Navigation and Exploration in Virtual Environment with Virtual Agent using Java 3D

By

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Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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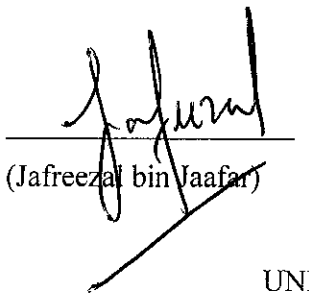
Approved by,

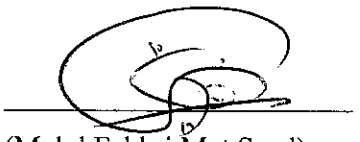


(Jafreezal bin Jaafar)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2004

CERTIFICATION OF ORIGINALITY

This is to 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 acknowledgements and the original work contained herein have not undertaken or done by unspecified sources or persons.



(Mohd Fakhri Mat Saad)

ABSTRACT

This project's objective was to investigate the potential used of Java 3D in developing a virtual environment integrated with virtual agent. The methodology of this project is constitutes on four (4) main phases; planning and analysis phase, modeling and development phase, integration construction phase and the last is testing phase. The testing phase indicates that in order to develop a virtual reality (VR) application, the developer must perform hard-coded programming to model the objects as well as to develop a behavior. Navigation and exploration activity in a virtual environment can be perform easily by using keyboard arrows. To develop a joint behavior between the virtual environment and virtual agent, complex and careful programming is required. This project's conclusion indicates that Java 3D provides other libraries to develop a VR application to better help user in navigation and exploration in a virtual environment. For that reason, further study and investigation can be conducted to achieve this goal.

ACKNOWLEDGEMENT

Alhamdulillah to Allah, the Most Gracious and Most Merciful

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CHAPTER 1

INTRODUCTION

This project investigates the development of virtual environment with virtual agent using Java 3D API. The purpose of the virtual agent is to help user navigation in the virtual environment. The design of the virtual environment is based on a layout of an outdoor environment consists of building, trees and areas. In the virtual environment, user can navigate and explore to see the objects being presented.

The main focus of this research is to examine the use of Java 3D API in developing a virtual reality application for navigation and exploration. In relation, the availability of virtual agent in the virtual environment is to study its nature and characteristic on helping user to interact with the application. Navigation in a virtual environment is limited based on the user's experience, age, skill as well as the system's goal. Users who are not familiar with virtual reality concept, model and representation are likely to face problem when using the application. However, in exploring a new virtual environment such as walk-through, application goals are quite difficult to achieve even with experienced users.

There are studies conducted by professional researchers whose main study was on the use of virtual agent such as intelligent agent or multi-agent system in an interactive learning environment. From these studies, a common understanding has been achieved where it agreed that virtual agent in a virtual environment has a good and positive impact on users who use the application. Hence, this project will take the opportunity offered to study about the common understanding specifically focusing on navigation and exploration in the virtual walk-through environment.

1. 1 BACKGROUND OF STUDY

Virtual reality has started since 1950 when a young engineer named Douglas Engelbart envisioned it as a tool for digital display. Since then, this interesting field of study has been evolved and the most influential virtual reality application is the flight simulator. Virtual reality is being used in entertainment industry, scientific purposes and now the usage of virtual reality is further expanded in the study of people interaction with the control of computers. What is actually the definition of virtual reality? There are many theories made by the professionals and experts in defining this term. Principally, virtual reality can be defined as a way for humans to visualize, manipulate and interact with computers and extremely complex data [2]. Put in simple word, virtual reality is like a cartoon that we can enter. Virtual reality consists of collection of technology and gadgets such as head mounted display (HMD), glove input device and audio. Some of the examples of virtual reality applications are video mapping, Window on World System (WoW), immersive system, mixed reality and Telepresence [5].

Nowadays, virtual agent is being used extensively in representing an organization or in other computer application. The use of virtual agent has been approved effective depending on the way it applies and also the environment where it is being applied. An example of virtual agent software is Leiki virtual personalities. Leiki virtual agent consists of automatic query answering software that understands natural language designed to support end user [1]. In relation, there are also research papers illustrating about autonomous intelligent agent in virtual environment. For instance, the JACOB and STEVE project which demonstrates lifelike character that is highly autonomous and can interact automatically according to changes in their virtual environment.

This project investigates the application of virtual reality techniques and involves the design and construction of virtual environment and virtual agent in a 3-dimensional environment. Agent is a computerized character that look, sound, move and seemingly thinks like a real people which can maximize computing experiences [3]. In this project, the agent will be integrated with the virtual environment. With respect to that, this project involves the integration of several disciplines such as virtual reality, application programming interface (API), and interactivity technique.

Application programming interface (API) is concern with the designing and modeling of the virtual environment together with the virtual agent. As for the interactivity technique, it represents the interaction process when the user is navigating and exploring the virtual environment based on their preferences. In relation, the virtual environment is based on an outdoor scenario consists of buildings, trees and areas. User will explore the virtual environment by navigating around the areas and view the objects being represented.

1.2 PROBLEM STATEMENT

1.2.1 Problem identification

Navigation can be defined as the science or art of conducting from one place to another. As for exploration, it can be describe as an action to travel for the purpose of discovery. With reference to that, the main concern of this project is the navigation and exploration aspects in a virtual environment. Basically, the common problem when user is in a virtual environment is for them to navigate and to explore the environment with ease and without much difficulty. The contributing factor of the problem is related with lack of navigation cues or assistance in the virtual environment, problem with user orientation and because of too close with the virtual world objects.

These day, most virtual reality application specifically related with virtual walkthrough usually focus on the use of virtual character in virtual environment. The intent of using virtual character in virtual environment is good as it can provide element of attractiveness to the virtual environment. However, sometimes the virtual character developed didn't provide the user especially the novice with the aids for navigation and exploration. In relation, there have been studies conducted by researches which related to this subject. For instance, in paper written by Roberto Ranon, Luca Chittaro and Lucio Ieronutti from University of Udine [4], they have pointed out some of the main issues in 3-dimensional design. The main issue is particularly with the insufficient assistance to users in navigating virtual world, find object/places of interests, and learn how to interact with them. From the study also, it describes that guidelines such as navigation cues or guides are relevant to improve user experience and familiarity when exploring a virtual environment.

Moreover, the issue stated above leads to a condition where user is left alone in the virtual environment without being assisted in navigating the environment. As stated on the previous paragraph this condition is primarily directed for novice users who must be helped as much as possible to navigate the virtual environment [6]. The consequences of not providing sufficient navigation support to the user are for example disorientation and problem in wayfinding.

Based on the scenario described above, we can notice that virtual reality specifically in virtual walkthrough application does have some problems and issues with navigation and exploration. Hence, there is an opportunity available to respond to these problems that can be further study and analyze with. Primarily, this project will try to investigate the development of virtual environment with virtual agent using Java 3D for navigation and exploration.

1.2.2 Significance of the project

This project will explore the process and activity involved in the design and construction of 3-dimensional environment which has virtual agent using Java 3D. Besides that, it will study about the requirements for a virtual agent to be correctly integrated with its virtual environment. Upon completion of the project it can provides an insight on the development of desktop virtual reality application using Java 3D based on both the developer and user point of view.

1.3 OBJECTIVES AND SCOPE OF STUDY

1.3.1 Objectives

- To investigate the potential used of Java 3D API in developing virtual environment and virtual agent
- To design and model virtual environment with virtual agent
- To integrate virtual environment and virtual agent for exploration and navigation

1.3.2 Scope of Study

The scope of study of this project can be divided into three parts. The first part will focus on the design and development of virtual environment using Java 3D. Basically, the virtual environment is an outdoor scenario consists or buildings, trees and areas .User can navigate through the environment to explore the areas and objects within the environment.

The second part of the study is on the design and development of virtual agent using Java 3D. The aim of developing a virtual agent is to integrate it with the virtual environment. The agent is non-embodied character.

