimised form, a notification will be displayed on the minimised form which requires the dashboard to be maximised.

Appendix C: Participant Consent Form

NELSON MANDELA METROPOLITAN UNIVERSITY
INFORMATION AND INFORMED CONSENT FORM

RESEARCHER'S DETAILS	
Title of Research Project	Using Multi-touch Tabletop Interaction Techniques to support Co-located Group Information Management
Reference Number	H13-SCI-CS-002
Principle Investigator	Mohammed Ali Ditta
Contact Telephone Number	041 504 2094

A. DECLARATION BY OF ON BEHALF OF THE PARTICIPANT		**INITIAL**
I, the participant and the undersigned	(full names)	

A.1 HEREBY CONFIRM AS FOLLOW		**INITIAL**
I, the participant was invited to participate in the above-mentioned research project		
that is being undertaken by	**Mohammed Ali Ditta**	
from	**Department of Computing Sciences**	
of	**Nelson Mandela Metropolitan University (NMMU)**	

A.2 THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT		**INITIAL**
Aim	The investigators are studying how multi-touch interaction techniques can support co-located Group Information Management (GIM). The information will be used for research purposes.	
Procedures	I understand that I am required to use a system to evaluate multi-touch interaction techniques for co-located GIM. I understand that a video camera will be recording the evaluation. The procedure shall take approximately one hour.	

Risks	I understand that there are no risks involved by participating in this process			
Confidentiality	The participant's identity will not be revealed in any discussion, description or scientific publications by the investigators.			
Access to findings	Any new information or benefit that develops during the course of the study will be shared in the dissertation on the research, available from the Department of Computing Sciences, NMMU.			
Voluntary participation / refusal / discontinuation	My participation is voluntary.	Yes	No	
	My decision of whether or not to participate will in no way affect my present or future career, employment or lifestyle.	True	False	
Costs	Participation in this study will not result in any additional cost to me, the participant.			
Other	No pressure was exerted on me to consent to participate and I understand that I may withdraw at any stage without penalisation.			

A.3 I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT	
Signed and confirmed at	**Port Elizabeth**
on this	(day) **Day**
of	(month) **2013**
Signature	**Signature (Witness)**
	Full names of witness:

Appendix D: Pre-test Questionnaire

NELSON MANDELA METROPOLITAN UNIVERSITY
PRE-TEST QUESTIONNAIRE

RESEARCHER'S DETAILS	
Title of Research Project	Using Multi-touch Tabletop Interaction Techniques to support Co-located Group Information Management
Reference Number	H13-SCI-CS-002
Principle Investigator	Mohammed Ali Ditta
Contact Telephone Number	041 504 2094

Biographic Information (Participant Details)						
1	**Gender**	Male			Female	
2	**Dominant Hand**	Right			Left	
3	**Do you suffer from colour blindness?**	Yes			No	
4	**Age**	18-20	21-29	30-39	40-49	50+
5	**Education**	Matric	Bachelors Degree	Honours Degree	Masters Degree	PhD Degree
6	**Occupation**	Student	Academic Staff		Other:	
7	**Have you completed an end-user computing course? (e.g. WRFC, WRFE)**	Yes	No, but computer literate		No	
8	**Computer Expertise**	Novice	Intermediate (frequent user)		Expert (in the field of computers)	
9	**How many years have you been using computers?**	0-2	3-5	6-9	10+	
10	**How often are you exposed to information sharing?**	Never	Rarely	Frequently	Daily	

<table>
<tr><td rowspan="1">11</td><td>How often do you work in a team?</td><td>Never</td><td>Rarely</td><td>Frequently</td><td>Daily</td></tr>
<tr><td rowspan="2">12</td><td>Have you used multi-touch hardware before?</td><td>Yes
(Large screen technologies)</td><td>Yes
(Tablets, smartphones)</td><td colspan="2">No</td></tr>
<tr><td>If so, which hardware (brand and model)</td><td colspan="2">(brand)</td><td colspan="2">(model)</td></tr>
<tr><td rowspan="2">13</td><td>Have you used multi-user / collaborative software before?</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td>If so, what software?</td><td colspan="4"></td></tr>
</table>

Appendix E: Task List

NELSON MANDELA METROPOLITAN UNIVERSITY
TASK LIST

Scenario

As members of the marketing team at Nelson Mandela Bay Tourism, you have been tasked to portray Port Elizabeth's best attractions in South African Airway's (SAA) Magazine, Sawubona. Sawubona Magazine is given out for free to all passengers that fly with SAA. It is a useful means of advertising Port Elizabeth's best attractions. The article should comprise of vibrant images and meaningful text.

As individuals, you had searched for multi-media and compiled text snippets for the article and have decided to utilise CollaGIM to present and discuss each other's findings as well as collate the article.

