

DEVELOPING VIRTUAL ENVIRONMENTS OF COMPUTER HARDWARE USING HIERARCHICAL-EMBEDDED VIRTUAL OBJECTS

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ABSTRACT

Various fields have been taking opportunities to fully utilize the strengths of Virtual Reality (VR) in developing robust and sophisticated applications. Computer hardware is one of the important topics formally and informally learned by students in all programs in universities and even in schools. Knowledge of computers become mandatory to learn since the students get involved in daily utilizing the computers for finishing assignments, social networking, downloading notes, answering test or quiz online and other learning and teaching activities involving the computers. Since the computer hardware consists of many devices, understanding and recognizing the devices are essential especially for the students who formally register or take this course. Furthermore, this registered course usually has its assessments such as examination, quiz and assignment to be evaluated. Due to the lacks and problems in recognizing the devices, they can lead to the misunderstanding and mistakes in the usages of the computers. In this paper, the development of virtual environments for the computer hardware using HEVO method has been proposed and discussed in detail to allow teachers creating and managing the 3D computer hardware and to enable students viewing, interacting and navigating in the VEs. Levels of students' knowledge and skill for this topic as well as the usability study of the created VEs are also analysed and evaluated.

KEYWORDS

Virtual Reality, Virtual Environment, Virtual Object & Computer Hardware

1. INTRODUCTION

Computer hardware is one of the important topics formally and informally learned by students in all programs in universities and even in schools. Knowledge of computers become mandatory to learn since the students get involved in daily utilizing the computers for finishing assignments, social networking, downloading notes, answering test or quiz online and other learning and teaching activities involving the computers. Since the computer hardware consists of many devices, understanding and recognizing the devices are essential especially for the students who formally register or take this course. Furthermore, this registered course usually has its assessments such as examination, quiz and assignment to be evaluated.

There are several ways in teaching and learning the computer hardware in universities and schools. The reference books provided for the students typically are equipped with 2D images of the computer hardware. These 2D images surely lack of interactivity and the students cannot view in different types of views as they are plain and static. The information using textual notes is sometimes insufficient to be understood and visualized by the students.

Sometimes there are students as well as teachers surf in the Internet to get and see 3D computer hardware. The interactivity and exploration as well as information of the 3D computer hardware in the Internet however are very limited. When they download the 3D computer hardware, the required 3D tools become major problems for display and interaction with it. The 3D tools such as 3D Studio Max, LightWave, Maya etc are costly to purchase [13]. Furthermore, those tools require particular knowledge and skill to be utilized and implemented. Creating self-3D computer hardware from the scratch by the teachers or students for teaching and learning are also limited and few since they are not mastered in that field.

Using real computer hardware is the best way and mostly used in teaching and learning this topic because it looks realistic and hands-on practices. This way possibly leads to the risk of damage of the hardware during the learning process. Furthermore, it is hard to explain certain devices because of the inability to see the hidden and small parts.

Based on the explanation above, the ways of teaching and learning of this important topic still need improvement, modification and enhancement. Therefore, it is better to have a system which enables teachers to manage the computer hardware in their desired ways to be displayed and taught to the students. The teachers can utilize the ready-made computer hardware they downloaded from the Internet previously to be simulated in interesting way especially it can involve activities of interaction or manipulation and exploration of the devices.

Virtual reality (VR) can meet such activities. In the created world of virtual reality called virtual environment (VE), users may navigate inside it as if they walk or run in the real world. The users may also interact or manipulate with objects inside the VE which are called as Virtual Objects (VOs). In this paper, virtual environments for the computer hardware have been proposed and discussed in detail using HEVO method to allow teachers creating and managing the 3D computer hardware and to enable students viewing, interacting and navigating in the VEs. Levels of students' knowledge and skill for this topic as well as the usability study of the created VEs are also evaluated.

Objectives of this research in this paper are as follow:

- To create virtual environments for computer hardware using HEVO
- To analyze the levels of the students' knowledge and skill in learning the computer hardware using the created virtual environments.
- To test and evaluate the usability study of the created virtual environments for the computer hardware.

2. BACKGROUND OF RESEARCH

2.1. Computer Hardware

Computer has been defined as an electronic device operating under the control of instructions stored in its own memory. It can accept and process data according to specified rules, produce and store results for future use. The computer contains many electronic components called computer hardware [1].

Computer hardware consists of many devices which are categorized as input devices, output devices, a system unit, storage devices and communication devices [1]. An input device refers to any hardware component that allows users to enter data and instructions into the computer such as keyboard, mouse, microphone, scanner and web cam. An output device is any hardware component that delivers information to the users. Printer, monitor and speaker are three commonly used as the output devices [1]. Both devices are able and visibly to be seen.