Finally, the third part of the study will be focus on the exploration and navigation aspects of the prototype using Java 3D. Because the prototype is a type of desktop walk-through application, user will use keyboard to navigate the virtual environment. A monitor will be use to display the virtual environment on a workstation or PC.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Virtual Reality and Virtual Environment

What is actually the connection between virtual reality and virtual environment? In principle, virtual reality is virtual environment and vice versa. In means that we can represents virtual reality by displaying virtual environment in 3-dimensional view. The association of virtual reality and virtual environment provides a means for human to visualize, manipulate, and interact with extremely complex data and computer [2]. Mainly, the visualization of virtual reality can be categorized into two different perspectives; broad and narrow.

The broad perspective illustrates a range of knowledge experienced by human when they interacts and explores a simulated spatial environment with a computer by using a joystick, a keyboard or a mouse. With reference to that, the broad perspective is also known as "desktop VR" or non-immersive VR. As for the narrow perspective, it describes a sense of total immersion or "cognitive presence" [7].

The architecture of virtual reality is constructed according to five (5) main elements that are interrelated with each other. These elements must work together in order to build up a virtual reality application [9]. The main elements of virtual reality architecture are input and output devices, reality engine, virtual reality (VR) software, and world database.

2.2 Navigation, Exploration and Wayfinding Concept in Virtual Reality

In principle, navigation can be defined as "a process by which people control their movement using environmental cues and artificial aids such as maps so that the people can achieve their goals without getting lost" (Darken & Sibert, 1993, p157) . From this definition, we can notice that cues and artificial aids are fundamental in order for the user to be successful in their navigation in virtual environment. In relation, users from the Information Technology (IT) non-professional are identified as the group who experiences more problems and difficulties related to these factors when they are in the virtual environment [8]. With reference to this statement, the contributing factors to the problems are for example unfamiliar environment, loss of overview, and disorientation.

Currently, research and study about virtual world is increasingly conducted by researchers and professionals. As a result, this latest development has indirectly directed the focus of people to exploration in virtual environment [8]. In terms of its nature, exploration is particularly an activity performed by the user in virtual environment without a specific target or purpose. Whereas, navigation is concerned with a specific goal which a user wants to achieved based on the cues provided in virtual environment. However, the nature of navigation and exploration activities in virtual environment is greatly interrelated with each other. On the other hand, wayfinding activity is comprises of exploration task; a task without knowledge of the target and search activities; a task performed by a user who has knowledge about the target.

Navigation can be further categorized into several types of activities (Benyon & Höök 1997). Examples of the activities are goal-directed, explorative, aiming at object identification, finding interesting configurations of objects, and finding information about objects. For the purpose of this research, activity of explorative and finding information about objects; user look around and find out what's in the environment will be the primary concern to focus with. It is not arguably that navigation in virtual environment is difficult because it provides less form of

sensory including visual, auditory or locomotive [8]. For that reason, users in virtual environment will experiences dissatisfaction, feeling of not having adequately explored the world, frustration, discontinued use of the environment. [4][8].

Based on the information described above, it is evident that navigation and exploration support is needed to help user in the virtual environment. For instance, visual cues can be added to the virtual environment to help user especially the non-professional groups in the navigation and exploration activity. One of the aims of using visual cues is to ease recognition by the user based on paths, landmarks, and the user's position in the virtual environment. N.G Vison (1999) state that navigational cues can functioning as reference points. Furthermore, Darken & Sibert (1996) suggest that the key to successful navigation is mainly the level of survey knowledge of the user. When user in a virtual environment is provided with cue or direction, eventually they will obtain the necessary information to successfully conducting the navigation and exploration activity. Thus, the navigation and exploration process will be more interesting and attractive for the user [4]. With reference to that, this project will study about the utilization of virtual agent or personal agent in virtual environment with the purpose to examine its usability in helping user to carry out the navigation and exploration activity.

2.3 Virtual Agent in Virtual Reality

Basically, in virtual reality there are several similar concepts with virtual agent. The concepts are for example; virtual host, intelligent agent, avatars, virtual character and others. Collectively, all these concepts are a type of 'supporting' element in virtual environment where each of the concepts has a unique and different set of tasks and objectives. For virtual agent, its main task and objective is assisting user in virtual environment with the wayfinding activity [8]. As mentioned earlier, one of the main problems in navigation and exploration activity is the level of assistance given to the user especially the Information Technology (IT) non-professional groups.

In relation, to reduce the significance of this problem, virtual agent can be deploy in virtual environment. Virtual agent will function as the navigation aid which can eliminate the problem of user being alone and unassisted in the virtual environment [4]. Rickel and Lewis Johson (2000) believe showing user how to get to relevant object/place is more effective than telling user where object/place is located. This opinion is further supported by a statement; "in virtual as well as real world environments, such personal assistants can be useful aids, helping people to find their way or to find relevant information"[8]. In relation, there are examples of previous successful projects using animated character in virtual environment.

One of the main projects related to this subject is *navigation assistance in virtual theater environment* done by Betsy van Dijk, Rieks op den Akker, Anton Nijholt and Job Zwiers of University Twenty, The Netherlands. This project emphasizes on different aspects of navigation assistance such as information agent, transaction agent and personal navigation agent. In this project, the information and transaction agent is known as Karin. The role of Karin is to gives information to user such as performances schedule, dates, prices, available places and information about the artists and performances. Mainly, Karin does not support navigation in the virtual world.

Instead, Karin supports navigation in the database that contains information and details about performances. This information agent is embodied (Figure 2.1), adaptive because she has no awareness of her visual environment and reactive as she only answers questions posed by the user.

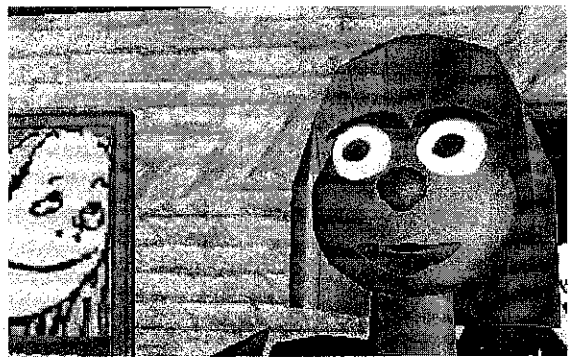

Figure 2.1: Karin, the information agent in virtual theatre

On the other hand, the agent for navigation assistance in the virtual environment is not embodied and takes the form of a narrow window that fits underneath the browser window. The agent has knowledge of the virtual environment and proactive as it presents advice to the user without being asked to do so. The presentation is convey to the user with the use of small and unobtrusive window. Figure 2.2 shows a view of the virtual theatre with the personal agent that gives a suggestion to the user.

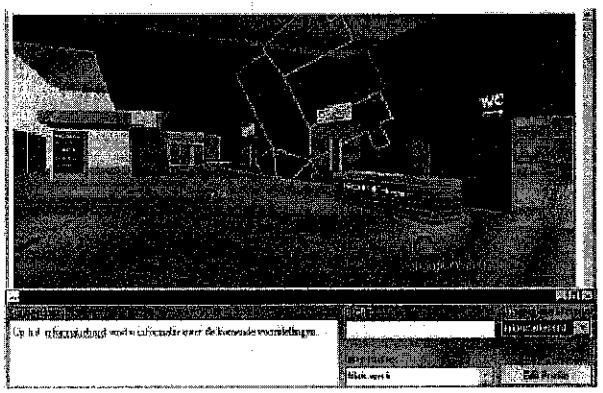

Figure 2.2: The personal agent in the virtual theatre

From the research conducted by Betsy van Dijk and his colleagues in the *navigation assistance in virtual theater environment* project, several idea and thought have been identified. The idea and thought identified are relatively relevant with the research question or situation of the problem for this project; can we improve the user navigation and exploration in a virtual environment with the use of virtual agent. An important note of this project will concern the degree of usability poses by virtual agent that is beneficial to user in a variety of ways such as eliminates dissatisfaction, being more familiar with the virtual environment, and feeling satisfy to continue using the environment Likewise, this concern is capable to have a strong motivational impact to the user who uses the application [4].

