Exploration Mixed Reality Environment for Teleoperation Interface: An Option to Provide Effective Information

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Abstract. Mixed reality creates opportunities to enable manipulation of information obtained from a remote location within a virtual environment. A gaming environment, such as Second Life (SL), has similar characteristics with teleoperation interfaces and allows the users to immerse themselves and achieve the flow. This experiment was designed to explore a game environment which provides combined information by enhancing video views within a virtual world. We also explored whether our subjects utilised the information provided by the 3D model as well as the video views. From the experiment we found that all our subjects paid attention to 3D model and video views in all experiment tasks. The result also showed that in a condition where the information provided by 3D model was the same as the video views, all subjects who paid dominant attention to 3D model were able to complete the task. Data questionnaire showed that almost three-quarter of our subjects perceived that they need very short to moderate time to get familiar with the interface. In conclusion, augmented video views within gaming environment can be used to provide information and all subjects paid their attention to both sources of information, even though most of them paid attention predominately to video views.

1 Introduction

The term of teleoperation or telerobotics is well known in some areas such as mining, industrial and others. Sheridan [1] defined teleoperation as a system built with artificial sensor and actuator which is used by the human operator to control a machine from a distance. Today, the technology of teleoperation is widely applied in order to increase human safety, comfort, and reduces the production cost. As a human machine interaction, teleoperation system is related with the communication between human and machine through the interface. One type of teleoperation interfaces which frequently applied to convey sufficient information to the operator is applying mixed reality environment.

Milgram [2] has defined mixed reality environment as a representation for showing real and virtual world objects which are presented together in a single screen. In mixed reality, there are two forms of environment which known as augmented virtuality and augmented reality. Augmented virtuality is defined as a subclass of mixed reality environment which enhances the virtual world with information from the real world [3], as opposed to augmented reality definition, which augments the real scene with artificial data. Augmented virtuality creates opportunities to enable manipulation of information obtained from a remote location within a virtual environment, and with enhanced information from the real scene, the provided information showed a vision similar with an operator vision onsite.

The numbers of research have been done to apply and improve this teleoperation technology for daily usage in mining and industrial or other areas [4-10]. However, there are number of problems still found and need to be improved [5, 7, 11]. One of problems implied from teleoperation with mixed reality interface, particularly in augmented virtuality, is the operators have a tendency to pay predominate attention to the video views rather than utilise information from the 3D model. It happens since most of the operator had been familiar with the real environment. Hence, it leads to a question "is the 3D model still useful in providing information for teleoperation interfaces?"

Based on the above question, an experiment was designed to explore a mixed reality interface, especially for augmented virtuality environment, to prove whether our subject utilised the information provided by 3D model as well as the video views. Moreover, on this experiment, we will utilised a gaming environment as a fundamental to build virtual environment and enhances information from the real environment (in this case, we augment two video views) to applied augmented virtuality concept.

Teleoperation and gaming environment have been seen as unrelated one another. However, we believe they share many similarities which have any possibilities in the future for them can be regarded as the same domain. By using gaming environment, we tried to explore the similarities and the differences between these environment that maybe useful for the development of advance teleoperation technology. A virtual game platform, such as Second Life (SL), provides required technology to build a teleoperation user interface. Moreover, as a gaming environment which designed to be easy to play, enjoyable and achieve flow [12-16], we believed it also can bring the operator get immerse with the teleoperation environment as well as they were on site location.

2 Previous Work

Exploration on virtual game SL was an experiment that we conduct to investigate a possibility of gaming environment for teleoperation interface. A Sophisticated circumstance to build a 3D model, ability to define the action/behaviour of the model, and communication as client server application were the reasons that interested us to explore this environment. As a previous research[17], we demonstrated a possibility of SL interface to communicate (send and receive data/information about target position on robot arm model) with the number custom built of external robot servers (Fig 1). As the result, this interface is possible to update and manipulate position on those custom built external server as teleoperation scenario. However, in real task teleoperation scenario, it is hard for virtual environment to cover some of dynamic information which caused some limitation by the operator to perform the task. Hence, an augmented video views inside virtual environment were used to complete information in this interface.

