# 3D Environment Based on Desktop Metaphor: A Usability Study

**By**

Suzanne Jamil Hilmi Sultan

B.Sc.: Al-Quds Open University
Hebron

Supervisor: Dr. Ghassan Al-Qaimari

A Thesis Submitted in Partial Fulfillment of Requirements for the Degree Master of Computer Science

Computer Science Department
Al-Quds University

December,2004

Department of Computer Science
College of Science and Technology
Deanship of Graduate Studies

# 3D Environment Based on Desktop Metaphor: A Usability Study

By

Student Name: Suzanne Jamil Hilmi Sultan

Registration No: 20011538

Supervisor: Dr. Ghassan Al-Qaimari

Co-Supervisor:

Master thesis submitted and accepted, Date: 30/12/2004
Names and signatures of the examining committee members:

1- Dr. Ghassan Al-Qaimari Head of Committee

2- Dr. Rashid Jayousi Internal Examiner

3- Dr. Yousef Asad Hassouneh External Examiner

Al-Quds University
2004

## Declaration

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis has not been submitted for higher degree to any other university or institution.

Signed,

Suzanne Jamil Hilmi Sultan.

Date: December-30-2004

## Acknowledgement

Completion of this thesis is the result of collective efforts of assorted individuals. My honest, candid thanks and gratitude to Dr. Ghassan Al-Qaimari, my notable highly professional supervisor who is the best to guide, advise, encourage, and criticize.

I would like to thank Dr. Badei Sartawi, Dr. Rasheed for their kind support and assistance.

Certainly, I'm genuinely grateful to my deferential husband who provided all best encouragement, endurance and full assistance.

My great esteem to Mrs. Hana Sughaier, Dr. Salman Talhmi, Eng. Sammer Al-Wohosh , Dr. Abd Al-haheem Edeh, Mrs Khawla Al-Mohtaseeb ,Moneer Karmeeh and Hana Hirbawi.

Deep thanks to PPU (Palestine Polytechnique University) for providing technical support and facilities and to experiments' participants.

## Abstract

Researchers are looking for new three-dimensional (3D) paradigms to replace the dominant two-dimensional (2D) Graphical User Interface (GUI). Still, there are ongoing researches trying to spot on the characteristics of 3D over 2D. In this research work we introduce a new 3D desktop entitled 3D Bibliotheca that resembles to reality with additional enhancement features by using 3D interaction techniques. This prototype is used as a vehicle to focus on the advantages and limitations of 3D with serious comparison of 2D Window desktop. Two empirical usability tests were conducted to investigate the effect of spatial memory on users' performance and to probe the attitude and satisfaction of different categories of users. The results of our empirical studies clearly demonstrate the 3D Bibliotheca is significantly improving users' performances over 2D desktop prototype. Further more, the results support the perceived utility of 3D Bibliotheca and thereof support the premise that 3D Bibliotheca is preferred over real 2D desktop.

## ملخص

يتطلع الباحثون إلي تطوير واجهات المستخدم الرسوميه ثنائية البعد (2D GUI s) عن طريق إحلالها بالواجهات ثلاثية البعد. فلذلك ما زالت الأبحاث مستمرة للكشف عن الخصائص التي تميز الواجهات الثلاثية عن الواجهات الثنائية. قدمنا في هذا البحث نموذج لسطح المكتب ثلاثي البعد باسم (3D Bibliotheca) حيث يشبه هذا النموذج إلى حد ما الواقع الذي نعيش به( Reality) ،علاوة على ذلك استخدمت تقنيات ثلاثية البعد في هذا النموذج.

استخدم هذا النموذج كأداة للكشف عن ميزات هذا النوع من الواجهات مقارنة بالواجهات ثنائية البعد الخاصة بالنوافذ. فلذلك تم اجرء اختبارين على عدد من المستخدمين (Empirical Usability Testing ) . تم خلالهما دراسة مدى تأثير الذاكرة المكانية (Spatial memory) على أداء المستخدم(User Performance) كما تمت دراسة آراء وتوجهات عدد من فئات المستخدمين ومدى رضاءهم أثناء استخدام هذا النوع من الواجهات مقارنة بواجهات النوافذ ثنائية البعد.

أظهرت نتائج الدراسة أن هناك تحسن ملحوظ على أداء المستخدم وسرعته أثناء تعامله مع الواجهة الثلاثية البعد (3D Bibliotheca) مقارنة بأدائه عند استخدامه واجهة النوافذ ثنائية البعد الخاصة بالنوافذ . كما دلت النتائج بان المستخدمين يرغبون في استخدام الواجهات الثلاثية البعد مقارنة بالواجهات الأخرى.

# Declaration

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis has not been submitted for higher degree to any other university or institution.

Signed,

Suzanne Jamil Hilmi Sultan.

Date: December-30-2004

# Dedication

To: My husband Dr. Sufian Sultan.

My reverential parents.

My children: Jamil, Mohamned, Amenah,
Ola and Haithem.

## Acknowledgement

Completion of this thesis is the result of collective efforts of assorted individuals. My honest, candid thanks and gratitude to Dr. Ghassan Al-Qaimari, my notable highly professional supervisor who is the best to guide, advise, encourage, and criticize.

I would like to thank Dr. Badei Sartawi, Dr. Rasheed for their kind support and assistance.

Certainly, I'm genuinely grateful to my deferential husband who provided all best encouragement, endurance and full assistance.

My great esteem to Mrs. Hana Sughaier, Dr. Salman Talhmi, Eng. Sammer Al-Wohosh , Dr. Abd Al-haheem Edeh, Mrs Khawla Al-Mohtaseeb ,Moneer Karmeeh and Hana Hirbawi.

Deep thanks to PPU (Palestine Polytechnique University) for providing technical support and facilities and to experiments' participants.

# Abstract

Researchers are looking for new three-dimensional (3D) paradigms to replace the dominant two-dimensional (2D) Graphical User Interface (GUI). Still, there are ongoing researches trying to spot on the characteristics of 3D over 2D. In this research work we introduce a new 3D desktop entitled 3D Bibliotheca that resembles to reality with additional enhancement features by using 3D interaction techniques. This prototype is used as a vehicle to focus on the advantages and limitations of 3D with serious comparison of 2D Window desktop. Two empirical usability tests were conducted to investigate the effect of spatial memory on users' performance and to probe the attitude and satisfaction of different categories of users. The results of our empirical studies clearly demonstrate the 3D Bibliotheca is significantly improving users' performances over 2D desktop prototype. Further more, the results support the perceived utility of 3D Bibliotheca and thereof support the premise that 3D Bibliotheca is preferred over real 2D desktop.

# ملخص

يتطلع الباحثون إلي تطوير واجهات المستخدم الرسوميه ثنائية البعد (2D GUI s) عن طريق إحلالها بالواجهات ثلاثية البعد. فلذلك ما زالت الأبحاث مستمرة للكشف عن الخصائص التي تميز الواجهات الثلاثية عن الواجهات الثنائية. قدمنا في هذا البحث نموذج لسطح المكتب ثلاثي البعد باسم (3D Bibliotheca) حيث يشبه هذا النموذج إلى حد ما الواقع الذي نعيش به( Reality) ،علاوة على ذلك استخدمت تقنيات ثلاثية البعد في هذا النموذج.

استخدم هذا النموذج كأداة للكشف عن ميزات هذا النوع من الواجهات مقارنة بالواجهات ثنائية البعد الخاصة بالنوافذ. فلذلك تم اجرء اختبارين على عدد من المستخدمين ( Empirical Usability Testing) . تم خلالهما دراسة مدى تأثير الذاكرة المكانية (Spatial memory) على أداء المستخدم( User Performance) كما تمت دراسة آراء وتوجهات عدد من فئات المستخدمين ومدى رضاءهم أثناء استخدام هذا النوع من الواجهات مقارنة بواجهات النوافذ ثنائية البعد.

أظهرت نتائج الدراسة أن هناك تحسن ملحوظ على أداء المستخدم وسرعته أثناء تعامله مع الواجهة الثلاثية البعد ( 3D Bibliotheca) مقارنة بأدائه عند استخدامه واجهة النوافذ ثنائية البعد الخاصة بالنوافذ . كما دلت النتائج بان المستخدمين يرغبون في استخدام الواجهات الثلاثية البعد مقارنة بالواجهات الأخرى.

# Table of contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction

Since the early eighties, computer users have been using two-dimensional (2D) Graphical User Interfaces (GUIs) currently recognized as the preferred interfaces for end users in most situations [Leach et a1. 1997]. Researchers in area of Human Computer Interaction (HCI) are exploring new paradigms to replace the existing 2D GUI in order to enhance users' interaction with computer. They believe that the natural progress is to move toward three-dimensional (3D) environments that make interfaces more intuitive and more natural; believing that the closer to reality, the easier to use. Scannel P. 1997 in page 2 described the advantages of 3D in these words:

> *"If we can find a way to "sense" this two-dimensional, virtual location, then the location becomes "real" in our perceptions. This way of "sensing" must take place in three-dimensional reality because we human beings are born into a three-dimensional navigational space in life".*

## 1.1 Research motivation

Since the mid of nineties, a number of 3D interfaces have been designed to surrogate from standard 2D GUIs to 3D in several environments such as window manager (operating system interfaces) and web/file interfaces. Some of these have been used for commercial products purposes, while others have been tested in research as prototypes.

These attempts based on believing that the interactions with real environment fit to cognition and spatial ability [Tavanti and Lind 2001]. Indeed, 3D display is more plausible and practicable than 2D. From which users may distinguish objects quickly with minimal interpretive effort [Smallman et al. 2001]. Thereof, it is crucially important to focus 3D nature representation that show more objects on a single screen [Robertson et al. 1991; Robertson et al. 1998; Tavanti and Lind 2001].

In spite of the mentioned benefits, none of these attempts successfully replaced the 2D desktop metaphor and until today, no dominant 3D Window Manager (WM) is adopted. As a result, there is still ongoing research to try to understand the characteristics of 3D interaction through carrying out more 3D design trials and further empirical testing.

It is worth mentioning that increasing hardware capabilities and declining hardware prices make three-dimensional GUIs possible to apply and affordable to use [leach et al. 1997]. Indeed, the successful 3D representations in some computer applications provide compelling evidence that GUI is able to support the interactive three-dimensional visualizations.

## 1.2 Research objectives

The main aim of this research study is to focus on some characteristic of 3D environments in order to reach a better understanding of the advantages of 3D Window Managers compared with 2D Microsoft™ Windows (2D desktop metaphor). In this research work, we have developed a 3D WM prototype, called 3D Bibliotheca, based on the main functions of real desktop metaphors in addition to some 3D techniques. Worthy to mention that 3D Bibliotheca resembles reality and at the same time capable of enhancing (simplifying) this reality by using additional 3D interaction techniques. However, this design does not attempt to address issues related to folders, recent documents, start menu and active applications. Correspondingly, this implementation is used as a vehicle to conduct two empirical studies with the help of users to evaluate the user performance, utility and user satisfaction comparing with 2D Window desktop.

Two usability experiments were designed and carried out with the help of users. The first experiment investigated the roll of spatial memory on the user performance across two different displays, 2D and 3D desktops. User performance was measured across two parameters. In the first one, the general performance was evaluated by measuring the number of accurately recalled documents using paper interfaces diagram. For the second parameter, the completion time of retrieving specific objects was measured systematically. In addition, this study investigated the effect of increasing documents on both parameters across of both 3D Bibliotheca and 2D Microsoft Window prototypes.

The second experiment scrutinized the attitude and satisfaction of different categories of users toward the utility of 3D Bibliotheca in comparison with Microsoft Window, the real 2D desktop. The two categories of users interacted with the basic operations in both interfaces in addition to some extra functions related to 3D only. The first category of users included participants with limited knowledge in using familiar desktop and playing games whilst the second category included subjects with more experience in both destinations.

The thesis is organized as the following: Chapter 2 presents background information about the generation of interfaces and available 3D graphical software packages; Chapter 3 reviews current commercial and prototyped 3D window/file/web managers. It also reviews the effects of 3D representation on spatial memory; Chapter

4 describes, in details, the requirement and design of our prototype, 3D Bibliotheca; Chapter 5 illustrates the experimental design for empirical studies; Chapter 6 includes the data analysis; Chapter 7 presents the conclusion and future research directions.

# Chapter 2

# Background

The first section of this chapter offers the some information about four different generations of user interfaces. The second section includes description for the main features and differences between the available graphical software packages.

## 2.1 Generation of User Interfaces

User interfaces passed through several generations that are roughly depending on the hardware development. Here is brief description about these generations:

### *2.1.1 Command-Line Interfaces (CLI)*

It is often called line-oriented interface. This type of interface is one dimensional through which users can only modify the last line. The only widely used device that the user could use in his interaction with the computer is the keyboard. While, command line and question-answer were the basic interaction styles [Nielsen 1993, p 52].

- **Command line style** [Dix A. et al. 1993, p 116]**:** It was the first interaction dialogue style to be commonly used and still used, based on function-oriented structure (using verb-noun syntax). Users are able to issue a set of commands directly to computer in order to achieve the desired result, through using function keys, single characters and abbreviation or whole word commands. Using abbreviation of the commands speeds up interaction and reduces spelling error. On the other hand, this style is flexible; the command often has a number of parameters that gives various behaviors. In addition, it is powerful; the command can be applied to many objects at once, which facilitate repetitive tasks. However, in spite of these advantages, still, it is difficult to use and learn. Also commands are varied across systems.

- **Question/answer** [Dix A. et al. 1993]**:** Simple techniques are depending on asking users series questions (yes/no, multiple choice, or codes) to lead them to the interaction step by step. They are easy to learn and use but they are limited in functionality. This interaction style is suited for novice and specific domain. Besides, there is a possibility of contradiction with previous answers and ignorance of next questions.

### *2.1.2 Full-Screen Interfaces*

The invention of mouse enhanced the way of interaction with the computer. So, user can move in two dimensions. The new interaction styles are used such as Form-filling and menus.

- **Form-Filling:** The technique of resembling a paper form has been used basically in data entry while being used also in data retrieval application. In addition, it is still used in modern interfaces as a form of dialog boxes. The user edits appropriate values besides suitable field in order to be entered into the application in the correct place.
- **Menus:** Menus technique free users from remembering options as the set of options are displayed on the screen. Although, they are slow and confused particularly if they depend on hierarchically nested menu.

### *2.1.3 Graphical User Interfaces (GUIs)*

It has been unleashed more than twenty years ago while achieving better usability characteristics compared to other interfaces. GUI referred to WIMP systems that stands for **w**indows, ***i***cons, **m**enus and **p**ointing device (sometimes **w**indows, ***i***cons, **m**ice and pull-down menus [Dix A. et al. 1993]. GUI is considered as 2½ dimensional interfaces because of the possibility of overlapping windows. GUI is object oriented; where users first access the object of interest then determines the desired operation upon it (noun-verb syntax). The main characteristics of GUI are dealing with objects and metaphors, besides using direct manipulation as a new style of interaction.

- **Metaphor:** It is defined as a visual representation. It can make use of a familiar concept in order to explain the new thing. The main point about the use of metaphor is that users already know how the familiar object works. A word-processor application is a good example that relied on the typewriter. Desktop metaphor is another example for office desktop. The first workstations based on the metaphor of the office desktop were Xerox Alto and Star [Dix A. et al. 1997].

Although metaphor may facilitate learning the interaction of the computer especially for novices as it may also be misleading since users may explain its meaning based on their own culture. Furthermore, sometimes it is hard to find metaphor from real world such as scroll bar. On the other hand, metaphor masks realities of implementation. To illustrate more this point, we can refer to the word processing as a good metaphor that completely rely on the typewriter. But the behavior of both of them is not exactly the same. Pressing on typewriter's space key produces nothing, whilst pressing on spacebar in word processor produces character. So, experienced typists are not going to know this reality according to their experience.

- **Direct Manipulation:** In 1982, Ben Shneiderman [Shneiderman 1998] is attributed with coining new term as the style of human computer interaction. The name of direct manipulation comes from replacement of complex command language with the actions to manipulate directly the visible objects. Direct manipulation has the following characteristics:
    - Continuous Visibility of objects of interest.
    - Using physical actions as movements and

selections by specific device or using labeled buttons instead of complex syntax.

- All actions are reversible. So, reducing error rate is available. Besides, users are encouraged to explore without fear.

Because of these characteristics, direct manipulation improved usage and achieve usability attributes. Even though, novice users can rapidly learn the functionality, experts may easily work to carry out a wide range of tasks and even define new functions and features. In spite of the benefits of direct manipulation, Shneiderman mentioned some of its disadvantages [Shneiderman 1998] such as:

- The possibility of increasing resources of the system.
- Some actions may be difficult to do.
- Macro techniques are not often strong.
- History and other tracing may hard to activate.

### *2.1.4 Next-generation of users interfaces*

Researchers in HCI are trying to depict a new generation of users interfaces. The next users' interfaces will move off the flat screen and get forward into the three dimensional interfaces and virtual reality.