One of the central question pertaining to the construction of virtual agent is whether the agent should be constructed in a full, half or non-embodied for its physical appearance. This topic is being highlighted in most of the research and studies related to the virtual reality application. Basically, the center of intention whether the virtual agent should be constructed in which way is greatly depends on its implementation in the virtual environment. For instance, an example given on the research conducted by Betsy van Dijk, Rieks op den Akker, Anton Nijholt and Job Zwiers of University Twenty, The Netherlands, the virtual agents constructed are based on its purpose in the virtual environment. For example, the agent for navigation assistance in the virtual environment is not embodied and it takes only in the form of a narrow window that fits underneath the browser window.

Using this kind of representation, it is easier for the user to understand the activity that (s) he need to perform in the environment. With respect to that, in this project the construction of the virtual agent is not primarily focusing on a full embodied agent. This can be supported by a statement; "Also, it is possible that if naturalistic human figures are chosen, students might critique the fidelity of the human figure model instead of focusing on the instruction and guidance provided by the agent" [10].

Therefore, the construction of the virtual agent without full embodied appearance should not be the primary concern as long as it delivers its purpose and function in helping user with navigation and exploration activity the virtual environment.

CHAPTER 3

METHODOLOGY AND PROJECT FRAMEWORK

3.1 Procedure Identification

The methodology for this project can be divided into several stages or phases. The initial phase of this project is planning and analysis. This first phase is the foundation of other phases and the most important phase in the methodology. This phase helps to identify the important information about the development of this project. This phase also helps to analyze the possible drawbacks and opportunities of this project in the future.

The second phase is the modeling and development phase. Basically, this phase can be divided into two parts. The first part is the modeling and development of the virtual environment and the second part is the modeling and development of the virtual agent. The modeling and development process for both the virtual environment and virtual agent is performed using Java API with Java 3D SDK.

The third phase in the methodology is the integration and construction phase. In this phase, the virtual environment and virtual agent will be integrated into one landscape. The next step in this phase is to construct the behavior for the interactivity process between the user and the virtual environment which consist the virtual agent. The construction of behavior for the interactivity is also performed using Java programming technique.

The last stage is the testing phase. The main purpose of this stage is to test the performance of the prototype in terms of its ability to conduct the exploration and navigation activity by using Java 3D API. Besides that, the characteristic of the virtual agent also will be examine and analyze. Figure 3.1 shows the work flow diagram for the methodology of this project.

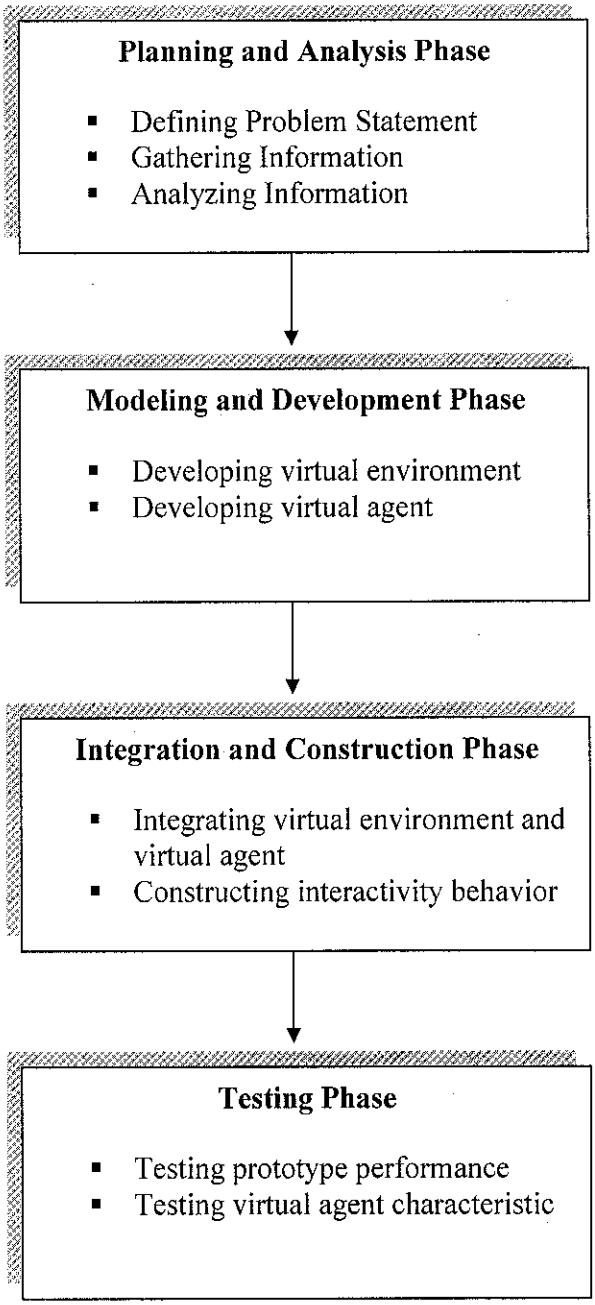

Figure 3.1: Project Work Flow

3.1.1 Phase I: Planning and Analysis Phase

The planning and analysis phase consist of three (3) stages; defining problem statement, gathering information and analyzing the gathered information. In the defining problem statement stage, the research question or situation of problem is being defined to understand the main concern of working on this project. It is very crucial to really understand the problem statement in order to direct the efforts of this project to produce the right solution for the problem. After the problem statement has been defined correctly, the information gathering stage is conducted.

There are two main concerns in the information gathering stage. The data and information gathered are mostly about virtual reality and issues and solutions related to the navigation and exploration problems faced by the user in handling virtual reality applications. This stage is an ongoing process where it is being conducted throughout the project phases. To gather the information, several methods are used which include;

- Collecting data and information from whitepapers, journals, research documents, referenced books, the Internet, interviewing and etc.
- Testing and observation on existing Java 3D application to get experience on how actually the functionality of the application when employing virtual reality approach.

After the information has been gathered, the final stage in this phase is to analyze the data and information. All the data, facts and information are filtered with the purpose of separating the primary information, secondary information and less important materials. By doing so, the primary information can be used as the basis to help specify the types of virtual reality application to be develop as well as the required tool and equipment. On the other hand, the secondary information can be used to support the primary information when working with the project. The second phase; design and modeling phase can be conducted after all the required and important information and specification are prepared and made available.

3.1.2 Phase II: Modeling and Development Phase

The modeling and development phase can be divided into two main stages. The first stage is the modeling and development of virtual environment and the second is the modeling and development of the virtual agent. Figure 3.2 shows the work flow diagram of this phase. Mainly, the modeling and development of both virtual environment and virtual agent is performed using Java programming technique specifically for Java 3D API. The modeling of virtual environment and virtual agent is performed based on several classes provided by Java SDK. The examples of the classes are shown in Figure 3.3.

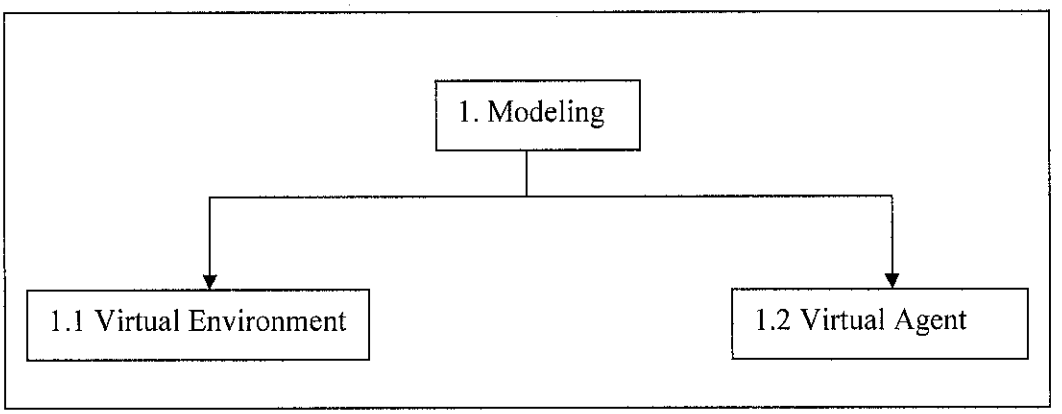

Figure 3.2: Design and Modeling Work Flow

```
import javax.media.j3d.*;
import javax.vecmath.*;
import java.awt.*;
import java.awt.event.*;
import com.sun.j3d.utils.geometry.*;
```

Figure 3.3: List of Java import statements

Basically, the modeling of both virtual environment and virtual agent involves the combination of simple primitives' geometry shape including box, sphere, cone and etc. The selected geometry shapes are combined to make the necessary figure or shape which represents the virtual environment and the virtual agent.