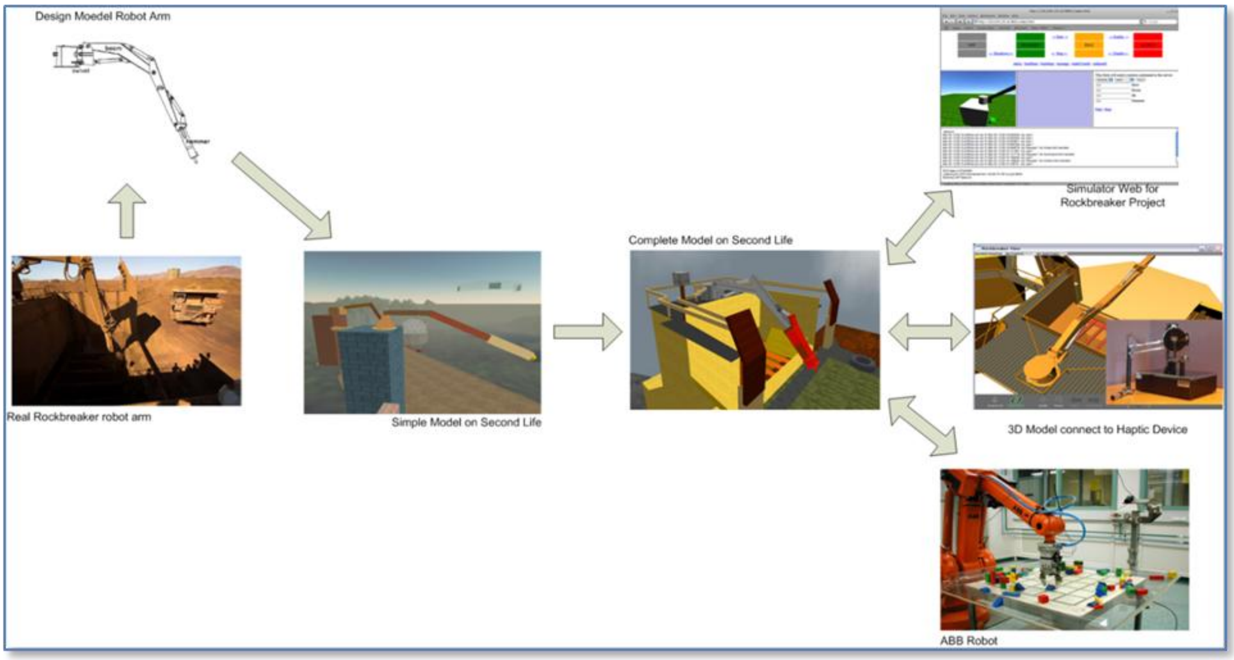

Fig. 1. Implementation designed SL interface with the number custom built of external robot server

3 User Study

3.1 Design

For the experimental design, we based our experiment on the commercial research performed by Duff et al. [5]. They introduced the development of shared autonomy in control systems and a mixed reality user interface of a telerobotic rock breaker. However, as we have limited access to the real operators and cannot interrupt mine production, we modelled the remote location using a small robot as a remote device and built a 3D model of the robot arm as a replica and synchronized the model position with the position of the real robot arm. We provided video views from two cameras in the remote location to show the position of the robot arm tip. The video views were overlaid as textures on the objects within the SL world. We added the pointer objects overlaying on each video view which corresponded to the position of the robot arm tip. In addition, to provide more information, we also created a shadow object of the robot arm as a desire predictive display of the robot movement. Fig 2 shows the design of our experimental, this scenario is designed to emulate as close as possible to the Duff et al.[5] teleoperation interface.