A case that contains the electronic components of the computer inside it for the use of processing data is called system unit. All components are connected to a circuit board called motherboard. Two main components on the motherboard are processor (Central Processing Unit, CPU) and memory [1]. Both two components cannot be seen physically since they are small, hidden inside the case and pasted on the motherboard.

Storage device refers to the hardware components that keep the data, instructions and information on storage media such as USB flash drive, hard disk, optical disk and memory card [1]. These components are also difficult to see if they are not detached or removed from the case. A communication device is a hardware component that enables a computer to transmit and receive data, instructions and information from and to one or more computers or mobile devices. Examples of the communications devices are modem, cable, telephone line, cellular radio network, satellite and other transmission media [1].

Therefore, recognizing the devices is important part for this topic. This knowledge possibly gives opportunities to the students to open and check the internal components of the computer, exchange and upgrade the capabilities and speed of the computer components and so forth [12]. Due to the lacks and problems as explained however, it can lead to the misunderstanding and mistakes in the usages of the devices.

2.2. Virtual Reality

Nowadays a number of VR applications in education have been developed for teaching and learning purposes such as in mathematic [9], manufacture [8], linguistic [6,7], forest [11], maritime [10] and so forth. VR has enabled a world of simulation to be generated through the usages of computer devices and software [2]. In VR, users are able to visualize, interact with the computer and complex data such as graphical objects and virtual agents [5,3]. Navigation and exploration within the area of space or virtual world enables the users to walkthrough as if they walk in the real world [4]. All applications of VR share and involve principles of immersion, augmentation to the real world and windows on World (WoW). The immersion allows the users to have feeling of being in a part of generated environment. The capabilities of VR devices such as desktop computer, head mounted display (HMD) and wired gloves contribute to the levels and quality of immersions. The augmentation to the real world involves the integrations of the virtual graphical, textual and sound data in the physical environment that make the users perceive such information exists in real-time [8]. WoW refers to a type of VR systems to generate the virtual environments. Sometimes, Artificial Reality, Cyberspace, Virtual World (VW), Virtual Environment (VE) and Synthetic Environment (SE) are the other concepts that also refer to the VR [10].

There are five important components of VR which are virtual environments (VEs), virtual objects (VOs), Viewing, Manipulation and Walkthrough [11]. VOs refer to models or objects that exist in virtual environment [4]. Some examples of VOs are people, animals, buildings and things. Many VOs are available online and ready to use. Users may download for free or purchase the ready-made VOs to be used in the VR applications. Some of the ready-made VOs available on the internet are shown in Table 1.

Table 1. URLs For The Ready-Made VOs

URL	Descriptions
http://www.amazing3d.com	Provides services to build 3D models or VE for multimedia project, movie, animation, video game, magazine, website, 3D simulator and accident reconstruction.
http://www.3dmodelfree.com/	Offers free 3D models for home decorations including furniture, cookware, bathroom products, electronics and outdoor.
http://archive3d.net/	Offers free 3D models for categories of doors and windows, structures, companies and collections and people.
http://www.sharecg.com/	Offers products of 3D models, tutorials, animation and art.
http://www.planit3d.com/source/meshes_files/meshes.htm	Provides free 3D products of workshop, seating, household, transport, furniture, aviation, aquatics and plant.
http://www.3dmodels.com/	Offers 3D contents and services.
http://www.turbosquid.com/	Provides services to sell 3D models, 3D modeling textures and plug-ins.
http://www.exchange3d.com/	Offers products of 3D models, texture collection, blueprints, rendering materials and tutorials.
http://www.fallingpixel.com/	Sells 3D Objects such as aircraft, anatomy, military, plants, electronic, interiors, architecture, vehicles and marine-craft.
http://www.the3dstudio.com/	Provides services to sell 3D models, images, textures, tutorials and software.

VE is an environment where the models or objects exist [4]. The VE provides a 3D space to place the models or objects inside it. House and room are two examples of real world objects that often become the VEs. Understanding of the coordination system is important to locate precisely the VOs in the VE. The coordination of x, y and z does not have gravity. The movements of the VOs in the VE are manipulated and controlled by the values of x, y and z. The x, y and z can also give the values of width, height and depth of the objects.

Viewing component helps explain the field of view, position and orientation and distance of the objects. It enables all operations or tasks exercised in the VE to be visualized. It is possible for the VR systems having several viewings which are commonly called as multi-views or multi-displays.

Walkthrough component allows the users to explore and navigate in the VE [3]. The users may go forward and backward or may turn left and right as if they walk or run in the real environment. Manipulation component refers to the users' interactions with VOs in the VE [3]. Examples of manipulation activities are selecting an object, changing the position and orientation of an object, rotating and scaling an object. This component mainly highlights the particular ways users interact with VOs in the VE.