The modeling requires the used of method called *BranchGroup()*, *TransformGroup() and Transform3D()* where these functions allow the implementation of virtual environment and virtual agent in the Java platform.

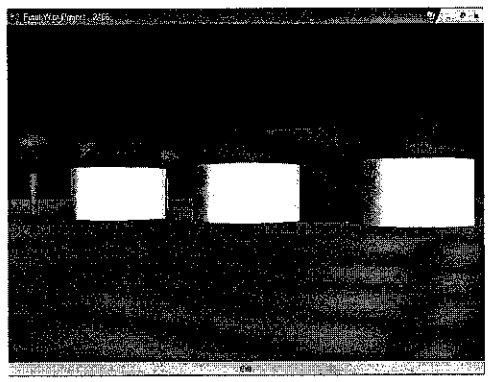

Figure 3.4: Rendered view of virtual environment

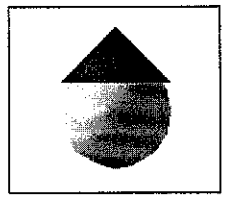

Figure 3.5: Rendered view of virtual agent

The result of the virtual environment and the virtual agent during modeling and development phase are shown in Figures 3.4 and 3.5 as the above. The results from this phase will be discussed further in Chapter 4 of this report.

3.1.3 Phase III: Integration and Construction Phase

The integration and construction is the phase where the virtual environment and virtual agent are integrated together to form an individual landscape. In Java 3D API, each component is treated separately. Therefore, this phase is required to group the agent and the environment together in one group. In order to integrate the virtual environment and the virtual agent, another Java 3D is required. The method is called *void addChild(Node)* where the function of this method is to accept any component to be group together in one scene. After the virtual environment and virtual agent has been group or integrate together in one scene, the process of constructing the behavior for interactivity between the user and the virtual environment can be done. The work flow for this phase can be illustrated in Figure 3.6;

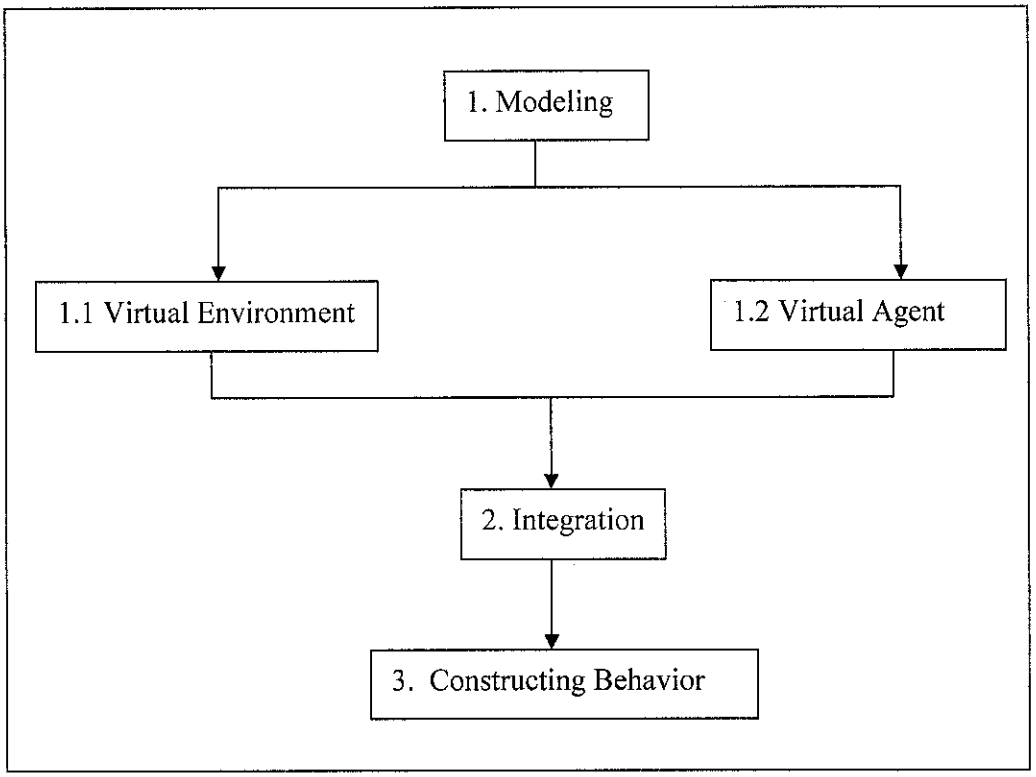

Figure 3.6: Integration and Construction Work Flow

3.1.4 Phase IV: Testing Phase

The last phase of the project's methodology is the testing phase. Mainly, this phase can be divided into two sections. The first section (Section A) is where the performance of the prototype is tested while the second section (Section B) involved testing the virtual agent characteristic in the virtual environment.

I. Section A

The main objective of conducting a test to the prototype is to find out about the functionality of the prototype in terms of its responsiveness to user action when they interact with the prototype. Another objective of this testing is to analyze the capability and capacity of Java 3D API in developing a navigation and exploration virtual reality application specifically when using keyboard.

II. Section B

In section B of the testing phase, the characteristic of the virtual agent will be test to study about its representation and utilization in the virtual environment as well as its capability when developed using Java 3D API for navigation and exploration activity.

In relation, two checklists will be produced for each of the testing as a guide to the tester. With respect to that, the person who will conduct both testing is the author himself. The reason of selecting the author is because the testing is concern to obtain information and feedback on the developer point of view and not from the user point of view. The checklists are included in Appendix A of this report.

Additionally, a table which describes the characteristics of Java 3D API and virtual reality modeling language (VRML) is also produced to give some insights in terms of its advantages and disadvantages. The results from the comparison of these two languages can be as a guideline for the developer who wants to develop a virtual reality (VR) application.

3.2 Tools and Equipments

Tools and equipments are very important in doing a project. The use of tools and equipment can help to make the processes involved in a project easier. Tools used to carry out this project can be categorized into two components; software and hardware.

3.2.1 Software

The software used in this project is mainly related to Java technology. The software used is listed as below;

1. **Java Runtime Environment, SE v1.4.2_05**
   Java Runtime Environment, SE v1.4.2_05 is the software which allows Java application to be run in a standard PC or workstation.

2. **Java 2 SDK, SE v1.4.2_05**
   Java 2 SDK, SE v1.4.2_05 is the software which functions specifically for developing Java application. With this software also, a Java program can be run on a standard PC or workstation.

3. **Java 3D 1.3.1 (OpenGL) SDK**
   Java 3D 1.3.1 (OpenGL) SDK is a software development kit which allows the development of 3D application using Java platform. This software has the bundles of required libraries that can be used for the development.

3.2.2 Hardware

1. **Central Processing Unit (CPU)**

   Central processing unit is used to run the desktop Java application. The operating system is Windows XP with 502 RAM and Intel Pentium IV 2.00 GHz

2. **Monitor**

   Monitor is used to display the prototype to the user for their viewing.