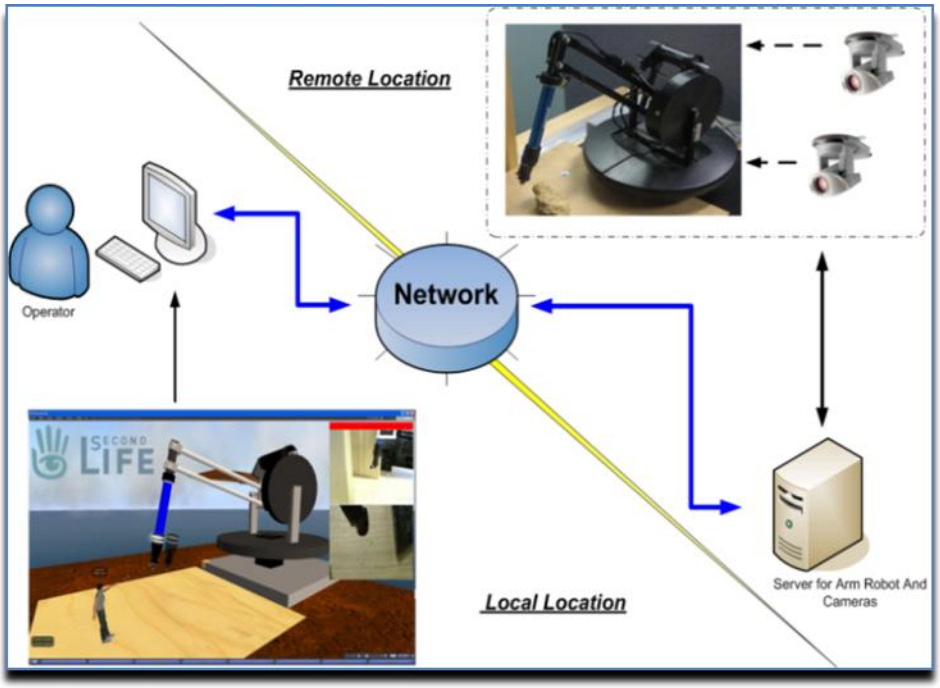

Fig. 2. Experimental Design

3.2 Subjects and Methods

Nineteen subjects were randomly selected to test Second Life as a mixed reality interface. All of them were coming from different background with various educational fields. In order to participate in this experiment, all subjects were required to be a regular computer user, have no previous experience with the experimental prototype and do not have any problem with colour blindness. The additional characteristics of the participants are described in the table I. In addition, we designed two different tasks and measured total completion time and total command sent to complete the task as objective measurements. We also provided self-administered questionnaire as a subjective measurement to assess the interface. We believed that, with all factors above, even though we did not test our interface by the real operators as a subject, it still gives reliable result.

Table 1. Characteristics of the Participants.

Characteristics	%
Gender	
Male	63.15
Female	36.85
Frequency in playing Computer Games (Habits)	
Often (> 1 hour/day)	47.37
Not Often (Occasionally & Never)	52.63
Experience with Second Life	
Yes	68.42
No	31.58

3.3 Apparatus and Implementation

As an interface, we ran the Second life viewer version 1.23 on a desktop PC (NVIDIA Quadro FX 1700 for VGA and 2814 MB in memory RAM). The display used was a standard 19” monitor with a resolution of 1280x1024 pixels.

In representing the remote location, we used a small robot arm viewed with two Canon cameras type VB-C50iR. One camera was installed 30 cm in front of the centre of the robot’s workspace and 25 cm above the work surface. The other was placed 10 cm to the right side of the centre of the robot’s workspace and 25 cm above the work surface. Both cameras point to the centre of the scene. The robot was controlled by a networked server. Moreover, we used a white board as an arena for position manipulation with 16 pictures of stars in four different colours (red, yellow, black, green) representing target positions. Each star of the same colour was placed 10 cm apart.

The interface built in SL (shown in Fig 3) had a 3D model of the robot arm, modelled the arena, and had two remote camera video displays.