Virtual reality present a three dimensional world by computers. It is to some extent simulation to the real world. Navigation and orientation through the 3D spaces are used to reach virtual objects. Users can explore the world at different scale while making hidden objects visible.

As predicted in few years, next interfaces will move beyond WIMP interfaces to involve head-mounted displays, multimedia, limited artificial intelligence and highly portable computers with wireless communications capabilities.

The most distinguished characteristic is moving from function-oriented and object-oriented structure to user-oriented [Nielsen 1993]. Users will not control computer's actions by commands. Computers will be able to observe and analyze users' actions by using non-command interaction style. Gesture recognition and eye-tracking are examples of non-command techniques. For example, Users become able to draw proofreading marks on the text itself by using pen-computed techniques (gesture-based interfaces).

Traditional interfaces are forcing users to be in one application at a time, even though other applications are running in the back. However, the new interfaces will move from application-oriented to document-oriented which currently achieved. Users will be able to integrate their tasks that require multiple applications. For example, users will be able to deal with multiple data type in one document by using composite-editors techniques. There is no single program that able to satisfy all users' requirements. Cut-paste technique is another example that allows live links back to the original application. Any changes in the original data will be reflected in the copy of the new document.

## 2.2 Computer Graphical Software and evaluation

In this section, main features for four computer graphical packages are depicted. Indeed, software evaluation are offered depending on some factors. Due to this evaluation, the most suitable package is selected and used to implement the 3D prototype.

### *2.2.1 Software packages*

Several graphical software techniques are developed to make 3D visualization applicable. This software is used in diverse markets as virtual environment, medical imagery, entertainment and simulation.

#### *2.2.1.1 Open Graphical Library[1] (OpenGL)*

It is a high level of graphics programming Application Program Interface (API) originally developed by Silicon Graphics Ins (SGI) in early1990, then it becomes the industry's most widely used. OpenGL is available on different platforms. GL, GLU and GLUT are three main parts of OpenGL. It is not only an API, but also an implementation that tries to use hardware acceleration for various graphics operations. Besides, it bases on client-server interpretation; as client (program) issues commands interpreted and processed by OpenGL (server).

#### *2.2.1.2 Direct3D*

It is a subset of Microsoft's DirectX API, which used for manipulating and displaying three-dimensional as OpenGL. Direct3D

---

[1] http://www.opengl.org

works only on windows platform; it is closed software [Dokic 2000] by contrast of OpenGL. So, this fact forced software vendors and hardware manufacturers to shift their attention to OpenGL. There are several releases for Direct3D (for example DirectX3, DirectX5 and DirectX9). These releases offer more than just 3D graphics. They control hardware components such as audio hardware, controllers, streaming media[1].

#### *2.2.1.3 Virtual Reality Modeling Language (VRML)*

VRML is text language for describing 3D, 2D, and interactive environments with multimedia for internet purpose. VRML1.0 was an initial release deprived of interpolator or API binding [Tittel et al. 1997] .VRML is a platform-independent that operates within a web browser as HTML. In order to manage and view VRML file, some type of plug-ins (VRML browser) is required such as Cosmo-player, Cortona4.0 and Live3D. By contrast of OpenGL and Direct3D, VRML is not a programming API. It is powered by scripting abilities and binding with external API as linking the VRML file with java API.

[1] http://www.webopedia.com

### *2.2.1.4 Extensible 3D (X3D)*

X3D is the enhanced successor to VRML97 (VRML2.0). X3d file is similar to VRML including the Extensible Markup Language (XML). It has some advantages over VRML. By using this application; the capability of scene graph expands. On the other hand, it supports multiple file encoding, VRML97and XML and compressed binary. In liaison, The XML encoding makes smooth integration with web servers. The compressed binary format increases data throughout while still being in development[1].

### *2.2.2 Software evaluation*

According to the main features for each package, software evaluation is offered depending on four main factors: portability, learnability curve, free resources and capability.

The table (2.1) illustrates the main features of each package against these factors.

[1] http://www.web3d.org/x3d

| Package | Portability | Learnability curve | Free Resources | Capability |
|---|---|---|---|---|
| **OpenGl** | Platform-independent | Has greater learning curve because it is only API; it is used by other languages. | Available | High<br>▪ Includes various APIs.<br>▪ Supports hardware accelerator. |
| **Direct3D** | Only widow Platform. | As OpenGl | Available | High<br>▪ As OpenGl |
| **VRML** | Platform-independent | It is easier to learn upfront. VRML is stand-alone language and powered by java script. | More available | Medium<br>▪ Has less capability than the others.<br>▪ No file compression |
| **X3D** | Platform-independent | Has medium learning curve because it is XMLized VRML. | Available | High<br>▪ Include XML + VRML classic and binary |

**Table 2.1 Software evaluation for four packages.**

As a result, VRML is selected and used to implement the 3D prototype. It can achieve all requirements of the prototype and has lower learning curve comparing with the others. Indeed, VRML is available on different platforms. It is worthy to mention that there are different sites with good tutorials, which facilitate learning the language.

## 2.3 Summary

In this chapter, some information about the generation of user interfaces and the related interaction styles are described. CLI is the first generation with one-dimensional interface. Invention of mouse device helps users moving in two dimensions through Full-Screen second-generation interface. GUI is the third most dominant generation that achieves better usability by using metaphor and direct manipulation techniques.

Continuous hardware development helps the fourth interface generation to exist in which we are. Some of its characteristics currently are achieved such as using composite-editors. While, others are still under development such as using non-command techniques and moving from 2D toward 3D virtual reality interfaces. Finally, some available packages for computer graphics are described and evaluated based on some factors.

# Chapter 3

# Review of 3D Environments

Since mid of nineties, there is a strong trend towards designing 3D interfaces. Several attempts were implemented in various environment either in desktop (Window Manager WM) or web-file management. This chapter is divided into two sections. The first and second sections give brief description of two classified categories of prototypes and commercial correlated design. The third section offers several studies that investigate the effectiveness of spatial memory in 2D versus 3D.

## 3.1 Three-Dimensional Window Managers

In the following subsections we introduce current commercial and prototyped 3D window managers.

### *3.1.1 MaW$_3$*

The MaW$_3$ [Leach et al. 1997] is WM that use 3D space to alleviate overlapping of multiple windows (window thrashing). Users can in fact arrange windows at arbitrary depth in the tunnel metaphor. The scaling of windows size decreases when users have pushed the selected windows further into the tunnel. Besides, users can move any window downward the tunnel, while a segment always remains inside. In addition, users can use window hanging techniques to obtain a global view of window locations. This hanging mode may be on both sides of the tunnel. Thereof, users can hang individual window or all windows at once.

Overview area and console are the other components of 3D window manager. It is located at the right of the tunnel with top view and down view. The selected windows can be moved up and down in the overview area. Windows' names are displayed in this area to identify specific window and overcome the small font of the name that are hard to see because of distance.

Console is located at the bottom of the screen and moves through the tunnel with users. It provides control buttons such as for hanging windows and for making the selected window transparent. This transparency is used to allow the obscured windows to become visible. This prototype is implemented in C and uses OpenGL.

### *3.1.2 The Task Gallery: 3D Window Manager*

It is another example of Microsoft research on 3D computer interaction. Task Gallery[1] [Robertson et al. 2000] is a window manager that provides direct support for task management and document comparison, deficient of desktop metaphor in the systems implementation. Task gallery metaphor is based on virtual art gallery, composed of unlimited sequence of rooms with one closed end called stage in which current task is displayed. Rooms have distinctive background to provide spatial cues and landmark that act as memory aids. It is important to know that choosing a gallery metaphor and few simple navigation controls support linear navigation to avoid users to get lost in 3D environment.

Users' tasks appear as an artwork hung on different places of virtual gallery. The new task will be created by picking on the item related in the menu or on start palette, subsequently, the system displace it on floor. In the same concern, the user can move the selected tasks by dragging them either to wall or to ceiling. Even though, transmitting them with its live windows from its frame to

[1] http://www.Research.microsoft.com /ui/Task Gallery

stage by clicking on the objective designed. A ghosted task view will remain in the task gallery so as to indicate its destination.

Navigational tool spaces are indeed placed in the lower left part of the screen around virtual body. As for tool spaces, they are associated with the virtual body as users are moving through the virtual gallery. These tools allow users to jump backward one room, forward, home (primary view that is a close-up of the stage), while bird's eye help users to show all tasks upward gallery. Task Gallery is implemented in C++, using Win32 and Direct3D APIs.

### *3.1.3 3DTop*

Since 1999, the first 3DTop design was introduced and has been updated continuously in order to reach its main appearance nowadays. 3DTop[1] is a desk plan on which several objects were distributed over the surface. These objects are divided into two categories. The first one consists of icons that exist on regular 2D desktop with extra objects such as light. The second one is icons that depend on the existence of the active applications and documents linked to the active unstable sticking bar.

[1] http://www.3Dtop.com

Due to this design, users can be able to fly around their desktop in order to reach any object. Besides, by clicking on 3D with no object selected, pop-up main menu will appear with different items such as minimize all windows; minimize 3Dtop, shut down the computer, changing background and sky texture and active applications on the desktop.

3DTop consists of two types of objects in 3D environment; movable and selected objects such as light, applications' icons and flag; objects cannot be movable as sky and floor. Selected several objects can be grabbed by little robot in order to facilitate at the same time the operation on all objects such as delete copy/cut or follow users. These objects can be resized; rotated with changed shapes.

Flag object is a marker for users, and enable him/her quickly to go to a particular position. If users create a flag, the position of their viewpoints at that time will be identified according to his own decision.

### *3.1.4 Win3D*

Commercial Clockwise Company produced Win3D[1] as a 3D desktop platform for windows operating system. It is demonstrated by a house in which all main tasks are represented by rooms' metaphor such as internet, games, multimedia and office. Each room has specific functions and displays the related applications and utilities.

Office room contains a table on which placed some objects such as floppy disk, CD-Rom and applications mostly used such as word processor and outlook. The two types of drawers are situated besides both sides of the table. Being on the left side, application drawers contain computer programs such as notepad, access and others. Right drawers are used to manipulate the system's parts as desktop and start menu. In this office room, navigation helps users reaching computer's peripherals as screen and printer.

In another side, navigation between rooms can be implemented either through channels' strolling or through

[1] http:// www.clockwise3d.com

jumping using the environment map (menu). In this stage, collision detection is strongly presented during navigation process. Recycle bin and recent documents are represented in a symptom hole in the ground.Win3D is implemented using DirectX 7, DirectX 8 and OpenGL.

### *3.1.5 3DNA*

The 3DNA Desktop[1] is a recent competitor design produced by 3DNA Company. It is 3D front ends that retain all windows and web functionality. It offers several worlds for users to work in, such as in undersea lab and loft.

Loft world contains different areas (bays) as application bay, web browser, media and option kiosk. Each bay is for a specific purpose. Teleport colored hotkeys are attached to the wall and they are used for quick teleportation to respective bay. Besides, users can define their own teleport hotkeys to any determinate location.

In the same concern, arrows key such as page up keys and others are used for navigation and moving around the 3DNA desktop. On the

[1] http://www.3DNA.net

other hand, users can use mouse look technique to look around the world without moving.

Application bay contains meaningful 3D objects placed on the table that let users to access some applications and system's functions as internet, e-mail and my computer. There are panels arranged in a grid pattern on the walls in order to create shortcut to the favorite folders and applications.

Indeed, users can decorate their world by hanging photos on the wall by dragging them into the picture frames. Movable objects such as furniture in the 3D environments are available.

### *3.1.5 Sphere XP*

It is 3D desktop for windows XP which still is under construction[1]. It is based on a sphere metaphor and users are central oriented. All objects regularly used are placed around. In fact, as users can easily turn around, they also may be manipulated with the objects such as icons and applications. Users can rotate their view by pressing the scroll and moving the mouse. This type of navigation prevents users from disorientation keeping them in a sphere environment called

[1] http://www.osnews.com

spherical navigation. The view port is always facing apart from the sphere center. Once users deviates the distance from the center, the view port can be more rotated around it.

Minimized version of the sphere is situated in the right bottom of the corner. It provides a global overview of the view port located with an identification of all objects positioned. The mouse is the only device by which users can navigate. For example, users utilize left mouse button to drag and drop objects in the environment whilst right mouse are exploited to move selected objects forwards and backwards

On the other hand, users are only allowed to change the background image. In consequence, they have to use only one environment that has the same functionality.

The table (3.1) illustrates comparison between several window manager designs. This comparison based on the using metaphor, navigation and main features/ techniques for each design.

| Design | Metaphor | Navigation | Main features/ techniques |
|---|---|---|---|
| **MaW3** | Tunnel for arranging windows arbitrary. | Linear navigation. | ▪ Hanging windows on both sides of tunnel individually or together.<br>▪ Allowing the obscure windows to be visible using transparency technique.<br>▪ Displaying windows' name clearly in spite of it's distant using overview area. |
| **Task Gallery** | Virtual art gallery with unlimited sequence of room and closed end. | ▪ Linear navigation.<br>▪ Navigation tools. | ▪ Provide direct support for document comparison. |
| **3DTop** | Desk plan over which objects were distributed in space | ▪ Every direction without constrains.<br>▪ Flags are used as a marker for quick navigation. | ▪ Grapping several icons together by little robot in order to make operation on all at the same time. |
| **Win3D** | House consists of several rooms. each room has specific functions and icons. | ▪ Every direction within the metaphor and collision can be occurred.<br>▪ Using menu for quick navigation between rooms. | Using ecological marks to locate applications and objects in fix place. |
| **3DNA** | House with different areas (bays) | ▪ All direction & Collision can be occurred.<br>▪ Using colored keys for teleportation.<br>▪ Arrows key such as page up to navigate and move outside. | Different worlds for users to work are offered. |
| **Sphere XP** | sphere | Spherical navigation; Only user can turn around the sphere by using scroll bar | ▪ Focusing techniques is used.<br>▪ Minimized version of sphere is used to be display user's location. |

**Table 3.1 comparison between window manager designs.**

## 3.2 Three dimensional interface as file and web manager

In the following subsections we review current commercial and prototyped 3D web/file managers.

### *3.2.1 Cone/Cam trees*

Cone tree visualization was first described by Robertson et al [Robertson et al.1991]. It is hierarchical structured 3D space to visualize density of information in single screen. Cards are used to represent tree's nodes. The card at the top of the hierarchy is placed near the virtual room’s ceiling. It is the apex of the cone with children arranged in the circle below the parent (cone's base). Parent node is connected with its children with lines. Lines are filled with translucent shading to make the cone shape more apparent. Each child is not a leaf as he is the apex of a cone. So, tree consists of layers. Each layer has cones of the same height. The aspect ratio of the whole tree is fixed to fit a room. Users can rotate the cone by grabbing any of its nodes using mouse to bring the selected node to the front.

Several cues are used to enhance the effectiveness of Cone Trees such as, providing fisheye view of information ( focus plus context displays) [Furness 1986] to speed navigation [Card et al.1991] and light cues in order to diverse coloring of closer nodes.

Cam tree is a horizontal version of the cone tree that has cards laid in the same direction, to be suitable for text label [Robertson et al. 1991; Mackinlay et al.1992].

This scheme applicable can be used in numerous applications such as visualizing file directory structure, organizational structure browser and company's operating plans. The cone tree interface is written in Tcl/Tk.

### *3.2.2 The Web Book and Web Forager*

Web Forager [card et al. 1996] is a 3D information workspace for World Wide Web that allows rapid interaction with more aggregate web entity. It includes web books, individual pages and bookcase in 3D workspace arranged hierarchically into three levels. Thus, users can interact through three hierarchical rates:

- Focus place in which large book or page is displayed for direct interaction between users and content.
- Immediate memory space in which the documents are arranged at

different depth in the air and on the desk in order to place pages and books in use.

- Bookcase for storing web books.

Web Book contains a collection of relative URLs (Uniform Resource Locators) in book metaphor to allow rapid access to web pages. Each page of the book is a page from the web. There are three scrollbars, vertically and horizontally destined for each page familiar to users. The unfamiliar one is for scaling the font size, since trade-off of front-size versus amount of page is viewed. Two colored links are used in pages, red or blue, to indicate whether the desired page is in the book or outside the book. If it is inside the book, pages will be flipped to the desired page. Otherwise, the current web book will be closed. If the page is in another web book and stored on a bookshelf, that web book will be opened to a desired page. Otherwise, web forager is used to display this individual page.

In addition, there are several buttons attached at the bottom of the book such as backward scan and forward scan. Scanning pages can be stopped when users click on a page. Besides, users can determine the scan rate and pause time at each page.

Automatic bookmark can be left on the last page that was viewed when the book is closed. This bookmark can help users reopening the last page being already viewed.

As for the pages, they can be seen simultaneously. Then by using Document Lens [Robertson et al. 1993] techniques, inspect portion of interest can be displayed.