3. **Mouse and Keyboard**

   Mouse and keyboard is used to interact with the prototype as well as to navigate and explore the virtual environment. The method of using these devices is similar to the standard way when using it with any computer application.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results and Discussion for Modeling and Development Phase

During the modeling and development phase, the virtual environment and the virtual agent are modeled. The development of both virtual environment and virtual agent are performed by writing Java 3D codes using notepad program. Before writing the codes, a scene graph drawing is created as the specifications of the program. A scene graph is created using instances of Java 3D classes. The scene graph is assembled from objects to define the geometry, lights, location, appearance and orientation of visual objects in a Java 3D virtual universe. The overall (general) scene graph drawing for this project is being represented is Figure 4.1.

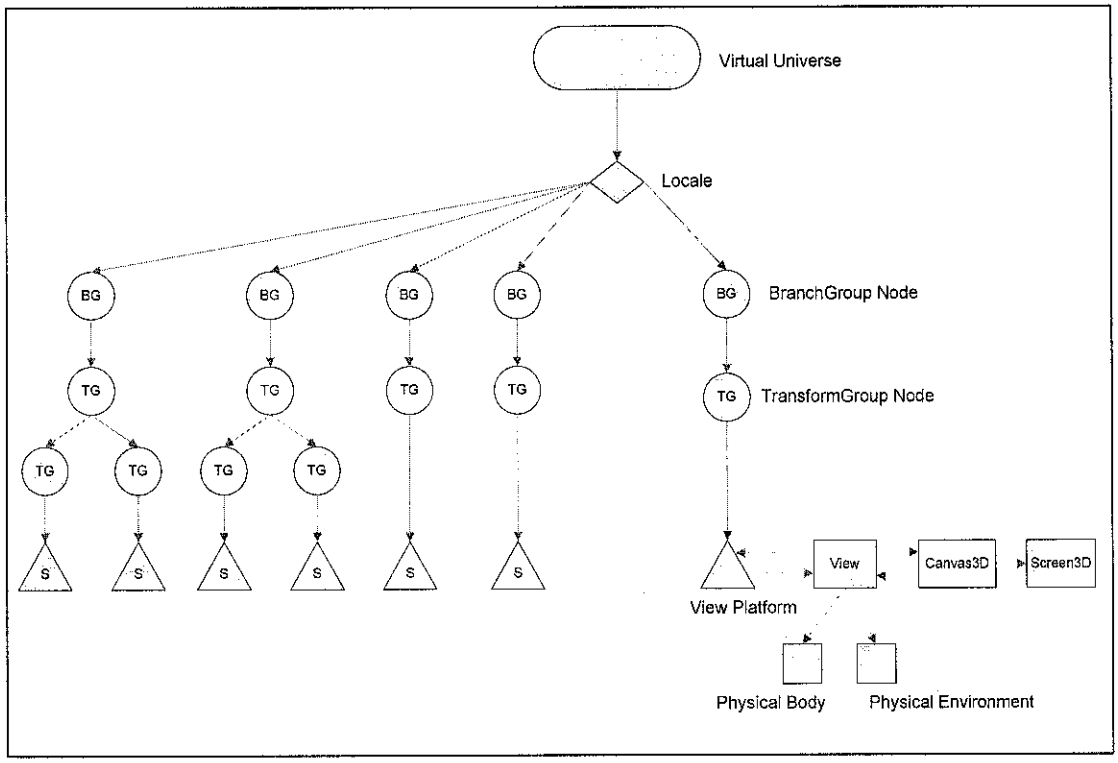

Figure 4.1: Overall (general) scene graph drawing

The first step is to model the virtual environment. Inside the virtual environment, there are several geometry shapes that are combined to create the objects. The objects are tent, tree, room and the ground for the scene. The geometry shapes used are for example cone, cylinder, sphere, and box. The modeling and construction of the four (4) objects are described in the following paragraphs.

a) The tent

The tent in the virtual environment is developed by combining cone and cylinder geometry shapes. There are three (3) tents in the virtual environment and are positioned horizontally side by side between one another by specifying the appropriate x, y, z coordinate values. The scene graph drawing for the tent is shown in Figure 4.2. The color for the roof (cone) is red while the color of the wall (cylinder) is white. The result of the tent object is shown in Figure 4.3.

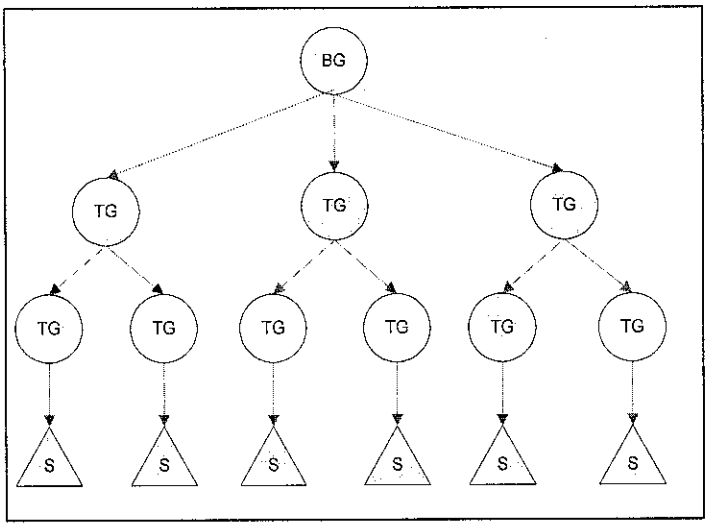

Figure 4.2: Scene graph drawing for tent object(s)

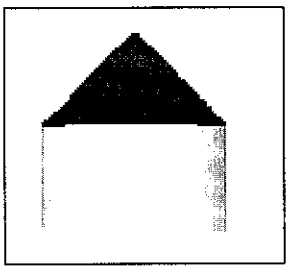

Figure 4.3: Tent object

b) The tree

The tree in the virtual environment is developed by combining sphere and cylinder geometry shapes. The quantity of tree object in the virtual environment is the highest with 16 trees. The trees are arranged accordingly to be as the border for other objects. The scene graph drawing for the tree is shown in Figure 4.4. The color for the trunk (cylinder) is dark grey while the color for the leaf (sphere) is green. The result of the tree object is shown in Figure 4.5.

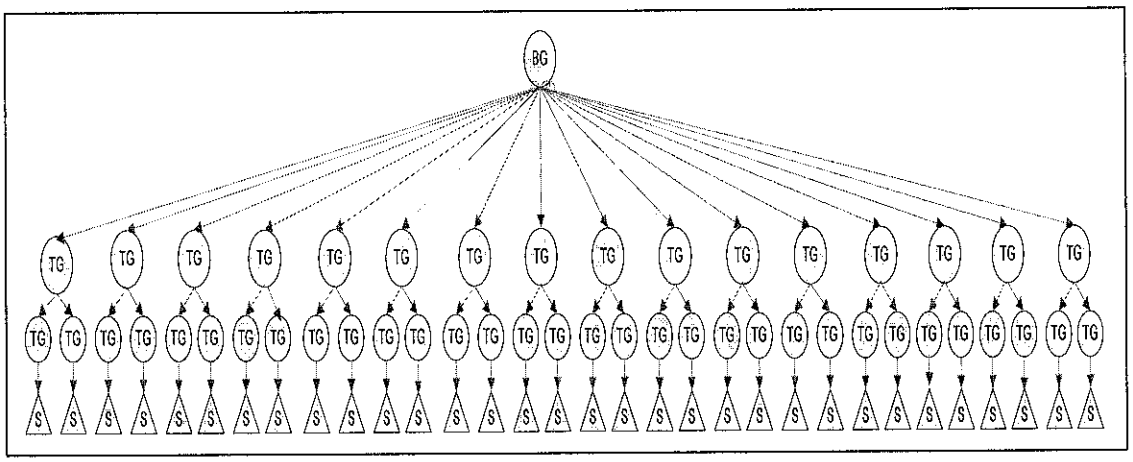

Figure 4.4: Scene graph drawing for tree (s)

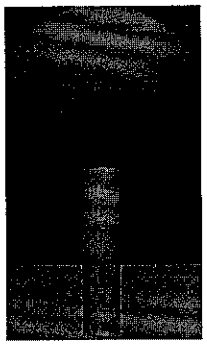

Figure 4.5: Tree object

c) The room

The room in the virtual environment is developed by using box geometry shape. There is only one room object in the virtual environment and is colored with blue. The room object is positioned behind the second tent, which is in the middle. The scene graph drawing for the room object is shown in Figure 4.6. The result of the tree object is shown in Figure 4.5 while Figure 4.6 shows the complete model of room object.

