

**EXPLORING VIRTUAL ENVIRONMENT USING STEREO SCOPIC DISPLAY
DEVICES**

by

MUHAMMAD AKBAR BIN IKHLAS

Dissertation submitted

In Partial fulfillment of the requirement for the
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(INFORMATION TECHNOLOGY)

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UNIVERSITI TEKNOLOGI PETRONAS

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- 3) IT / IS - thesis

CERTIFICATION OF APPROVAL

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A Project dissertation submitted to the
Information Technology Programme
Universiti Teknologi PETRONAS
In Partial fulfillment of the requirement for the
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Approved by,

(Mr Jafreezal Jaafar)

**UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JUNE 2004**

CERTIFICATION OF ORIGINALITY

This is certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement, and that the original work contained herein have not been undertaken or done unspecified sources or persons.



(Muhammad Akbar Bin Ikhlas)

ABSTRACT

The aim of this project is to provide users of the system with different perspective and views of a particular model in a virtual reality environment with as much realism as possible. Apart from that the objective of the system is to design and build a virtual mosque, to investigate effective ways to present virtual environment thru highlighting the issues of graphic displays and user orientation for best realism and to evaluate the realism navigation and interaction of the virtual environment. Initially most new designs and models are projected only on paper and miniature models, and some are generated in computer thru 3D modeling. Although so the models lack realism and provide little views to the observer. In order to achieve the project objectives, four vital phases of development are conducted. The phases are data gathering and analysis, prototype design, prototype implementation and prototype evaluation. After the prototype is evaluated and data are analyzed, it is found that there is improvement in realism, navigation and interaction. In conclusion, the use of effective graphic displays such as HMD and proper input devices for navigation and interaction helps to increase realism to the virtual reality. For further studies, it is recommended that the use of more devices that can bring all the five senses to work and capture each action that to user carries out in the virtual environment be use. This is to enhance further the feeling of immersive ness and reality. The idea is to bring virtual reality users to a whole new level of experiencing reality in the virtual world.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Virtual Reality has significantly played an important role in our lives today. It has moved from military application to entertainment, training and education, arts, medical, marketing, manufacturing, robotics, information visualization, design and development.

There are many definitions for virtual reality as it is hard to specifically define the term VR because of its use in different contexts. A very general definition was elaborated by Aukstakalnis and Blatner [2]:

“Virtual Reality is a way for humans to visualize, manipulate and interact with computers and extremely complex data”.

Generally it means Virtual Reality (VR) allows the observer to act in synthetic, computer generated worlds in contrast to conventional visualization systems, the user may become an active part of the scene. Virtual Reality usually works with sophisticated hardwares such as graphics Subsystems, head mounted displays (HMD), 3D-mouse, data glove, various types of joysticks and embedded in all of them is the tracker.

There are also different types of VR systems, they are Walk-troughs, Window on world systems (WoW), Video mapping, Immersive systems, Telepresence, mixed reality and Fish Tank VR.

Virtual Reality is the latest approach to computer interaction which enables users to utilize the use of computers.

1.2 Problem Statement

The project main concern is dealing with navigating and interacting in a 3D virtual environment. To ensure realism when using the VR system, navigation thru the environment need to be as naturally as possible for the users. This means every actions conducted by the users need to be reflected in the virtual environment real-time and interaction with the virtual objects need to have some feedback to the users. Other problems faced in VR environments are problems with user orientation, 3D realism display and navigation cues.

For this project the focused is set on issues of effective graphic displays and user orientation. In order to achieved realism, users need to feel that they are been brought into the virtual environment themselves. Previous system limits user's movement and views of the virtual environment which is affect the level of realism it is able to achieve. This can be achieved by using an immersive system which completely immerses the user's personal viewpoint in side the virtual world. This is done by using Head Mounted Display (HMD).

1.3 Aims and Objectives

The aim of this project is to design and develop a Virtual Floating Mosque which allows users to move, navigate and view freely of the environment as they are seeing it in real life. The project is focused on the use of virtual reality technology which are the head mounted display and the tracker.

Main Objectives of this project are:

- To design and build a virtual floating mosque
- To investigate effective ways to present virtual environment thru highlighting the issues of graphic displays and user orientation for best realism
- To evaluate the realism navigation and interaction of the virtual environment

1.4 Scope of Study

Developing a virtual environment of a floating mosque will require the study of the background and original plans of the mosque. This includes studying the exterior designs as well as the interior designs. Because the mosque is not in completion, models and architecture diagrams are used to project and build the 3D virtual model of the floating mosque.

Include in this study is the use of sophisticated virtual reality devices, which are the HMD and the Tracker. The HMD or Head Mounted Display is a helmet with stereoscopic goggles for the wearer's eyes and stereo headphones for the wearer's ears used as an interface for the wearer to experience the virtual environment with more realism. The Tracker is used to position an object or the wearer in the virtual environment with that of the movement made in the real world. Usually a tracker will be used with other devices together such as the data glove or the HMD itself.

In this project the study will be more focused on the HMD and HMD tracker. Together the devices should enable users to explore the virtual environment with ease and realism in mind.

CHAPTER 2

LITERATURE REVIEWS AND THEORY

The main focus of the project is to stress on realism within the virtual environment which includes scenery, navigation and interaction. The virtual environment in this project is a virtual model of the future UTP floating mosque. The mosque is still in construction and is estimated to be finished in the year 2006.

The project utilizes the use of virtual reality to enhance realism in the computer generated world.

2.1 History of Virtual Reality

Virtual Reality application originated more than 40 years ago. Sensorama Simulator invented by Morton Heilig was the first virtual reality video arcade. The Sensorama used film loops, stereo sounds, smells, wind, vibrating handlebars and seat to create the illusion of motorcycle ride through New York.

In 1966 a professor name Ivan Sutherland work on head-mounted displays (HMD). He used two cathode ray tubes mounted along the user's ears. During that time the HMD was heavier and need to rely on a mechanical arm to support the weight of the display. While working on his head-mounted display, Sutherland realized that he could use computer-generated scenes instead of the conventional analog images taken by cameras. He began to design a scene generator. This is the earliest type of modern graphics accelerator, a key part of VR hardware. Sutherland's contribution to the VR world didn't only stop at the graphics area. He also came out the theory of haptics that allow users to feel the virtual objects within the virtual environment.

The term 'Virtual Reality' (VR) was coined by the founder of VPL Research Jaron Lanier in 1983. VPL Research is the first commercial company that sells virtual reality products. Some of the products that are released commercially include the HMD, the famous "EyePhone" system in 1989 and also one of the first dataglove.

The term 'Cyberspace' was later coined by a writer name William Gibson in his novel titled Neuromancer in 1984. In that book, 'cyberspace' is a metaphor that allows us to

take hold of the place where we experience digital and virtual realities. The term is now widely used as a second name for virtual reality. [3]

2.2 Definition of Virtual Reality

What is virtual Reality? *“Virtual Reality is a way for humans to visualize, manipulate and interact with computers and extremely complex data”*. This general definition was elaborated by Aukstakalnis and Blatner (1992) [2]. Visualization in the definition refers to the computer generating visual, auditory, or other sensual outputs to the user within the computer world. This world may well be a CAD model, a scientific simulation, or a view into a database. The user can interact with the world and directly manipulate objects within the world [4].

In another definition, Virtual Reality is described as a high-end-user-computer interface that involves real-time simulation and interactions through multiple sensorial channels. These sensorial modalities are visual, auditory, tactile, smell and taste [5]. Basically this means that virtual reality is a computer generated world which uses human senses to interact with it.

2.3 Introduction to types of Virtual Reality Systems

Virtual reality describes a variety of experiences that a person interacts with and explores a computer simulated spatial environment using input devices such as a mouse, joystick or a keyboard. This type of VR setting is known as non-immersive VR. While another type of setting is known as “cognitive presence” where it has to meet four minimum criteria [4]: -

- i. A head-mounted devices with a wide field of view
- ii. A tracker to track the position of the participant’s body
- iii. Transducers that interprets users’ natural behaviors
- iv. Insignificant delays in the rate at which the virtual environment is updated in response to users’ movements and actions

This means that users need to be interfacing with a computer generated 3D world with artistic rendering of real or imagined spaces [2]. In addition, interaction with the virtual environment must at least be with near real time control of the viewpoint which is critical issue for virtual reality applications [4].

