A Visualization Method of Working Activities in a Mixed Reality Space for Supporting Work Analysis

Kazuhiro MIYASA* Yuichi BANNAI** Akihiro MIYATA*
Hiroshi SHIGENO* Ken-ichi OKADA*

* Department of Information and Computer Science, Faculty of Science and Technology, Keio University, Japan
{miyasa, akihiro, shigeno, okada} @mos.ics.keio.ac.jp

** MR Systems Laboratory, Canon Inc.
bannai.yuichi@canon.co.jp

Abstract

Mixed Reality (MR) technology, which merges virtual objects into the real world, enables to simulate several work. Though it is possible to get the video from a camera attached to the HMD that the user is wearing, it is not sufficient enough to analyze the work. We propose a new method to analyze the work in a mixed reality space by visualizing information about the worker and virtual objects connected with the video. We have implemented a work analysis support system called MR Quick Analyzer, and we evaluated the effectiveness of the system.

1 Introduction

MR technology, which overlays electronic data such as text or CG data on our real space, is currently applied in various fields such as industry [1][2], entertainment [3], and medical-care [4]. We focus on supporting work using MR in the industry field. In this field we can simulate various work by interacting with virtual objects in a MR space.

We assume that after recording the simulation of work in a MR space we review and analyze the work process from the record.

The conventional methods to analyze the work were based on the video. However, it is difficult to find the necessary scene in the video because the video itself has no indices. Moreover, the video has not enough viewpoints to analyze the work environment spatially because it is 2D pictures from a fixed viewpoint.

In this study, we propose MR Quick Analyzer to support the work analysis in the MR space from a work record. MR Quick Analyzer provides not only the video viewer from a worker's camera but also a 3D viewer of the workshop to solve above problems.

We describe a background and problems of the conventional methods of work analysis in Chapter 2, design of MR Quick Analyzer in Chapter 3, implementation of it in Chapter 4, an experiment to evaluate our proposal in Chapter 5, and a conclusion of this study and the future work in Chapter 6.

2 Background and Problems

In this chapter we explain the background in this study and problems of conventional work analysis.

2.1 Simulation of Work in Mixed Reality

When we design a workshop and a process, it takes long time and high cost to build the workshop or is dangerous to carry out the work process for some kinds of work. MR technology enables to simulate the work design without making real workshops. For example, in layout planning, we can simulate the layout plan while changing virtual objects in the real space.

In our system, the worker wearing a video see through HMD (Head Mounted Display) shown in Figure 1 manipulates virtual objects in a MR space. In a work design simulation of parts assembly task, we can make a MR workshop using virtual parts shelves so that we decide the most suitable shelf layout with changing location of the virtual shelves. It is the greatest advantage of MR that a worker can simulate by his motion in the real space, which is different from VR (Virtual Reality).

2.2 Problems of Current Work Analysis

It is assumed that we review and analyze the work after recording working activities in a MR space. We make use of the recorded data in order to improve the design of the workshop and the work process. It is very common to use video for the work analysis [5].

However, a method using only video is not sufficient to get useful information due to the following points.

- Video has no indices to find a necessary scene, because it is only time sequential information. As a result, it is time-consuming task to find a particular

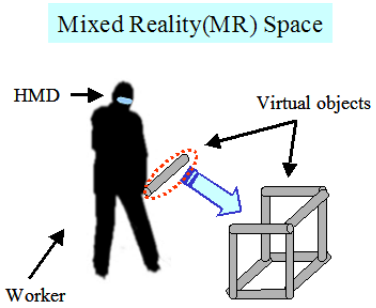

Figure 1: Interaction with virtual objects in Mixed Reality

scene from the video without indices. This problem is an obstacle to achieve efficient work analysis.

- It is difficult to get position and distance information of objects directly from the video, because the video does not contain 3D information. Moreover, as the video is captured from a fixed video camera, it is impossible to look at the workshop from arbitrary view points. Consequently, we cannot aquire the sufficient information of collocation of objects and the worker in a 3D space.

3 Design of MR Quick Analyzer

In this chapter, we describe the design of MR Quick Analyzer which visualizes the working activities in a MR space with two visualization functions.

3.1 Proposition

We think the scene where a worker manipulates virtual objects in a MR space can be a good index to understand the work process. In addition, the 3D information of objects and the worker is important when we analyze the work process spatially.