### *3.2.3 Data Mountain*

It is one of Microsoft research on 3D computer interaction for document (Web) management [Robertson 1998]. Data Mountain is designed as an alternative to current Web Browser Favorite or Bookmark mechanism. This technique allows arranging various document thumbnails on inclined fixed plane (tilted at 65 degrees) in 3D desktop metaphor with passive landmarks that help users grouping documents into categories (category with no titles). Using tilted plan metaphor avoids overlie labels which appear in cone tree design [Robertson et al. 1991].

Users can place documents anywhere on mountain at arbitrary positions by using direct manipulation mechanism. When page is being dragged, other pages move out of the way in order not to be occluded. The Selected page appears in preferred legible viewing position; but another click will put the page back in its previous location.

Pop-up titles and shadow around thumbnail are used to distinguish documents. Using various cues to increase visual as perspective view, occlusion, shrinking document's size and audio cues (i.e. users hear hamming sound which changes pitch depending on the page’s speed) .

Data Mountain could work in other environment besides desktop virtual environment such as Fish Tank VR (Virtual Reality) [Ware et al. 1993], or VR with head-tracked head-mounted displays.

In 1999, the second evaluation [Czerwinski et al. 1999] was using automatically implicit queries mechanism that highlights stored pages related to the selected page. Data Mountain is written in C++, using OpenGL.

### *3.2.4 Buzz 3D My Space*

It is a new product for browsing web pages in 3D space work[1]. Several pages are displayed on the Piazza's walls. Forty-eight different web pages are displayed in a 3D scene simultaneously through which users can navigate and select the page they want to see. Through this technique, users can continue loading the wanted pages for display on Piazza's wall while they are reading another. Thus, more pages in one screen can be seen by contrast of 2D. On the other hand, users can create and watch their own video, music and photographs.

Table (3.2) illustrates comparison between web/ file manager designs from different aspects.

[1] http://www.buzz3d.com

| Design | Metaphor | Navigation | Main features |
|---|---|---|---|
| **Cone/Cam tree** | Tree with nodes to represent the web / file names in hierarchical structured | User can rotate the cone by grabbing any node. | Using fisheye techniques to speed navigation. |
| **Web Book and Web forager** | Web book based on book metaphor while web forager based on room metaphor. | Using colored link to navigate in the same book or outside the book. | ▪ Automatic bookmark is used to help user to reopen the last page is viewed.<br>▪ Document lens techniques are used to see pages simultaneously |
| **Data Mountain** | Inclined plan at 65 degree. | ▪ No navigation.<br>▪ Focusing techniques are used to focus the selected web. | ▪ Pop up titles and shadows around thumbnail are used.<br>▪ Using technique to prevent occlusion thumbnail. |
| **Buzz 3D Space** | Piazza on which pages displaced. | ▪ As in Win 3D and 3DNA.<br>▪ Collision may occurs | User can read the page while another is loaded |

**Table 3.2 Comparison between web/file manager designs.**

## 3.3 Spatial Memory and User Interface performance

Spatial memory is an essential focus for this type of research field because it is correlated with performance. Although researchers believe that moving from 2D to 3D will enhance users' performance, few researchers' experiments showed contradiction result.

Robertson et al. [Robertson et al. 1998] showed via their prototype named Data Mountain that the task completion times and error rates were lower when retrieving web pages using 3D version of

Data Mountain than when using the standard internet explorer4 (IE4). More remarkably, a follow up evaluation showed that subjects were rapidly able to retrieve pages, being represented as thumbnail images and blank icons from their spatial arrangements four months after creating them [Czerwinski et al. 1999].

Cockburn and McKenzie [Cockburn and McKenzie 2001] were contradicting the previous result when they have examined two versions of data mountains 3D and 2D versions; 3D version has additional cues than 2D as size gradients. Their results showed that the mean task completion times for retrieval and storage tasks were lower when using 2D than 3D. The differences were not statistically significant. The authors believed that there were confounding factors which altered the results and overcame any performance benefit that might have been gained in the 3D interface. Some of these factors:

- Existence of the banners on the thumbnail images.
- The more flexibility in layering controls in 2D interface than 3D.
- Subject's familiarity with dealing objects in 2D and the lack of

fidelity in 3D.

Ark, Dryer, Selker and Zhai [Ark et al.1998] have examined two forms of interfaces (2D iconic, 3D realistic) with two layouts to each:

- Regular with rows and columns typical to users interface.
- Ecological environment with spatial placement.

Their results indicated that both form and layout have significant affect on performance. The subjects have located targets more quickly when using interfaces with 3D objects and ecological layouts than they did with 2D objects and regular layouts .The authors have also suggested the use of 3D realistic and ecological layouts for tasks that require identifying and learning the locations of objects [Ark et al.1998].

Tavanti and Lind [Tavanti and Lind 2001] performed two experiments to examine spatial memory performance across different instances of 2D and 3D. All instances were representing hierarchical information structure. The results of the test showed that 3D representation improve performance in the designed spatial memory task.

Cockburn [Cockburn 2004] based his experiment on previous Tavanti and Lind's study. He represented 2D interface differently from Tavanti 2D interface. The results disagreed with the previous work, and showed that the effectiveness of spatial memory is unaffected by absence or presence of the three-dimensional perspective effects.

In 2002, Cockburn and McKennzie have compared six different types of interfaces, physical and virtual interfaces with different forms (2D, 2½D, 3D) [Cockburn and McKennzie 2002] that enable them to evaluate the effectiveness of spatial memory in those types of interfaces. The experimental design has measured retrieval time through different dimension forms with three levels of density factor sparse (33 pages), medium (66) and dense (99). Starting with an empty interface, subjects began to add 33 pages one at a time till proceeding to the other level of density. Results ended that there were no noticeable performance differences between the three different types of virtual interfaces; instead, this performance is in deterioration as the dimension increases Thereof, users have indicated 3D interfaces as more cluttered and less efficient.

Brunstad and Eie [Brunstad and Eie 2002] have compared Robertson's researches [Roberson et al. 1998; Robertson et al. 2000] to Cockburn and McKenzie's research [Cockburn et al. 2002]. They found that 3D interfaces have different success. In the same regard, they have explained some reasons why Robertson is more positive to this technology than Cockburn since he has displayed Data Mountain on a 2D surface that emulated the 3D effects; the z axis is really y-axis. Indeed, Robertson has used some cues to indicate the apparent of three dimensional such as receding plane and decreasing the dimensions.

On the other hand, the interaction devices used in Cockburn's experiment are not suitable for 3D interaction, but they may be sufficient for 2½ dimensional prototypes shown as in the Data Mountain [Brunstad and Eie, 2002] and Tavanti's experiments. It is important to show that there are different points of views of Robertson and Cockburn to 3D display; while Robertson's 3D display is the same of Cockburn's 2½ D display.

According to this detailed study, the impact of the spatial memory to users interface performance is in fact depending on the related prototype. Therefore, the designers must test the effect of spatial memory in their own prototypes in order to be able to identify their particular results.

## 3.4 Findings

Several attempts have been made in designing 3D interfaces to enhance computer interactions. These attempts use various metaphors, different kinds of navigation and techniques[1]. So far, none of these attempts successfully replaced existing 2D designs. In addition, the impact of spatial memory on user performance is remained unclear; there is contrary conclusion whether 3D displays provide enhancement to user performance comparing with 2D. Some of studies showed that the effectiveness of spatial memory is unaffected by absence or presence of three-dimensional perspective effects [Cockburn et al. 2002, Cockburn 2004]. Whilst, others showed that 3D representation improves performance [Robertson et al. 1998, Tavanti and Linds 2001].

[1] Please refer to tables (3.1 – 3.2)

As a result, carrying out further empirical testing are needed to focus on some characteristics of 3D environments compared with existing 2D designs. So that, this study is not aimed to come up with a new and novel metaphor, but to compare some characteristics of 3D with existing 2D designs. For that reason, 3D prototype named 3D Bibliotheca is designed as a WM (desktop) based on office metaphor. The 3D design is similar in main functions to 2D Window desktop. It is worth to mention that some characteristics of this prototype are inspired from prior designs such as using linear and quick navigation. This 3D prototype is used as a tool to investigate the impact of 3D and 2D representation on user performance, the ease of use, ease of learn and users' satisfaction compared with 3D Window desktop.

## 3.5 Summary

Many attempts have been made to provide WMs managers and web/fie managers. Some of them are commercial products while the others are research prototypes. These designs based on different metaphors and techniques. So far, none of them successfully replaces the existed designs/interfaces.

In the other hand, there are different researches tried to discover the effect of spatial memory on user performance across different 2D and 3D prototypes. This literature study concludes to different findings that lead to design 3D bibliotheca to be as a tool to investigate several parameters comparing with 2D window desktop.

# Chapter 4

# Requirements, Design and Implementation of 3D Bibliotheca

In this chapter we discuss the general and detailed requirements of our prototype, 3D Bibliotheca. We then describe the implementation of 3D Bibliotheca and its advantages comparing with other 3D designs. Finally, we discuss the limitation of the prototype, which we regard as future enhancements of 3D Bibliotheca.

Indeed, this prototype of 3D graphical user interface is designed as an alternative to the main functions of a regular 2D desktop. The 3D Bibliotheca was prepared according to the proposed guidelines, and recommendations of designing 3D interfaces [Shneiderman 2003]. According to previous views of Shneiderman and other researchers in the concern, we have adapted the following requirements for 3D Bibliotheca.

## 4.1 Requirements of 3D Bibliotheca

3D Bibliotheca requires the listed characteristics that are some of them specific to this prototype while the others are inspired from several prior designs. 3D bibliotheca joined all characteristics in one prototype listed below:

1. It should simplify reality by using the so-called enhanced or constrained 3D [Shneiderman 2003] illustrated through the following criteria:
   - The needed navigation is limited; users only can navigate backward and forward. This criteria is similar to $MaW_3$ and Task Gallery and contrast with 3Dtop, Win3D and 3DNA.
   - Teleportation is a substitute to navigation for quick traveling to view different scenes in the same workspace to reach hidden objects as in Task Gallery, Win3D, 3DNA. Teleportation is well-explained in section 4.2.5 in detail.
   - The design should avoid complete occlusion of documents' thumbnail by using the inclined table located in front of the user, as in section 4.2.3. Partially documents' occlusion is not available in Win3D, 3DNA and Buzz3D. In these designs, there are fixed places for situating the documents' icons and folders.
   - Keep text readable in all cases; the titles of documents are

located beside user and displayed vertically on the documents. This prevents user turning around which is not permitted because of one-way navigation.

2. It promotes reality by supporting familiar metaphors and interaction style. For example, it supports:

- Using several ecological landmarks as tables, fences, ground and cupboard. Some, for locating documents' thumbnails whilst others for placing other objects/icons.
- Personal location to the documents' thumbnails; user is able to locate these anywhere on the existed ecological landmarks. This is not available in Win3D and 3DNA. Indeed, user can locate documents' thumbnail on several landmarks by contrast of Data Mountain.
- Using 3D depth cues to facilitate spatial cognition such as existence of office perspective view, partially occlusion previously explained.
- Focusing technique is used to view the documents' thumbnail closer to user's vision. This technique simulates Data Mountain, cone tree and sphere. However, this is not available in Win3D

and 3DNA and 3Dtop.

▪ Resizing the documents in order to be suitable to its distance from the user’s vision as in Data Mountain and contrast to Win3D and 3DNA.

3. It should promote locality that makes links between what users can see and what they can expect in the proposed operation. For example, to change displays' themes, users click on the screen object in order to be able to select the wanted operation.
4. It must have meaningful objects to assist users reaching specific function successfully such as using global rotate earth metaphor.
5. It should group the applications together for ease of use. This grouping is inspired from Win3D whilst it does not exist in the other designs.
6. It should reduce time and increase performance while completion tasks. This can be achieved by locality property, identifying the most common used objects in front of user vision all the time and using focusing techniques that descried in section 4.2.4.
7. 3D Bibliotheca should be used distinguish audio and animation cues designed to facilitate spatial cognition as discussed in section

4.2.3 in details.

## 4. 2 3D Bibliotheca design

Bibliotheca is an intuitive interface based on office metaphor since it includes basic practical objects that facilitate the implementation of any related task. This virtual office varied essential components such as two desks, cupboard and shelves.

### *4.2.1 The used metaphors in 3D Bibliotheca*

3D bibliotheca is based mainly on office metaphor. This metaphor simulates reality and is used in Win3D. This virtual office contains several metaphoric objects. Some of them are completely simulate reality such as floppy and CD-ROM while the other are resemble reality.

Rotate global earth metaphor is selected for web browser and internet operations. This selection is chosen to express the ability of users to contact any area on this earth. Indeed, several attempts are done depending on users' view before selecting global earth metaphor. It worthy to mention that this evaluation is based on star (user-center) software development lifecycle [Preece J. 1994].

3D Bibliotheca represents bookshelves with metaphorical fences that prevent darkness and closed space, on which users can locate their thumbnails. It is worthy to mention that fence metaphor simulates advertisement board on which papers hung. The selection for this metaphor was after considering users' opinions depending on star (user-center) software development.

### *4.2.2 Main components*

The main desk (table) inclined at 30 degree, is placed in direct façade of the users for locating and arranging documents. Users can distinguish and identify documents through its thumbnails representation. The idea of tilted table was inspired from Data Mountain design [Robertson et al. 1998]. As required, this is one of the reality enhancement criteria to facilitate documents' occlusion. While the main desk is for placing documents' thumbnails, a special area of its right side is equipped with some essential and mostly used objects such as floppy, CD-ROM and web browser metaphor.

The second desk in liaison to the main one is located on its right side. The angle parameter between the two desks forms an extent degree about ninety. This Right desk holds the computer case and its peripherals like screen, mouse and keyboard.

As required for ease of use, the application cupboard as in Win3D[1] lay on the left side of the main desk contains several applications' drawers. Each drawer represents one application that can be distinguished through its color and opened music (See figure 4.1).

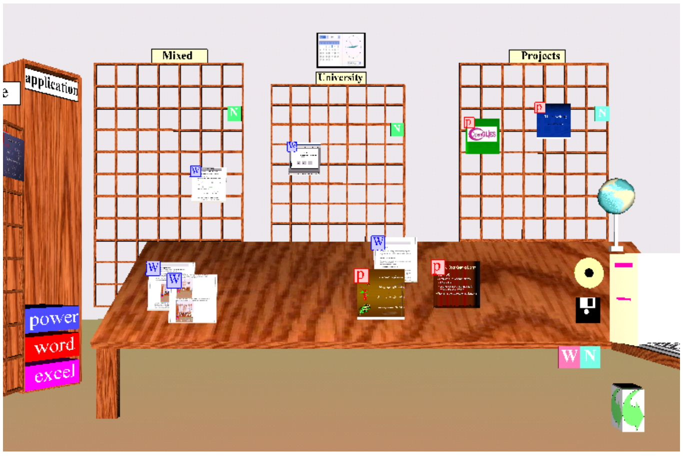


**Figure 4.1** The 3D Bibliotheca - normal (basic) view.

There are four fences distributed in different depth in order to assist users in their distinguishing between the used documents. As an example, the entitled archived fence, which is illustrated in normal view partly to the users' vision, is used for replacing infrequent used documents. As for the other three fences, the deeper is in fact located in the center front of the main desk. Near distance to users, the other

[1] http:\\www.win3d.com

two fences are situated with same level depth behind the main desk. Each fence has its own label, placed over each one as prolific guideline for users since these labels facilitate their retrieving documents.

Some basic objects are regularly used in 2D desktop design with complete awareness of their importance but neglect to their right location according to normal basic rules. As an example, 3D spaces consider recycle bin as a metaphor entity that should be placed in reality under the desk. As the calendar and clock, they are placed indeed in a distance of the user's front visions. Ultimately, they usually need to check date and time while working. Even, using focusing techniques can promote the existing dimension of both calendar and clock to user position as shown in figure (4.2).

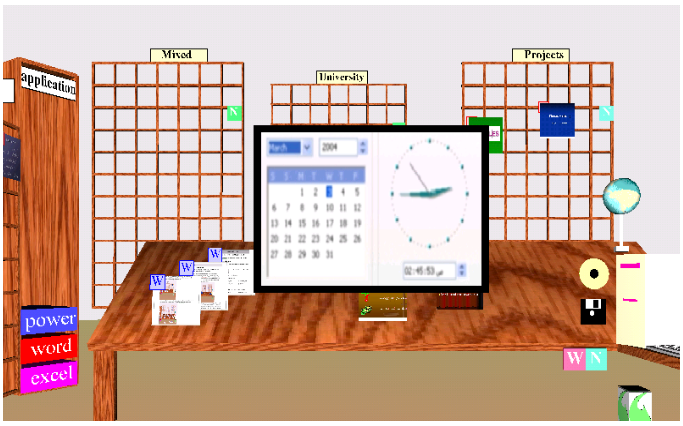


**Figure 4.2. Calendar and clock are focused to nearer distance.**

### *4.2.3 3D Bibliotheca visual and audio cues:*

There are a number of cues designed, as one of 3D Bibliotheca requirements, to facilitate spatial cognition. The most obvious one is the perspective view that can be used to represent a large number of documents' thumbnails [Robertson et al. 1998]. This can be achieved by the existence of several ecological objects that are distributed in 3D space. These ecological objects are used as criteria to promote reality as required.