There are basically 6 types of VR systems [2]: -

i. Window on World Systems (WoW)

Many VR systems use a conventional computer monitor to display the visual world. Such systems are called Desktop VR or a Window on a World (WoW).

ii. Video Mapping

A variation of the WoW approach merges a video input of the user's figure with a 2D computer graphic. The user watches a monitor that shows his body's interaction with the virtual world.

iii. Immersive Systems

These VR systems completely immerse the user's personal viewpoint inside the virtual world. These Immersive VR systems are often equipped with a Head Mounted Display (HMD). This is a helmet or a face mask that holds the visual and auditory displays.

iv. Telepresence

Telepresence is a variation on visualizing complete computer generated worlds. This technology links remote sensors in the real world with the senses of a human operator. The remote sensors might be located on a robot. For example, fire fighters use remotely operated vehicles to handle some dangerous conditions, or surgeons use very small instruments on cables.

v. Hybrid/Mixed Reality

Merging the Telepresence and Virtual Reality systems gives the Hybrid/Mixed Reality or Seamless Simulation systems. Here, the computer generated inputs are merged with telepresence inputs and/or the user's view of the real world. For example, a fighter pilot sees computer generated maps and data displays inside his helmet visor or on cockpit displays.

vi. Fish Tank VR

The term Fish Tank VR was used to describe a VR system that combines a stereoscopic monitor display using LCD Shutter glasses with a mechanical head tracker. The resulting system is superior to simple stereo-WoW systems due to the motion parallax effects introduced by the head tracker.

2.4 Navigation and Interaction Concept in Virtual Reality

Navigation is defined as the act of navigating or the state of being navigable [8]. Navigation in a virtual environment simply means moving around and exploring the virtual environment. Navigation was also originally defined as the process of moving through an environment. Darken & Sibert (1993) extend this definition of navigation to include the process of way finding (determining a path to be traveled). They define navigation as the process of determining and traveling a path through an environment.

They extend this definition even more with a reference to the aids and cues people need for successful navigation in virtual environments, to arrive at the following definition: "Navigation is the process by which people control their movement using environmental cues and artificial aids such as maps so that they can achieve their goals without getting lost" [9]. Common types of navigation in VR are walking and flying.

Visual Navigation controls what the user sees as they move through the virtual environment and pilot around using input device such as HMD or mouse. Two main factor are concerned during the visual navigation; the user's location in the virtual

environment and also the gaze direction. Changes in user's location within the virtual environment can be affected by a virtual vehicle, by the specification of new vantage point within the virtual environment and the execution of logical command to fly to that point or by simulated teleports in the distance at which user can suddenly appear without moving through the intervening space. The book also stressed out that the changes of location or user movement must consider the factor of how the visual scene should be changed and provide navigation aids to prevent the user from getting lost in the virtual environment [10].

Generally, interaction can be defined as action that may increase the response, decrease the response, cause toxicity or completely change the response expected from either substance [6]. According to National Research Council [NRC] the meaning of interactivity is not fully explored, thus suggesting for further studies of multidisciplinary approach. Furthermore the report states that a research on virtual reality should concentrate on understanding interaction in terms of how it is defined and perceived, what is expected and needed, what are the analogues require for example in theatre, storytelling, improvisation, and the entertainment industry. The definition of interaction differs according to research domain. Behavioral and educational sciences use the word interaction quite differently than engineering and information processing sciences. The definition of interaction in the context of this research can be considered to follow the lines of natural interaction occurring in real life environments [7]. However certain limitations of technology have made interaction in the context of virtual reality to be a bit lower than how we interact in real life environments. Referring to a book by National Academy Press (1997) [1], interactions in virtual reality make use of outputs of human-machine control devices such as mouse, keyboard, joystick, speech recognition system and position trackers. The devices are used to modify the virtual environment that they integrate with. Besides that, tasks in virtual environments are also performed using a number of control techniques in combination. This is because none of the control techniques are adequate on their own.

In a shell, interaction in virtual reality is to allow users to manipulate virtual objects that have been programmed to allow certain types of manipulations. The types of

manipulations allowed to be done on these objects is dependent on the initial programming definition of the interaction actions and modifications to objects.

2.5 Virtual Reality Devices

When talking about virtual Reality, state of the art devices will always follow the topic. This is because in order to incorporate and maximize the potential of virtual reality, technology devices need to be used.

To view 3D images correctly and more realistically, devices such as passive stereo glasses, dual 3D LCD projector, head mounted display and the active screen panel can be used. Those are the devices that will be used in this project. Before the devices can be used, the 3D model needs to switch into stereoscopic projection to enable stereoscopic viewing.

Stereoscopic viewing is the ability to see and assess the size of a distant object quickly. A stereoscopic projection system provides two images with parallax information, giving the illusion of depth and relief [10].

In stereoscopic projection the models are drawn normally and then rendered for the viewer's left eye and for the viewer's right eye separately, which will have slight angular offset in either direction. The resulting pair of images are displayed or projected onto a viewing surface, alternating at a high rate between the left and right eye images. There are basically two different types of electronic Stereo-3D-Devices [11]: -

- i. Devices which actually produce an image by themselves such as VR-Helmets/Head Mounted Devices
- ii. Glasses which influence the way user sees the image on a standard monitor such as Liquid Crystal-Shutter glasses / Polarization Glasses

2.5.1 HMD

The head-mounted display (HMD) is the basic output device of the VR system. Two color displays located inside the HMD provide the user with the only visual signal received, effectively isolating the user from the external world and immersing him or her in the displayed imagery. The HMD also houses a pair of stereo earphones, which are used as the output device for the Convolvotron, an audio spatialization system. Finally, a position/orientation sensor is located on top of the HMD. The sensor, connected to the tracking device, provides information about the user's position and orientation in space [12]. Figure 2.1 shows an example of what today's HMD look like.

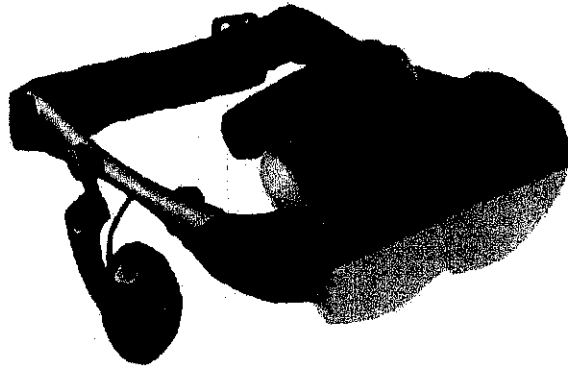


Fig.2.1: Head Mounted Display (HMD)

2.5.2 Glasses

There are two types of glasses. One is known as active stereo glass and another is known as passive stereo glass. In active stereo glass, the opacity of the left and right LCD lenses is synchronized via infrared transmitter attached to the computer graphics processor. For passive stereo eyewear, the viewing display rely on two projectors or overlaid display surfaces and polarized lenses to filter the correct image to the correct eye. These passive stereo glasses have lenses polarized differently for the right and left eye. Therefore each eye sees the image component of the stereo pair with matching polarization. The brain then integrates the two images for stereo effect. Passive glasses (figure 2.2) cost less expensive than the active glasses [5].



Fig.2.2: Passive Glass

2.5.3 Dual-Projector

Dual-projector 3D- projection system (figure 2.3) is used in viewing the output of the project stereoscopically using special glasses. Within the system, the stereo converter will convert incoming stereo 3D signal from the workstation which will transmit two signals, one signal for the right eye and one for the left eye. The signals are then sent to two projectors, which are stacked and project images in register. To achieve the 3D effect, a polarized filter must be fitted in front of the lens on each projector, and the images produced are projected onto an active screen panel. Users need to be using the passive stereo glasses to view the images [11].