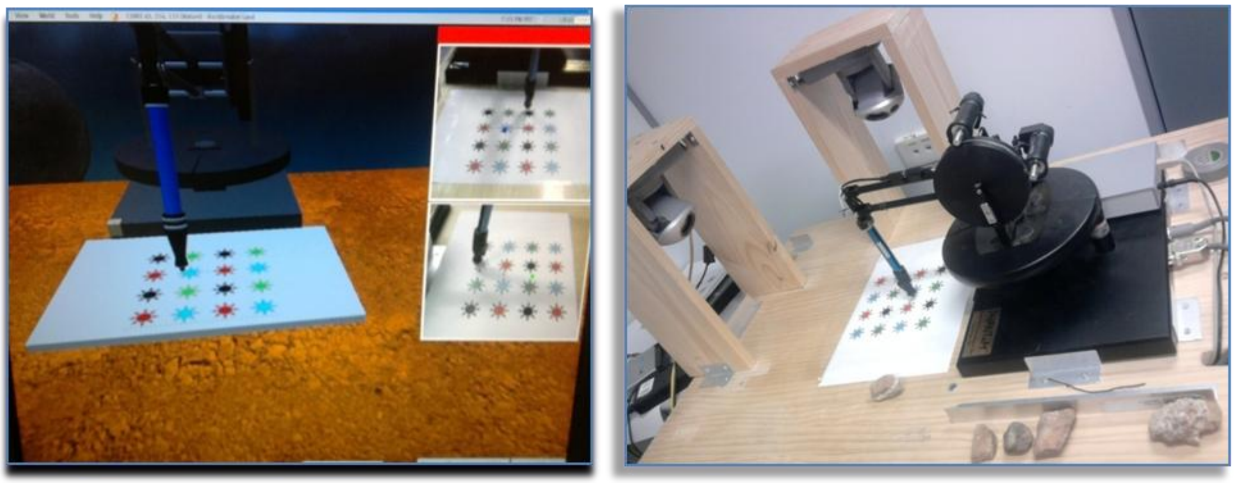

Fig. 3. Teleoperation User Interface using Second Life Interface and Remote Location

3.4 Experimental Design and Procedure

The subjects specified target locations to which the robot attempted to move then the robot returned its last position for display in the interface. During the process, the operator also receives information from the remote environment via video streaming.

Two tasks were undertaken for this experiment. First, the task is to move the robot arm, touching a star of one colour to other star of same colour. To complete the task, we asked the subject to do the task four times in both clockwise and counter-clockwise direction within 2 minutes for each direction (total 8 targets). This task was designed to present all the information required to undertake the task in the virtual environment and the subjects received the same information regarding the arm and target positions in both the 3D model and streamed video. While for the second task, we asked the subject to push a rock continuously to four different target positions. Each target position must be reached within two minutes. For this task the subjects received information regarding the arm and target positions in both the 3D model and streamed video while the rock position was provided by video views only.

The maximum time on each task was set based on the pre-trial experiment. Prior to the experiment, subjects were given a short verbal introduction including a brief description of the interfaces, instruction on how to use the interfaces, and the task scenarios. At the end of the introduction session, all subjects were required to confirm their understanding of the information conveyed. The subjects then practiced the tasks for up to five minutes.