Users are somewhat capable of deliberately to replace the documents' thumbnails on these ecological landmarks as inclined desk, front fences and ground. These landmarks offer apparent cues, which help in placement and retrieving documents [Ark et al. 1998].

The second essential cue is the occlusion documents partially illustrated on both the tilted table and ground (see figure 4.3). Both previous cues (landmarks, occlusion) help users to create meaning by grouping documents in the space on these landmarks; as the layout is very personal with meaning for each individual. Consequently, this operation helps users to retrieve their documents with minimal cognitive load. Besides, naming fences provides visual aids in finding documents by grouping them as users' favorites.


**Figure 4.3** Occlusion documents for grouping.

On the other hand, the perspective of 3D Bibliotheca allow users to be in the same view scene deprived of somewhat changing interfaces. So, by shifting the users' from restricted viewpoints to wider space ones, visualize extra objects for other operations become feasible (figure 4.4). Since as an example, Control Panel interface can be considered useless while 3D perception diversify many objects in one screen.


**Figure 4.4** A wider view to display more objects.

Audio cues accompany some users' actions; music sounds are unleashed when operation is completed such as displaying the component of floppy disk. Each operation has it's distinguish music sound.

Besides, animations cues are activated while mouse is over some objects like rotating floppy disk and opening application drawer. At the same concern, continuous animation still, is applied in globe spherical emblem rotation to indicate that linking to internet is available.

On the other hand, distinctive labels with colored character are used to indicate the documents' type. As an example (W) is used for word documents whilst (P) is used to distinguish power point files.

Usually, users can read tiles of the documents only when they are located in front of them. When documents are located besides, they need to turn vision or faces to check with. In this prototype, we prevent users turning by using vertical titles. This characteristic keeps text readable as required to enhance reality.

#### *4.2.4 3D Bibliotheca interaction design*

When users click on any power point document, the title hover

over and emissive colors change, creating a visual link to the hover title (figure 4.5). As sequence, by doing a second click, the same document move forward to a certain legible position as shown in figure (4.6). This focusing technique is very useful, close to reality, practical and save time. To clarify this intermediate stage, we should refer to the users who are doubtful about looking for his favorite document among some files. By reading titles, they can move the selected documents to nearer position till finding the desired one. When users fail to reach their aimed document, another click can be done to return the document to its normal position. Successfully done, the users are supposed to open the related application. Hence, this focusing technique prevents us from opening the designed application more than one time in the real system.

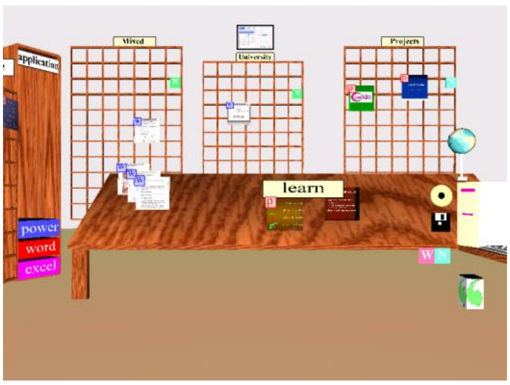


**Figure 4.5** Hovering title over clicked thumbnail


**Figure 4.6** Focusing techniques to selected page**.**

Direct manipulation techniques are used while dragging the word documents. In the same regard, pressing left mouse button on a certain thumbnails able users to replace it somewhere according to their concern. While dragging thumbnails, size changes and shrinks as far as pushing it into farther depth. Whilst, pulling it forward will increase its size.

### *4.2.5 Navigation and teleportation through 3D Bibliotheca*

As required, restricted navigation and teleportation are used to enhance the complexity of reality. Navigation can be used in several cases to view other space scenes. Objects usually used are situated in front of users' vision whilst others are located far away. While, backward navigation is crucially needed to see more objects, forward is required to reverse back. For example, to change the display properties; users need to go back to make the hidden objects visible so as to manipulate the wanted operation.

As an alternative to navigation, other technique called teleportation is available with more benefits. It is increase performance by saving time and helping users not to get lost by contrast of navigation. Teleportation can be achieved either by anchoring on the same object or by using colored hotkeys (figure 4.6).

As an example for anchoring objects, we start clicking on any front fences, and then the selected fence will enforce users to be teleported to a certain position for clear vision of the related eligible document (figure 4.7). Therefore, users become able to recognize visibility of fences labels and thumbnails. Stability into fixed position prevents designers from working with scrolling techniques.

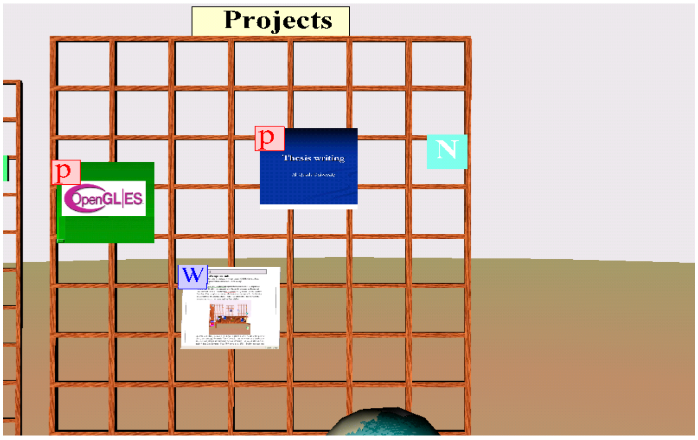

**Figure 4.7** Teleportation to the right fence.

On the other hand, there are colored hotkeys attached either to the right edge of the main table or to the front fences. They are used to change users' viewpoints. There are two hotkeys, W (whole key) is used to fit all the prototypes' objects in one scene (gain farther view), whilst R (regular key) is designed to change users view to its initial.

### 4.3 Implementation

This design runs on current high-end PCs under windows platform equipped with standard hardware graphical accelerator and software accelerator as DirectX if needed in order to achieve quick and correct rendering.

This prototype's code is mostly written in VRML language using Java script. Due to the difficulty of forming complex objects in VRML 3DMAX has been used in order to draw some objects with high proficiency and competence. In this operation, we used 3DMax to draw keyboard and mouse transferred into wrl extension with import command.

It is important to mention that this prototype operates within Web Browsers as HTML documents and VRML browser (plug-in).

### 4.4 Advantages of 3D bibliotheca

3D Bibliotheca has some advantages that advocate the current designs while others are additional as illustrated below:

1. It sponsors the reality by using real features as in normal life. Additionally, it enhances the complexity of reality by using some

techniques.

2. Teleportation are available in same space to see more objects by contrast of Win3D[1]. Nevertheless, last mentioned design uses teleportation to navigate between rooms. While navigation is essential to be used in office room of Win3D to see more objects.
3. 3D bibliotheca is able to arrange unlimited documents into palpable several levels of depth while using ecological landmarks that facilitate memorability. This is by contrast of Win3D and 3DNA[2] in which folders-documents are somewhat limited in numbers while being arranged into two-dimension space.
4. In Data Mountain [Robertson et al. 1998], clustering documents are partially occluded on one plan contrary to 3D Bibliotheca where users are able to gather related documents on extra place as on the ground and fences.
5. By using this design, users can divide their documents into two categories depending on the mostly and seldom used. To achieve this purpose, there are archive fence located behind users.

---

[1] http:// www.clockwise3d.com
[2] http://www.3DNA.net

6. There are two kinds of grouping documents. Some of them can be grouped into rows and columns as in Win3D and 3DNA. At the same time, grouping operation can be achieved by clustering and occlusion.
7. 3D Bibliotheca prevent cluttering objects by distributed objects found into 3D space, only some can be in front of users' visions and others are behind them.

## 4.5 Limitation of this prototype

The aim of this prototype is to test the utility and usability characteristic of 3D interfaces. So, the following aspects of the 3D Bibliotheca will not be attempted in this work:

1. In this design, only two types of documents are represented word and power point documents, while other types and folders are not presented.
2. In this prototype, we have divided the operation implemented on the documents' thumbnail into two groups. Word documents can be dragged to certain locations whilst power point documents are used to let users identify the documents by two techniques either

displaying its title or focusing techniques.

3. The designed prototype will not allow users to access real system.
4. As the 3D Bibliotheca is a prototype, therefore collision detection between objects is not presented.
5. The 3D prototype is deficient of many implementations of desktop metaphor.
6. The 3D design will not allow users to locate their documents on archive fence.
7. The 3D prototype will not allow users to name the fences.
8. This design does not prevent users to locate the documents in free space.

## 4.6 Future enhancements of 3D Bibliotheca

As the design is a prototype system, it has shown limitation in its current functions. We believe that the functionality described in this thesis needs to be successfully implemented with some proposed modification so that this design can be adequately explored. Future possible improvements to this prototype can be summarized in the following axis:

1. Increase the inclined table's degree to more than 50 in order to display more parts of the occluded documents.
2. Accomplish two Algorithms, one for collision detection between objects while the other should prevent completely covered documents whilst using dragging techniques as in Data Mountain [Robertson et al. 1998]. We rely on developing algorithm to prevent completely documents' occlusion on fences.
3. Users are expected to name and rename fences' label. Since, this personal naming will increase performance while retrieving.
4. The identification of the new components is initially systematic. Most used devices are located on right side of tilted table. Whereas, others are situated on the other table ready to expand when necessary.
5. The focusing technique can be in suitable position where users can be able to read rather than in fixed position.
6. Based on the fact that 3D is layers of 2D, our modified design can be promoted in order to exploit depth space by increasing the distributed number of fences. Most parts of fences are hidden whereas their labels are visible. Besides, exploiting Z depth with

mostly hidden fences prevents cluttering.

7. Different worlds can be selected by users in order to place the component of the desktop such as sea lab, natural sphere.
8. Users are able to choose suitable motif for their desktop components.
9. Users are able to displace all visual components according to their interests; perquisites and personal vision. As an example, we may refer to left-handed users who are able to relocate the mostly used objects in the apt side.
10. Adding meaningful metaphor objects for games start menu, multimedia and search. Some objects can systematically displace either in front or behind the user depending on its frequent use.

## 4.7 Summary

In this chapter, 3D bibliotheca is designed with potential features such as locality, focusing and teleportation techniques by using both hot keys or anchoring on the same object. Indeed, limitation and enhancements of 3D bibliotheca are depicted. It is crucially needed to mention that this prototype is a vehicle to discover the advantage of 3D over 2D window desktop.

# Chapter 5

# Evaluating the Utility and Usability of 3D Bibliotheca: Experimental Design

This chapter describes the usability experiments conducted on both, the 2D Windows desktop metaphor and 3D Bibliotheca. Parallel to development of an interface, participation of users plays a major role in determining the final outcome of the interface's design. In usability experiments, the designer must employ a close prototype of the actual interface to receive interactive interface [Preece J. et al. 2002].

This chapter is divided into four sections. The first and second sections give brief description about the definition of usability and the related evaluation methods. The third and forth sections describe material ,participant profile and procedure for each experiment.

## 5.1 Usability and attributes (goals):

To most people, usability is defined as "user friendly" [Nielsen 1993]. This term is used by the computer world to describe their software and hardware to customers. In fact, this definition is a deceptive description that narrowed down users' needs to one dimension of whether or not the interface was friendly. However, usability is still somewhat narrow but it has multiple attributes that are pertinent to interface design. Generally speaking, usability is broken into the following goals [Nielsen 1993]:

- Learnability that describes how easy the design is to learn.
- Efficiency (performance) that maintain how effective the product is in end-stage of work. The design interaction can be achieved by minimal steps.
- Memorability that helps users remember how to carry out tasks, so that the casual users are able to use the system after intermittent period.
- Errors (safe to use) that measure the quality of the interface so as to protect the users from mistakes and risks.
- Satisfaction that evaluates subjectively users' impression about the interface.

## 5.2 Usability Evaluation Methods (UEMs)

Evaluation is a process for producing a measurement of usability

.It examines how the design is easy to learn and use as well as efficient, safe, and satisfying. So, the evaluation prevents the wasting of resources; whereas problems are discovered and dealt before. Usability evaluations can be conducted at any stages during and after the design and development process. Usability evaluation can be managed using different methods. These methods can be classified into two broad categories based on users present.

- Empirical methods is the most powerful methods for evaluating a design that based on controlled experiments. It based on observing the actual users while they are working on testing design. This provides empirical evidence to support specific hypothesis or claim [Dix et al. 1997]. Empirical methods are the most effective for usability evaluation and produce good results. However they are expensive and require more time and equipments.
- Inspection methods relies on the experience and knowledge of the evaluators (usability specialists) who attempt to inspect the usability problems of the design. Different specialists find different problems, so adding more evaluators enhances the

ability to detect problems. Heuristic evaluation is the most common usability inspection methods that inspect the design based on set of usability guidelines (principles). It developed by Nielson and Molich [Dix et al. 1997].These methods for quick, cheap, and easy evaluation of a user design. However, actual users do not participate in this methods, difficulties in evaluation of users' performance and misleading to users' goals.

### 5.3 Usability Experiment (I)

The goal of this usability experiment is to portray how the spatial memory plays a significant role in user performance across two different prototypes 2D and 3D desktops by measuring the number of accurately recalled document icons and retrieval completion time.

Indeed, the effect of documents' density[1] is measured through the two previous parameters; the accurately recalled document icons and the completion time of retrieving specific icons. So, two iterations with half hour time separated addressed for the experiment has been testified; in the first iteration, 28 document icons were displayed in

[1] Number of documents shown on the screen

each of 2D and 3D prototypes whilst in the second iteration 42 icons were displayed in each one.

### *5.3.1 Screen Layout*

In both, 2D and 3D, prototypes, twenty-eight icons representing blank documents distributed arbitrary on screen were shown to our participants in the first iteration. These documents referred to two types of files; Power Point and Word. The number of icons displayed in each prototype in the first iteration was similar – 28 icons in each prototype. In the second iteration, the number was increased to 42 icons in each prototype.

As mentioned earlier, the icons displayed on the screen represent power point and Word documents. In both prototypes, the document's title appears with mouse over and emissive color changes to create a visual link to the title. When the mouse was displaced, the title and color would disappear. English alphanumeric characters are presented as documents' titles for ease of use.

In the case of 2D prototype (phase 1), icons behave similar to those displayed in Microsoft Windows desktop - arranged in columns.

Each column contains seven icons (as in normal resolution of Microsoft Windows desktop 800 X 600 pixels). This means that there are full four columns in 2D prototype. It is important to mention that the first column is left for essential and permanent icons already seen in 2D windows interface as my document and my computer. Only recycle bin is presented as shown in figure (5.1).

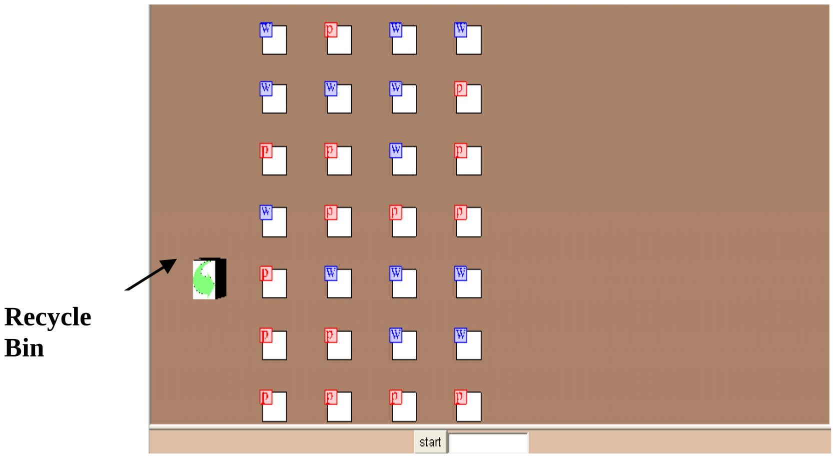


**Figure 5.1** 2D desktop with 28 icons arranged for experiment 1,

In 3D Bibliotheca (phase 2), icons are arranged based on ecological landmarks (places), which are distributed in different depth. For example there are documents on the table, ground and on labeled fences (See figure 5.2).

