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Utilising Virtual Environments To Research Ways To Improve Manipulation Task

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Abstract

Real-time feedback systems has been widely used and become very important in many fields. In this project Microsoft Visual C++ together with OpenGL programming software were employed to create a Tower of Hanoi which was used as the experiment task. The real-time system has been studied by adding a real-time visual feedback into a simulation task. Two types of real-time visual feedback were discussed in this work, which were colour feedback and text feedback. Visual feedback techniques were design to give the cues to the users about the reasons for errors occurrence. Four different methods were compared and contrasted which are no feedback, with feedback, with text feedback and with colour feedback. The Tower of Hanoi is also programmed to provide different feedback in real time for the purpose of investigating the effect of auditory feedback to the user. Moreover, the Tower of Hanoi is programmed in stereoscopic for virtual reality manipulation task. Three types of feedback were evaluated. It consists of non-speech, speech auditory feedback and without feedback. The goals of this study were to explore real-time visual feedback technique and compare the effectiveness of different types of real-time visual feedback technique. For the purpose of investigating the effect of auditory feedback to the user, the result of the project showed the participant performance in solving the Tower of Hanoi is better in the non-speech auditory feedback. Beside that, speech auditory feedback provides greatest understanding to the user throughout the experiment, but the drawback is the participant cannot complete the task in shorter time.

1. Introduction

Nowadays, real-time feedback application is become more important in many fields such as communication products, consumer appliances, telephone switch and others (Michael, 1992). Real-time feedback from a system is crucial to determine the success of a process or activity. The meaning of real time refers to the immediate response of the system. The term is used to describe a number of different computer features. Real-time system is a computer-based system which can resolve a number of difficult issues simultaneously with rapid response (Philip, 2004). For example, real-time operating systems are systems that respond to input immediately. They are used for such tasks as navigation, in which the computer

must react to a steady flow of new information without interruption. Most general-purpose operating systems are not real-time because they normally take a few seconds, or even minutes, to react. It has become a common practice to use digital computer for the real-time application such as computer-integrated manufacturing (CIM), industrial process control, defenced systems and, electric power distribution and monitoring. All these applications usually require getting the response from operating system instantly or as fast as possible (Sang, 1995). Real-time feedback application allows the user can straight away know the error while any mistake of input has been given to the real-time feedback system. Instead of telling the error to the user, real-time feedback system also can react as the medium for training the new user to become familiar with new system and to train new user not to make any mistake that may caused error to the system.

Virtual reality system is used to create a virtual world for the user for various applications in training users by giving real-time feedback to the users. Flight simulators for training airplane pilots and astronauts were the first form of this technology, which provided a very realistic and very expensive simulation (www.techweb.com). Lai et al. (Lai et al., 2008) conducted a study in solving the task of "Tower of Hanoi" by adding auditory feedback and the results showed that the users improved their performance and completed the manipulation task in shorter time.

A number of studies have shown that audio contributed to the interaction process in order to provide richer, more robust environment than with mere graphic feedback (Heeter and Gomes, 1992). Auditory feedback can present further information when the bandwidth of graphic information has been exhausted, as is often the case with the present emphasis on graphic presentation (Rauterberg, 1999). By expanding conventional interfaces in another dimension, sounds make tasks easier and more productive. Other studies have even shown certain types of information to be represented better by sound than through graphics or text. Additionally, audio feedback may complement graphics and text to create valuable redundancy, reinforcing or reconfirming a concept in the user's mind (Winberg and Bowers, 2004).

In this work, a study on a real-time visual feedback manipulation task as well as real time auditory feedback technique in manipulation task will be carried out to solve three discs Tower of Hanoi, invented by the French mathematician Edouard Lucas in 1883. The user needs to move all the discs from the left peg to the right peg. The rules for the task are only one disc can be moved at one time and the larger disc may not be placed on top of the smaller disc. The objective of this work is to create the task of 3 discs 'Tower of Hanoi' using OpenGL together with Microsoft Visual C++, apply real time visual feedback and investigate the effectiveness on various type of real time visual feedback technique for solving the task of Tower of Hanoi. The best method of real-time visual feedback in simulation task will be evaluated. A group of user has been chosen and test on the "Tower Of Hanoi" game that has different type of visual feedback such as "colour" or "text" feedback and the time to complete the task has been plotted and analysed. The second objective is to investigate the effect on real time auditory feedback technique and solving the Tower of Hanoi manipulation task in virtual reality. Three auditory feedback techniques will be tested which include task with speech auditory feedback, task with non-speech auditory feedback and task without auditory feedback.

2. Methodology

Since there will be two different type of feedbacks being investigated in this work, the scope of the methodology taken to perform those tasks are divided into two parts. The first part explained the procedures taken to perform a real-time visual feedback manipulation task to solve the 'Tower Of Hanoi' problem. The following part explained on the methods taken to solve the Tower of Hanoi with real time auditory feedback technique. Finally, the Tower of Hanoi manipulation task is solved in virtual reality using visual and auditory feedbacks. The OpenGL has been utilized in programming Tower of Hanoi to be solved using visual and auditory feedback.