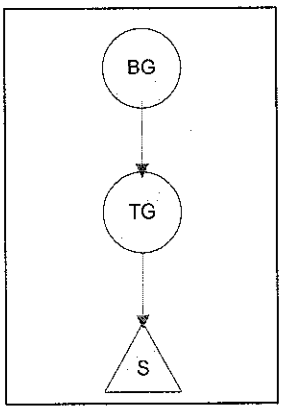

Figure 4.6: Scene graph drawing for room

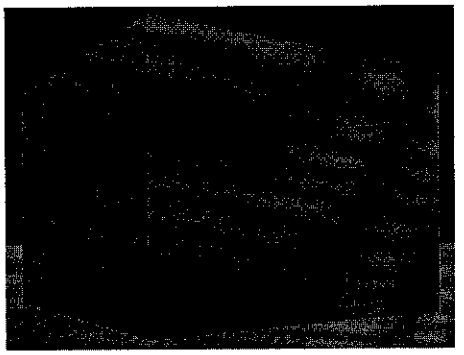

Figure 4.7: Room object

d) The ground for the scene

The ground for the scene is developed using box geometry shape. The ground object is colored with green and is very useful in representing an outdoor scenario. The y-coordinate for the ground object is set to negative value in order to place it under the other objects in the virtual environment. The scene graph drawing for the ground object is shown in Figure 4.8 while Figure 4.9 shows the complete model of ground object.

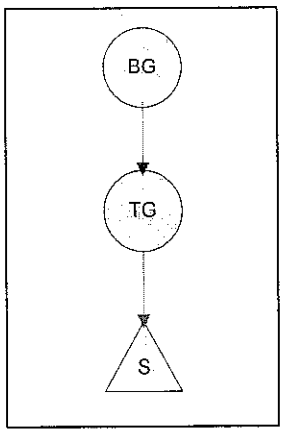

Figure 4.8: Scene graph drawing for ground

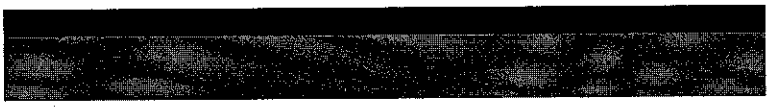

Figure 4.9: Ground object

The second step of this phase is to model the virtual agent. Similarly, the virtual agent is developed by combining two geometry shapes. The geometry shapes used to develop the virtual agent is a cone and a sphere. Figure 4.10 shows the scene graph drawing for the virtual agent object and the complete model of it is shown in Figure 4.11. The virtual agent is a non-embodied agent where it only has head and body. With respect to that, the head of the agent is colored with blue and the body is colored with yellow. The reason why the agent is developed as a non-embodied agent is because it does not emphasize on the physical motor movement of the agent, but it focuses on the availability of the agent in the virtual environment.

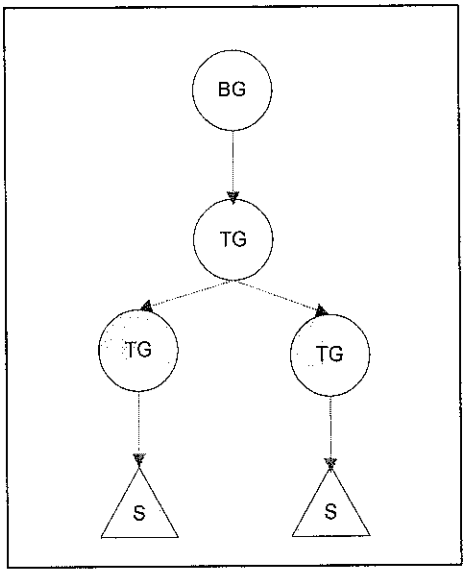

Figure 4.10: Scene graph drawing for agent

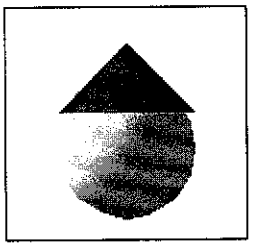

Figure 4.11: Virtual agent object

Another component in the virtual environment is lights. Mainly, in the virtual environment, there are two directional lights. The scene graph drawing for lights is shown in Figure 4.12. The light source objects of the scene graph influence the light of the visual object depend on the specified bounds of the visual objects which intersects the region of influence of the light objects.

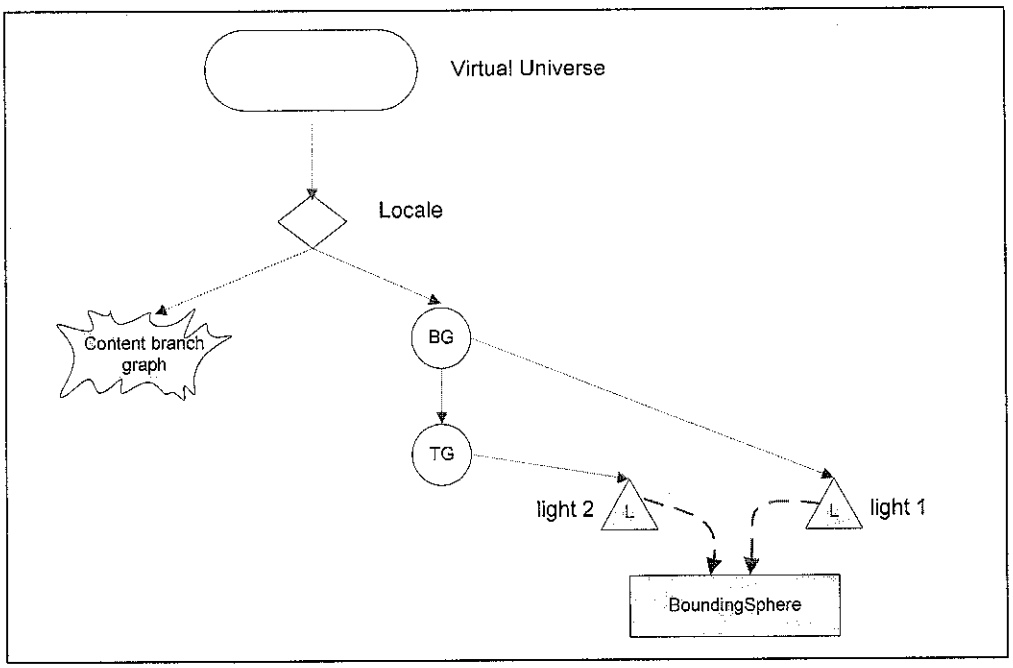

Figure 4.12: Scene graph drawing for lights

4.2 Results and Discussion for Integration and Construction Phase

After completing modeling and developing the virtual environment and the virtual agent, both of these components are integrated together into one landscape. The result of the integration is shown in Figure 4.13. The overall (general) scene graph drawing after the integration represented is Figure 4.14.