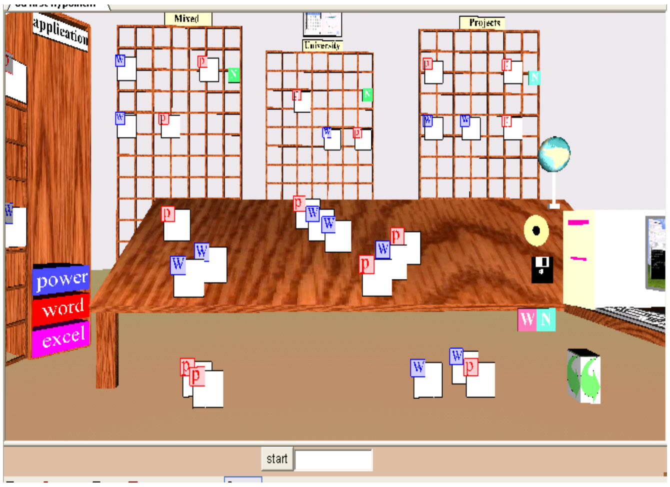


**Figure 5.2** 3D Bibliotheca with 28 icons distributed in experiment 1, phase 2.

Timer interface is attached at the bottom of both interfaces (2D 3D) in order to measure the time in seconds. When participants click on the ***Start*** button, the message *"would you like to reset timer?"*, is displayed. Users have to choose either ***OK*** or ***Cancel*** as illustrated in figure (5.3). If ***OK*** button is pressed, timing begins and the ***Start*** button changes to ***Stop*** button. Users click on ***Stop*** button when they finish the task. Then, task's time is displayed to avoid users' anxiety and stress.

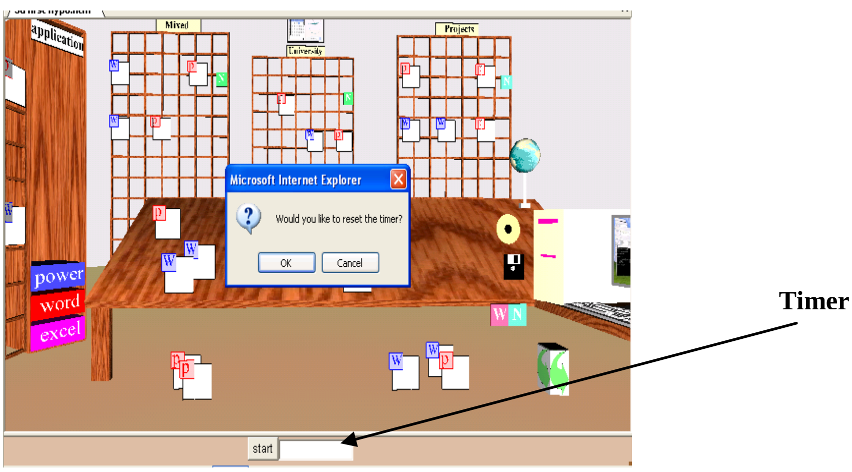


**Figure 5.3** Message is displayed after clicking on the timer (***Start*** button).

It is important to know that all factors were fixing the only active dimension factor. As an example, we refer to the using of blank documents rather than thumbnail as in 3D Bibliotheca along with showing titles only if the mouse is over by contrast of regular 2D windows desktop.

### *5.3.2 Experiment material and user profile*

As indicated earlier, two prototypes were used in the first experiment, 2D and 3D. The experiment was divided into two iterations: in iteration 1, 28 icons were displayed in both prototypes; in iteration 2, 42 icons were displayed in both prototypes.

Demographic survey (user profile) is shown in Appendix A, and used before testing whilst Spatial Memory Questionnaire (SMQ), shown in Appendix B, is used afterwards. Fourteen students from PPU (Palestine Polytechnic University), regardless of their age, with intermediate experience of interacting computers as a minimal range participated in two iterations as shown in section 5.2.3.

The study was run on Pentium 4 machine, with 128 MB of memory and 15-inch display. On the other hands, this study run on windows XP platform and internet explorer 6 that are used to view the prototype.

### *5.3.3 Procedure*

As mentioned earlier, subjects participated in two iterations with different document densities (28 and 42 icons). Indeed, in each iteration they have respectively interacted with 2D and 3D prototypes (two phases). In each phase, participants were required to recognize documents' positions, and consequently performing the retention and retrieval tasks. These two tasks are conducted to measure the effect of spatial memory across 2D Window desktop and 3D Bibliotheca as described bellow:

- Retention task: In this task, subjects used the 2D and 3D screen layouts as described in section 5.3.1. They were requested to fill the interface paper diagram with the documents' titles after being given a specific time to explore documents' locations. This task is designed to measure how many accurate document titles participants are able to remember and locate in correct position on both 3D and 2D interface paper diagram. In other words, it supposed to measure the general performance (first parameter) by calculating the number of accurately recalled documents' titles. In addition, retention task is performed to measure the user general performance while changing the document's density in both 3D and 2D.

Means that related to both interfaces should be calculated after subjects finished the task in both densities. In order to determine the existence of significant differences between the means paired T-test is calculated to examine the null hypothesis. Null hypothesis ($H_0$) assume that there is no difference in the mean number of accurately recalled documents while the objective assumption ($H_1$) is that the mean of correct recalled documents of

3D is greater than 2D. Depending on the result of T-test, we reject or accept the assumptions as displayed in appendix (H) in details.

- Retrieval task: In this task, subjects used the same screen layouts as in previous task. It is designed to measure the completion time of retrieving specific objects systematically (second parameter). In order to do that participants must set the timer before starting the task and stop it after. This task [Appendix C] contains twelve documents' titles to be found sequentially. Subjects should retrieve all items in order without skipping any of them.

    As in previous task, means and T-test should be calculated in both densities to determine if there are significant differences or not. In order to do that, null hypothesis ($H_0$) assume that there is no significant difference in documents' retrieval time between 2D, 3D layouts while the objective assumption ($H_1$) is that the mean of 3D's retrieval time is less than in 2D. Rejecting or accepting the assumptions are depending on the result of T-test.

It is worth to mention that only ten minutes have separated the two phases in order to give the participants a rest and to prepare for the second phase. Figure (5.4) illustrates the experiment diagram.

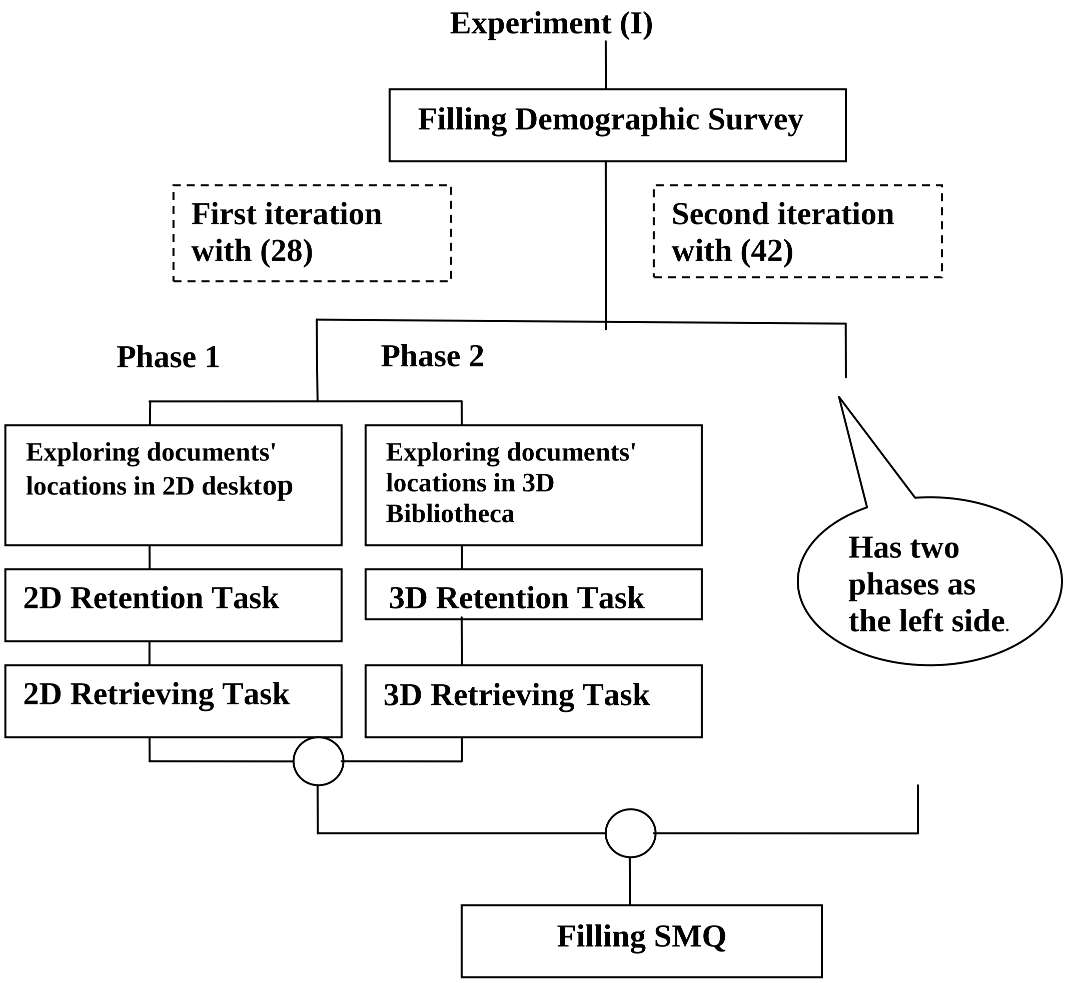


**Figure 5.4** Experiment (I) diagram

Each phase of the experiment is articulated in the following three parts:

1. Participants have explored the documents position in the specific prototype, allowed only two minutes for iterate one whilst three minutes for iterate two to complete the exploration of the documents.
2. They have to perform Retention Task in which they are requested to write down the documents' titles on the interface paper diagram of specific 2D and 3D.
3. In second task, participants have clicked on the timer to start completing the task given. By pressing the mouse button on the blank document, the shadowing color become visible and music sound heard, but no other feedback is allowable. Hence, the participants are overlooked whether their selection is correct or not. In addition, they can only search for the next document until they find the previous one. Thereof, participants click on the **Stop** button after finishing the complete task.

After finishing the two iterations, Participants are requested to fill spatial Memory questionnaire [Appendix B] to identify the role of memorable factors in both 2D and 3D. It is important to point that Appendix D relates to the second iteration and participants did not interact 3D prototype using neither teleportation nor navigation.

## 5.4 Usability experiment (II)

The primary purpose of this experiment was to scrutinize the attitude and satisfaction of different categories of users toward the utility of 3D Bibliotheca in comparison with 2D Window.

### *5.4.1 Experiment material and user profile*

The basic material for this study is 3D Bibliotheca as described in the previous chapter. 3D Bibliotheca contains two types of documents' thumbnails; drag able word documents and focusing power point ones. Indeed, 2D Windows desktop that includes, beside basic icons, same two types of documents. Folder titled applications in which shortcut icons for each word, excel and power point application located on this desktop. Training materials are provided to each participant before each experiment phase.

Before the experiment, participants were asked to fill out a Demography Survey Form [Appendix E] that basically, identifies information about their ages and level of computer expertise. After finishing the task, they are asked to fill in the Subjective User

Satisfaction Questionnaire [Appendix F]. Worthy Mentioning is that the study was run on the same machines described in the previous experiment and fifteen subjects, regardless to their age, with low to intermediate English knowledge and different experience in using computers have participated in experiment (II).

### *5.4.2 Procedure*

Participants have carried out six tutorial trials, three for each type of interface before starting the related test. Respectively, they commence to perform 2D tutorial trials first in which they are instructed to identify the following:

- To determine the location of basic components specified as CD-player, floppy, partitions of hard disk and some other applications.
- To open and close some of these components.
- To detect the contents of recycle bin.
- To discern the properties of both display and key board.
- To drag word documents
- To read power point's titles and open them to recognize the

contents of each of them.

Once it was determined that the participants could perform all these trials, the testing task began. There are two phases for this experiment, 2D and 3D phases as shown in figure 5.5. In each phase 2D- 3D task are performed [Appendix G] as described bellow:

- 2D-3D task: In this task subjects used real 2D Window desktop interface and 3D bibliotheca. They are requested to do some various main Windows operations using both interfaces. Firstly, participants had to carry out three trials related to 2D before performing operations using this type of interface. Secondly, after carrying out trails related to 3D, subjects perform the same operations as in 2D task test. At the end of 3D phase participants were introduced for extra functions (task2) [appendix G, page 2] related only to 3D bibliotheca in order to be able to use them as hot keys, teleportation features and clustering word documents.

  The aim of this task is to find out the attitude and satisfaction of participants toward the utility of 3D Bibliotheca in comparison of 2D Window. For this purpose, participants have to fill out User Satisfaction Questionnaire (USQ) after performing operations using both interfaces. As in previous tasks, means are calculated for each item in USQ questionnaire in order to compare these means and calculate T-test for some items as the item related to the ease of use of the interface and user satisfaction. In addition, means of factors that facilitate the use 3D desktop are calculated.

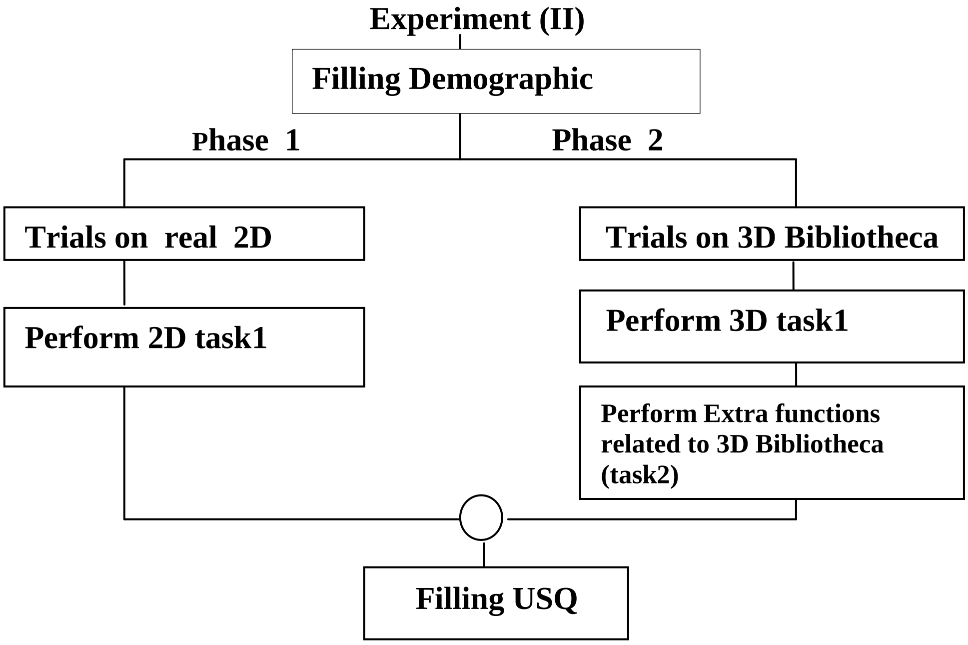


**Figure 5.5** Experiment (II) diagram.

## 5.5 Summary

In order to investigate if there are advantages of 3D over 2D, two experiments are conducted on both 2D Microsoft Window desktop prototype and 3D Bibliotheca, which are used as tools. The first experiment is designed to investigate the user performance by measurement of two parameters through performing two tasks, retention and retrieval.

Retention task measures general performance (first parameter) while retrieval task measures the completion time of retrieving specific objects. Indeed, both tasks are employed to probe the effect of increasing documents on user performance.

The second experiment is conducted to investigate some of usability attributes mainly the ease of use, ease of learn and satisfaction of 3D comparing with 2D.

# Chapter 6

# Data Analysis

Through series of experiments and data analysis phase, we have tried to illustrate the demonstrative practical impact of using 3D as a proposed alternative to 2D.

Since data analysis is crucially needed, we have used converting collected data into more suitable format for analysis to give us indication results highly considerable for the identification of the experimental design purpose.

This chapter includes two analytical sections, one for results of experiment (I) while the second for experiment (II). Since these are an exploratory studies, a significance level $\propto = 0.05$[1] is chosen as decision criterion and statistical tests are performed. Because same participants performed the two types of interfaces (2D-3D) and sample test is less than thirty, dependent or paired T-test is calculated to prove a given statistical hypothesis. Depending on t-test, we reject or accept the assumption as displayed in appendix (H) in details.

[1] Alpha is defined as the risk of rejecting the Null hypothesis when in fact it is true. The alpha value corresponds to the confidence level of a statistical test, so a level of significance alpha = 0.05 corresponds to a 95% confidence level.