2.1 Tower of Hanoi OpenGL programming

The Towers of Hanoi utilized many features and special functions found in the three OpenGL libraries, enabling endless possibilities. In this project, the author is required to combine these elements into a single application (Segal and Akeley):

- Display Lists: were used to quickly and efficiently render the pole objects and disc objects. The disc objects were created by glut library toruses, which being a solid torus. This created a specific visual effect desired by the programmer. The poles were solid cone, transformed and placed within the display list to automatically come in the correct size and object placement when initialized requiring a programmer to merely place a pole object.
- Reshape change subcomponents: Handles the rendering of the viewing space, and the reshaping of the window.
- Transformation Functions: The program relied heavily on the Translate and Scale functions to accurately place and sizes the discs, as the discs themselves were at the same size and location at initialization. Rotation was used to properly orient the pole cube to the base cube of the pole object.
- Geometric Objects: Advanced geometric objects such as, glutSolidTorus(), and glutSolidCone() were used to render the objects in the scene.
- Lighting: Many material and lighting functions of OpenGL was used to create the look of the Towers of Hanoi. The materials of the scene were given ambient, diffuse, specular and shininess settings to make the solid objects in the scene appear shiny yet dull to their reflective properties.
- Keyboard Function: Keyboard was used to handle the various keyboard function and data input.
- Mouse Function: The mouse was used for simple controls and interface for the user where the users are able to move the disk to their desired location to complete the task that is to solve the tower of Hanoi.

2.2 Real-time visual feedbacks to solve Tower of Hanoi

The scope of the methodology applied for a study on a real-time visual feedback manipulation task is mainly divided into several stages. The author needs to program the Tower of Hanoi using OpenGL together with Microsoft Visual C++ with visual feedback which will be used as the experiment task. Then, the author needs to conduct the experiment on different visual feedback technique to investigate the performance of solving the task of Tower of Hanoi.

Each of the real-time feedback system has the ability to let users to input the data before it calculates the available results within an interval time. Thus, in this stage, the ability of the manipulation task to receive the incoming data has been tested before interpret it. At the beginning of this stage, the author tried to give some input by using keyboard. The input can be the steps of completing the manipulation task, the hints to complete the manipulation task. Then, the author also enabled the ability of manipulation task to get the input by clicking or dragging by using mouse.

The author tried to put some warning message when a user (a person who manipulates the task) has keyed in the illegal move that is not allowed by the rules for the task. Later in advance, the author also tried to put some animation when the errors occurred.

2.3 Real time auditory feedback to solve Tower of Hanoi

The scope of the methodology applied for technique in manipulation task is mainly divided into four major stages. Firstly, the OpenGL programming language has been explored and tested by practicing various examples available form the internet and also programmed by the authors. The code has been programmed specifically to be used in solving the Tower of Hanoi problem and enhance the understanding of auditory feedback and virtual reality. Secondly, to provide auditory feedback to enhance the manipulation task. Thirdly, to conduct the experiment on different auditory feedback technique and investigated the performance of solving the task as well as the experiment done in virtual reality for Tower of Hanoi manipulation task. Finally, analyze the result and identify the cause and effect for the different feedback. Here are the detailed steps taken to perform the auditory feedback simulation.

2.3.1. Tower of Hanoi feedback simulation

This experiment examined whether different auditory feedback techniques may affect the participants performance in solving the task. Three conditions were programmed separately as the experiment tasks, which were the Tower of Hanoi without auditory feedback, Tower of Hanoi with non-speech auditory feedback and the Tower of Hanoi with speech auditory feedback. The auditory feedback will be provided whenever there is any mouse-clicking occurred, error movement, complete or fail to solve the task in a given time and pre-start game sound as illustrated below:

2.3.1.1 Start game

The game starting sound will be provided when the user press 'S' to start the game.

2.3.1.2 Mouse clicking

The mouse-clicking sound will be provided when the user click to move and place the disc on the pole (as shown in Figure 1).

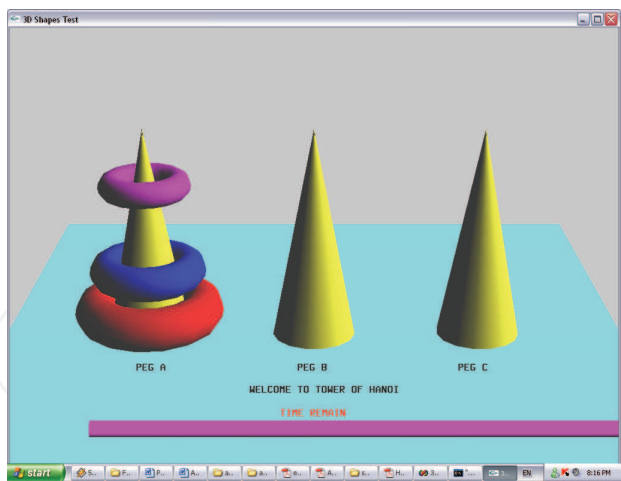


Fig. 1. Mouse-clicking sound

2.3.1.3 Error movement

The sound feedback will be provided when the error movement was made, such error include:

- Put the bigger disc on top of the smaller disc (as indicated in Figure 2).