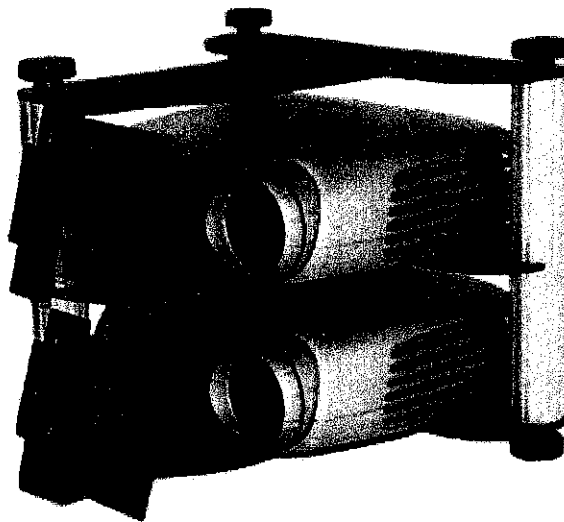


Fig.2.3: Dual-projector 3D- Projection System

2.6 Effect of Graphics mode on task learning system

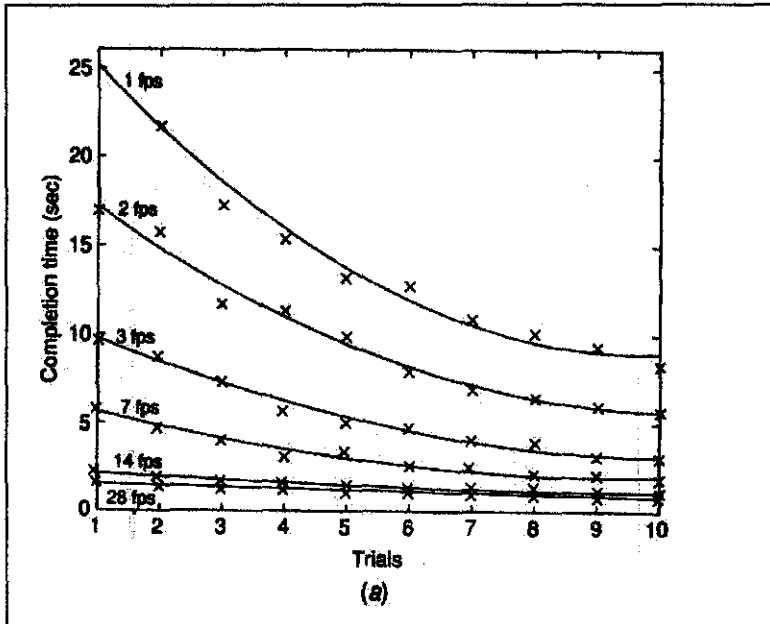


Fig.2.4: Groups seeing monoscopic graphics

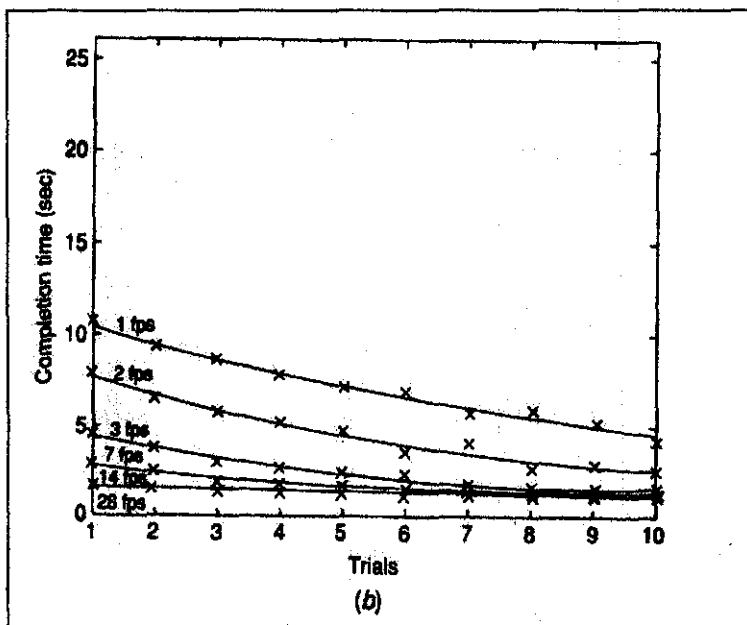


Fig.2.5: Groups seeing stereoscopic graphics

Figure shows the impact of frame refresh rate on a task performance to capture a ball in the virtual environment on a task learning system. It can be seen that subjects learned differently at 28 and 14 fps than they did at 1 fps.

Figure 2.4; When the system responsiveness was poor and the graphics was monoscopic, subjects took longer to capture the virtual ball. However after the 10th trials the time to capture the ball reduced significantly, indicating there is a learning curve.

Figure 2.5; There was essentially no learning curve in the group that had 28 fps graphics. Comparing the two graphs, we see that the impact of the graphics mode plays a significant role for navigation and interaction. Stereoscopic graphic mode proved beneficial in reducing the time to complete the task in the virtual environment [5].

CHAPTER 3

METHODOLOGY

3.1 Methodology Framework

This section of the report describes the methodology that was used in completing the project. The duration of the project is about four months from January 2004 to April 2004. The author decides to use the waterfall model or known as the linear sequential model which is slightly modified to suit the project. This model has 4 main phases which we'll be discussing in detail later in this chapter. The initial plan was to develop the project phases by phases starting from data gathering and analysis but because of the time constraint that is faced when developing the project, the phases are done in parallel of each other. This means that instead of a plain linear approach, the author is able to develop the project according to the resources and time available at the time.

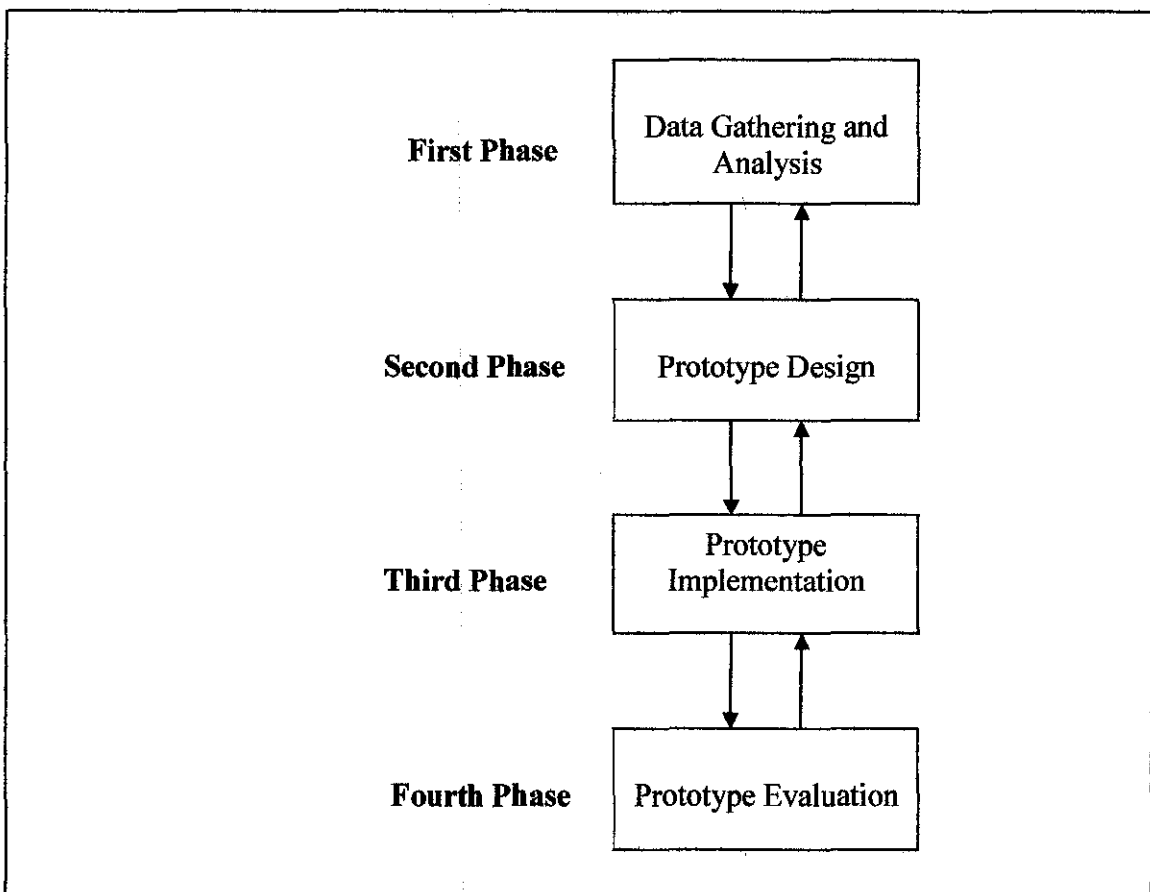


Fig. 3.1: Project Framework

3.2 Data Gathering and Analysis

The first step when initiating a project is to gather enough data and requirements in order to understand the nature of the project. The author first gathers requirements from the supervisor. These include details about the project from the beginning till the end. Apart from that, data is gathered thru other references and resources which include publication, journals and websites. After obtaining enough data, analysis is done to filter out unwanted data and keep only the necessary information that is related to the project.

From the data gathered, decision on what type of tools and equipments that are best to use are listed down.

3.2.1 Tools and Equipments

Tools and equipments used in developing the project are listed in this section. The use of tools and equipments is to assist processes and construct the system. These tools and equipments used can be divided into two categories, which are software and hardware.

Software

Software is the computer program that tells a computer's hardware what to do. Among 15the software used are: -

i. 3D Studio Max 6.0

3D Studio Max is a 3D modeling software that is used to author 3D models with more ease. All 3D virtual models for the project are built using this software. Once all parts of the model is finished, they will be put together in a single environment and exported to .wrl (VRML) format to be modified by other software for enhancements.

ii. Amira and Open Inventor

Amira is a powerful visualization technique which allows users to gain detailed insights of data. It's also an automated and interactive segmentation tools which

support processing of 3D image data. Amira is fast and its robust reconstruction algorithms make it easy to create polygonal models from segmented objects.

Open Inventor is the underlying language of Amira which uses C++. It contains a library of objects and methods used to create interactive 3D graphics and virtual environment.

iii. Microsoft Visual C++

Microsoft Visual C++ is the most productive C++ tool for creating a powerful and high performance application. In this project Microsoft Visual C++ is used to write the functions and codes for Open Inventor. This software is also used to combine and integrate the VRML and Open Inventor file format.

Hardware

Hardware is the physical part of a computer system and equipment. Among the hardware used are: -

i. Personal Computer

Personal Computer is used to built and develop the 3D model of the UTP floating mosque. The PC is powered by Intel Pentium 4, 2.0GHz processor with 512 MB random access memory running on Microsoft Windows XP operating system.

ii. VR workstation

The VR workstation is a more powerful PC then mention above. The purpose of using this workstation is to further improve the time spent developing the model, as it takes longer time on a normal personal Computer.

iii. Mouse

Mouse is used as the navigation and interaction input device for the virtual model.

iv. HMD

Head Mounted Display or HMD is a helmet with stereoscopic goggles for the wearer's eyes, and stereo headphones over the ears. It is used as an interface through which the wearer can experience a virtual reality environment.