Knowledge and skill of learning the computer hardware refer to the facts and experiences that the students obtain from the previous formal and informal learning about the field of computer hardware. Before they get involved in the VE of computer hardware, data about their knowledge on utilizing computer, surfing web or Internet, using 3D software such as 3D Studio Max, Lightwave 3D, Maya etc and playing virtual reality system or 3D Games are gathered to measure the relation and level of knowledge before and after they test the VR system.

3. LITERATURE REVIEWS

In this topic, we analyse and study the prior researches on the implementation of VR systems in education. CyberMath is an avatar-based shared virtual environment for mathematics education. It has studied on issues of immersion, collaboration and realism in VE. CyberMath allows users to do activities such as accessing the VE distributely through the network; pointing, rotating and translating the object using computer mouse; changing objects and user avatar at different levels of realism; associating URLs with CyberMath exhibition objects (to offer additional information about the exhibited objects); and communicating with other users through computer microphone. The study has implemented two usability tests respectively for a group of 3 users in computer lab and another group of 14 users. All respondents were undergraduate students from different universities in the Stockholm region. The results show that majority of the respondents understood the presented material and enjoyed the experience even though some users reported problems with navigation and that the avatars of other users hide their views [9]. Even many activities can be done through it, the creation of its VEs can be improved and enhanced by managing the VOs. By doing so, it can help the lecturers/facilitators to prepare and create the VEs better.

HEVO method has also been used in creating and managing VOs in VEs of biology, maritime and forest fields. It allows students to navigate in the VEs of amino acids group and interacted with them. Usability study of the VR system has been implemented for a number of forty two undergraduate students who take Biology field from UMT. The VR system has shown that it is useful for teaching, easy and fun to use. In maritime field, the VEs consist of different types of virtual fishes, sea plants and an ocean. In forest field, it explains on how to create the virtual forest with various types of trees using HEVO method [11]. This research motivates to study and create other fields in education.

Previously, a framework to manage VOs in VEs using Virtual Reality System-Hierarchy Embedded Virtual Objects (VRS-HEVO) has been presented. It comprises Stand-Alone VRS-HEVO and Distributed VRS-HEVO components. The framework has allowed creating and managing VE of underwater world which contains of whales, dolphins, sharks, plants and ocean as its VOs [10].

Yuan et al. [8] have proposed assembly guidance techniques using the Virtual Interaction Panel (VirIP) and the Visual Assembly Tree Structure (VATS). VirIP is used to track the real-time interaction pen using a Restricted Coulomb Energy (RCE) neural network. VATS is used to represent the assembly sequences of complex products. VATS specifically works for management of assembly information and retrieval for the AR-assisted assembly guidance system. VATS comprises nodes that represent the assembly information such as geometric properties of an assembly part, sub-assembly and so on.

A contextualized 3-D Virtual English Classroom (VEC3D) is a language learning and teaching project that promises 3-D immersion, live voice interaction and social context. Building on goal-based instructional design, VEC3D learners embody avatars and meet each other in virtual spaces. VEC3D can be integrated into various educational settings, student needs, paces, styles and research goals. Java was used as the primary programming language for the development of the VEC3D. A number of undergraduate students from national university in Taiwan are tested using VEC3D to develop their communicative competence. They also construct their knowledge through interactive online virtual environment and events [6].

This research has been expanded to create a multimodal communication in collaborative virtual environments (CVEs) for English as Foreign Language (EFL) learners using text, voice, lip

motion and body language. The VEC3D 3.0, is once again utilized to elicit multimodal communication [7].

4. METHODOLOGY

In this paper, HEVO method has been proposed and discussed in detail. This method allows teachers to create and manage VEs of computer hardware and let the students view, interact and navigate in the created VEs. HEVO is a hierarchical, tree-structured approach that emulates a tree structure with a set of linked nodes. The tree structure consists of root, parent, children and leaves nodes.

HEVO method allows the root node to become main VE. The sub-nodes in the tree structure may represent the other VEs or VOs. Parent node may turn out as VEs. Child node may become VOs. These two situations apply to all parents and child nodes in the tree structure. The leaves nodes certainly represent as VOs [10].