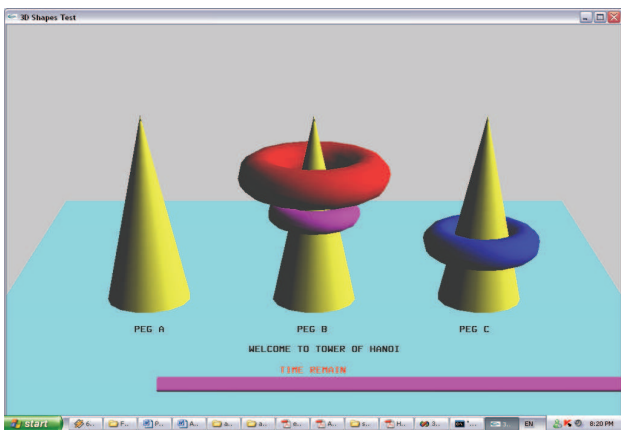


Fig. 2. Sound for error movement

- Did not put the disc at a proper location (as indicated in Figure 3).

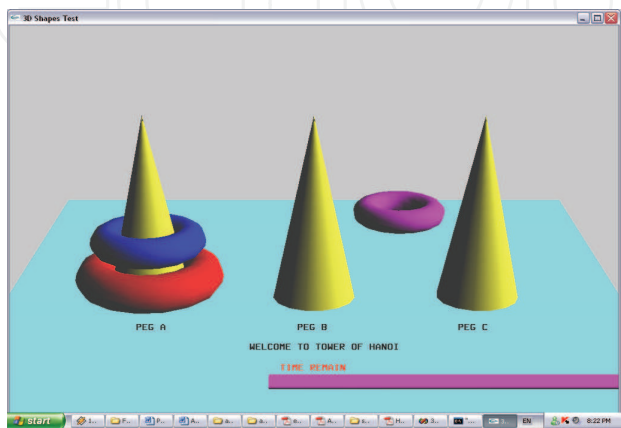


Fig. 3. Improper location

- Try to move a disc in the position to the other pole (as indicated in Figure 4).

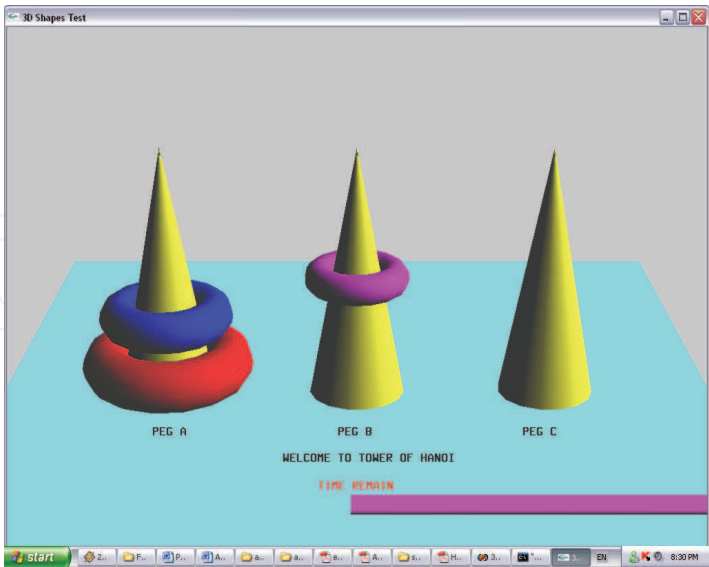


Fig. 4. Putting in the other pole

2.3.1.4 Game over

The sound feedback will be provided when the times is run out. It indicates that the game is over (as shown in Figure 5).

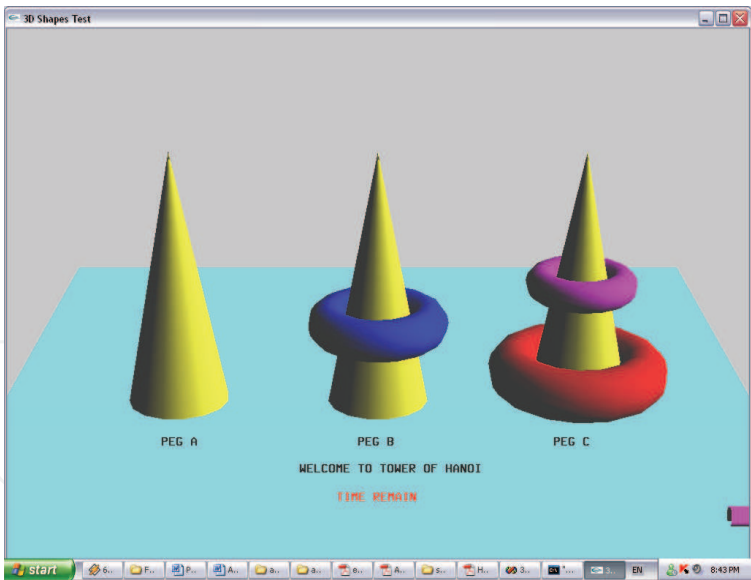


Fig. 5. Game over

2.4 Virtual reality for Tower of Hanoi

An experiment will be carried out in virtual reality for the Tower of Hanoi manipulation task at Virtual Reality Laboratory, Faculty of Computer Science in University Malaya.

3. Experiment

Experiments were conducted to evaluate the effectiveness of real time feedbacks in solving the Tower of Hanoi simulation task. The first part of the experiment evaluated the effectiveness of real-time visual feedback system while the second part of the experiment studied on the effect of auditory feedback technique in solving the Tower of Hanoi. In the first part of the experiment, there are two types of visual feedbacks being experimented. They were simulation with real-time visual feedback to be compared with simulation without real-time feedback and simulation with real-time text feedback which is compared to simulation without real-time feedback. The second part of the experiment involved three different sections. They are Tower of Hanoi with speech auditory feedback, Tower of Hanoi with non-speech auditory feedback and Tower of Hanoi without auditory feedback. The results and discussion for all these experiments are presented in the following section.