3.3 Prototype Design

The next step is to visualize and design the prototype that is required to be developed. Since the project deals with virtual reality, 3-D models need to be visualized or constructed from images or a miniature model. There are no real images of the model acquired since the model is not yet constructed. Therefore photographs of miniature model and architecture drawings are acquired.

After this is done, the next step is to address the issue of navigation to the model. It is decided that the navigation would include the use of HMD and a tracker. Alternatively the navigation also can be done using common equipments such as a keyboard and a mouse.

The final touch is to decide on the kind of interaction that the user will have with the environment, what they can do and can't do.

3.4 Prototype Implementation

In this phase, the real construction is done. All the information and design is used to build the prototype. First the model is constructed within the virtual environment. For this task 3D Studio Max 6 is used to build the 3-D model. The model is built by phases starting from the bottom to the top. Only at the end of the construction the models are put together in one environment to form the whole replica. After this is done, the navigation system is programmed to match the environment. As mentioned above, the navigation system which includes the use of a HMD. After that the interaction is implemented by coding the

system with a few sets of instructions to allow and limit user's movement within the environment.

3.5 Prototype Evaluation

After the prototype is ready, the system will undergo a testing process or also known as evaluation process. In this phase the prototype will be tested thoroughly by evaluating different aspects of the prototype by a sample of users. The main aspect of the prototype to be tested is the **Realism of the virtual environment**.

Realism refers to how real the virtual surrounding environment in comparison to reality to the user. The level of realism that is sense by the user can be group to many different parts. Some of the parts could be on *physical perception of the objects within the environment*, the *interaction between the objects and the user*, the *navigation thru the virtual environment*. All this depends on to what extent the feeling of immersive ness is felt by the user.

The prototype evaluation phase can be divided into three different stages. The stages are *hypothesis formulation stage*, *evaluation and data collection stage* and the *evaluation data analysis stage*.

3.5.1 Hypothesis Formulation Stage

Hypothesis provides guidelines to carry out evaluation of the product. Once hypothesis is decided, data collection and analysis process will be much simpler and direct. The output from the data collection and analysis will be the results of the test.

The hypothesis of this project is *'improvement of realism, navigation and interaction'*. To test the hypothesis, an evaluation plan is designed to ensure the desired outcome is obtained. The purpose of the evaluation is to test whether the hypothesis can be accepted or not. In the evaluation process, a prototype of the virtual UTP floating mosque is prepared and evaluated by 5 respondents.

The evaluation will be able to tell whether the use of proper graphic display and input device has help to improve the realism, navigation and interaction of the application. The hypothesis is as below: -

The evaluation: *Improvement in realism, navigation and interaction*

H₀: There is No improvement in realism, navigation and interaction

H_A: There is Improvement in realism, navigation and interaction

3.5.2 Evaluation and Data Collection Stage

In evaluation and data collection phase, a prototype will be prepared for evaluation. The purpose of this evaluation is to determine whether the use of HMD as graphic display and mouse as navigation input device, have improved the realism, navigation and interaction of the virtual environment. During the evaluation the evaluators will be asked to try the prototype and evaluate it using the short questionnaire provided. There are five evaluator's chosen to try the prototype.

- **Evaluator's profile**

Five students from the IT study field have been chosen to evaluate the prototype. Each evaluator has experience and knows what virtual reality is. This is to ensure that the evaluator knows what to observe during the test.

- **Methods of conducting evaluation**

Before the evaluation begins, a short briefing is conducted. The purpose of this briefing is to explain to the evaluators their task in evaluating the product. During the test evaluators are given 5 to 10 minutes to explore the virtual environment. After they have used the prototype, the users are required to answer some questionnaire in relation to the system they have just used. Refer to **Appendix A** for the questionnaire form. After the form is filled and feedback received, the

forms will be analyzed to measure whether the prototype have met its objective or not. If objectives are not met, recommendations for corrections are noted.

3.5.3 Data Analysis Stage

After the evaluations have been done, data is collected from the checklist and short interviews with the evaluators are summarized and noted for recommendations. The purpose of analyzing the data is to prove the hypothesis of the project is true. The data are processed and tabulated in tables and graphs. All the results and details of the data are discussed in chapter 4, Results and Discussion.

The hypothesis is accepted if $R < M$ (all), which is calculated using a simple calculation.

Attributes of Realism and Navigation/Interacation	Mean
A ₁	M ₁
.	.
.	.
A ₂	M ₂
.	.
.	.
A _n	M _n

$A_1, A_2, \dots, A_n =$ Attribute

$M_1, M_2, \dots, M_n =$ Mean each attribute

Range (R) = $M_{n \text{ (max)}} - M_{n \text{ (min)}}$

Overall Mean, $M_{(all)} = \frac{M_1 + M_2 + \dots + M_n}{n}$

n

H_0 hypothesis will be rejected if $R < M_{(all)}$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Design and Implementation Phase

During the design and implementation phase, the future UTP floating mosque is modeled. Modeling is done with the guide from images of the miniature model which the author obtained from contractors and architects for the mosque. The miniature model is shown in figure 4.1. 3D Studio Max 6 is used to model the object and the surrounding environment. Because of the complexity of the scene, the model is built phase by phase to reduce confusion and to avoid degrading the workstation performance. Basically the mosque is built parts by parts, starting from the dome, to the hall till the surroundings; trees and lake.

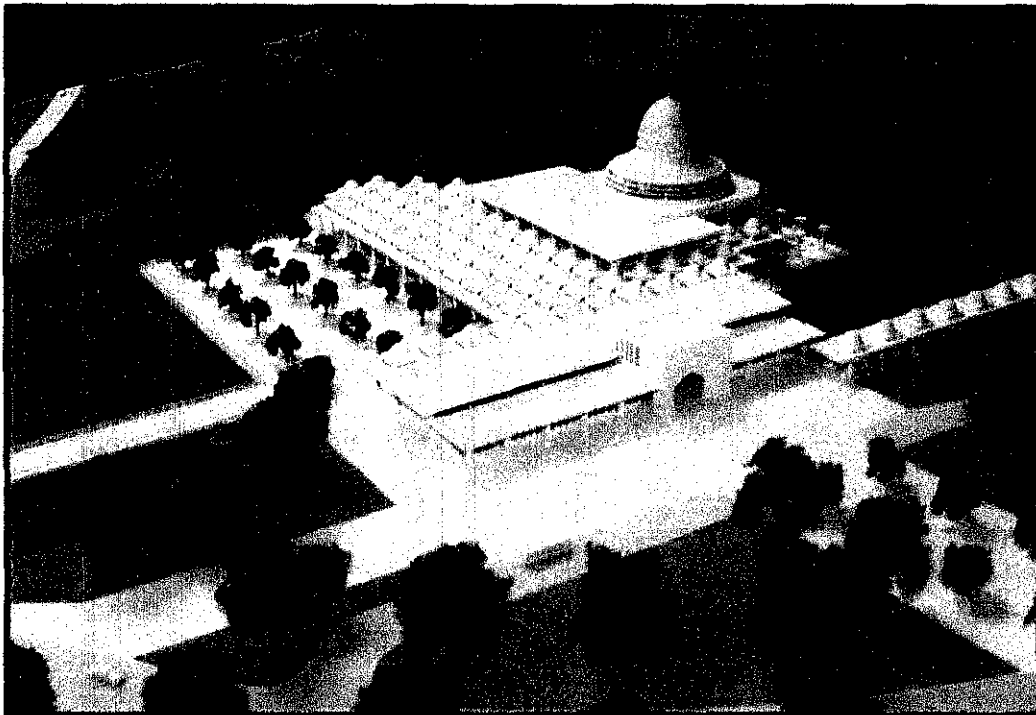


Fig.4.1: Image Miniature Model of UTP Floating Mosque

Texturing and lighting was also done using 3D Studio Max. The texturing is done by adding material skin to the object. Texturing can be an easy or complex task. This depends on the parts of model you are working on. Simple shapes are easy to texture and complex shapes are harder to texture. Basically texturing is done to make the model or the environment more real and lively.

Lighting is another process added to the virtual environment. With proper lighting, objects will look more real when the users explore the environment. There are three main lighting, ambient, diffuse and spotlight. Ambient light is the general light that illuminates the entire scene. It has a uniform intensity and is uniformly diffuse. It has no visible source and no visible direction. Diffuse light emits light from a surface. Light that leaves the surface at a right angle is at the light's greatest intensity. At increasingly oblique angles, the intensity of the emitted light diminishes. A spotlight emits a focused beam of light like a flashlight, a follow spot in a theater or a headlight.