## 6.1 Results of experiment (I)

As mentioned in the previous chapter, the goal of this experiment was to probe the effect of spatial memory across 2D Windows Desktop versus 3D Bibliotheca. Fourteen students from PPU (Palestine Polytechnic University) participated in two iterations. The table (6.1) illustrates the characteristics of subjects that participated experiment (I).

| | | | | | |
|---|---|---|---|---|---|
| Age | 57% from 18-20 | 43% from 21-23 | | | |
| Gender | 50% male | 50% female | | | |
| Major | 86% IT[1] | 7% CBA[2] | 7% IS[3] | | |
| Education level at the university | 29% 1st | 21% 2nd | 43% 3rd | 7% 4th | |
| memorization[4] | 7% 2 points | 72% 3 points | 21% 4 points | | |
| Using computer – hour/week | 7% 0-2 | 7% 3-5 | 14% 6-10 | 14% 11-12 | 58% >20 |
| Skill in using 2D window desktop[4] | 14% 1 point | 7% 2 points | 7% 3 points | 43% 4 points | 29% 5 points |
| Experience with computer graphic programming[4] | 14% 1 point | 21% 2 points | 21% 3 points | 44% 4 points | |
| Playing games[4] | 29% 1 point | 14% 2 points | 7% 3 points | 14% 4 points | 36% 5 points |
| Used/saw 3D desktop | 93% No | 7% Yes | | | |

**Table 6.1 Subjects 'characteristics of experiment (I).**

[1] Information Technology
[2] Contemporary Business Administration
[3] Information System
[4] Five-point scale are used

As mentioned in previous chapter this experiment try to measure its goal through two parameters:

1. The number of accurately recalled documents: participants try to write the titles of documents in correct positions on the paper-interface diagram after limited time given for recognizing documents' locations. This parameter was used to evaluate the general performance of participants interacting with both types of interfaces. Indeed, the effect of documents density on general performance is measured.
2. The completion time of retrieving specific document icons : to measure in seconds how quick the participant is in completing retrieving specific documents systemically. Also, The effect of documents density on retrieval time is measured.

### *6.1.1 General performance*

Participants have limited time to explore the documents' positions in both prototypes before writing down the documents' titles on paper-interface diagram. Figure (6.1) illustrates the mean values of accurately recalled documents across 2D, 3D layouts in different densities that measured in two iterations as the following:

1. First iteration in which 28 documents are displayed in both 2D and 3D interfaces: 2D mean is 12.79 while 3D mean is 20.21.
2. Second iteration in which 42 documents are displayed in both interfaces: 2D mean is 9.64 while 3D mean is 26.21.

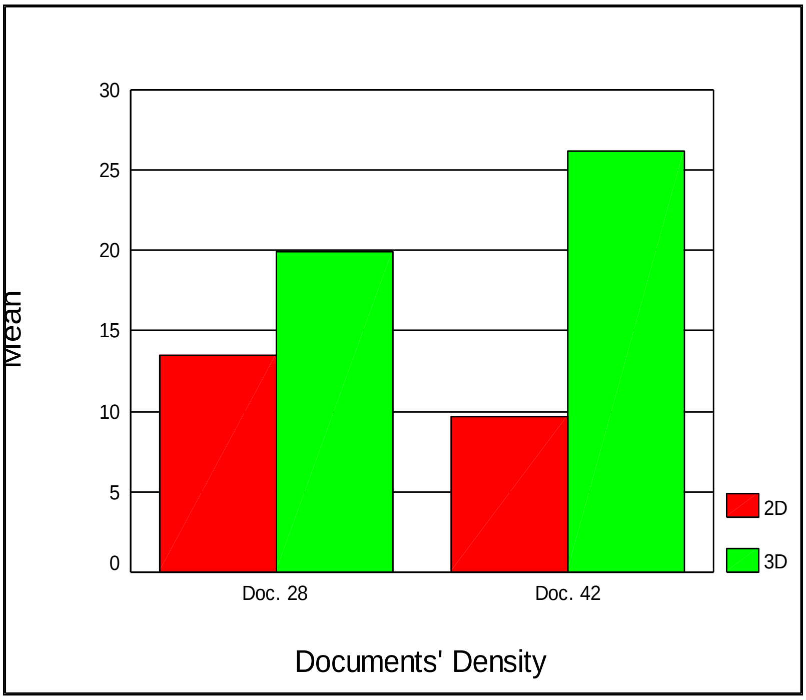


**Figure 6.1** The mean values of accurately recalled documents with various densities.

The figure 6.1 illustrates that the 3D means in both densities are larger compared with the 2D means. This result indicates that participants' ability to remember the correct position of documents in

3D Bibliotheca is superior to 2D interface in both densities. T-test is measured to determine the existence of significant differences between these means. In order to do that, null hypothesis ($H_0$) assume that there is no difference in the mean number of accurately recalled documents while the alternative assumption ($H_1$) is that the mean of correct recalled documents of 3D is greater than 2D. Two T-tests were carried out in preceding iterations. Table (6.2) presents the Mean, Standard Deviation (SD), T-value, P-value and Degree of Freedom (DF)[1] for correct responses in the first iteration (in which 28 documents are displayed).

| Interface | Mean | SD | Absolute T-value | P-value | DF |
|---|---|---|---|---|---|
| 2D | 12.79 | 7.21 | 4.135 | 0.001 | 13 |
| 3D | 20.21 | 4.25 | | | |
| Absolute Mean difference | 7.43 | | | | |

**Table 6.2** Analysis data for correct responses of 28 documents**.**

As P-value is less than 0.05 ($\propto$ value), the null hypothesis ($H_0$) is rejected while the alternative assumption ($H_1$) is accepted. As a result, general performance is more significantly higher when 3D display with twenty-eight documents is interacted.

[1] DF= participants' no.- 1

Table (6.3) depicts the statistical results for second iteration.

| Interface | Mean | SD | Absolute T-Value | P-Value | DF |
|---|---|---|---|---|---|
| 2D | 9.64 | 2.76 | 7.626 | 0.000 | 13 |
| 3D | 26.21 | 7.94 | | | |
| Absolute Mean difference | 16.571 | | | | |

**Table 6.3** Analysis data for correct responses of 42 documents' **location.**

As previously described, same results is revealed with statistically significant difference in accurately recalled documents between 3D and 2D layouts. There are statistical significance in general performance between 2D and 3D interfaces with 42 documents displayed on screen. 3D is reliably superior.

In order to address the effect density of documents on both types of interfaces, T-tests were conducted. Two T-tests were examined on 2D with two various densities and 3D with the same densities (twenty-eight, forty-two) as illustrated in (6.4).

| Same interface with different Density | Absolute Mean Difference | Absolute T-value | P-value | DF |
|---|---|---|---|---|
| 2Ds/ 28 – 42 | 3.14 | 1.410 | 0.182 | 13 |
| 3Ds/ 28 – 42 | 6.00 | 3.267 | 0.006 | |

**Table 6.4** Analysis data for correct documents of 2D, 3D interfaces with various densities.

Referring to figure 6.1, it is clear that the participants are able to remember less documents' titles while increasing documents in 2D layout by contrast of 3D. T-test is calculated to examine if means differences is significant or not.

While P-value for 2D interfaces with different densities are greater than 0.05, there is no significant statistical difference between two means of 2D's (2D interface with 28 documents and 2D interface with 42 documents). As a result, we accept the null hypothesis. In spite of increasing documents numbers and contrary to 3D, the participants were able to remember almost the same number of documents' titles which is in fact is smaller (see figure 6.1). This result is in contrast to 3Ds; participants were significantly able to remember larger number of document titles in 3D Bibliotheca in spite of increasing documents. At the same time, all participants have strongly noted that 2D layout become more difficult to memorize even though documents' density is high whilst 3D Bibliotheca facilitate all impediments.

### *6.1.2 Retrieval time*

The second analysis is performed to compare the completion time of retrieving specific document icons in both interfaces (2D and

3D). Figure (6.2) demonstrates the mean of retrieval time in seconds across 2D, 3D layouts in different iterations as the following:

1. First iteration where 28 documents are located: 2D mean is 86.36 second while 3D mean is 59.74 second.
2. Second iteration where 42 documents are located: 2D mean is 112.46 second while 3D mean is 69.21 second.

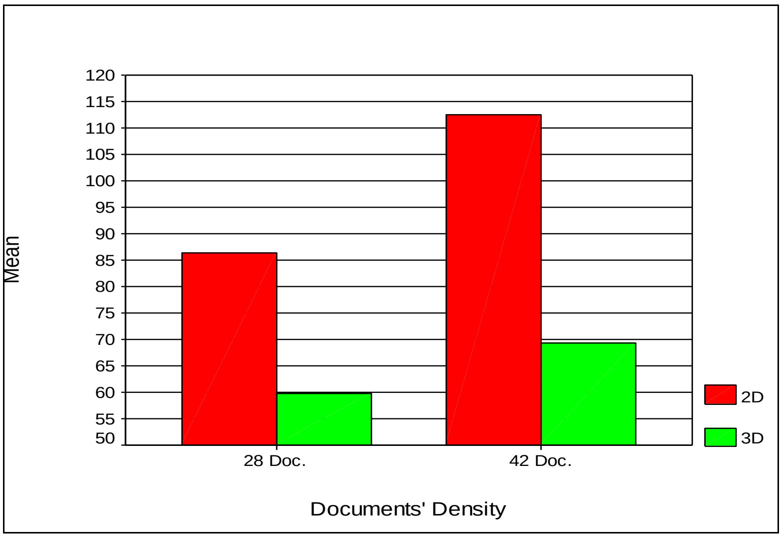


**Figure 6.2** The mean values of retrieval time with modified documents' density.

Figure (6.2) shows that the means of retrieving time of 3D is less than the means of 2D in different densities. This result demonstrates that participants in 3D Bibliotheca need less time to complete the same task than in 2D interface in both densities. As in previous section, T-test is measured and null hypothesis ($H_0$) assume that there is no significant difference in documents' retrieval time between 2D, 3D layouts while the alternative assumption ($H_1$) is that the mean of 3D's retrieval time is less than in 2D. Two T-tests have been carried out and tables (6.5 and 6.6) illustrate the analysis in both iterations when $\propto = 0.05$.

| Interface | Mean in seconds | SD | Absolute T-value | P-value | DF |
|---|---|---|---|---|---|
| 2D | 86.36 | 38.5 | 3.97 | 0.002 | 13 |
| 3D | 59.74 | 20.8 | | | |
| Absolute Mean difference | 26.62 | | | | |

**Table 6.5** The mean, SD values, T-value when 28 documents are situated.

| Interface | Mean in Seconds | SD | Absolute T-value | P-value | DF |
|---|---|---|---|---|---|
| 2D | 112.46 | 37.17 | 4.803 | 0.000 | 13 |
| 3D | 69.25 | 29.74 | | | |
| Mean Difference | 43.21 | | | | |

**Table 6.6** The mean, SD values, T-value when 42 documents are located.

In both iterations, the result confirms that there are statistically significant differences between two layouts in which 3D is lower. Therefore, we agree with the second assumption while the first is redundant.

As before, in order to examine the effect of documents' density on both interfaces, two T-test are carried out and table (6.7) demonstrates the results.

| Interfaces with different Density | Absolute Mean Difference | Absolute T-value | P-value | DF |
|---|---|---|---|---|
| 2Ds/ 28 – 42 | 26.097 | 2.207 | 0.046 | 13 |
| 3Ds/ 28 – 42 | 9.51 | 1.654 | 0.122 | |

**Table 6.7** The mean, SD values and T-value of both 2D and 3D interfaces with various densities.

Referring to figure (6.2), the task retrieval time of 3D Bibliotheca is less than retrieval time of 2D prototype (Windows) in both iterations. Increasing documents' numbers makes both means of 2D and 3D larger, but this growing means is statistically significant in 2D layouts with different densities contrary to 3Ds. P-value of 2Ds' interfaces is less than 0.05 and P-value of 3Ds' is greater than 0.05 (see table 6.7). Although documents are increased in 3D, participants almost are able to maintain their retrieval speed.

To conclude, spatial Memory of 3D representation affects positively general performance and retrieval time. Naturally, the increasing documents' density impedes memorization; however 3D representation facilitates this difficulty. Participants are reliably able to increase their accurately recalled document titles and maintain their retrieval speed in spite of increasing documents' density. By contrast the 2D layout, the increasing documents affect negatively the general performance and the retrieval time.

Spatial Memory Questionnaires (SMQ) are analyzed in next section in order to know about the factors that affect memorization in both interfaces (2D desktop – 3D Bibliotheca).

### *6.1.3 Spatial Memory Questionnaire (SMQ) Analysis*

SMQ contains several items as illustrated in table (6.8) that contains five point scale (1=min, 5=max) for each items. Comparison of the first and the second items display that 3D layout is more helpful in memorization than 2D. The general mean of 3D display is 3.71 whilst the average of 2D is 2.14 [Appendix J] and the SD is 0.53, 0.86.

| Items of SMQ | Mean | SD |
|---|---|---|
| 1. I find the layout of the 2D interface helpful in remembering document's locations (in general). | 2.14 | 0.86 |
| 1.a The layout of documents in the 2D interface is simple | 2.14 | 1.1 |
| 1.b The grouping of documents in rows (R) and columns (C) helped me remember document's locations. | 2.57 | 1.16 |
| 1.c The document's type helped me remember the document's location. | 1.79 | 0.97 |
| 2. I find the 3D layout of interface helpful in remembering document's locations (in general). | 3.71 | 0.53 |
| 2.a The existence of ecological landmarks helped me remember document's locations. | 4.21 | 0.58 |
| 2.b The difference of document thumbnails' size helped me remember document's locations. | 3.21 | 1.12 |
| 2.c The clustering documents helped me remember document's locations. | 4.29 | 0.47 |
| 2.d The existence of fences' labels helped me remember document's locations. | 2.71 | 1.27 |
| 2.e The existence of fences in different depth and locations helped me remember document's locations. | 3.43 | 0.94 |
| 2.f The document's type helped me remember document's locations. | 2.14 | 1.1 |

**Table 6.8** The mean, SD values for each item in SMQ.

As an explanation to the previous result, there are several factors playing essential roles with considerable assistance to participants' memorization. The previous table portrays the mean and Standard Deviation (SD) for each affective factor in 2D, 3D layouts.

For more illustration, comparison between these factors using 3D layout is shown in figure (6.3).

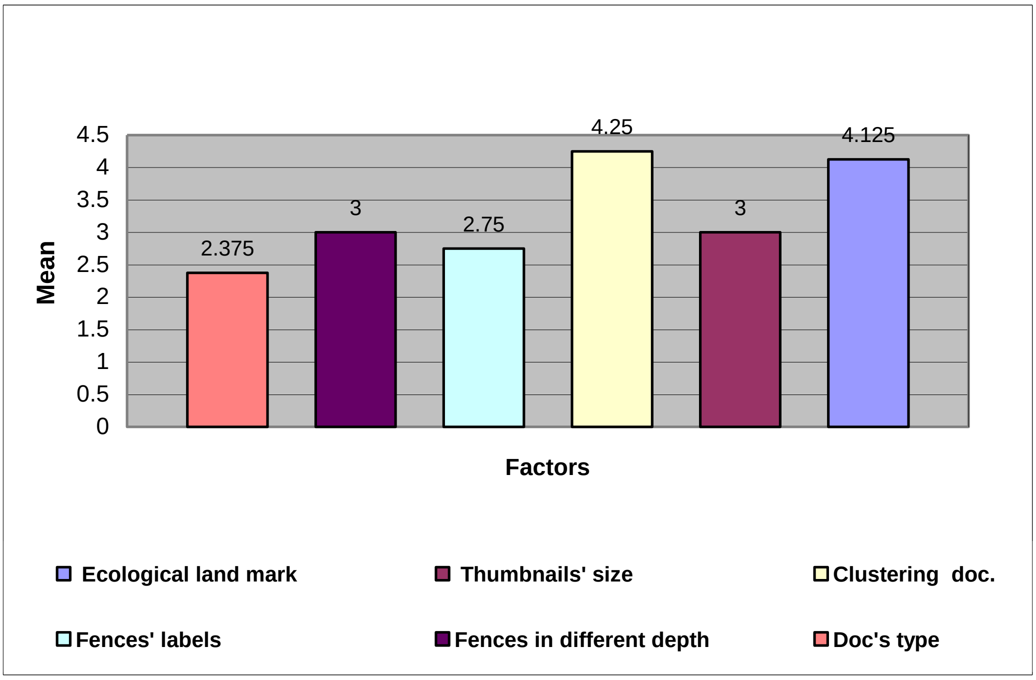


**Figure 6.3** The mean values of effective Factors in 3D Bibliotheca.

Depending on means' results in the previous figure (6.3), we have rated helpful factors in memorization into three levels- starting from high- as the following:

1. Clustering documents and existence of ecological landmarks.
2. Different thumbnails' size, existing fences in different depth-locations and the existence of fences' labels.
3. Document' types are rated in lower level.

On the other hands and after analysis of the averages of helpful factors in 2D memorization, we deduce that the existence of documents in rows and columns score 2.57 while both simplicity of 2D layout and documents' types score 2.14, 1.79 respectively. Figure (6.4) depicts these results.