3.1 Effectiveness of real-time visual feedback system

An experiment was carried out to investigate the effect of visual feedback technique. The experiment result will determine whether the visual feedback from one system is encouraging or giving a negative effect on the user performance.

3.1.1 Participants

Sixteen males and four females between the ages of 23 and 24, with the mean age of 23.5 years old with a standard deviation of 0.5 years old have participated in this study. The entire users have been told about the goal of the game. The group of participant has been divided into 2, where group A is for the evaluation on the effective of occurrence of real-time visual feedback while group B is for the evaluation on the effectiveness of the type of real-time visual feedback. None of the subjects had an experience on manipulating the "Tower of Hanoi" puzzle.

3.1.2 Experimental procedure

Each of the experiment has been conducted separately by each user and each user has the time limit of 100 seconds to complete the task for the "3 discs Tower of Hanoi". Before they start to do the experiment, the user has been briefly taught by the author on the goal of the simulated task. The goal for the task is to move all the discs from peg A to peg C. Before the experiment begin, the users have been divided into 2 group where group A is doing the evaluation on the effective of occurrence of real-time visual feedback and group B is for the evaluation on the effectiveness of the type of real-time visual feedback. The users need to key in their information and the data has been save automatically in a notepad as .txt file. Then, the experiment of "3 discs Tower of Hanoi" has been conducted by the user. The user must finish the task within the time frame given for the experiments. After they finish the task, the time, the steps and the error steps in completing the task have been save automatically in the notepad as .txt file.

3.1.3 Results and Discussion

The results for each types of experiment have been saved in different file name. Figure 6 shows the graphic that created from the programming code. This is "Tower Of Hanoi" with

3 different colour discs which are magentas, blue and red. The bar below the peg shows the time indicated for the simulation task.

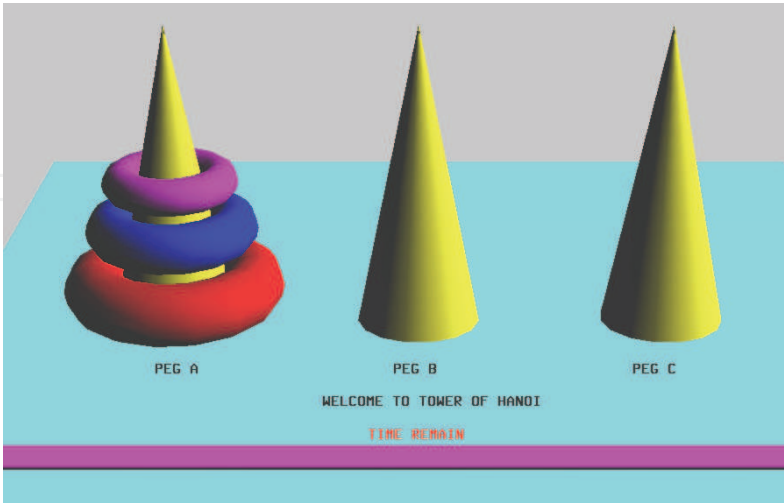


Fig. 6. Simulation task on “3 discs tower of Hanoi”

Table 1 showed the results for the real-time visual feedback. Table 2 showed the results for the simulation without real-time visual feedback. Table 3 showed the results for the simulation real-time text feedback. Table 4 shows the results for simulation with real-time colour feedback.

Participant	1	2	3	4	5	Average
Task Completion Time(s)	18.98	24.66	41.47	15.72	56.83	31.53
Number of steps	7	13	8	7	12	9.4
Error Steps	3	1	3	0	1	1.6

Table 1. Results for simulation with real-time visual feedback

Participant	1	2	3	4	5	Average
Task Completion Time(s)	23.56	13.42	23.42	21.32	56.83	22.88
Number of steps	10	8	13	9	14	10.8
Error Steps	1	0	2	4	3	2

Table 2. Results for simulation without real-time feedback

Participant	1	2	3	4	5	Average
Task Completion Time(s)	7.42	32.41	23.89	45.97	16.52	25.24
Number of steps	7	18	15	20	8	13.6
Error Steps	0	3	2	2	1	1.6

Table 3. Results for simulation with real-time text feedback

Participant	1	2	3	4	5	Average
Task Completion Time(s)	28.9	12.88	15.32	8.92	25.21	18.24
Number of steps	16	25	8	7	32	17.6
Error Steps	3	10	2	0	7	4.4

Table 4. Results for simulation with real-time colour feedback

Figure 7, 8 and 9 showed the results on task completion time, number of steps and error steps on 4 simulation tasks which are simulation task with real-time visual feedback, simulation task without real-time visual feedback, simulation task with real-time text feedback and simulation task with real-time colour feedback.

Average task completion time for all the experiments conducted is shown in figure 7. The experiment with colour feedback showed the shortest time, followed by experiment without feedback, experiment with text feedback and finally experiment with feedback.