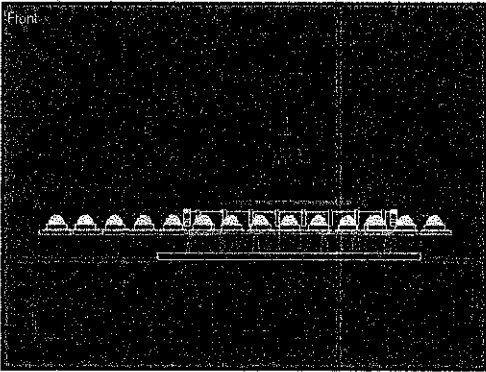


Fig.4.2: Wire frame front view of mosque

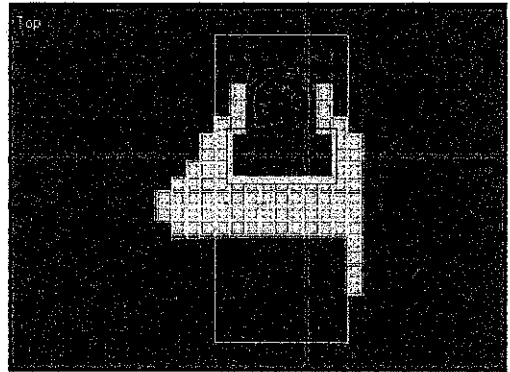


Fig.4.3: Wire frame top view of mosque

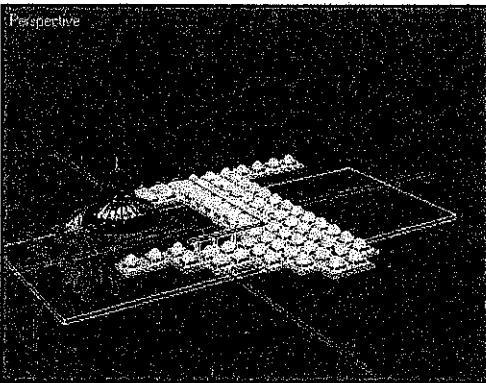


Fig.4.4: Wireframe 3D view of mosque

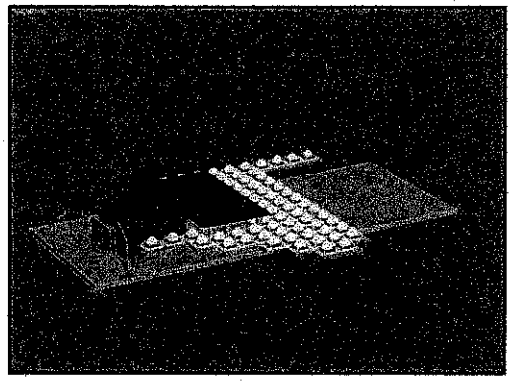


Fig.4.5: Smooth 3D view of mosque

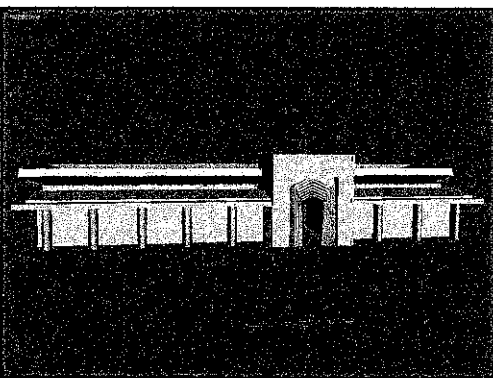


Fig.4.6: 3D Model of front entrance to mosque

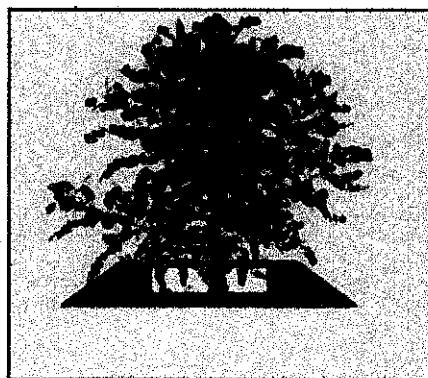


Fig.4.7: Model of a tree

After the modeling is done, the 3D model is exported from 3D Studio Max format (.max) to VRML format (.wrl). There are two reasons for doing this. First is because to project the virtual environment stereoscopically the virtual environment needs to be in VRML format. Secondly is because Amira can only support VRML (.wrl) and stereoLitho (.stl) format. Amira need to be used for further development. The mosque is then imported into Amira Scene Viewer for further manipulation and putting in the functions. One of the functions is collision detection.

Collision detection is the function that prevents user from walking through walls and objects in a virtual environment. This gives the environment a sense of realism like in the real world where we can't walk through walls and objects in the real world. If the user tries to walk through a wall, the system will make a sound. The sound indicates that the user has accidentally tried to walk through an object or wall. The function is implemented by calling the virtual mosque file in the library (predefined) codes developed by Open Inventor. The codes are shown in figure 4.8.

```

}
// Adding collision prevention

m_collision_viewer = new SoXtCollisionViewer(my_viewer);
m_collision_viewer->addCallback (onCollision, NULL);

// Main loop
SoXt::show(myWindow);
SoXt::mainLoop();

return 0;
}
//*****

// Function called when there is a collision

void
onCollision(void *, SoXtCollisionViewer *)
{
#ifdef WIN32
    PlaySound ("Collision.wav", NULL, SND_FILENAME + SND_ASYNC);
#else
    printf ("%c", 7);
    fflush (stdout);
#endif
}

```

Fig.4.8: Collision Detection Function Codes

After completing the programming task, the next phase is to project the model stereoscopically before implementing the HMD. This is to ensure that the model will appear more realistically when using HMD later. Any alterations to the model will be done if the standard of realism is not tolerable. Projection is done by using the dual projector which will project the model on the active screen. Passive glasses is use to view the model stereoscopically. Navigation is done thru a mouse, and all functions are tested to ensure everything is running in order.

The final step is to configure the Head Mounted Display (HMD) to be used with the prototype. The HMD is plug to the workstation and the environment is loaded. Users can browse and view the environment by moving the head and use the mouse to navigate around.