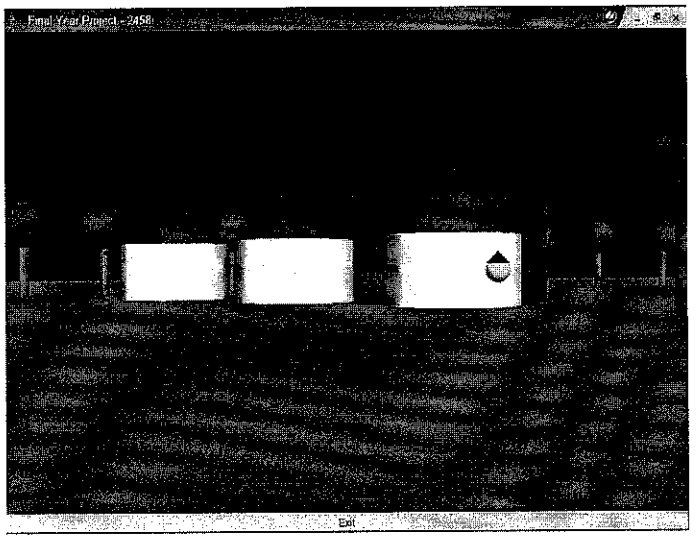

Figure 4.13: Complete design of the virtual environment with the virtual agent

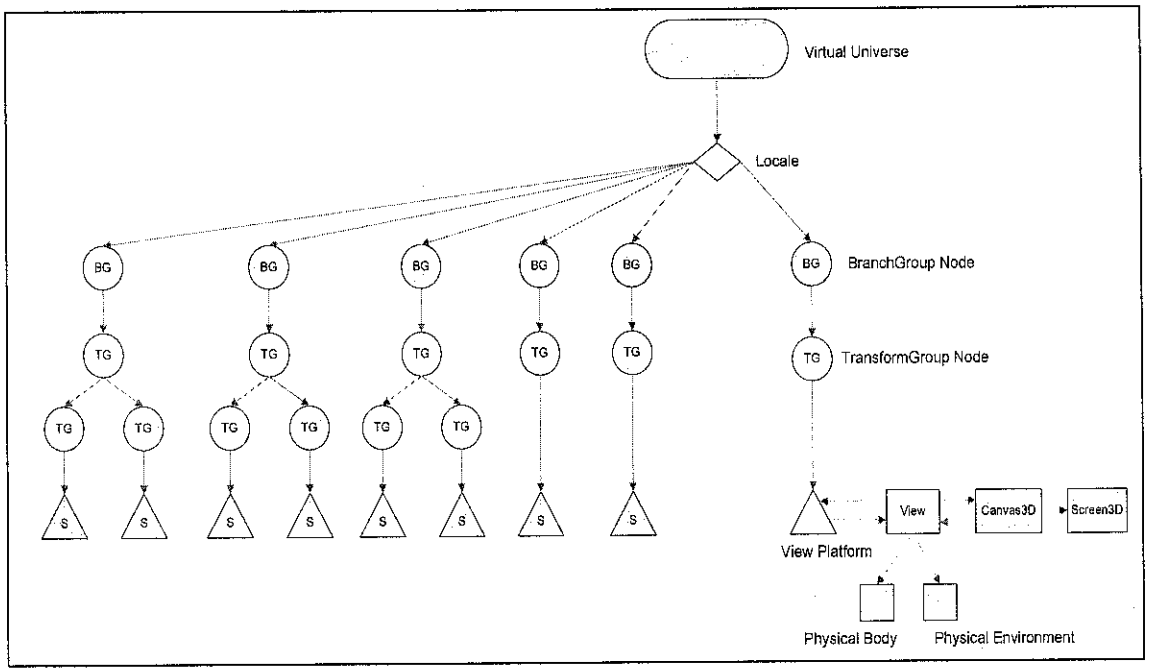

Figure 4.14: Scene graph drawing after integration

After the integration process has been done, a behavior class is included to carry out the navigation and exploration activity. To do so, a separate import statement and several lines of codes need to be included in the main program. The import statement and the additional codes for the behavior class are represented in Figure 4.15. The additional line of codes is included in the ViewBranch section of the program. The insertion of the behavior code in the ViewBranch section can be illustrated by a scene graph drawing like in Figure 4.16.

```
import com.sun.j3d.utils.behaviors.keyboard.*;
viewXfmGrp.setCapability(TransformGroup.ALLOW_TRANSFORM_READ);
viewXfmGrp.setCapability(TransformGroup.ALLOW_TRANSFORM_WRITE);
 BoundingSphere movingBounds = new BoundingSphere(new
Point3d(0.0,0.0,0.0),100.0);
 BoundingLeaf boundLeaf = new BoundingLeaf(movingBounds);
KeyNavigatorBehavior keyNav = new KeyNavigatorBehavior(viewXfmGrp);
keyNav.setSchedulingBounds(movingBounds);
viewBranch.addChild(keyNav);
```

Figure 4.15: Import statement and additional codes for keyboard behavior class

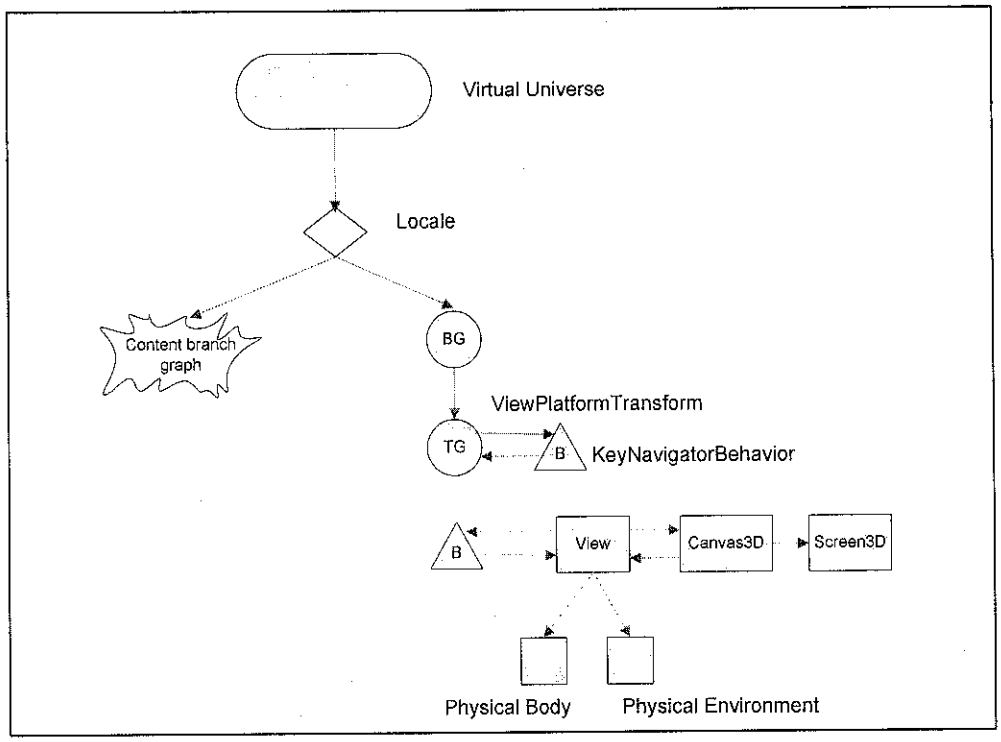

Figure 4.16: Scene graph drawing for KeyNavigatorBehavior

The implementation of KeyNavigatorBehavior utility class in the program allows navigation in the virtual environment by using the standard arrow keys (↑ ↓← →) of a keyboard.

4.3 Results and Discussion for Testing Phase

During the testing phase, valuable data are collected by the author. The data collected are then being converted to meaningful information and table for ease of interpretation and understanding. In the testing phase, the prototype is tested by the author based on a checklist. There are two checklists produced; the first checklist is for testing the functionality of the prototype and the other one is used for testing the virtual agent characteristic.

Table 4.1 and 4.2 shows the results of the testing for section A and section B. The results obtained from the test are converted to a table for study and analysis. The first column of the table describe the question arise, and the second column describe the author justification and explanation on the result for the particular question. The checklists for section A and B testing are included in Appendix A while the raw data of the testing is included in Appendix B.

On the other hand, Table 4.3 shows the comparison of Java 3D API and virtual reality modeling language (VRML) characteristics. The results obtained from the comparison are very useful as a guideline for both the developer and user when developing or using a VR application.