HEVO method furnishes six benefits in VR system [10] as follow:

- Categorization of VOs. It is based on parent nodes and their own child nodes. The child nodes are said to be grouped or classified in their own parent nodes' category. The parent nodes that contain of their child nodes are defined as a collection of groups or categories.
- Areas of interests (AoI). Categorizing the objects will also produce a number of levels or depths. Each group or category which contains of parent and its child nodes is defined as an AoI. In this case, any AoI will be a VE while the child nodes will turn out as the VOs in the VE.
- Addition of More Information. Detailed information may be inserted for each VO in each area (AoI). By separating the areas, all nodes that are resident inside each area will be more obvious to display. Other descriptions of a VO may include its name, location, path, parent node, child nodes, numbers of child nodes and clarifications of VO.
- Modifications of Information and VOs. Any modification on the information or VOs especially in terms of their positions and orientations can be made independently. The modification only affects at the particular infected area. The rest of areas are not influenced by the modification.
- Iterations of VOs. A VO in the tree structure can be reused or repeated. There is no limitation in the duplication of VOs. The duplicated VO then can be manipulated to produce a unique VO that differs from the other VOs. For such purpose, a mechanism in HEVO to manipulate the VOs' rotation, translation and scale is used.
- Synchronization of VEs. In HEVO, the VOs is managed and arranged in synchronized. A systematical flow of VOs' node can be seen in the tree structure from the root node till the leaves nodes. Each area of interest produced according to parent-child concept is managed in sorted. Therefore, it leads to the synchronization of VEs.

To create and manage the VEs of computer hardware using HEVO method, the teachers / facilitators should follow 3 modules as illustrated in Figure 1. Then, the students who get involved in the learning and teaching of this topic utilize the module 4 as illustrated in Figure 2.

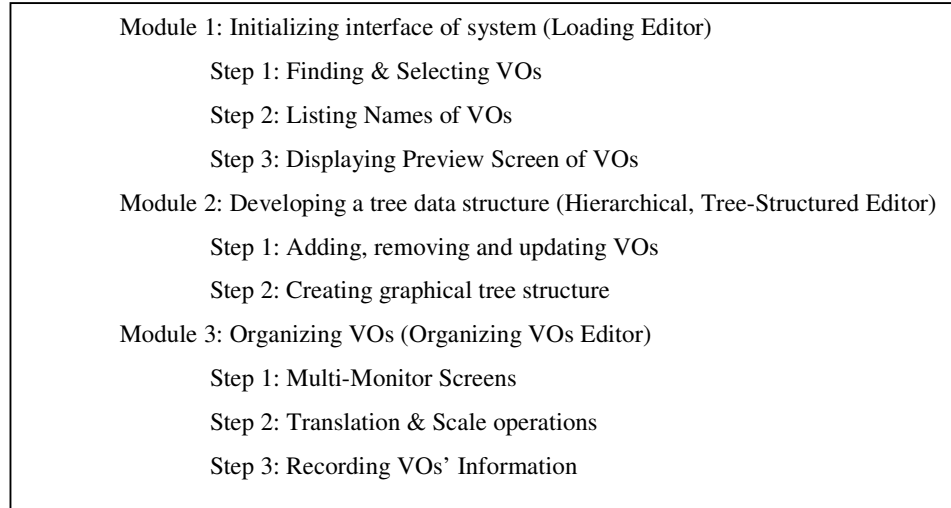


Figure 1. Modules for teacher/facilitator using HEVO.

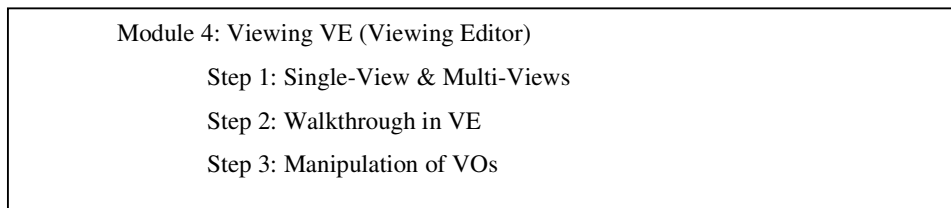


Figure 2. Modules for students using HEVO.

In the first module, an interface of virtual reality system called Loading editor is initialized. This interface allows users to search the location of VOs either in users' computers or in the server and select the desired VOs to be loaded in the system; list the names of VOs that are successfully loaded; and display the sample of VOs selected from the list.

The second module provides the use of data structure using hierarchical, tree-structured editor. The lecturers/facilitators can create the graphical tree structure through several types of operations provided in this editor such as adding new VOs in the tree structure, adding new group of VOs, removing unneeded VOs and clearing all VOs in the tree structure.

Organizing VOs editor in the third module works to manage the VOs in the VE in terms of position and orientation. The lecturers/facilitators can view a certain VE in multi-monitor screens to help precisely locate the VOs at the desired places. Each monitor screen projects different viewing such as front, left, top and perspective views. Through translation and scale operations, the selected VO can be moved at new location in the VE and resized. Information about VOs such as file, caption, description, parent, path, location, scale and rotation can also be saved systematically in the text file with extension *.hevo for reference, distribution and display in future. Thus the users do not need to rebuild the VE from the beginning.