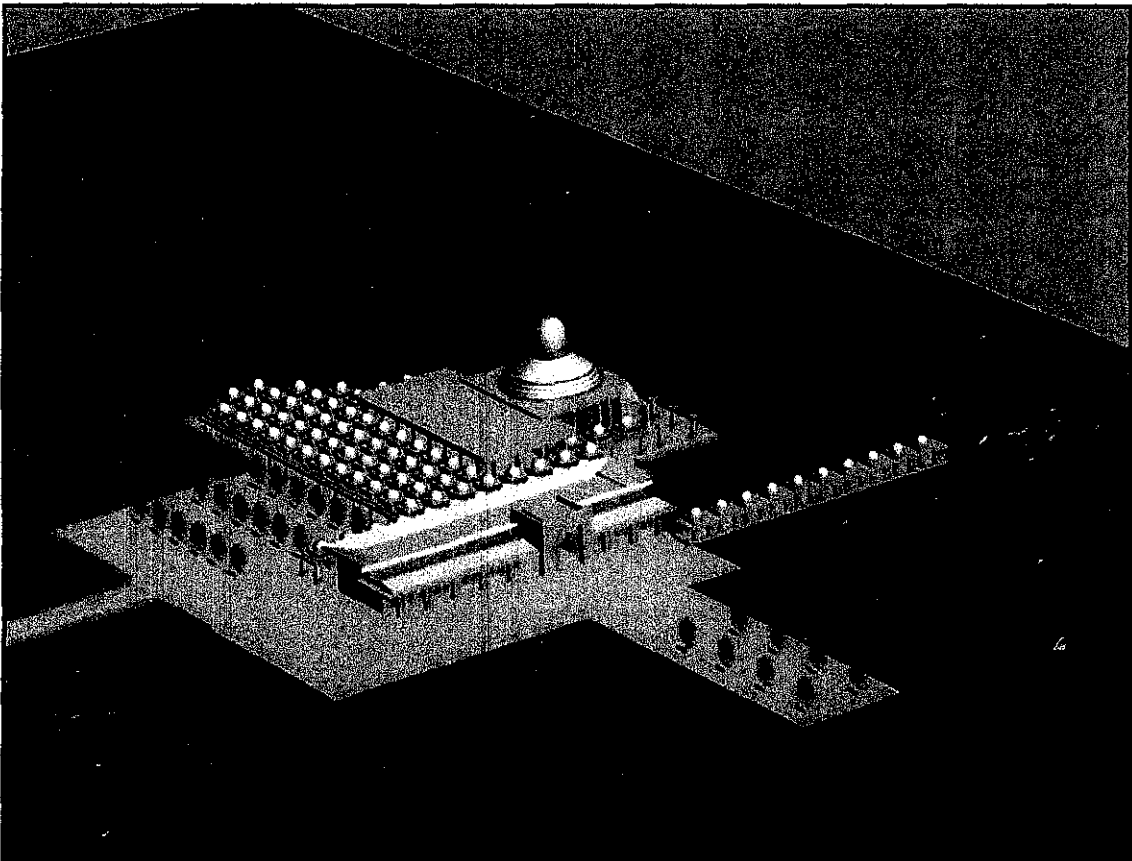


Fig.4.9: Complete Design of the Virtual UTP Floating Mosque

4.2 Evaluation Phase

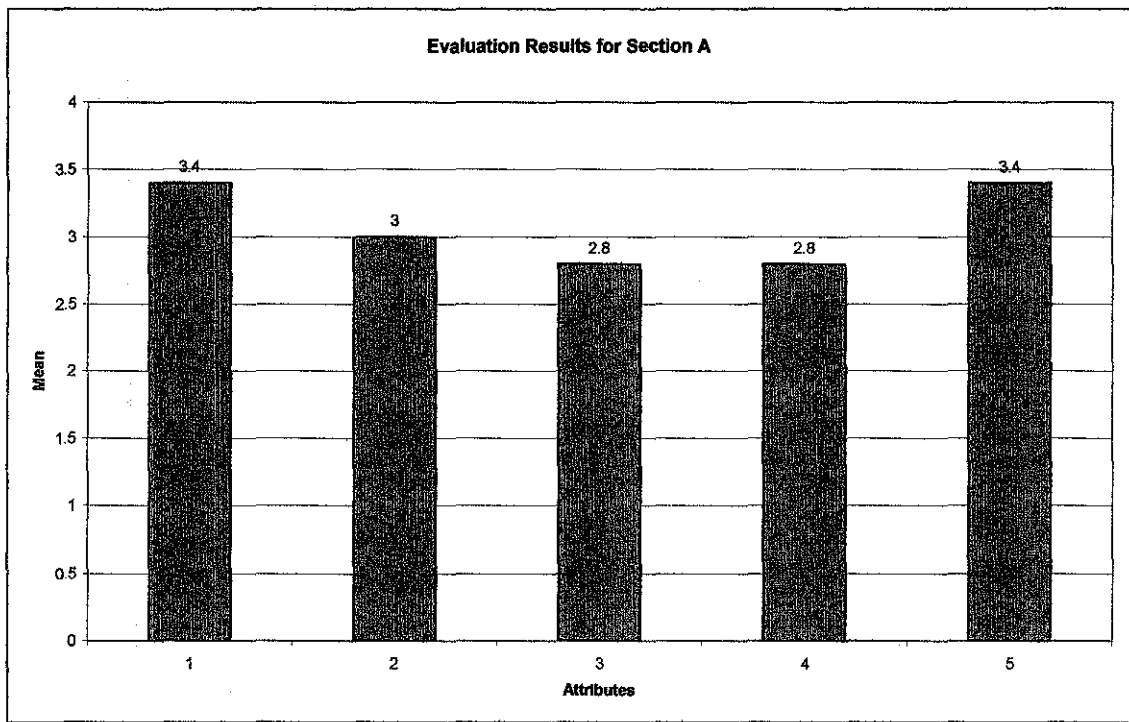
In the evaluation phase, valuable data are collected from evaluators. All data collected are later analyze by converting them to statistical and graphs form for easier interpretation.

Five evaluators have been chose to evaluate the prototype. The evaluators are asked to use the prototype. Later they are given a questionnaire for them to fill in. The questionnaire is divided into two sections. The first section is to evaluate the realism of the prototype. The second section is to evaluate on the navigation and interaction part of the prototype.

Table 4.1 and 4.2 shows the results of the evaluation. The data are converted to histogram chart for further analysis. The x-axis of the histogram represents the attributes of the evaluation and y-axis represents the mean (average) result of the evaluation. The questionnaire of the evaluation can be referred in the Appendix A, and the gathered data is in Appendix B.

Table 4.1; Summarization Evaluation Results for Section A- Prototype Realism

Attributes	n	Sum	Mean
1. Realism of the virtual mosque	5	17	3.4
2. Lighting of the virtual mosque you've just experience	5	15	3
3. Experience natural sensation during exploration	5	14	2.8
4. Are you distracted by the outside world when using the system	5	14	2.8
5. Smoothness of view changing	5	17	3.4
Overall Mean		3.08	

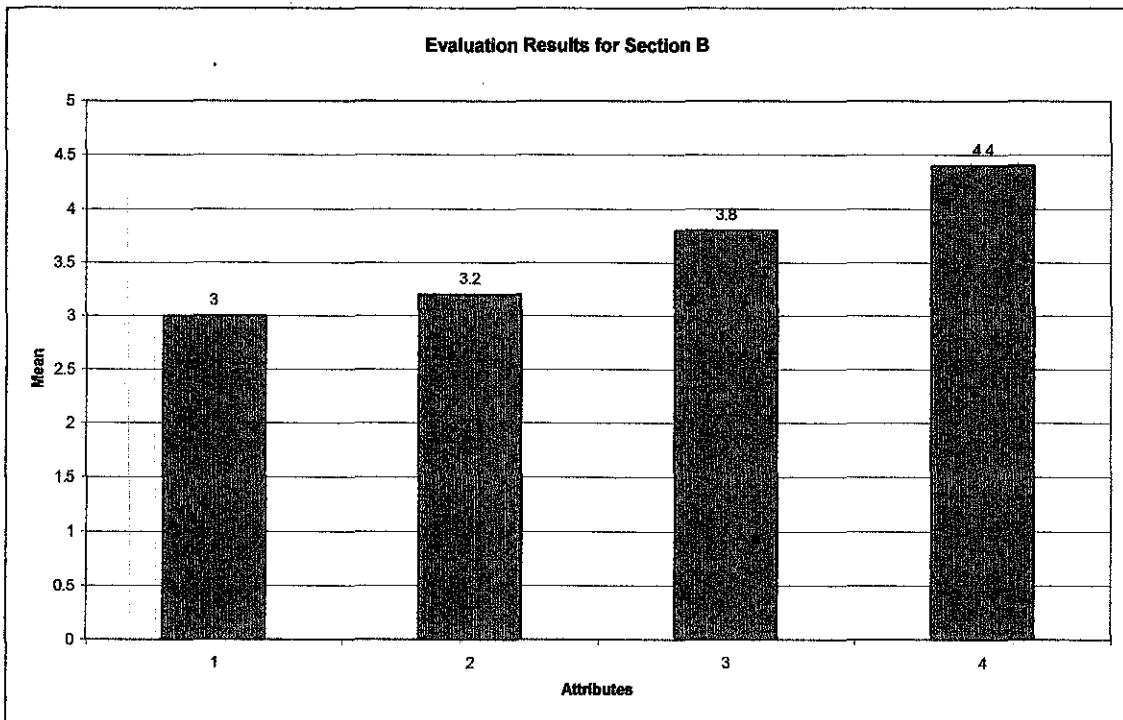


Graph 4.1: Histogram Evaluation Result for Section A- Prototype Realism

For the test results of Section A, the minimum mean is 2.8 and the maximum mean is 3.4. The range for section A is $R = 0.6$. The mean overall for this section is $M(\text{all}) = 3.08$. This shows that $R < M(\text{all})$, which leads to the hypothesis can be accepted for section A, There is improvement in realism, navigation and realism.

Table 4.2: Summarization Evaluation Results for Section B- Prototype Navigation and Interaction

Attributes	n	Sum	Mean
1. Ease of Navigation	5	15	3
2. Ease of Interaction	5	16	3.2
3. Possibility of getting lost	5	19	3.8
4. Importance of limiting users from walking into a wall	5	22	4.4
Overall Mean		3.6	



Graph 4.1: Histogram Evaluation Result for Section B- Prototype Navigation and Result

For the test results of Section B, the minimum mean is 3 and the maximum mean is 4.4. The range for section B is $R = 1.4$. Mean overall for this section is $M(\text{all}) = 3.6$. The results from this section shows that $R < M(\text{all})$, which again leads to hypothesis can be accepted.

Hypothesis of the project:

The evaluation: *Improvement in realism, navigation and interaction*

H₀: There is No improvement in realism, navigation and interaction

H_A: There is Improvement in realism, navigation and interaction

Analyses of both evaluation results have proven that the hypothesis (*H_A*: There is improvement in realism, navigation and interaction) can be accepted as true. This means that using proper display equipments and input devices to explore the virtual environment is one of the factors to improve realism, navigation and interaction.

CHAPTER 5

RECOMMENDATIONS AND CONCLUSION

5.1 Project Summary

UTP floating mosque is indeed a sight for sore eyes in the future to come. By building a virtual environment with the model, the mosque is able to be projected first to all who wants to see it. Virtual reality is one way to enable users to visualize and feel something that still doesn't exist.

The project had managed to achieve the initial objectives drawn out earlier in this chapter. Many obstacles and new experiences were felt during the project development. New knowledge and new things are learnt during this period. Learning to use softwares such as Amira, Open Inventor programming and 3D Studio Max for modeling, is a time well spent. Learning to manage time and sticking to the schedules is a sturdy experienced. However despite all the obstacles faced, the project is able to meet its objectives with excellent results.

The evaluation tests conducted on this project have proved that using proper display techniques (using HMD or stereoscopic glass) to present virtual reality, realism as well as navigation and interaction success is able to be improved further. Ensuring users are able to immerse themselves when they use virtual reality will allow system objectives to be fulfilled better and allow greater satisfaction.