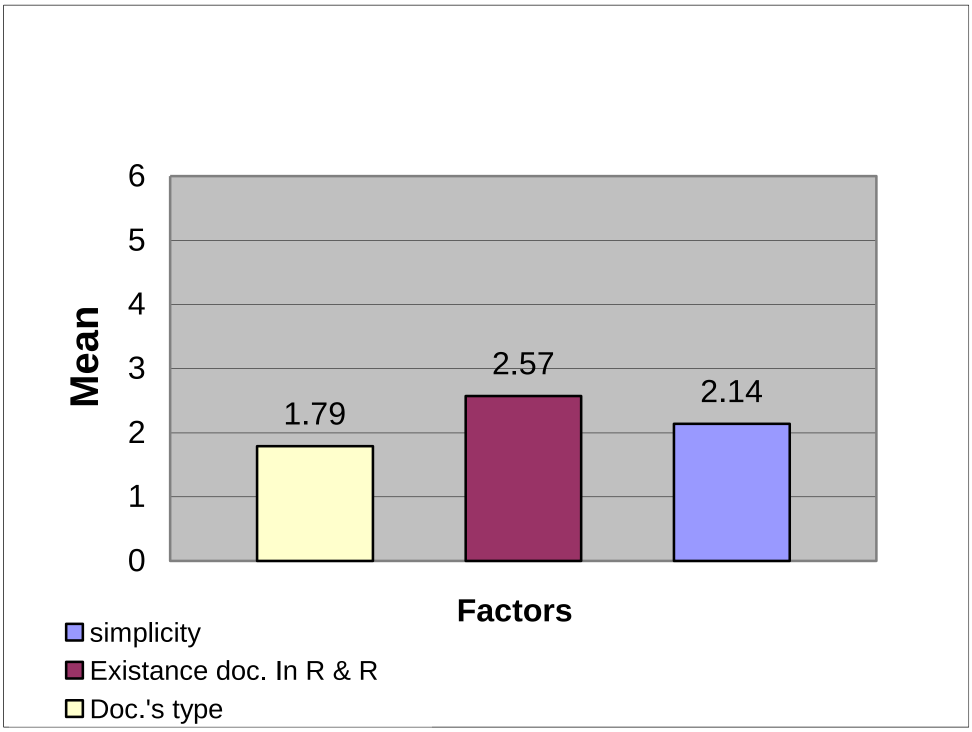


**Figure 6.4** The mean values of effective Factors in 2D layout.

## 6.2 Results of experiment (II)

The second experiment is conducted to scrutinize the attitude and satisfaction of different categories of users toward the utility of 3D Bibliotheca in comparison with 2D Window. For this purpose, fifteen subjects performed the basic operations in both, the real Windows 2D desktop and 3D Bibliotheca. Table 6.9 illustrates the characteristics of subjects that participated experiment (II).

| | | | | | |
|---|---|---|---|---|---|
| Age | 73% from 11-20 | 7% from 21-30 | 20% from 40-50 | | |
| Gender | 47% Male | 53% female | | | |
| Education level | 14% Primary | 47% intermediate | 32% secondary | 7% university | |
| Using Window desktop[1] | 40% Novice | 20 round novice | 20% 3 points | 20% 5 points | |
| Using computer hour/week | 33% 0 h | 27% from 1-3 | 20% from 8-10 | 13% from 11-13 | 7% >13 |
| Playing games[1] | 40% Nothing | 20% 2 points | 40% from 4-5 | | |

**Table 6.9 Subjects' characteristics of experiment (II).**

Depending to the last three items in table 6.8, participants are divided into two different categories as the following:

1. Category (A): includes nine novice (60%) participants (four male, five female) whose knowledge in both games and using desktop is limited. Their ages are ranged between 11-50 and the average age is 26.
2. Category (B): comprises six (40%) young users whose practice in using computer desktop and playing games is high. They use the computer from 8 to more than 13 hours per week. The average age is 15.

[1] Five-point scale is used

### *6.2.1 Category (A) analysis*

Table (6.10) portrays USQ's items, the mean of five point scale (1=disagree, 5=agree) and standard deviation (SD) for category (A) (novice subjects).

| USQ's items | Mean | | SD | |
|---|---|---|---|---|
| | 3D | 2D | 3D | 2D |
| 1. I find the interface to be attractive. | 4.78 | 2.33 | 0.44 | 1.12 |
| 2. I am comfortable with the arrangement of objects/icons on interface screen. | 4.78 | 2.67 | 0.44 | 0.97 |
| 3. The resembling interface to reality simplify the interaction with interface. | 4.89 | 2.67 | 0.33 | 1.09 |
| 4. It is easy to use this interface. | 4.78 | 3 | 0.44 | 0.71 |
| 5. I feel that the interface is familiar to me. | 4.78 | 2.67 | 0.44 | 1.32 |
| 6. I like to use the interface for my home PC to rearrange the desktop. | 4.89 | 2.56 | 0.33 | 1.33 |
| 7. Overall, the interface is easy to learn. | 4.89 | 2.78 | 0.33 | 1.09 |
| 8. Overall, the interface is efficient to use. | 4.67 | 2.56 | 0.71 | 1.13 |
| 9. Overall, I am satisfied with the interface. | 4.56 | 2.67 | 0.73 | 1.22 |

**Table 6.10** The mean and SD values for each item in USQ is related to category (A).

There are differences between means for each item related to 2D and 3D layouts. Results show that 3D Bibliotheca has higher means over 2D Windows. Further more, because the same participants conduct two different interfaces, dependant T-text can be applied on each item to infer whether there are significant differences or not. Only, two T-tests are carried out for two items number (4 and 9) as shown in tables (6.11) and (6.12).

| Interface | Mean | SD | Absolute T-Value | P-Value | DF |
|---|---|---|---|---|---|
| 3D | 4.56 | 0.73 | 4.464 | 0.002 | 8 |
| 2D | 2.67 | 1.22 | | | |
| Absolute Mean difference | 1.89 | | | | |

**Table 6.11** The mean and SD values related to category (A) satisfaction in both interfaces.

| Interface | Mean | SD | Absolute T-Value | P-Value | DF |
|---|---|---|---|---|---|
| 3D | 4.78 | 0.44 | 8.00 | 0.000 | 8 |
| 2D | 3 | 0.71 | | | |
| Absolute Mean difference | 1.78 | | | | |

**Table 6.12** The mean and SD values related to the ease of use of category (A) to both interfaces.

There are significant differences in the user satisfaction scores between 3D and 2D interfaces. Category (A) demonestrates a higher mean level of satisfaction with 3D interacted interface. At the same time, the same category has significant advanced mean level of ease of use with 3D interface.

### *6.2.2 Category (B) analysis*

Table (6.13) represents USQ's items, the mean of five point scale and standard deviation (SD) for category (B) (young with high computer practice).

| USQ's items | Mean | | SD | |
|---|---|---|---|---|
| | 3D | 2D | 3D | 2D |
| 1. I find the interface to be attractive. | 4.67 | 3.17 | 0.52 | 1.17 |
| 2. I am comfortable with the arrangement of objects/icons on interfaces screen. | 5 | 2.17 | 0 | 0.75 |
| 3. Resembled interface to reality makes the interaction with this interface simple. | 4.83 | 2.5 | 0.41 | 0.84 |
| 4. It is easy to use this interface. | 4.67 | 2.33 | 0.82 | 0.52 |
| 5. I feel that the interface is familiar to me. | 4.17 | 2.5 | 0.75 | 0.84 |
| 6. I like to use the interface for my home PC to rearrange the desktop. | 4.67 | 2.83 | 0.52 | 0.75 |
| 7. Overall, the interface is easy to learn. | 5 | 2.83 | 0 | 0.75 |
| 8. Overall, the interface is efficient to use. | 4.67 | 3 | 0.52 | 1.26 |
| 9. Overall, I am satisfied with the interface. | 4.83 | 3.17 | 0.52 | 0.41 |

**Table 6.13** The Mean and SD values for each item in USQ related to category (B).

As previously described, there are differences between means for each item related to 2D and 3D layouts. It is apparent that 3D Bibliotheca has higher means level than 2D interface. As in preceding section, two T-tests are applied on the same previous items number (4 and 9). Tables (6.14) and (6.15) show analysis result for both items correspondingly.

| Interface | Mean | SD | Absolute T-Value | P-Value | DF |
|---|---|---|---|---|---|
| 3D | 4.83 | 0.52 | 4.392 | 0.007 | 5 |
| 2D | 3.17 | 0.41 | | | |
| Absolute Mean difference | 1.5 | | | | |

**Table 6.14** The Mean and SD values related to category (B) satisfaction in both interfaces.

| Interface | Mean | SD | Absolute T-Value | P-Value | DF |
|---|---|---|---|---|---|
| 3D | 4.67 | 0.816 | 7.00 | 0.001 | 5 |
| 2D | 2.33 | 0.516 | | | |
| Absolute Mean difference | 2.33 | | | | |

**Table 6.15** The mean and SD values related to the ease of use of category (B) to both interfaces.

There is significant differences in the user satisfaction scores between 3D and 2D interfaces. Category (B) has a higher mean value of satisfaction with 3D interacted interface. In the same concern,the same category has also significant higher mean value of ease of use with 3D Bibliotheca interface.

As a conclusion, both groups of participants prove a higher average level of satisfaction when interacting with 3D Bibliotheca. They agree strongly with the utility of 3D Bibliotheca comparing with 2D Windows due to its ease of use and to ease to learn. They agree that resemblance to reality simplifies the interaction with 3D Bibliotheca in comparison with 2D (see item 3).

Ultimately, participants are requested to rate the factors that facilitate the use of 3D desktop Bibliotheca. Table (6.16) shows the Mean and Standard Deviation scores on a five-point scale (1=disagree, 5=agree) for participants' responses to that factors.

| USQ's items | Category (A) | | Category (B) | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| 1. Clustering documents together. | 4.44 | 0.53 | 4.17 | 0.41 |
| 2. Using hot keys. | 4.78 | 0.44 | 4.33 | 0.82 |
| 3. The ability of navigation using arrows. | 3 | 1.22 | 2.8 | 1.17 |
| 4. The ability of teleportation to fences. | 4.56 | 0.88 | 4.5 | 0.55 |
| 5. Using focusing technique. | 4.44 | 0.73 | 4.33 | 0.52 |
| 6. Meaningful icons. | 4.78 | 0.44 | 4.83 | 0.41 |
| 7. Grouping of applications in cupboard. | 4.44 | 0.73 | 4.17 | 0.75 |
| 8. Arranging documents on different ecological landmarks | 4.89 | 0.33 | 4.5 | 0.55 |
| 9. Locality (I can reach the object's properties by Its icons). | 4.78 | 0.44 | 5 | 0 |

**Table 6.16** The mean and SD values for each factor that makes 3D Bibliotheca easy to use for both categories of participants.

### 6.3 Summary

This chapter analyzed the result of the designed two experiments. The result of the first experiment focused significantly the positive affect of 3D spatial space on the user performance in both densities (28 – 42 documents). 3D spatial space helped participants to remember the accurate location of documents' positions in 3D Bibliotheca. Indeed, it makes the retrieval time faster than 2D window desktop. Complementary to the investigation of spatial memory, SMQ's are analyzed to study the factors that helped participants' identification of located documents.

The result of second experiment showed that both categories of users have higher satisfaction comparing with 2D. They agreed that 3D perspective' view facilitate ease of use and ease of learn.

# Chapter 7

## Conclusion and Future Expectation

In this research work, the 3D Bibliotheca is used as a vehicle to discover if there are advantages related to 3D over 2D window desktop. It is developed to conduct some usability testing related to user performance and the satisfaction of different user categories toward the utility of 3D.

Two usability experiments were conducted. The first experiment aimed to investigate the impact of spatial memory on user performance across 2D and 3D representations. In order to do that, two parameters are measured general performance and retrieval time. First parameter measured general performance by calculating the number of accurately recalled documents using 2D and 3D paper-interface diagrams. Indeed, this calculation is done in different densities (24 and 42 documents). Finally, the result showed that the mean of the correct recalled documents of 3D is significantly greater than 2D. In other words, the result indicated that the abilities of participants to remember the position of documents in 3D Bibliotheca were statistically significant in both densities. Indeed, with increasing documents in 2D layout, the result indicated that the participants almost were not able to remember more documents' titles as in 3D. At the same time, all participants have strongly noted that 2D layout is more difficult to memorize even though documents' density is high.

On the other hand, the second parameter measured the completion time of retrieving specific documents systematically. The related result proved that the mean of 3D's retrieval time is less than in 2D. In other words, this study indicated that participants' speed in retrieving specific document icons is significantly faster in 3D than 2D in both densities/iterations. Indeed, increasing documents' numbers makes both means of 2D and 3D larger. However, this increasing is statistically significant in 2D which is contrary to 3D. Although documents' density is increased in 3D, participants were able to maintain their retrieval speed.

The concluded results related to general performance and retrieval time (both parameters) showed that spatial memory of 3D representation affects positively on user performance. In addition, these results are considerably marked due to memorable features such as existence of ecological landmarks, clustering documents and shrinking documents' size. It is worth to mention that the positive roll of 3D spatial space agreed with Tavanti's experiment[1] [Tavanti et al. 2001] and Robertson's research[1] [Robertson et al. 1998] whilst disagree with Cockburn experiments[1] [Cockburn and McKenzie 2001; Cockburn 2004].

The second experiment aimed to explore the attitude and satisfaction of different categories of users toward 3D Bibliotheca compared with 2D Window desktop. The result of this experiment demonstrates that participants have significantly more satisfaction toward the utility of 3D in comparison of 2D. The resembling 3D Bibliotheca to reality simplifies the interaction, facilitates ease of use, ease of learn and cause more satisfaction for both examined categories (A and B). Category (A) included novice-adult and novice non-adult, while category (B) involved young with high computer practice. 3D interface encourages the mentioned users to be more interactive.

Despite the limited scope of our study, we strongly believe that 3D interfaces will replace 2D in near future when adroit metaphor

[1] Please refer to page (14) in chapter (3)

appears. This claim is supported by our statistical analysis. It is very possible that 3D desktop interface might appeal more to certain categories of users such as novice and young who are familiar with advanced computer applications, such as 3Ds games, which will be an insipient stage to 3D future interface generation.

## 7.1 **Future Research Directions**

1. Possible future improvements to 3D Bibliotheca are mentioned in chapter 4 section 4.6.This enhancement is for the sake of conducting further usability testing in this area. It is not for developing full product.
2. Replicate the first experiment where users become able to store the blank documents freely in personal manner. We expect that this will increase obviously the retrieval performance.
3. Make empirical evaluation to measure the ability of participants to memorize after locating the thumbnail personality in a period of time.
4. Measuring both general performance and retrieval time with other different densities of documents.

5. Comparing retrieval time of 3D Bibliotheca with hierarchical layout in order to try to discover other advantage of 3D over 2D.
6. Conduct experiments on others types of users with more depending on different users such as adult with high computer experience, educated and illiterate.

## References

Ark W., Christopher D., Selker T. and Zhai Sh. 1998. Representation Matters: The Effect of 3D Objects and a Spatial Metaphor in a Graphical User Interface. Proceeding of HCI'98 Conference on People and Computer XCIII, pp.209-219.

Brunstad, S. and Eie, Th. F. 2002. Adding a D to 2D - a better interface? IFI, UiB, Bergen, Norway / IHA, Man-Machine Interaction.

Card S. K., Robertson G.G. and Mackinlay J.D. 1991. The information Visualizer: An Information workspace. Proceeding of ACM CHI'91, p.181-188.

Card S. K., Robertson G.G. and York W. 1996. The WebBook and the Web Forager: An Information Workspace for the World-Wide Web. Proceeding CHI'96, ACM, p.111-117.

Cockburn A. and McKenzie B. 2001. 3D not 3D Evaluating the Effect of the Third Dimension in a Document Management System. Proceeding of CHI'2001 Conference on Human Factors in Computing Systems, p. 434-441.

Cockburn, A. and McKenzie B. 2002. Evaluating the effectiveness of Spatial Memory in 2D Physical and Virtual Environments. Proceeding of CHI' 2002 Conference on Human Factors in Computing Systems, ACM, p. 203--210.

Cockburn, A. 2004. Revisiting 2D vs. 3D Implication on Spatial Memory. Proceeding of Fifth Australasian User Interface Conference (AUIC) Dunedin, p 25-31.

Cockburn, A. and McKenzie B. 2002. An Evaluation of Cone Trees. People and Computers XIV: British Computer Society Conference on Human Computer Interaction, p. 425--436.

Czerwinski M. , Dumais S., Robertson G., Dziadosz S., Tiernan S. and Dantzich M. 1999. Visualizing Implicit Queries for Information Management and retrieval. Proceeding of CHI'99, ACM Press, p.560-567.

Czerwinski M. P., Dantzich M., Robetson G. and Hoffman H.1999. The Contribution of Thumbnail image , Mouse-over Text and Spatial Location Memory to Web Page Retrieval in 3D.

Dix A. J., Finlay J. E. and Abowd G. D. and Beale R. 1997. Human-Computer Interaction. Glasgow: Bath Press Colourbooks, 2nd edition. ISBN 0-13-239864-8.

Dokic G. 2000. 3D user Interfaces.HCI'2000.

Furness G. 1986.Generalized fisheye views. Proceeding of CHI'86 Conference on Human Factors in Computing Systems, p. 16-23.