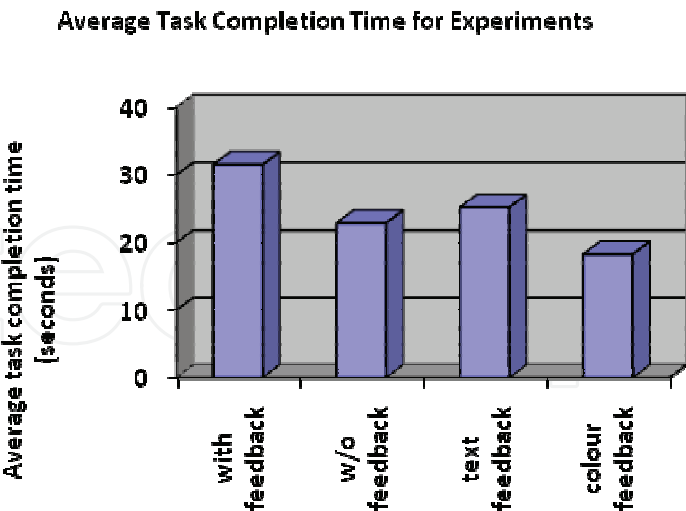


Fig. 7. Average Task Completion Time

Average number of steps for all the experiments conducted is shown in figure 8. The experiment with feedback showed the shortest time, followed by experiment without feedback, experiment with text feedback and finally experiment with colour feedback.

Average number of error steps for all the experiments conducted is shown in figure 9. The experiment with text feedback showed the shortest time, followed by experiment with feedback, experiment without feedback and finally experiment with colour feedback.