5.2 Recommendations

With any given project, there will always be limitations and constraints, be it time, resources, knowledge or technology no matter what the reasons are there will always be room for improvements.

In this project, time limitation and resources have cost some limitations to the prototype. The virtual environment is constraint to only to exterior part of the mosque. This means that users can only look at the outside part of the mosque only. With more given time and proper interior plan drawings, implementing the interior of the mosque would be possible. This is because modeling the interior is much more complex as it needs more texturing and realistic feel to it. Adding the interior part of the virtual environment will surely enhance the realism to a greater extent.

Adding slight animations to the environment like winds blowing on leaves, and water movements can formulate a better feel to the environment. Characters and life like plants can further make it better. Including natural sounds, like the sound of wind blowing or 'Azan' reciting will take the project to a whole new level of realism.

One other restriction in this project is the navigation technique. Initially the prototype uses mouse to navigate around the mosque. Using a device that enables user to use the movement of their body to explore the virtual world is a better way for navigation. This can be done by using a tracker. A tracker will coordinate the users' movement to the virtual environment and reflect the action real time. This is one way to improve navigation and the feeling of immersive ness to users.

Collision detection is the only interaction that the users have in this project. Adding more interactions with the objects in the virtual environment can increase the realism. One way is to use a haptic glove which allows user to touch and feel the objects within the virtual environment. Haptic gloves could also do modifications or initiate functions to objects inside the environment if the object is programmed to have functions to it.

With more technological advances, it is hope that one day the user can immerse him or herself in the virtual environment by allowing a character to be generated within the virtual environment representing the user.

5.3 Conclusion

In conclusion, the project has managed to fulfill its objective. A virtual reality environment with UTP's future floating Mosque has been developed. The system uses HMD or special glasses for visualization. It is proven that using such devices allow more realism and easier navigation as well as interaction to users.

APPENDICES

Appendix A: Evaluation Form

Appendix B: Evaluation Response Data

Appendix C: Images of the Virtual Environment

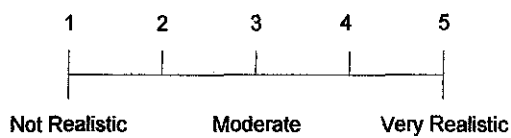
APPENDIX A

Evaluation Form

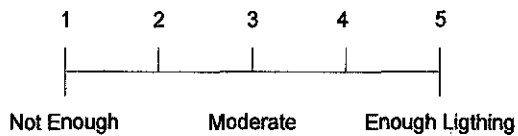
Section A: Evaluating Prototype Realism

Please rank your answer for each question

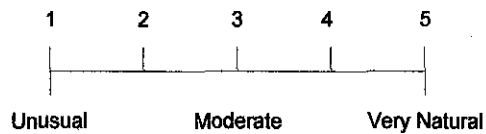
1. Realism of the virtual mosque you've just experience



2. Lighting of the virtual mosque you've just experience



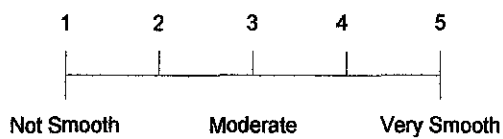
3. Experience natural sensation during exploration



4. Are you distracted by the outside world when using the system

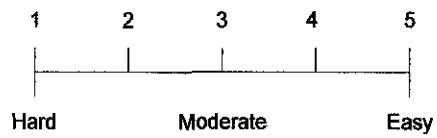
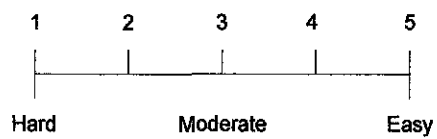
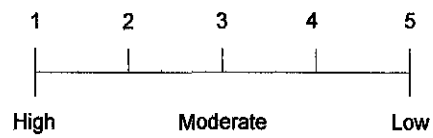
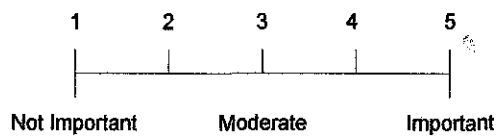


5. Smoothness of view changing



Section B: Evaluating Prototype Navigation and Interaction

Please rank your answer for each question

1. Ease of Navigation**2. Ease of Interaction****3. Possibility of getting lost****4. Importance of limiting users from walking into a wall**

APPENDIX B

Evaluation Response Data

Section A: Evaluating Prototype Realism

1. Realism of the virtual mosque

	Data
Respondent 1	4
Respondent 2	3
Respondent 3	4
Respondent 4	4
Respondent 5	2
Sum	17
Mean	3.4

2. Lighting of the virtual mosque

	Data
Respondent 1	3
Respondent 2	2
Respondent 3	4
Respondent 4	3
Respondent 5	3
Sum	15
Mean	3

3. Experience natural sensation

	Data
Respondent 1	3
Respondent 2	2
Respondent 3	3
Respondent 4	3
Respondent 5	3
Sum	14
Mean	2.8

4. Are you distracted by the outside world

	Data
Respondent 1	4
Respondent 2	3
Respondent 3	3
Respondent 4	2
Respondent 5	2
Sum	14
Mean	2.8

5. Smoothness of view changing

	Data
Respondent 1	4
Respondent 2	3
Respondent 3	4
Respondent 4	3
Respondent 5	3
Sum	17
Mean	3.4

Section B: Evaluating Prototype Navigation and Interaction

1. Ease of Navigation

	Data
Respondent 1	3
Respondent 2	4
Respondent 3	3
Respondent 4	3
Respondent 5	2
Sum	15
Mean	3

2. Ease of Interaction

	Data
Respondent 1	3
Respondent 2	3
Respondent 3	4
Respondent 4	3
Respondent 5	3
Sum	16
Mean	3.2

3. Possibility of getting lost

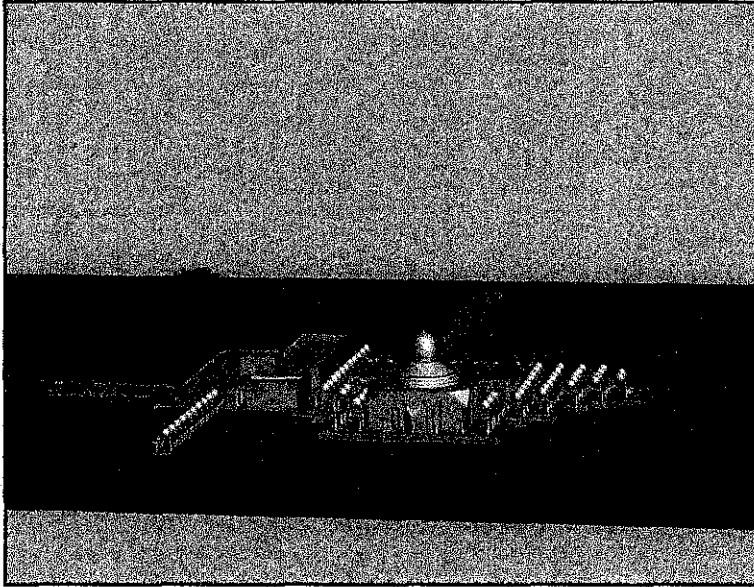
	Data
Respondent 1	4
Respondent 2	3
Respondent 3	5
Respondent 4	3
Respondent 5	4
Sum	19
Mean	3.8

4. Limiting users from walking into a wall

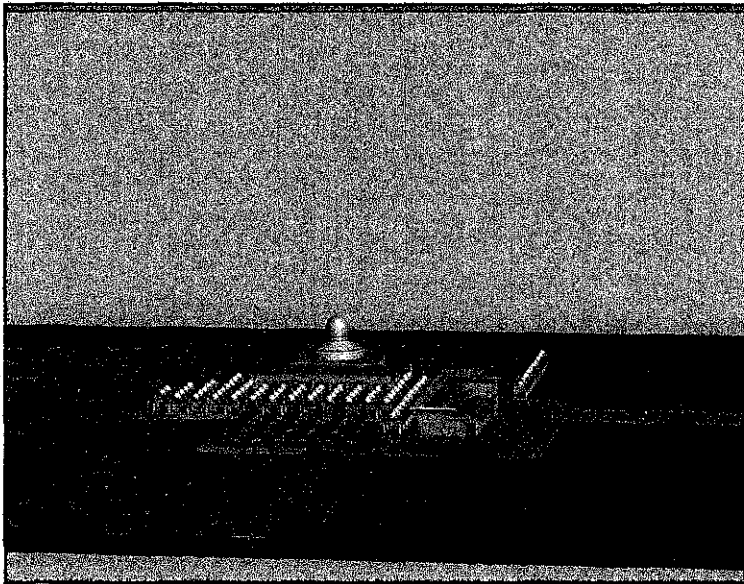
	Data
Respondent 1	3
Respondent 2	4
Respondent 3	5
Respondent 4	5
Respondent 5	5
Sum	22
Mean	4.4