In this paper, we suggest a visualization method of working activities in a MR space for supporting work analysis. As the work process is recorded in our system, it is possible to acquire not only the video image from a camera attached to the worker's HMD (HMD camera) but also the manipulation information including the 3D positions of worker and objects when the worker was manipulating a particular virtual object. Note that the video image acquired by the HMD camera completely corresponds to the viewpoint picture of the worker due to the video see-through mechanism. Therefore, we can look at the recorded scene from the worker's viewpoint.

By connecting the video images with manipulation information and visualizing these data, we developed so called MR Quick Analyzer to help supporting a work analysis.

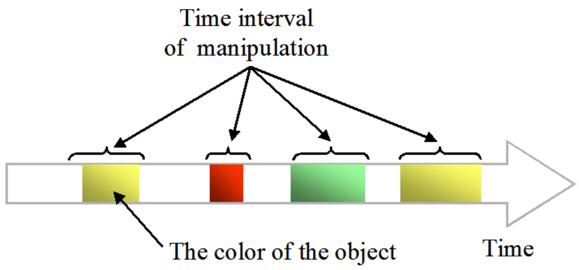

Figure 2: Object Manipulation Index

3.2 Visualization of Working Activities in Mixed Reality

We have developed two visualization functions of working activities: one is creating an index by manipulation information of virtual objects; the other is constructing a 3D graphical view by 3D information of the worker and the virtual objects.

3.2.1 Visualization of Object Manipulation

Figure 2 shows the index so called Object Manipulation Index. The information when and which object the worker had been grabbing is mapped as manipulation information on the index. The colored area on the index shows the time interval in which the worker has been grabbing the object. We can review the desire video scene by synchronizing this index with the video movie.

This visualization method requires less space than the method using letters or numeric characters. The reviewer can understand the worker's operation at a glance by the color information.

3.2.2 Visualization of 3D Information

We constructed a 3D graphical view of the workshop including the virtual objects and the worker. It is assumed that the positions of the worker(eye position, its orientation, and hand position) are detected by sensors in a MR space. The reviewer of working activities can look at the workshop from various viewpoints besides the worker's viewpoints as shown in Figure 3. The 3D graphical viewer has the capability of displaying symbols of the working history (the sequence of the positions described above) and synchronizing them with the video movie. This function allows the reviewer to access the desired video scene by clicking the corresponding symbol of the 3D graphical viewer.

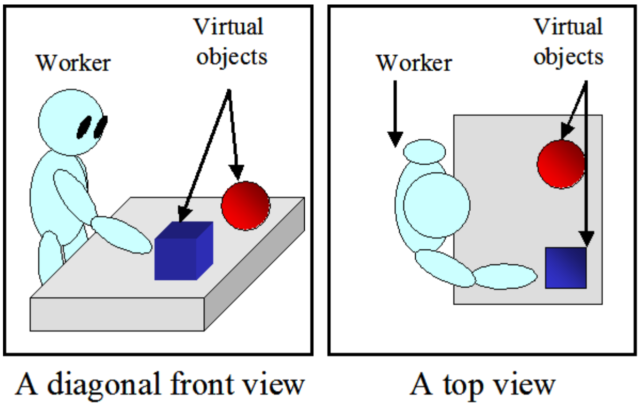

Figure 3: Examples of 3D graphical view

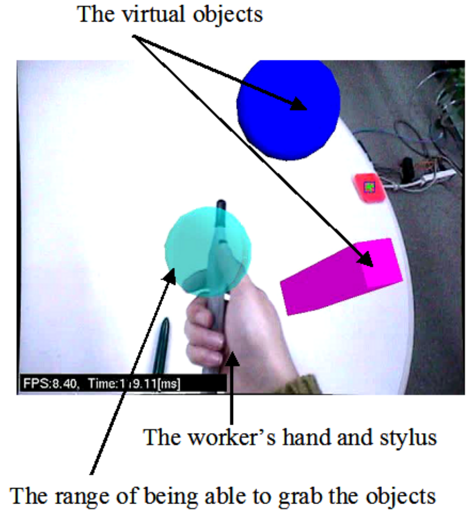

Figure 4: Video from the HMD camera

4 Implementation

In this chapter, we describe the implementation of MR Quick Analyzer, including the system configuration, the method of recording working activities, and the user interface to review this recorded information.