Table 4.1: Result for testing in Section A: Prototype Functionality

Question	Justification
1. Is it easy or suitable to use keyboard arrows to navigate in the virtual environment?	By using keyboard arrows, the direction is easier to understand and to perform. It provides more control and command to the navigation and exploration activity. In relation, the level of responsiveness also can be considered as high.
2. Does the navigation activity is according to user preference?	The navigation activity is according to user preference as it is not based on predefined path in the virtual environment. Thus, this will increase the level of satisfaction.
3. Is there any collision detection /avoidance function in the prototype?	Java 3D API specifically allows the function to be used when two objects collides with each other. Careful programming is needed to incorporate the function for navigation and exploration in virtual environment. Furthermore, Java 3D only can handle one collision at a time.
4. To develop a VR application, it is easier to use modeling language or/ and animation software;	Modeling language and animation software such as VRML and 3D's Max are equipped with comprehensive built-in functions. As a result, it is easier to develop a VR application using these tools.
5. When developing a VR application, Java 3D API requires everything on hard-coded;	Java 3D offer features for developing Java programs that incorporate 3D graphics. The programming technique is similar to other Java program. The difference is just for the libraries used in the program.

Table 4.2: Result for testing in Section B: Virtual Agent Characteristic

Question	Justification
1. Can the agent move together when navigating / exploring the virtual environment?	Java 3D requires a careful and complex programming in order to develop a joint behavior in the virtual environment
2. Is it compulsory to represent a virtual agent in full embodied with color?	The representation of virtual agent depends on its function in the virtual environment. For instance, to guide user in navigation the agent does not necessarily need to have legs. As long as it can 'move' for instance by 'flying', it still performs its function in the virtual environment.
3. Can the problem of having loss in the virtual environment be reduced or eliminated with the availability of an agent?	By having a virtual agent in virtual environment, the VR application will be more interesting and meaningful. However, the most important factor relies on the function of the agent.
4. Does the location of the virtual agent appropriate in the virtual environment?	The location of virtual agent in the virtual environment must be established in a way where it fully performs its function. For example, if the agent is required to follow user, then it is suitable to position the agent in front or beside the user.
5. It is difficult to create the behavior of the agent using Java 3D API?	If the agent need to perform an activity by itself, then the process should be relatively easier. For instance, like picking an object in the virtual environment.

Table 4.3: Comparison between Java 3D API and VRML

Java 3D API	VRML
Extends core Java language to create 3-dimensional graphical applications using Java	Has a specific file format and requires VRML browser to view a scene
Built on lower level API such as DirectX or OpenGL	Higher level modeling language which has no lower level API
Platform independent	Platform dependent because operating systems(OS) must has the VRML browser
Provides program-centric approach to build 3-dimensional world	Provides content-centric approach to build 3-dimensionl world
Good when content operations are complex and application specific	Good when content operations are known and simple
Has superior rendering, texturing, 3D geometry and provides more features	Has better scene creation and provides more control on user interaction
More suitable for application developers such as programmers	More suitable for content developers including animators, artists and non-programmers
More powerful than VRML	Easier to use compare to Java 3D

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Summary of Project

This project has managed to achieve its objectives identified earlier during the initial stage. With respect to that, the prototype is developed by integrating two of its main components; the virtual environment and the virtual agent. While working on this project, many valuable experience and new knowledge are obtained especially about programming to develop a virtual reality (VR) application using Java 3D application programming interface (API). With reference to that, the experience and knowledge gained can be as a means to improve the programming technique of Java 3D in specific and Java as a whole in the future.

The testing phase of this project has help to identify and to explore the functionality of Java 3D in developing VR application specifically for navigation and exploration in a virtual environment. The results also describe the significance of having a virtual agent in the virtual environment for example to assist user in navigation or provide information about objects in the virtual environment. With the information, the capability and capacity of Java 3D in developing VR application can be further examine and study to fully employ the set of libraries offer by Java 3D. In addition, the scope of this project can be further expand in creating another VR application for navigation and exploration in a virtual environment.

5.2 Recommendation

After the completion of this project, there are many opportunity and prospect that can be benefit with. Moreover, the opportunity can help to enhance and improve the functionality of this project. Basically, the opportunity is related with the scope of study of the project. For instance, in the future the scope of this project can be about providing navigational cues or visual cues to help user understands the objects in the virtual environment. In relation, user can be provided with a brief direction of the path that she will be follow when navigating and exploring the virtual environment. On top of that, it is advisable to develop the prototype using Java 3D in order to further explore the program programming techniques.

This project also can be enhance and improve by converting the prototype to an executable file format. By converting the prototype to an executable file format, the prototype can be run directly without needed to be compile and run from the command prompt program. Besides that, the stereoscopic view capability can be incorporated to the prototype. Then, it can be viewed with VR devices such as 3D glasses to add more realism features to it. At the same time, the representation of the virtual environment will be more interesting and attractive to the viewer.

5.3 Future enhancement/ Research

For further development and improvement of this project, there are some suggestions that can be considered. The suggestions are for example;

a. Instead of using keyboard to navigate in the virtual environment, mouse is use to perform the activity or combination of both devices.

b. Implements collision detection/ avoidance function to make the virtual environment more realistic and meaningful.

c. Make the virtual agent move together with user or viewer when performing the navigation and exploration activity.

d. Make the virtual agent proactive or reactive in response to user request.

e. Include navigational or visual cues to the viewer.

5.4 Conclusion

As a conclusion, this project has successfully develop a VR application using Java 3D. In the project, an outdoor virtual environment is integrated with a virtual agent. User /viewer can navigate and explore the objects in the environment according to their preference. In relation, this project demonstrates that by using keyboard arrows it is easy to perform the navigation and exploration activity. On the other hand, this project can be as the pilot project to study and to develop intelligent virtual agent in a virtual environment. Most importantly, this project can contribute some insights to the virtual reality community for the study of navigation and exploration in a virtual environment with the availability of virtual agent using Java 3D.

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APPENDICES

Appendix A: Testing Checklist

Appendix B: Testing Raw Data

APPENDIX A

Testing Checklist

Section A: Prototype Functionality

1. Is it easy or suitable to use keyboard arrows to navigate in the virtual environment?

Yes / No

2. Does the navigation activity is according to user preference?

Yes / No

3. Is there any collision detection /avoidance function in the prototype?

Yes / No

4. To develop a VR application, it is easier to use modeling and animation software;

Yes / No

5. When developing a VR application, Java 3D API requires everything on hard-coded;

Yes / No

Section B: Virtual Agent Characteristic

1. Can the agent move together when navigating / exploring the virtual environment?

Yes / No

2. Is it compulsory to represent a virtual agent in full embodied with color?

Yes / No

3. Can the problem of having loss in the virtual environment be reduced or eliminated
with the availability of an agent?

Yes / No

4. Does the location of the virtual agent appropriate in the virtual environment?

Yes / No

5. It is difficult to create the behavior of the agent using Java 3D API?

Yes / No

APPENDIX B

Testing Raw Data

Section A: Prototype Functionality

Question	Answer
1. Is it easy or suitable to use keyboard arrows to navigate in the virtual environment?	Yes
2. Does the navigation activity is according to user preference?	Yes
3. Is there any collision detection /avoidance function in the prototype?	No
4. To develop a VR application, it is easier to use modeling language or/ and animation software;	Yes
5. When developing a VR application, Java 3D API requires everything on hard-coded;	Yes

Section B: Virtual Agent Characteristic

Question	Answer
1. Can the agent move together when navigating / exploring the virtual environment?	No
2. Is it compulsory to represent a virtual agent in full embodied with color?	No
3. Can the problem of having loss in the virtual environment be reduced or eliminated with the availability of an agent?	Yes
4. Does the location of the virtual agent appropriate in the virtual environment?	No
5. It is difficult to create the behavior of the agent using Java 3D API?	Yes