APPENDIX C

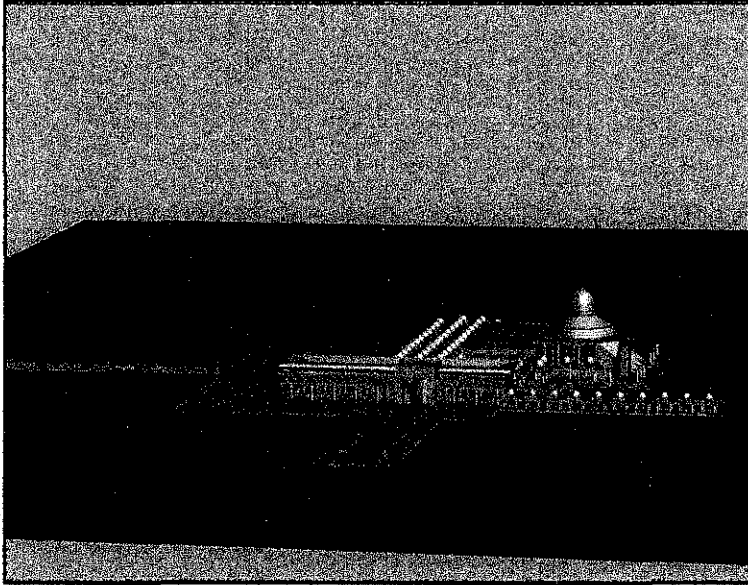
Images of the Virtual Environment



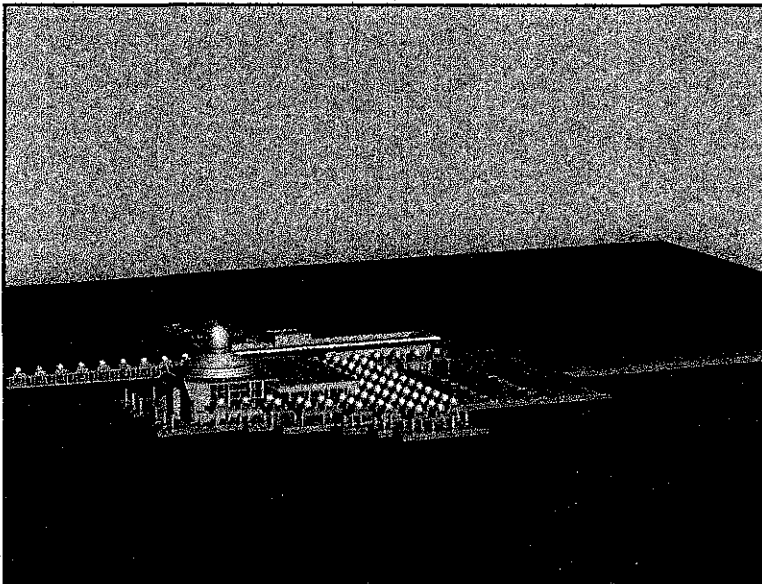
Front view of mosque



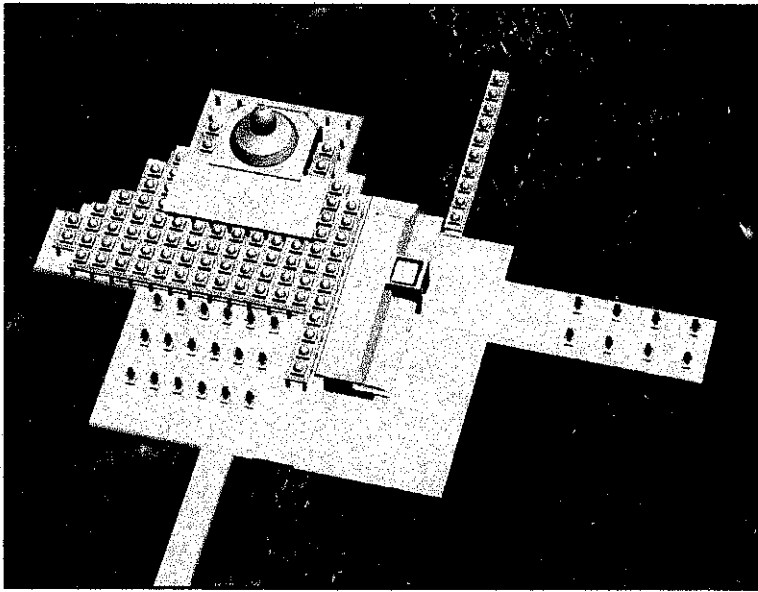
Back view of mosque



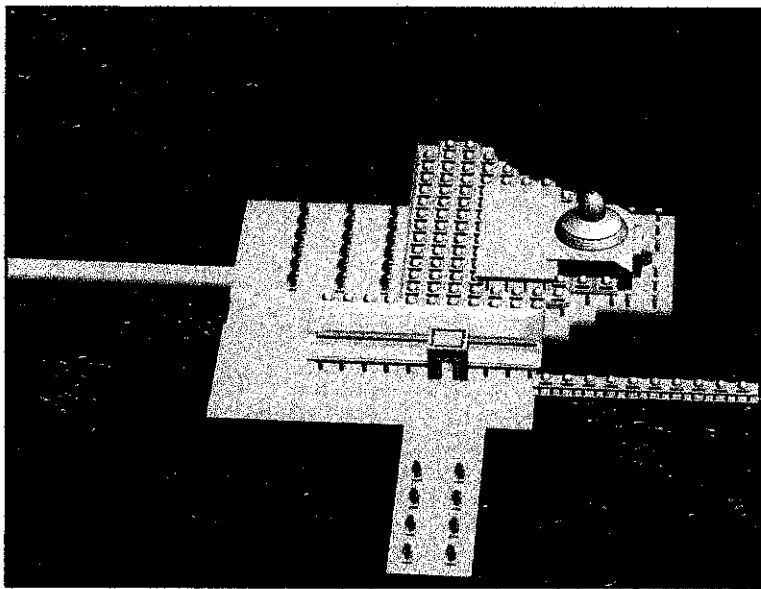
Right view of mosque



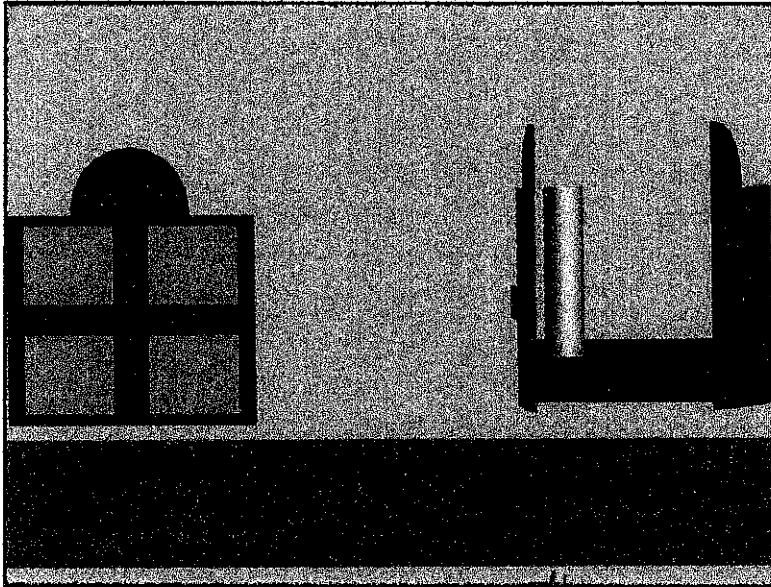
Left view of mosque



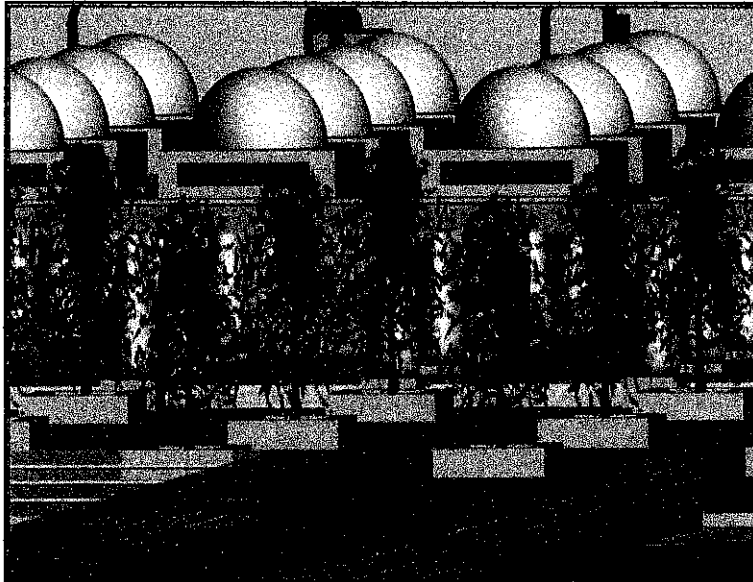
Top view of mosque



Top right view of mosque



Door to main hall mosque



Trees surrounding the entrance to mosque