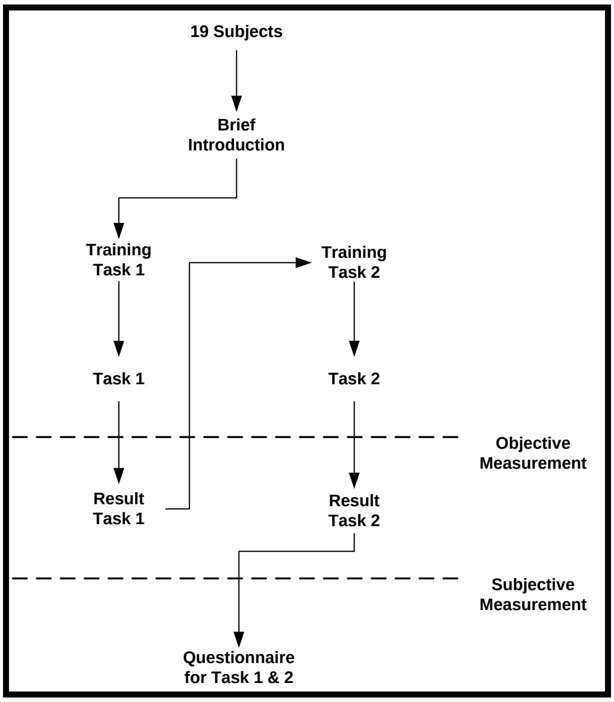

Fig. 4. Scenario experiment

3.5 Analysis

The study was designed as a descriptive study with objective and subjective measurement as outcomes variables. For the objective assessment we measured the total number of commands sent and the time taken to reach each target position. While for the subjective assessment, a questionnaire with Likert scale, ranging from 1 to 5, was used to determine subjective time needed to get familiar with the interface, level of attention paid to the 3D model and video views, self assessed level of difficulty and subjects' perception of the interface performance.

This experiment was not designed to specifically address time delay or the latency problem for teleoperation interfaces. However, based on Domaingues et al. [18], many researcher have used Mixed Reality environment to solve time delay problems by using predictive display concept. Moreover, similar argument also came from Fong et al. [6]. He stated that "Supervisory control interfaces are well-suited for application which must operate with low-bandwidth communication links or the presence of high delay". Hence, this experiment was designed by using mixed reality environment and supervisory control concept to present information and assistance in minimising the effect of time delay problem.

4 Result

Based on the data from the subjective measurement, we grouped our subjects who completed the task into three groups, (1) subjects who paid dominant attention to the 3D model, (2) those who paid dominant attention to the video views and (3) those who paid equal attention between 3D model and video views. During the experiment, we found that all of our subjects paid attention either to 3D model or video views in both tasks, even though most of subjects paid more attention to video views, especially in second task where the rock's information only provided from video views.

Table 2 showed that in the first task, our subjects could reached 6 to 8 targets within the required time limit with the average of 7.63 (SD 0.69) targets. Furthermore, the data showed that there were 14 of our total subjects (73.7%) could complete the first task within the required time (reaching 8 targets). Among those subjects who succeed to complete the task, 57.14% subject paid dominant attention to video, 7.14% subject paid equal attention between both 3D model and video views and 35.72% subjects paid dominant attention to model. The data also showed that in a condition where information provided by 3D model was the same as the video views, 100% of our subjects who paid dominant attention to 3D model were able to complete the task, and only 72.7 % subjects paid dominant attention to video.

Table 2. Success rate and proportion attention of source information (3D model and video views) in Task 1.

Total target reached	Total subjects	Dominant attention (N(%))		
	N (%)	model	equal	video
6	2 (10.53)	0	1 (33.33)	1 (9.09)
7	3 (15.79)	0	1 (33.33)	2 (18.18)
8 (complete)	14 (73.68)	5 (100)	1 (33.33)	8 (72.73)
Total (N(%))	19 (100)	5 (100)	3 (100)	11 (100)

While for the second task (see Table 3), the subjects were required to push the rock into 4 different targets as task completion. The average for total targets reached was 3.16 (SD 1.01) targets. We also found that there was one subject could not reach any target until maximum time provided. The average of success rate for this task was much lower than the first task (42.11%). Moreover, among those subjects who succeed to complete the second task, 75% paid dominant attention to video, 25% equal attention to 3D model and video views, and no one paid dominant attention to 3D model.

Table 3. Success rate and proportion attention of source information (3D model and video views) in Task 2.

Total target reached	Total subjects	Dominant attention (N(%))		
	N (%)	model	equal	video
0	1 (5.26)	0	1 (16.67)	0
2	2 (10.53)	0	1 (16.67)	1 (8.33)
3	8 (42.11)	1 (100)	2 (33.33)	5 (41.67)
4(complete)	8 (42.11)	0	2 (33.33)	6 (50.00)
Total (N(%))	19 (100)	1 (100)	6 (100)	12 (100)

Fig 5 described the task completion time for subjects who have dominant attention to 3D model, video or equal attention in first and second task. For the first task, the data showed that the subject who paid dominant attention to the 3D model and video views had similar task completion time with only 2.5 seconds differences. While in second task the different was 21.3 seconds between subject who paid dominant to video and those who paid equal attention. Unfortunately, we cannot provided the mean of subject who paid equal attention in first task and subject who paid dominant attention to the 3D model in task two, since we only have one subject who paid equal attention and none of subject with dominant attention to 3D model.