The last module allows the students to view the final results of VEs either in single-view mode or multi-views mode. They can walkthrough in the VE using arrow keys on the keyboard. Mouse can be used to allow the students manipulating and interacting with VOs in the VE. Figure 3, 4, 5 and 6 show the interfaces of editors in the VR system which implements the four modules as described above.

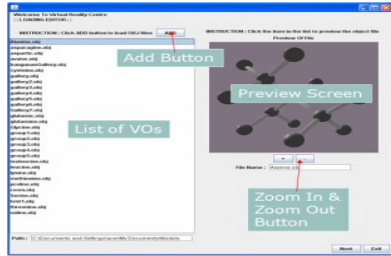


Figure 3. Interface of Loading Editor

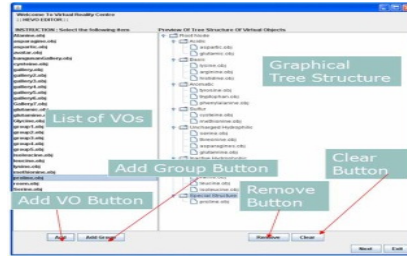


Figure 4. Interface of HEVO Editor

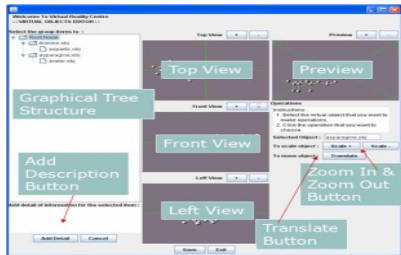


Figure 5. Interface of Organizing Editor

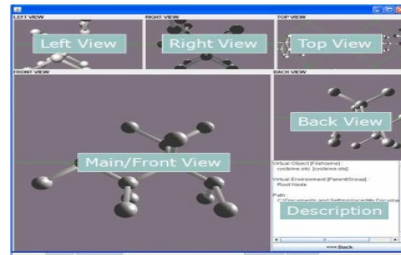


Figure 6. Interface of Viewing Editor

4.1. Development of VEs of Computer Hardware

For this case study, ten VEs of different devices for computer hardware have been developed. In each VE, the VOs have been placed and located in scattered so that the students who test the VR system may put affords to find the VOs and navigate in the VE using the arrow keys on the keyboard. The VOs have also been transformed at different sizes so that they utilize the interaction or manipulation activity using mouse to recognize the selected VOs. The total number of VOs in all VEs are twenty.

HEVO method has produced the tree structure as illustrated in Figure 7. Each VE of the computer device reflects to the question in the quiz. Figure 8 illustrates the ten different VEs using HEVO method in the VR system.