4.1 System Configuration

We used MR Platform [6] System developed by Canon to build a workshop in a MR space. The Canon's video see-through HMD has two cameras that acquire a pair of stereo images from user's exact viewpoint without parallax. A magnetic sensor receiver of Polhemus that detects 6DOF position/orientation information is attached on the HMD. A stylus with a magnetic sensor receiver with which the worker manipulates virtual objects is also equipped in the MR Platform System. The registration of virtual objects to the real space is done by the hybrid method of the magnetic sensor and markers.

The video movie from the HMD camera for the worker's left eye and the positions of the HMD and the stylus are recorded at the same time.

When the button of the stylus is pressed by the worker, the distance between the stylus and the virtual object is calculated. If the distance is less than the predefined range, the virtual object can be grasped. Then the worker can move the object while pressing the button, and put it at the stylus position when he releases the button.

As it is assumed that the worker grasps only one object at a time, if more than one objects are within the range the nearest one from the stylus is selected. The range where virtual objects can be grasped is shown as a transparent blue sphere in Figure 4. The radius of the sphere is 5 cm.

4.2 Recording

When MR Quick Analyzer captures a video image from the worker's view, it also acquires information of the object at the same time. The object color and the current time are recorded with a captured video image if the object is grasped at the time. The distance information is also recorded simultaneously after calculating it from both positions of the stylus and the grasped object.

Regarding 3D information, the system records 6DOF data of the worker's head and all virtual objects at the moment of capturing a video image. Not only 6DOF data of the worker's head (HMD) but also that of the worker's hand (stylus) are significant, because these data determine the worker's position and reflect worker's activity greatly. Both data are acquired from the receivers of magnetic sensors equipped in the HMD and the stylus.

4.3 Interface for Work Analysis

We implemented a GUI of MR Quick Analyzer for reviewing and analyzing work activities in a MR space. The GUI consists of 2 interfaces: one is an object manipulation indicator, and the other is a 3D information indicator.

4.3.1 Object Manipulation Indicator

An interface of the object manipulation indicator shown in Figure 5 consists of two parts: the upper is the video movie player panel where the movie from worker's view is played; the lower is Object Manipulation Index described in 3.2.1.

We created this index corresponding to the video movie sequence captured by the HMD camera. The

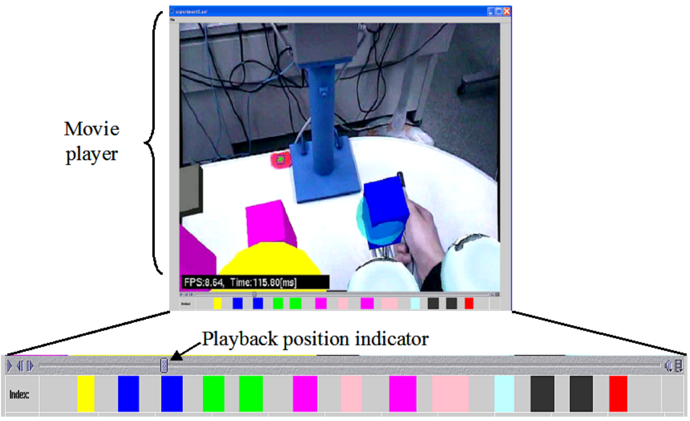

Figure 5: Interface of object manipulation indicator

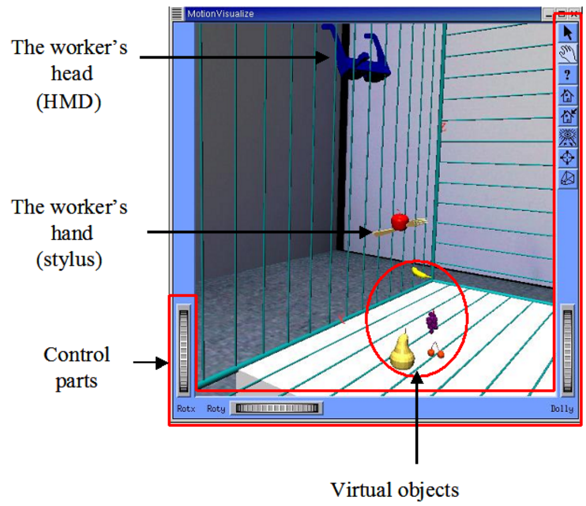

Figure 6: 3D graphical viewer

playback position indicator under the index goes from left to right as the video movie plays back. The reviewer of working activities can quickly access the manipulation scene of virtual objects by sliding the playback position indicator along Object Manipulation Index.