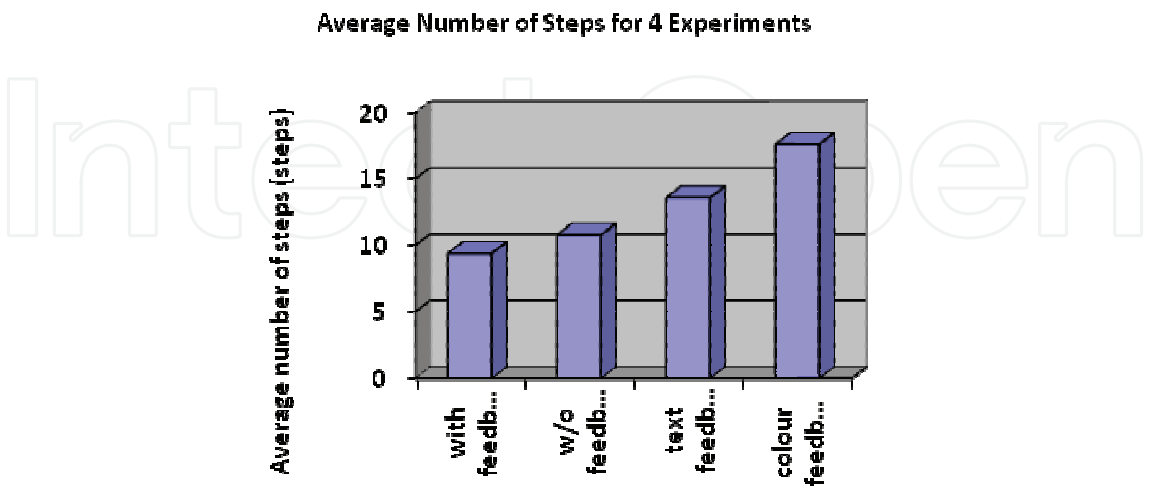


Fig. 8. Average number of steps

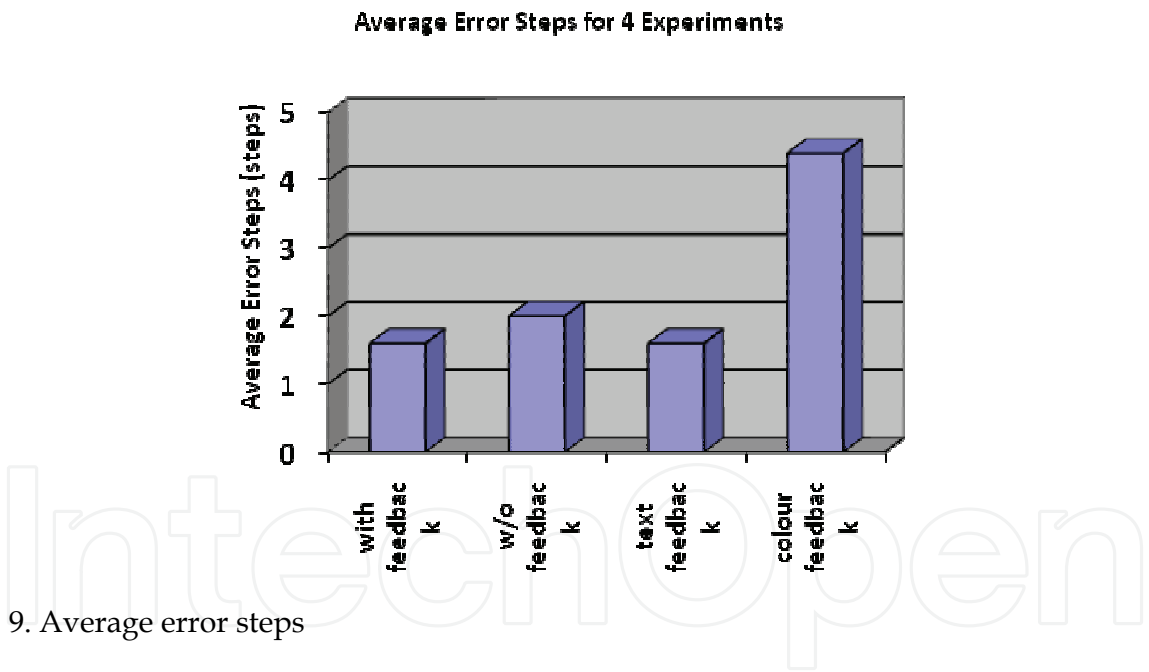


Fig. 9. Average error steps

The average task completion time for the simulation task with real-time visual feedback is slightly longer than the simulation task without real-time visual feedback. However, the average error steps for the simulation task with real-time visual feedback are lower than the simulation task without real-time visual feedback. This is because while the visual feedback is added to the simulation, the user need sometime to figure out what is the error steps that has been make through out the text of error that shown on the screen as in figure 10. After knowing the reasons for the errors, the user will avoid doing the same errors and the errors steps for them are lower when comparing to the

user that using the simulation task without visual feedback. The main reason is because they did not know the reasons of the errors.

As a conclusion, the simulation with real-time visual feedback is better than the simulation without real-time visual feedback. The simulation with real-time visual feedback has taught user knowing the reasons of errors and do not repeat the errors.

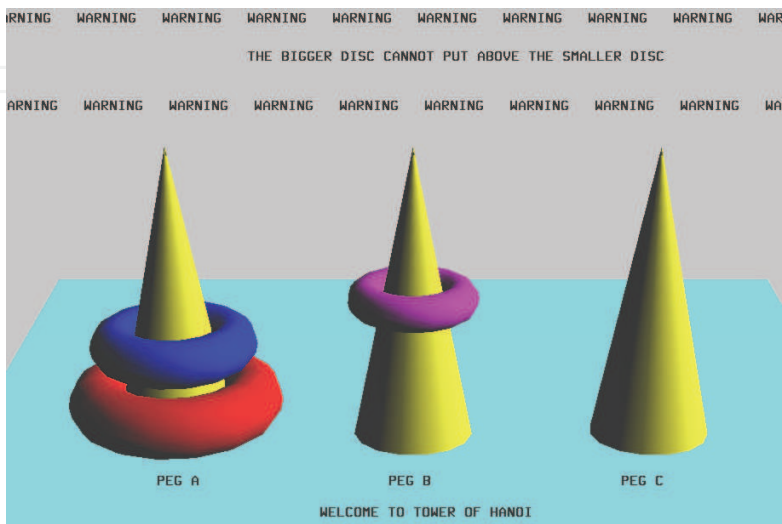


Fig. 10. Figure show the text notice for errors.

Next experiment has been carried out to evaluate the best method of real-time visual feedback. These experiments were conducted to evaluate whether a system with real-time text feedback is better than system with real-time colour feedback or vice versa. From the experiment, we can see that the average task completion time for the simulation task with real-time text feedback is slightly longer than the simulation task with real-time colour feedback. However, the average error steps for the simulation task with real-time text feedback are lower than the simulation task with real-time colour feedback.

This is because while the text feedback is added to the simulation, the user need sometime to read the text and figure out what is the reasons for error steps that has been made through out the text of error that shown on the screen as in figure 5 while for the colour feedback, the user only know the error has occurred but they may be do not know what causes of the error and does not need time to read or understand the reasons of an error step. After knowing the reasons for that particular error, the user will avoid for doing the same errors again, and the errors steps for them will become lower than the user that using the simulation task without visual feedback.

It has been found that the simulation with real-time text feedback is better than the simulation with real-time colour feedback. The simulation with real-time text feedback has taught the user understand the reasons of errors and do not repeat the errors.

3.2 Effectiveness of real time auditory feedback

An experiment will be carried out to investigate the effect of auditory feedback technique. The experiment result will determine whether the auditory feedback from one system is encouraging or giving a negative effect on the user performance. Fifteen participants were instructed to solve the three discs Tower of Hanoi without auditory feedback and the Tower

of Hanoi with non-speech and speech auditory feedback created by the programmer using the OpenGL software. The performance in solving the task will be analyzed.

3.2.1 Participant

There were 15 participant from the age group 23-25 had been instructed to solve the Tower of Hanoi with speech/non-speech and without auditory feedback. None of them have experienced to solve the task before and suffering any hearing illness.

3.2.2 Material

The Tower of Hanoi created using Microsoft Visual C++ together with OpenGL is used as the experiment tasks. The program used was divided with speech/non-speech and without auditory feedback to provide real time feedback to the participant during the process for solving the task.

The computer mouse and keyboard were used as input devices to move the disc and keyed in the participants' personal detail. The output device such as CRT or LCD monitor used for graphic display, and a speaker is used as a sound output device.

3.2.3 Procedure

All participants are required to complete a questionnaire for general information, read and sign a health consent form prior Tower of Hanoi solving experience.

Five participants were instructed to solve the 3 disc Tower of Hanoi with speech auditory feedback and five participants were instructed to solve the 3 discs Tower of Hanoi with non-speech auditory feedback. Another five participants were instructed to solve the 3 discs Tower of Hanoi without auditory feedback.