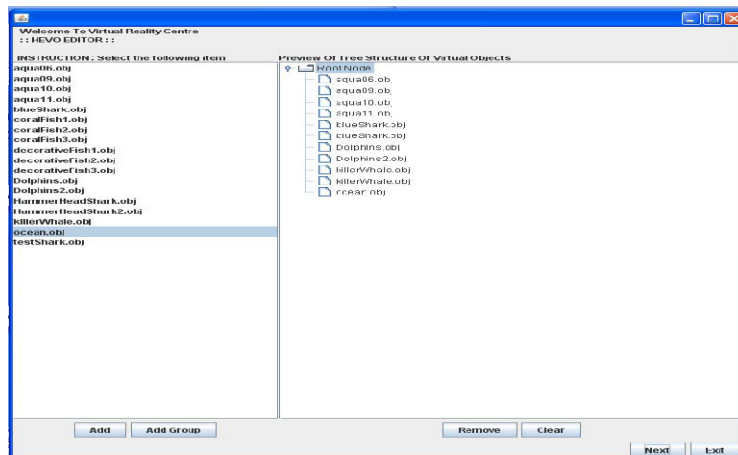


Figure 7. Tree Structure in HEVO Editor

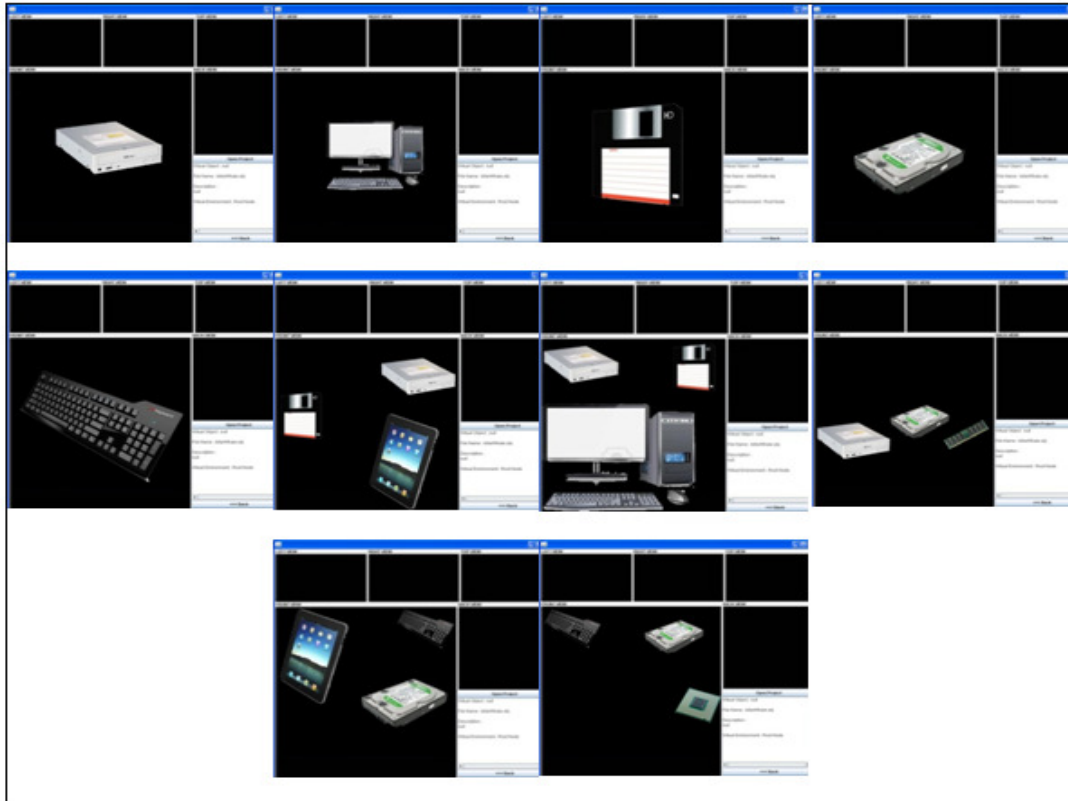


Figure 8. Ten VEs using HEVO

4.2. VEs of Computer Hardware-Based Assessment

To test and evaluate the levels of the students' knowledge and skill in learning the computer hardware using the created virtual environments, we have implemented the assessment using quiz. The quiz comprises ten questions with regard on the computer hardware field. The types of questions in the quiz are based on the recognition of the computer hardware and the selection of the right computer hardware. A number of nine undergraduate students in Computer Science course from Universiti Sultan Zainal Abidin (UniSZA) have been selected to test the VR system and answer the quiz.

Before the test, demonstration on how to use the VR system has been exposed to the students. The students need to open relevant VE in the VR system based on the question they want to answer first. The created VEs encourage them to use the keyboard and mouse devices for navigation and interaction activities. The students need to navigate and manoeuvre in the VEs to find the right locations of the VOs which have been placed in scattered. The interaction with the VOs is also crucial for recognizing and selecting the right VOs to be answered in the quiz.

4.3. Usability Performance of the Created Virtual Environments

Once the respondents have finished testing the VR system and answering the quiz, questionnaires have been distributed for each respondent to evaluate the usability performance of the created VEs for computer hardware. The questionnaire consists of demographic section, experience section and system usability scale section.

The demographic section covers the respondents' background including institution, unit/department/ faculty, position, gender, age, race and qualification. The experience section refers to

the levels of the respondents' practices in utilizing computer; surfing web or Internet; using 3D software such as 3D Studio Max, Lightwave 3D, Maya etc; and playing virtual reality system or 3D Games. The system usability scale section refers to the usability levels of the proposed VR system in terms of the respondents' feel fun; help in the learning; easiness to use; better understandability in the learning; need of guidance; suitability to use in the learning; acceptance to use in the future; clarity and comparability of the VOs; importance of manipulation activities; suitability of manipulation activities using mouse; importance of walkthrough activity; suitability of walkthrough activity using keyboard; and acceptance of utilizing multi-views.

5. RESULTS & DISCUSSIONS

In this section, we discuss in detail about the assessments of the respondents' knowledge and skill levels, the usability study of the VR system used by the respondents and the quiz answered by the respondents.

5.1. Analysis of knowledge and skill levels

In this discussion, the respondents' knowledge and skill are measured. Table 2 and Figure 9 show the respondents' frequencies in utilizing computers. Four respondents state that they are very experienced while the other four respondents are experienced in utilizing and using the computers.