4.3.2 3D Information Indicator

3D information indicator consists of a 3D graphical viewer of a workshop and control parts of the viewer around it as Figure 6. The 3D graphical viewer shows a current position of the worker (HMD and stylus) and objects, and provides zooming in/out and changing viewpoint functions activated by a scroll bar in the control parts and so on.

Figure 7 shows that the video movie player and the 3D

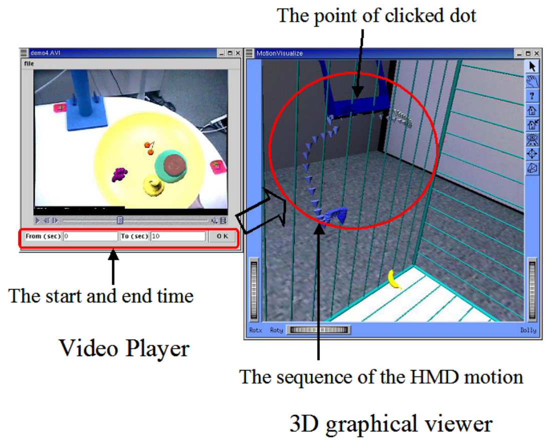

Figure 7: The video movie player and 3D graphical viewer

graphical viewer are synchronized in a playback mode so that the CG data of HMD, the stylus, and the virtual objects in the 3D graphical viewer move along the sequence of working activities as the video movie plays back. And by setting the start and end time shown as the lower left of Figure 7, the history of HMD positions presented by the sequence of dots corresponding to the time interval. These functions enable the reviewer not only to check the worker's 3D position at certain video scene, but also to catch the corresponding video scene by clicking the specified dot of HMD history in the 3D graphical viewer.

5 Evaluation

The purpose of the experiment is to confirm how useful Object Manipulation Index is in order to understand the process of virtual parts assembly tasks.

In this chapter, we explain the details of experiment and describe the results and consideration of it.

5.1 Experiment Design

Before the experiment, a worker practiced an assembly task using virtual parts in a MR space. Figure 8 shows the illustration of the task. The task for the worker is to select a virtual part at a time from a pile of parts that are arranged at regular intervals on a desk, and to connect it to the assembled parts except the first one.

The conditions of the assembly task are as follows. There are 8 types of virtual parts, and the total number of the assembled parts is 15. The worker did two different tasks, and the video movie from his left HMD camera is recorded for each task. The duration of each movie is 2 minutes.

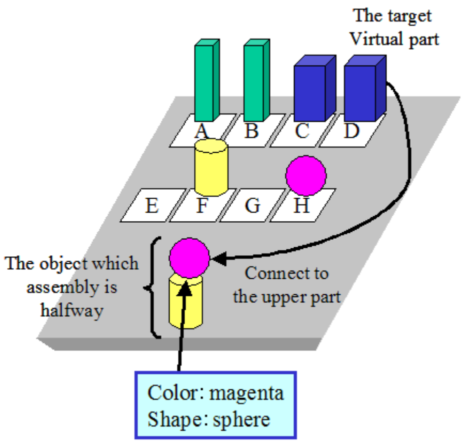

Figure 8: The illustration of the assembly work

5.1.1 Task for Participants

Participants consisting of 24 students are expected to answer the questions about the assembly process in a limited time (4 minutes) while watching the video movie which is recorded beforehand. The question is to answer the initial position of one virtual part and color/shape of another virtual part to which the worker connected it. The participants repeat the answer for each part in order of the assembly. The details are the following.

- Initial position
  A participant is expected to answer the initial position (one of the fifteen positions from 'A' to 'O') of the virtual part which is being manipulated in the video from the table containing positions of the virtual parts.
- Color and shape of the object
  When the worker in the video connected a virtual part to another virtual part, a participant is required to answer the color and the shape of the object to which the worker connected. For example, as shown in Fig 8 when the worker connected the blue box of which initial position was 'D' to the magenta sphere located on the upper part of object, the participant should answer "magenta" and "sphere".