Leach G., Al-Qaimari G., Grieve, M., Jinks, N.and McKay C. 1997. Elements of a Three-Dimensional Graphical User Interface. In S. Howard, J. Hammond, and G. Lindgaard (eds) Human Computer Interaction, INTERACT’97 London: Chapman and Hall.

Mackinlay J. D., Robertson G. G. and Card S. K. 1992. The Information Visualizer: A 3D User Interface for Information Retrieval. Advanced visual interfaces. World scientific publishing, Singapore: p.173-179.

Nielsen J. 1993. Usability Engineering Academic Press.

Preece J. 1994. Human-Computer-Interaction. Addison-Wesley, Harlow.

Preece J., Progers Y. and Helen Sh.2002. Interaction design: Beyond Human-Computer interaction. Wiley Text Books, 1st edition, ISBN 0-47-149278-7.

Robertson G., Mackinlay J. and Card S. 1991. Cone Trees: Animated 3D Visualizations of Hierarchical Information. In Proceeding of CHI'91 Conference on Human Factors in Computing System New Orleans, p. 189-194.

Robertson G. and Mackinlay J.D. 1993. The Document Lens. ACM Conference on User Interface Software and technology, p.101-108

Robertson G., Czerwinski,M., Larson K., Robbins D. C., Thiel D. and Dantzich M. 1998. Data Mountain : Using spatial memory for document manager. Proceeding of UIST'98, San Francisco, California, ACM Press,pp.153-162.

Robertson G., Dantzich M., Robbins D.,Czerwinski M., Hinckley K., Risden K., Thiel D. and Gorokhovsky V.2002. The Task Gallery:A 3D Window Manager. Proceeding of CHI 2000, ACM Prec.,p.494-501. Microsoft Research.

Scannel P. (dissertation). 1997. Three-dimensional information space: An exploration of a world wide web-based, three-dimensional, hierarchical information retrieval interface using Virtual Reality Modeling Language. University of North Texas.

Smallman H.,John M.,Oonk H., "Information Availability in 2D and 3D displays".IEEE Computer Graphics and Applications,vol.21,no.2001,pp. 51-57.

Shneiderman B**.** 1998.Designing the User Interface: strategies for effective human computer interaction**.** Addison-Wesley Longman, Icn.3 rd edition.

Shneiderman B. 2003. Why Not Make Interfaces Better than 3D Reality? IEEE Computer Society nov./dec.

Tavanti M. and Lind M. 2001. 2D vs. 3D, Implications on Spatial Memory. Proceedings IEEE InfoVis 2001 Symposiun on

Information Visualization, pp.139--145.

Tittel E., Scott C., Wolfe P. and Sanders C. 1997. Building VRML Worlds. Osborne: McGraw-Hill. ISBN 0-07-882233-5.

Ware C., Arthur K. and Booth k. 1993, Fish Tank Virtual Reality. INTERCHI'93. April 1993.

Wiss U., Carr D. and Jonsson H. 1998. Evaluating Three-Dimensional Information Visualization Designs: a Case Study of Three Designs. Proceeding Int'l Conference Information Visualization, IEEE Press, p. 137-144.

**Web Pages references:**

http://www.hitl.washington.edu/scivw/EVE/I.D.2.c.DirectManipulation.html
www.clockwise.com
http://www.cs.vu.nl/~gdokic/hci/
http://vrg.dur.ac.uk/misc/PeterYoung/pages/work/documents/lit-survey/IV-Survey/index.html#Rekimoto93
http://www.useit.com/alertbox/981115.html
http://www.cg.tuwien.ac.at/studentwork/CESCG/CESCG99/PZikovsky/
http://www.cas.mcmaster.ca/~se4d03/cacm96aug2u.pdf
http://www.usabilitysa.co.za/hcigloss.htm#SecM
http://www.useit.com/papers/noncommand.html
http://www.calsoft.co.in/techcenter/visualization.html#k
http://www.webopedia.com/TERM
http://www.web3d.org/x3d/overview.html
http://www.otal.umd.edu/SHORE2001/winDesktop/

# Appendix

# Appendix (A)

| Demographic Survey |
|---|
| **Participant # (  )** |

This form was built for scientific purpose. All answers are kept confidential; please do not write your name on the form.

This section of the survey gathers general information about you and your knowledge of computers.

**Please check the blank, which applies to you, or fill the information requested**.

1- Age : (  ) 18-20 (  ) 21-23 (  ) older.

2- Gender : (  ) Male (  ) Female.

3- Major :________________________________________.

4- Education level at the university:

1- (  ) first year 2- (  ) second year

3- (  ) third year 4- (  ) forth year

5- How can you rate your memorization?

|----------------|-----------------|-----------------|----------------|

**Bad 1 2 3 4 5 Excellent**

6- How often do you use the computer?

1- (  ) 0-2 hour/week 2- (  ) 3-5 hour/week 3- (  ) 6-10 hour/week

4- (  ) 11-12 hour/week 5- (  ) >20 hour/week

7- How can you rate your computer skill in using 2D window desktop?

|----------------|-----------------|-----------------|----------------|

**Novice 1 2 3 4 5 Expert**

8- How much experience with computer graphics programming do you have?

|----------------|-----------------|-----------------|----------------|

**Novice 1 2 3 4 5 Expert**

9- How can you rate yourself in playing games?

|-----------------|------------------|------------------|-----------------|

**No experience 1 2 3 4 5 High experience**

10- Have you ever used or saw 3D desktop?

Used (   ) yes (   ) no .If yes where ____________________.

Saw (   ) yes (   ) no .If yes where ____________________.

## Thank you

# Appendix (B)

## Spatial Memory Questionnaire
## Participant's # (   )

This form was written for scientific purpose. All answers are kept confidential; please do not write your name on the form.

This section of the questionnaire gathers specific information about the factors related to spatial memory performance across two different prototypes 2D and 3D desktops.

**Please circle on the suitable number, which applies to you, or fill in the information requested.**

1- I find the layout of the 2D interface helpful you in remembering document's locations (in general).

|----------------|----------------|----------------|----------------|

**Min** 1 2 3 4 5 **Max**

2- Rate the factors, which are helping in remembering document's locations in 2D prototype?

2-a The layout of documents in the 2D interface is simple.

|----------------|----------------|----------------|----------------|

**Min** 1 2 3 4 5 **Max**

2-b The grouping of documents in rows ( R ) and columns( C ).

|----------------|----------------|----------------|----------------|

**Min** 1 2 3 4 5 **Max**

2-c The document's type.

|----------------|----------------|----------------|----------------|

**Min** 1 2 3 4 5 **Max**

3- I find the layout of the 3D interface helpful in remembering document's locations ( in general).

|----------------|----------------|----------------|----------------|

**Min** 1 2 3 4 5 **Max**

4- Rate the factors, which are helping in remembering document's locations?

4.a The existence of ecological landmarks.

|----------------|----------------|----------------|----------------|

**Min** 1 2 3 4 5 **Max**

4.b The difference of document thumbnails' size.

|----------------|-----------------|-----------------|----------------|

**Min** 1 2 3 4 5 **Max**

4.c The clustering documents.

|----------------|-----------------|-----------------|----------------|

**Min** 1 2 3 4 5 **Max**

4.d The existence of fences' labels.

|----------------|-----------------|-----------------|----------------|

**Min** 1 2 3 4 5 **Max**

4.e the existence of fences in different depth and locations.

|----------------|-----------------|-----------------|----------------|

**Min** 1 2 3 4 5 **Max**

4.f The document's type.

|----------------|-----------------|-----------------|----------------|

**Min** 1 2 3 4 5 **Max**

**Comments:**

**Thank you**

# Appendix (C)

## Retrieval Task

**Participant # (  )**

Please try to find these documents' titles that are located into both interfaces sequentially. Both interfaces contain **twenty-eight** documents.

Follow these steps in order to finish this task:

1- Click on start button when task's time is began.

2- Press OK in the appeared message.

3- Search on the titles that are listed in table (1) sequentially. Please do not skip any title. Click on the demanded title in order to hear music sound.

4- Click on stop button when completing the task.

5- Please write down a displayed time in table (2) for both types of interfaces.

**Table (1):**

| NO. | Documents' titles |
|---|---|
| **1-** | **S** |
| **2-** | **Y** |
| **3-** | **G** |
| **4-** | **B1** |
| **5-** | **Z** |
| **6-** | **I** |
| **7-** | **E** |
| **8-** | **X** |
| **9-** | **D** |
| **10-** | **N** |
| **11-** | **A** |
| **12-** | **F** |

**Table (2)**

| | 2D interface | 3D interface |
|---|---|---|
| **Time** | | |

**Thank you**

# Appendix (D)

## Retrieval Task
## Participant # (  )

Please try to find these documents' titles that are located into both interfaces sequentially. Both interfaces contain **forty-two** documents.

s Follow these steps in order to finish this task:

6- Click on start button when task's time is began.

7- Press OK in the appeared message.

8- Search on the titles that are listed in table (1) sequentially. Please do not skip any title. Click on the demanded title in order to hear music sound.

9- Click on stop button when completing the task.

10- Please write down a displayed time in table (2) for both types of interfaces.

**Table (1)**

| NO. | Documents' titles |
|---|---|
| 1- | **O** |
| 2- | **E1** |
| 3- | **G** |
| 4- | **U1** |
| 5- | **Z** |
| 6- | **Y** |
| 7- | **E** |
| 8- | **X** |
| 9- | **D** |
| 10- | **R** |
| 11- | **A1** |
| 12- | **S** |

**Table (2)**

| | **2D interface** | **3D interface** |
|---|---|---|
| Time | | |

**Thank you**

## Appendix (E)

Demographic Survey (Experiment 2)
**Participant # (  )**

This form was built for scientific purpose. All answers are kept confidential; please do not write your name on the form.

This section of the survey gathers general information about you and your knowledge of computers.

**Please check the blank, which applies to you, or fill the information requested**:

1- Age : ________________.

2- Gender: (  ) Male (  ) Female.

3- Education level:

1- (  ) primary 2- (  ) intermediate

3- (  ) secondary 4- (  ) university

4- How can you rate your knowledge in using window desktop?

|----------------|-----------------|-----------------|----------------|

**Novice 1 2 3 4 5 Expert**

5- If you are not novice how often do you use the computer?

1- (  ) 1-3 hour/week 2- (  ) 4-6 hour/week 3- (  ) 8-10 hour/week

4- (  ) 11-13 hour/week 5- (  ) >13 hour/week

7- If you are novice, check in the circle what can you do:

□ Nothing

□ Power on –off –using keyboard and mouse.

□ Open floppy drive

□ Open CD-player

□ Change the properties of screen.

□ Change the properties of keyboard.

□ Change the properties of mouse.

□ Display the content of recycle bin

□ launch word-excel-power point application.

□ Check Time/Date

9- How can you rate yourself in playing games?

|-----------------|------------------|------------------|-----------------|

**No experience** **1** **2** **3** **4** **5** **High Experience**

## Thank you

# Appendix F

**User Satisfaction Questionnaire (experiment 2)**
**Participant's # (   )**

Thanks for participating in the experiment. This is last stage of the experiment. Please fill up this satisfaction questionnaire so that we can understand the subjective impressions of both the 2D Windows XP Desktop and 3D Bibliotheca.

**Please circle on the suitable number and fill in the information requested.**

1- I find the interface to be attractive.

***3D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

2- I am comfortable with arrangement of objects/icons on interface's screen.

***3D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

3 - The resembling interface to reality simplify the interaction with the interface.

***3D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

4- It is easy to use this interface.

***3D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D***

|----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

5- I feel that the interface is familiar to me.

***3D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

6- I like to use the interface for my home PC to rearrange the desktop.

***3D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

7- Overall, it is easy to learn.

***3D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

8- Overall, it is efficient to use.

***3D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

9- Overall, I am satisfied with the interface.

***3D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

***2D*** |----------------|----------------|----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10- Please, from your point of view, rate the features (factors) that make 3D desktop interface easy to use.

10.a Clustering documents together.

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.b Using hot keys.

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.c The ability of navigation using arrows.

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.d The ability of teleportation to fences.

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.e Using focusing technique..

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.f Meaningful icons.

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.g Grouping of applications in cupboard.

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.h Arranging documents on different ecological landmarks (on ground, table and fences).

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

10.i Locality (I can reach to the object's properties by its icons).

|----------------|-----------------|-----------------|----------------|

**Disagree** 1 2 3 4 5 **Agree**

**Comments:**

**Thank you**

## Appendix G

| 2D- 3D Task1<br>**Participant # (  )** |
|---|

Please follow these steps to perform the entire task.

1- Execute the ordered tasks in the table below without skipping any if you can in 2D Windows XP.

2- Write down in 2D Windows XP blank what is requested.

3- Repeat first step in 3D Bibliotheca after it is opened.

4- Fill down in 3D Bibliotheca blank what is requested

**Task Table:**

| NO. | Description |
|---|---|
| **1-** | Open floppy disk then close it.<br>Describe the position of floppy in both interfaces.<br># Windows XP desktop: ___________________________________.<br># 3D Bibliotheca: ________________________________________. |
| **2-** | Read the display properties. Write down different properties for both interfaces.<br># Windows XP Desktop: ___________________________________.<br># 3D Bibliotheca: _________________________________________. |
| **3-** | Display the partitioning of hard disk and write down one<br># Windows XP Desktop: ___________________.<br># 3D Bibliotheca:_________________________. |
| **4-** | Open word application. |
| **5-** | Open the recycle bin.<br>Describe where you found it in both systems.<br>#Windows XP desktop: ___________________________________.<br>#3D Bibliotheca:__________________________________________. |
| 6- | Open internet browser and close it. |

| | |
|---|---|
| **7-** | Open CD-player.<br>Describe the position of it in both interfaces.<br># Windows XP desktop: ___________________________________.<br># 3D Bibliotheca: ________________________________________. |
| **8-** | Drag three word documents into space :<br># Windows XP Interface: distribute them on the desktop as you want.<br># 3D Bibliotheca: put one on the ground ,one on the middle fence whilst the other on the left fence. |
| **9-** | What is the time in both interfaces:<br>#Windows XP desktop: ___________________.<br># 3D Bibliotheca:_________________________. |

## Extra functions
## Task2

**After finishing this pilot study for both interfaces, please execute this extra task related to 3D Bibliotheca.**

**1-** Teleport to the right fence.

**2-** Go back to normal vision.

**3-** Cluster word documents as you desire (ex. two on the ground –others on the table).

**4-** Read the title of light brown power point document located on the table.

4.a Write down its title:_______________________.

4.b Focus this document and write down some about its contents:_______.

5- View whole interface's components by pressing on suitable hot key. Then read one of the title of the document located on archive fence.

5.a Write down its title:_______________________.

5.b Focus this document and write down some about its contents:_______.

6- Return to the normal view.

7- Use navigation to see the screen.

8- Return to normal view.

## Thank you

**Appendix H**

## T-test

The t-test employs the statistic (t), with n-1 degrees of freedom, to test a given statistical hypothesis about a population parameter. Usually used with small sample sizes (<30). It is used when population standard deviation (SD) is unknown.

In order to calculate t-test two hypothesis are formed, the null hypothesis and the alternative one. The null hypothesis shows that there are no differences between the related means while the other assumption give the opposite. Due to comparing P-value[1] with significance level ($\propto$) there are three possibilities:

1- If P-value is equal to the significance level of the test for which we would only just reject the null hypothesis.

2- If P-value is smaller, the Null hypothesis is rejected and the alternative one (assumption of the study) is accepted and the result of the alternative one is significant.

---

[1] The probability of wrongly rejecting the null hypothesis if it is in fact true.

3- If the P-value is larger than significance level (∝) we accept the Null hypothesis and reject the alternative assumption.

**Al-Quds University**

# 3D Environment Based on Desktop Metaphor: A Usability Study

**Suzanne Jamil Hilmi Sultan**

**M.Sc. Thesis**

**Jerusalem – Palestine**

2005

**3D Environment Based on Desktop Metaphor:**

# A Usability Study

**By**

Suzanne Jamil Hilmi Sultan

B.Sc.: Al-Quds Open University
Hebron

Supervisor: Dr. Ghassan Al-Qaimari

A Thesis Submitted in Partial Fulfillment of Requirements for the Degree Master of Computer Science

Computer Science Department
Al-Quds University

December,2004

Department of Computer Science

College of Science and Technology
Deanship of Graduate Studies

# 3D Environment Based on Desktop Metaphor: A Usability Study

By

Student Name: Suzanne Jamil Hilmi Sultan

Registration No: 20011538

Supervisor: Dr. Ghassan Al- Qaimari

Co-Supervisor:-

Master thesis submitted and accepted, Date : 30/12/2004

Names and signatures of the examining committee members:

1- Dr. Ghassan Al- Qaimari Head of committee

2- Dr. Rashid Jayousi Internal Examiner

3- Dr. Yousef Asad Hassouneh External Examiner

Al-Quds University
2004