Table 2. The respondents' frequency in utilizing the computers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Experienced	5	1.1	55.6	55.6
	Very Experienced	4	0.9	44.4	100.0
	Total	9	2.0	100.0	

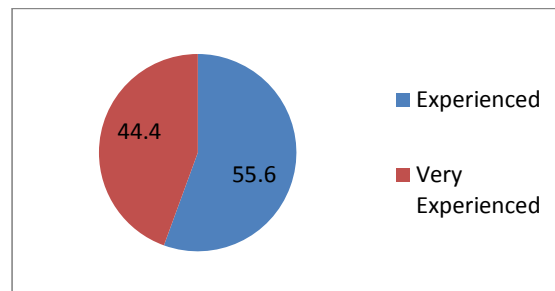


Figure 9. Percentage in pie chart for the respondents' frequency of utilizing computers

Table 3 and Figure 10 illustrate the respondents' frequencies in surfing web or Internet. Three respondents express that they are very experienced while the other six respondents are experienced in surfing web or Internet.

Table 3. The respondents' frequency in surfing web or Internet

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Experienced	6	1.4	66.7	66.7
	Very Experienced	3	0.7	33.3	100.0
	Total	9	2.0	100.0	

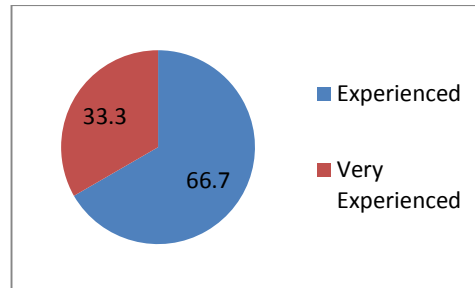


Figure 10. Percentage in pie chart for the respondents' frequency of surfing web or Internet

Table 4 and Figure 11 describe the respondents' frequencies in utilizing 3D software such as 3D Studio Max, Lightwave 3D, Maya etc. Three respondents express that they are not experienced, five respondents are less experienced and one of them is average in using the 3D software.

Table 4. The respondents' frequency in utilizing 3D software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Experienced	3	0.7	33.3	33.3
	Little Experienced	5	1.1	55.6	88.9
	Average	1	0.2	11.1	100.0
	Total	9	2.0	100.0	

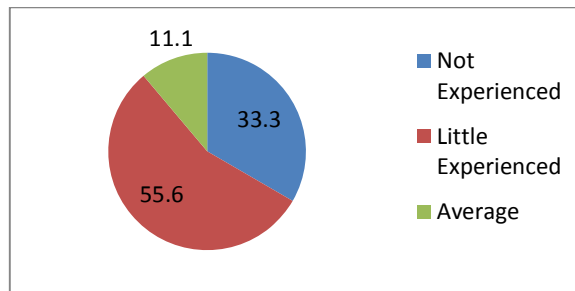


Figure 11. Percentage in pie chart for the respondents' frequency of utilizing 3D software

Table 5 and Figure 12 describe the respondents' frequencies in playing virtual reality system or 3D Games. Four respondents indicate that they are little experienced, three respondents are average and one respondent is categorized respectively in experienced and very experienced in playing virtual reality system or 3D Games.

Table 5. The respondents' frequency in playing virtual reality system

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Little Experienced	4	0.9	44.4	44.4
	Average	3	0.7	33.3	77.8
	Experienced	1	0.2	11.1	88.9
	Very Experienced	1	0.2	11.1	100.0
	Total	9	2.0	100.0	

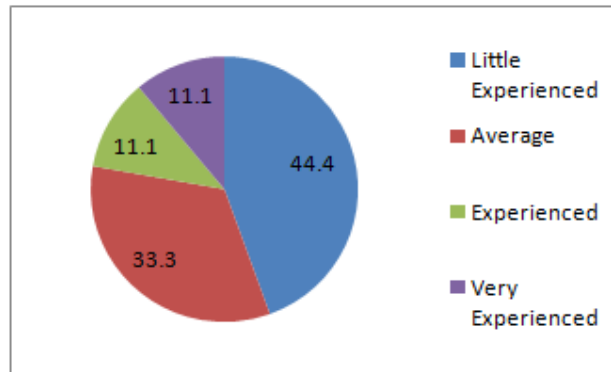


Figure 12. Percentage in pie chart for the respondents' frequency of in playing virtual reality system or 3D Games

5.2. Analysis of the usability study

Table 6 and Fig 13 show the mean scores of the responses in the usability study of the system in terms of factors: the respondents' feel fun; help in the learning; easiness to use; better understand ability in the learning; need of guidance; suitability to use in the learning; acceptance to use in the future; comparability of the VOs; suitability of the VE; importance of interactivity technique; effectiveness of interactivity technique using mouse; effectiveness of walkthrough technique; suitability of walkthrough technique using keyboard; clarity of the VOs; and comfortability of utilizing multi-views mode.