We can confirm by imposing the task how well the participants understand the assembly process; i.e. from which location the worker picked up the part and to which part he connected? We used the correct answer rate for these questions as a quantitative measure how precisely the participants understand the work process.

5.1.2 Comparison

We made a comparison between the two cases: one is the case where the participants use the playback position indicator and Object Manipulation Index while watching one of 2 video movies; the other is the case in which they slide the playback position indicator without the index to get the desired scene while watching the other video movie. We assume that the comparison of the result leads to the effectiveness of Object Manipulation Index.

Table 1: The result of the experiment

	With Object Manipulation Index	Without Index
Rate of blanks in the answer sheet	0.138	0.251
Rate of correct answers	0.796	0.657

(All values are average, N = 24)

5.2 Results and Consideration

The upper row of Table 1 shows the average rate of blanks in the answer sheet in two cases. The value of the case of answering the questions without Object Manipulation Index is 1.8 times as high as the case with the index. From the observation of participants and the result during the experiment, it becomes clear that no blanks were in the part participants finished answering in the time limit but all blanks existed in the part they could not answer due to a shortage of time.

We can confirm that it was possible to answer more questions using the index than not using it. In other words, using both video and Object Maninpulation Index reduces the time of checking the work process.

The lower row of Table 1 shows the average rate of correct answers in two cases. The average rate was higher in the case using Object Manipulation Index than in the case without the index. We found the significant difference between the two cases by examining t value with rejection rate of 0.01.

$t(24) = 2.802$ $(p < 0.01)$

The result shows that we can understand the work process more precisely and efficiently by using both video and Object Manipulation Index than by using only the video.

Putting together the consideration of the rates of blanks and correct answers mentioned above, it turns out that it becomes possible to understand the work process more precisely and quickly with Object Manipulation Index.

Consequently, visualization of manipulating virtual objects can be a significant means for understanding work process.

6 Conclusion

In this paper, we proposed a visualization method of working activities in a MR space for supporting a work analysis. As our MR Platform System allows us to acquire not only a video from the worker's viewpoint but also 3D information of virtual objects and the worker, we introduced Object Manipulation Index which represents the types of objects and the time interval in which the worker is grabbing the object and the 3D graphical viewer which shows positions of the worker and the objects. Then we developed MR Quick Analyzer consisting of the video player, Object Manipulation Index, and the 3D graphical viewer, with synchronized playback function. The experimental results showed that Object Manipulation Index helped reviewers to understand the work efficiently.

Another experimental task should be conducted to investigate the effectiveness of the 3D graphical viewer for work analysis. We plan further experiments to evaluate MR Quick Analyzer for various tasks.

References

[1] Anthony Webster, Steven Feiner, Blair MacIntyre,William Massie, Theodore Krueger: "Augmented Reality in Architectural Construction, Inspection, and Renovation", Proc. ASCE Computing in C.E., pp.913-919, 1996.

[2] Yuichi Bannai, Hiroyuki Yamamoto: "Mixed Reality Systems for Supporting Spatial Work" IPSJ SIG Technical Report GN-49-4, pp19-24, 2003.

[3] Toshikazu Ohshima, Kiyohide Satoh, Hiroyuki Yamamoto, Hideyuki Tamura: "RV-Border Guards:A Multi-player Mixed Reality Entertainment" Transactions on VRSJ Vol.4, No.4, pp.699-706, 1999.

[4] Hongen Liao, Susumu Nakajima, Makoto Iwahara, Etsuko Kobayashi, Ichiro Sakuma, Naoki Yahagi, Takeyoshi Dohi: "Development of Real-Time 3D Navigation System for Intra-operative Information by Integral Videography", J.JSCAS Volume2, pp.245-252, Number 4, 2000.

[5] Takao Suguro: "IT tool in Management Engineering" 50th Anniversary Volume of IPEJ, pp.84-87, 2001.

[6] S. Uchiyama, K. Takemoto, K. Satoh, H. Yamamoto, and H. Tamura: "MR Platform: A basic body on which mixed reality applications are built," Proc. IEEE and ACM Int. Symposium on Mixed and Augmented Reality (ISMAR 2002), pp.246-253, 2002.