3.2.4 Measure

In this project, the task solving performance will be measure where the time for the participants for solving the task will be recorded for all cases with speech/non-speech and without auditory feedback and the number of error step made by the participants on the process of solving the task is recorded.

3.2.5 Results and Discussion

- Participant

The Tower of Hanoi experiments were performed by 15 adult participants, with a mean age of 24.2 years. The participants were in good health with no history of hearing illness. None of the participants has experienced in solving Tower of Hanoi problem. Trials were carried out by each participant individually.

- Task solving performance

The task solving times and the number of error made by the participant in the experiment is recorded for three types of auditory feedback technique which is Tower of Hanoi with speech auditory feedback as in Table 1, Tower of Hanoi with non-speech auditory feedback as in Table 2 and Tower of Hanoi without auditory feedback as in Table 3. Beside that, a graph is plotted for the comparison between these three different auditory feedbacks technique in term of task solving time as shown in Figure 11.

No.	Time (s)	No. of error
1	20.78	0
2	26.46	2
3	20.48	2
4	30.52	2
5	23.74	1
Average	24.40	1.4

Table 1. Speech auditory feedback

No.	Time (s)	No. of error
1	16.65	2
2	15.83	1
3	11.21	0
4	18.23	1
5	15.90	2
Average	15.56	1.2

Table 2. Non- Speech auditory feedback

No.	Time (s)	No. of error
1	21.12	3
2	25.21	4
3	18.03	2
4	20.90	2
5	14.23	1
Average	19.90	2.4

Table 3. Without auditory feedback

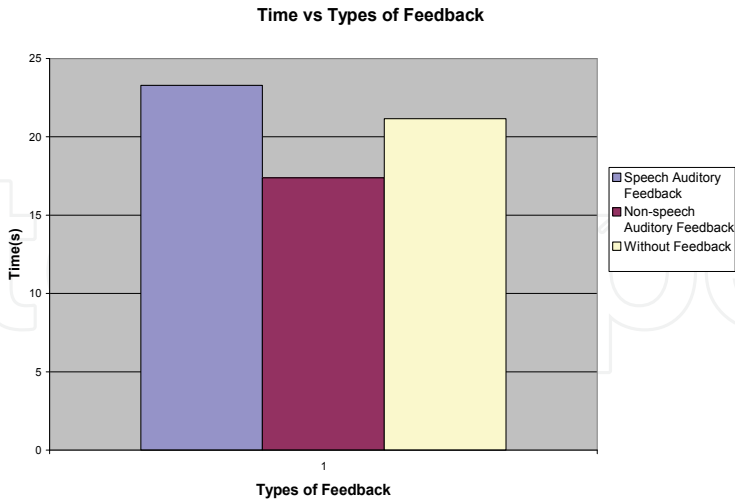


Fig. 11. Task Solving Time

• Discussion

From the result obtained throughout the experiment, it showed that the time taken to solved the task is shortest for the cases where non-speech auditory feedback used as task feedback,

where the average of 15.56s, followed by without feedback: 19.90s, and speech auditory feedback: 24.40s.

The number of errors recorded was found best (least error) which performed by non-speech auditory feedback; 1.2, followed by speech auditory feedback: 1.4 and the worst was without feedback: 2.4.

Throughout the experiment process, the auditory feedback was observed effective in the following way. Auditory feedback helped participants keep track of the ongoing process. For example, auditory alarm (non-speech) feedback alerts the participant for any errors disc movement therefore reduce the possibility for participant of making the same error repeatedly, besides that, a sound generated before the game is going to start, make the participants to be more prepare for the up coming task. It helps on reduce the lagged starting time to the participants. The same situation is happen in which the speech auditory has selected as task feedback. In this case, a more detail feedback message is conveyed to the participant, the participants are more understand what is going on for the occurrence of all that error instead of just an alarm indicated there is an error. For example, a human speech of “error, error, the bigger disc cannot put above the smaller disc”, inform the participant the reason of such error.

Auditory Feedback		
Criteria	Speech	Non-speech
Presenting information	Slow	Fast
To assimilate information	Hear from beginning to end	Messages are shorter
	Need many word to be understood	None
	Messages are straight forward	Need to think
	No learning necessary	Required learning to understand
	Not universal (different language)	More universal
Presenting continuous information	Good	Better
Rapid feedback	Good	Better
Convey instruction	Better	Good

Table 4. A comparison between Speech and Non-speech Feedback.

However, the drawback of using speech auditory feedback is presenting information was much slower because of its serial nature, to assimilate information, the participant must typically hear it from beginning to end and many words have to be comprehended before a message can be understood. Therefore, it is time consuming for a participant in solving the task if compared to the other two methods used in these experiments.

For the experiment with no audio feedback technique, the participant seems to solve the task a bit faster than speech auditory feedback but the error made was the most frequent compared to others. This is because the participants had observed to carry a 'try and error' style in solving the task, the drawback is some of the participants made the same error twice, and some of them are not even know why their disc movement were not allowed if performed wrongly. Table 4 shows a comparison between Speech and Non-speech Feedback.