Table 6. The mean scores of the responses in the usability study of the VR system for each factor

	N	Minimum	Maximum	Mean	Std. Deviation
Feeling fun	9	3	5	4.11	0.601
Help learn	9	4	5	4.22	0.441
Easy to use	9	4	5	4.22	0.441
Help understand better	9	3	5	4.00	0.500
Without demonstration	9	2	5	3.78	0.972
Suitability for learning	9	4	5	4.44	0.527
Use in the future	9	4	5	4.33	0.500
Differentiate the virtual objects	9	4	5	4.33	0.500
Suitability of Ves to be navigated	9	4	5	4.33	0.500
Importance of interactivity technique	9	4	5	4.44	0.527
Effectiveness of interactivity technique	9	2	5	4.22	0.972
Impotence of navigation technique	9	4	5	4.44	0.527
Effectiveness of navigation using keyboard	9	2	5	4.22	0.972
Contrastness of virtual objects	9	4	5	4.33	0.500
Comfortability using multi-views mode	9	3	5	4.11	0.601
Valid N (listwise)	9				

In general, most of the mean scores in each factor are above 4.0 points. These scores mean that each factor shows the positive responses from the respondents during utilizing the VR system. In other words, the results show:

- The respondents feel fun;
- The VR system can help learn;
- The VR system is easy to use;
- The VR system can help in better understanding the subject;
- The VR system is suitable to be used in the learning;
- The respondents are willing to use the VR system in the future;
- The respondent can differentiate the VOs appeared in The VR system;
- The VE is suitable to be navigated;
- The interactivity technique is important in the VR;
- The interactivity technique using mouse device is effective;
- The walkthrough technique is important;
- The walkthrough technique using keyboard device is suitable;
- The respondents can view clearly the VOs displayed in the VE;
- The respondents are comfortable utilizing multi-views mode.

The mean score of the factor need of guidance however is 3.78 points. It means that the respondents feel that they still need demonstration on how to use and master the VR system.

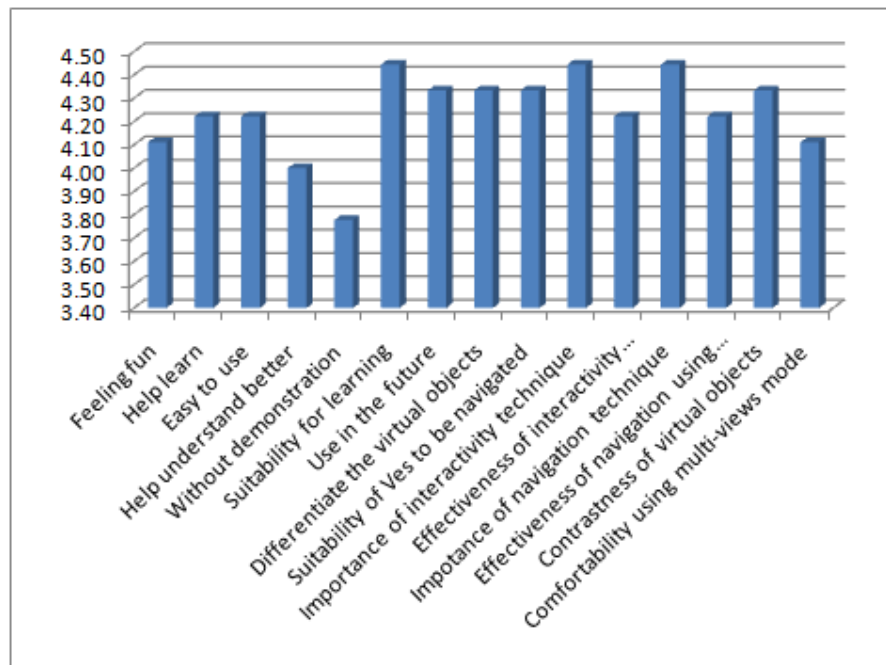


Figure 13. Bar chart for the mean scores of the responses in the usability study of the VR system

5.3. Analysis of the quiz

All respondents get full marks in their quiz. This result shows that the respondents have knowledge in computer hardware field. Even majority of them express that this is the first time use of the VR system, they can learn faster. The result also indicates that they can understand better and help them in learning when using the VR system.

Since there are twenty VOs in the created VEs, it also shows that they have skills in utilizing the tools in VR system for interaction and navigation in the VEs. The skill helps them find the relevant VOs and recognize precisely the desired VOs in the VEs. Without such skill, surely they can not answer the quiz correctly.

6. CONCLUSIONS

This paper has presented virtual environments for computer hardware using HEVO to test and evaluate the levels of the students' knowledge and skill in learning the computer hardware. HEVO method allows teachers to create and manage VEs of computer hardware and let the students view, interact and navigate in the created VEs. The findings have shown that the created VE is useful for teaching, easy and fun to use. The students have also designated that they could understand the subject better using the system. For the future works, we believe that many applications can be developed using this study from various fields including manufacture, gaming, architecture, medicine, entertainment.

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