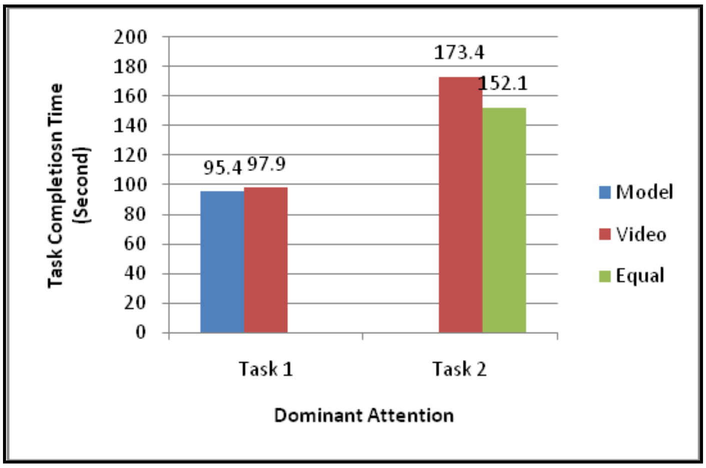

Fig. 5. Bar chart of average task completion time for series level of attention to 3D model and video views.

We also compared total command sent for subject who paid dominant attention to 3D model, to video, and equal attention in first and second task (see Fig 6.)

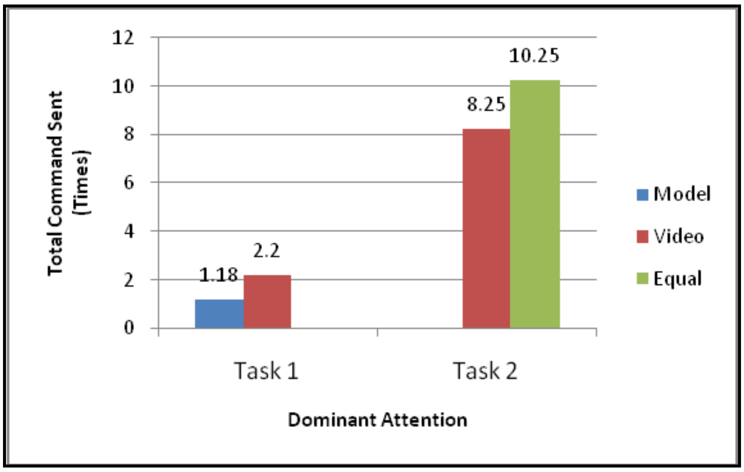

Fig. 6. Bar chart of average command sent for series level of attention to 3D model and video views.

While for the subjective measurement, data from the questionnaire showed that 73.7% of our subjects perceived that they need very short to moderate time to get familiar with the interface. Furthermore with a score ranging from 1 to 5 (lowest to highest) in Likert scale, the mean score for SL performance and ease of use assessed by our subjects were 3.36 (SD 1.12) and 3.21 (SD 1.03).

5 Conclusion

Even though most of them paid attention predominately to video views, all of our subjects paid their attention to both sources of information. However, dominant attention to 3D model seems to be able to help them in completing the task when similar information provided by both 3D model and video. We suggest that even though our subjects have been familiar with the interface (e.g. how to control the robot arm), most of our subjects were not able to complete the second task due to the incomplete information provided by 3D model, in addition to the task difficulty.

Our experiment showed that utilising gaming environment by applying mixed reality concept applied has worked well and able to help the operator to perform the tasks. It was shown by the total number of subject that can complete the task within required time, especially for first task scenario when the required information was provided by all source of information. Rather than negatively impact to subject divided attention, multiple source of information, in this case video views and 3D model, work in synergic to providing information to the subjects and able to help them in performing their tasks. Unfortunately, due to the inadequate number of subjects who paid equal attention between 3D model and video views, we were unable to find out whether paying equal attention to both source of information will lead to a better outcome than paying predominant attention to one source of information. Moreover, our developed interface is considered to be user friendly and has a good performance.

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