4. Virtual reality for Tower of Hanoi

In this project, an experiment had been carried out in virtual reality for Tower of Hanoi manipulation task at Virtual Reality Laboratory, Faculty of Computer Science in University Malaya. The virtual reality lab is equipped with many virtual reality advanced equipments. By having a stereoscopic view of Tower of Hanoi task, the user will feel the depth of the virtual object, therefore it will enhance the realism of conducting a real experiment.

The experiment is done by compiling and executing the stereoscopic Tower of Hanoi programming source code on the computer which had connected to stereoscopic display device. The user is able to solve the Tower of Hanoi manipulation task in virtual reality environment by using a clicking device (as an input device) that work together with the tracker and sensory device (as shown in Figure 12).

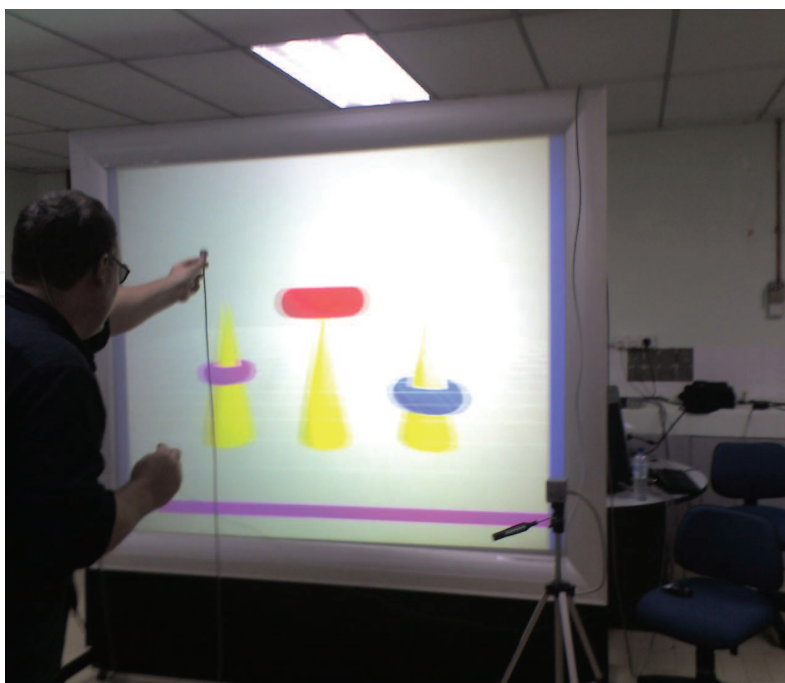


Fig. 12. Manipulating Tower of Hanoi in VR

5. Conclusion

From the results and analysis presented, there are a few conclusions which can be drawn according to experiments.

In general, simulation with real-time feedback is better than simulation without real-time feedback. With real-time feedback, the system can be used to train the user to conduct a proper technique or method, and at the same time avoid making any mistake which may cause errors to the system. For experiment of the effectiveness of visual feedback, it can be concluded that text feedback is better than the colour feedback since the colour feedback only tell the errors but the text feedback has give the description on errors instead of showing the user about the occurred errors only. Colour feedback only can use if the user already been told which colour represent which error message. However, the colour feedback can be used to notify a user on error quicker than the text feedback. Since both of colour and text feedback have their own advantages on errors notification to the user, the combined colour and text feedback will be the best real-time visual feedback among the application with colour feedback only and the application with text feedback only. For the experiments of the Effectiveness of real time auditory feedback, the results of these experiments showed that, the performance of the participants for solving the experiment tasks of Tower of Hanoi could be significantly improved when non-speech auditory feedback is provided throughout the task. It can also been observed that a decrease in error movement made by the participants in solving the task with auditory feedback than without feedback. Using sounds to provide system information is important for several reasons. First, by adding sound to the interface the bandwidth of communication can be significantly increased. Second, the information conveyed by sounds is complementary to that available visually.

6. Future Work

The study was developed to provide real-time visual feedback to the systems to tell the users about the error steps. Future works may include other real-time feedback techniques. Simulation on stereoscopic vision on real-time feedback may also be considered to study the stereoscopic effects on the time taken to complete the task.

7. Acknowledgements

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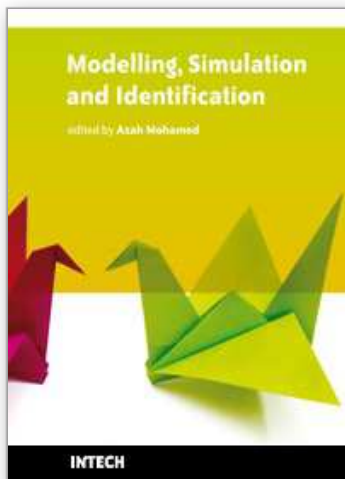
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Modeling, simulation and identification has been actively researched in solving practical engineering problems. This book presents the wide applications of modeling, simulation and identification in the fields of electrical engineering, mechanical engineering, civil engineering, computer science and information technology. The book consists of 17 chapters arranged in an order reflecting multidimensionality of applications related to power system, wireless communication, image and video processing, control systems, robotics, soil mechanics, road engineering, mechanical structures and workforce capacity planning. New techniques in signal processing, adaptive control, non-linear system identification, multi-agent simulation, eigenvalue analysis, risk assessment, modeling of dynamic systems, finite difference time domain modeling and visual feedback are also presented. We hope that readers will find the book useful and inspiring by examining the recent developments in the applications of modeling, simulation and identification.

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