Task List – (You may use system task list)

1. Login

1.1 Add user one and login

1.1.1 Username: user1 → Password: abc → Select a colour

1.2 Add user one and login

1.2.1 Username: user2 → Password: abc → Select a colour

2. Find relevant information

2.1 Find and open the images named "Greenacres Entrance" and "Greenacres Logo" by dragging it onto the workspace. (Note: 1 image per user)

2.1.1 Move the images to a location that is easily accessible. Resize if necessary.

2.1.2 Flip the images and:

2.1.2.1 Discuss and decide on a rating for the images. (based on quality)

- *One image should be >5 and the other <5.*

2.1.2.2 Make personal notes if necessary

2.1.3 Share the images such that both users have both the images

2.2 Find and open the images named "Shamwari Logo" and "Leopard" by dragging it onto the workspace. (Note: 1 image per user)

2.2.1 Move the images to a location that is easily accessible. Resize if necessary.

2.2.2 Flip the images and:

2.2.2.1 Discuss and decide on a rating for the images. (based on quality)

- *One image should be >7 and the other <4.*

2.2.2.2 Make personal notes if necessary

2.2.3 Share the images such that both users have both the images

2.3 Find and open the text files named “Greenacres Trading Hours” and “Greenacres Mall” by dragging it onto the workspace. (Note: 1 text file per user)

2.3.1 Move the text to a location that is easily accessible. Resize if necessary.

2.3.2 Flip the text and:

2.3.2.1 Discuss and decide on a rating for the text. (based on quality)

- *One text should be >5 and the other <5.*

2.3.2.2 Make personal notes if necessary

2.3.3 Share the text such that both users have both the text files

2.4 Find and open the text files named “Shamwari History” and “Shamwari Definition” by dragging it onto the workspace. (Note: 1 text file per user)

2.4.1 Move the text to a location that is easily accessible. Resize if necessary.

2.4.2 Flip the text and:

2.4.2.1 Discuss and decide on a rating for the text. (based on quality)

- *One text should be >7 and the other <4.*

2.4.2.2 Make personal notes if necessary

2.4.3 Share the text such that both users have both the text files

3. Sorting the personal information space and workspace

3.1 Sort your **personal information space**

3.1.1 View files with a rating of 5+ only

3.2 Open the **workspace sorter** from the main widget

3.2.1 Select “All Users” → “All” → Rating 5+ → Check “Close excluding files”

3.2.2 **Touch and Hold** at an empty location on the workspace to call all open files with the matching criteria.

4. Collate a Document

4.1 Open the collaborative document builder (CDB)

4.1.1 Drag all information for Greenacres to Section 1

4.1.2 Drag the text information for Shamwari to Section 1

4.1.3 Drag the image for Shamwari to Section 2

4.1.4 Move the text for Shamwari in Section 1 to Section 2

4.1.5 Rearrange the content such that the images precedes the text

4.1.6 Save the Document

Thank You

Appendix F: Post-test Questionnaire

NELSON MANDELA METROPOLITAN UNIVERSITY

POST-TEST QUESTIONNAIRE

A. Cognitive load									
1. Mental demand: How mentally demanding were the tasks?									
	Very Low	1	2	3	4	5	6	7	Very High
2. Physical demand: How physically demanding were the tasks?									
	Very Low	1	2	3	4	5	6	7	Very High
3. Temporal demand: How hurried or rushed was the pace of the tasks?									
	Very Low	1	2	3	4	5	6	7	Very High
4. Performance: How successful were you in accomplishing what you were asked to do?									
	Very Low	1	2	3	4	5	6	7	Very High
5. Effort: How hard did you have to work to accomplish your level of performance?									
	Very Low	1	2	3	4	5	6	7	Very High
6. Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?									
	Very Low	1	2	3	4	5	6	7	Very High

B. Overall satisfaction									
1. Overall, I am satisfied with how easy it is to use the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
2. Overall, I am satisfied with the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
3. It was easy to learn to use the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
4. It was simple to use the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

C.	**Usability**									
1.	I can effectively access information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
2.	I can quickly access information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
3.	I can effectively retrieve information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
4.	I can quickly retrieve information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
5.	I can effectively visualise information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
6.	I can quickly visualise information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
7.	I can effectively share my information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
8.	I can quickly share my information using the system.									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
9.	I can effectively organise information using the system. (move, sort, etc.)									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
10.	I can quickly organise information using the system. (move, sort, etc.)									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
11.	I can effectively maintain information using the system (i.e. annotate, adjust ratings).									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree
12.	I can quickly maintain information using the system (i.e. annotate, adjust ratings).									
		Strongly disagree	1	2	3	4	5	6	7	Strongly agree

13. I can effectively save information using the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
14. I can quickly save information using the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
15. I became productive quickly using the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
16. I can effectively create and use a collaborative document									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
17. I can quickly create and use a collaborative document									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
18. The system has all functions and capabilities I expect from a co-located group information management system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

D. Collaboration									
1. The system effectively provides access to an information space.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
2. The system enabled us to search the information space effectively.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
3. The system effectively visualised the information.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
4. We could effectively view the visualised information.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
5. We could open all the necessary document sources (web pages, images)									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
6. We could effectively manipulate the visualised objects.									

	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
7. The system allowed us to add useful ratings and annotations.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
8. We were aware of other team member's actions.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
9. We communicated effectively whilst using the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
10. The system helped us to divide the workload effectively.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
11. The system logged our actions.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
12. We were able to locate recently used information using the system.									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
13. We were able to collaboratively create a document									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
14. We were able to sort our information effectively									
	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

E. General Comments
1. Identify the most positive aspect of the system.
2. Identify the most negative aspect of the system.

3. Please provide any general comments or suggestions for improvement .
4. Other remarks.

Thank you for your participation.