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To cite this version :

Bo LI, Hongyi ZHANG, Ruding LOU - Study of efficiency of multi view system in multi-disciplinary collaboration task - Research and Science Today n°supplement 2, p.92-100 - 2017

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Engineering

STUDY OF EFFICIENCY OF MULTI VIEW SYSTEM IN MULTI-DISCIPLINARY COLLABORATION TASK

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ABSTRACT:
IN THIS PAPER, WE AT FIRST INTRODUCE THE CONTEXT OF MULTI-DISCIPLINARY COLLABORATION AND THE USAGE OF MULTIPLE COMPUTER-HUMAN INTERFACES (CHIS) WITH DOMAIN SPECIFIED SOFTWARE. THEN WE PROPOSE THE CO-LOCATED MULTI-VIEW SYSTEM WITH THE TECHNOLOGY OF MULTI-REPRESENTATION, MULTI INTERACTION AND VIRTUAL REALITY. A STUDY IS INVESTIGATED TO EVALUATE THE CONTRIBUTION TO THE PROPOSED MULTI-VIEW SYSTEM IN COMPARING WITH THE TRADITIONAL MONO-VIEW SYSTEM DURING A MULTI-DISCIPLINARY COLLABORATIVE TASK. A MULTI-ROLE COLLABORATIVE APPLICATION IS DEVELOPED TO TEST THE CO-LOCATED COLLABORATION WITH MULTIPLE REPRESENTATIONS IN VIRTUAL REALITY ENVIRONMENT. THIS COLLABORATIVE APPLICATION CONSISTS OF A COLLABORATIVE TASK WHICH SIMULATES INDUSTRIAL PROJECT REVIEW USING MULTI-REPRESENTATION DIGITAL MOCK-UP (DMU). THE EXPERIMENT IS CONDUCTED WITH TWO PERSONS UNDER TWO DIFFERENT COLLABORATIVE CHI'S CONDITIONS: TWO MONO-VIEW SYSTEMS AND SINGLE MULTI-VIEW SYSTEM. THE DIFFERENCE IN TERM OF VERBAL COMMUNICATION, CONTRIBUTION AND EFFICIENCY OF COLLABORATION DURING THE MULTI-DISCIPLINARY COLLABORATIVE TASK IS ANALYZED TO COMPARE THE TWO CONDITIONS.

KEY WORDS: COLLABORATION WORK, MULTI-VIEW SYSTEM, VIRTUAL REALITY

1. INTRODUCTION

Nowadays, more industries are adopting the new strategy of product development, the Concurrent Engineering (CE), to replace the traditional Sequential Engineering (SE). This new design management system asks people to take into consideration in the early design phase all the information on a product's lifecycle, such as production, assembly message, maintenance[4]. Furthermore, CE allows people to conduct all production activities in a parallel manner and to integrate technical data for sharing among different experts. These two concepts make sure that all errors and redesigns could be realized and resolved in the early

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design process to avoid the economic and time loss[5]. Because of CE's collaborative nature, there must be much more communication with various domains of expertise in the whole product lifecycle. It means individual experts must work together in an interactive way in the different phases of product life cycle. That is why we need real-time and co-located collaboration.

In practical operations, experts on different specialties need to have their proper representations of the product to make their own designs. Each expert must use a domain-specific tools or software to produce various data. These data can be shared and sent into a global database. The organizing and planning process of this package of data is usually called Digital mock-up (DMU) of the product lifecycle[6]. In collaborative design activities, these DMUs should be shared among the different sorts of domain-specific software and among the experts' communication. DMU can offer to expert multiple representations with different technical data or in different forms. Each expert has their own perspective. For the same model in 3D, DMU allows that different information could be provided to different users at the same time.

All the product activities need both software and human beings. CE asks not only the more closely communications with human beings, but also the better interface between human and machine or human and design tools. Computer-human interface (CHI) is described as the communication medium between people and computers[7]. It is a link between human and machine. Because the tools used are different, users may have different kind of CHI to use. If engineers need collaborative work, the interoperability of different CHIs is important. Users can interact with a good CHI by using multiple metaphors and achieve to more than one command by one metaphor[8]. In this case, different expert should have their own specified metaphor according to their specified needs. As described on the left of Figure 1, users interacted with different software and different data formats; right of the figure allows users to interact with each other by one single CHI with one file format that could reduce the misunderstanding and save the communicating time among experts.

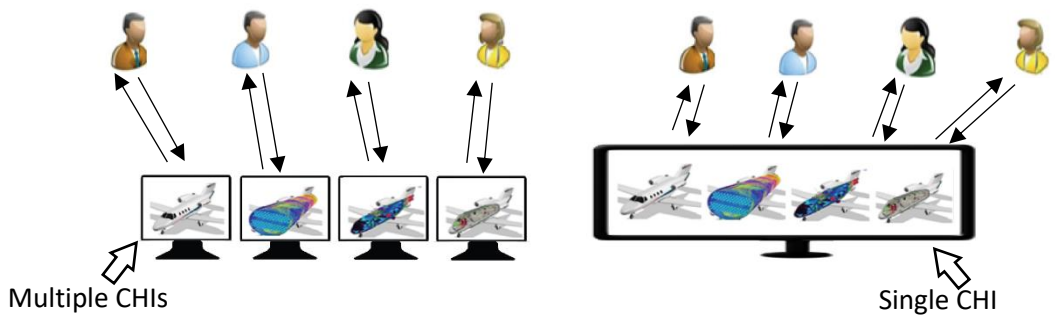

Figure 1: Left: multiple CHIs; Right: One single CHI replaces several CHIs may let the collaborative work between multiple users more efficiently[9].

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To support collaborative work using DMU, CHI must have function to support multiple representations of virtual content and multi-user interaction. Virtual reality is a kind of support technology which allows the collaborative work by DMU become more intuitive. For example, in tradition CAD work, there are usually some problems in conceptual design in architecture: the shape and resolution of the typical workstation screen will affect designers' judgement about geometric structure. However, by using virtual reality technology, designers do not have a "screen" anymore. They are being placed in an environment which may be more suitable to watch and create the geometry form. As this support technology, our multi-view CHI technology can help users to work with each other in 3D virtual environment co-located and concurrently[10].

2. RELATED WORK

For a collaborative work in a virtual environment where each collaborator has a specific role, a proper representation of the virtual world for each user is significant. Each user must have the own point of view so that they could inspect the virtual world from different angles and positions. Snowdon proposed the framework of individual perspective in virtual environment: What You See is Not What I See (WYSNWIS)[11]. Each user has view-independent representations of the virtual environment. However, the awareness of other people's activities is necessary in collaboration too. The other framework: What You See is What I See (WYSWIS) is proposed for changing the perspective of users. Users can choose the point of view and switch the perspectives between egocentric (first person) and exocentric (third person). Further research by Huahai.Y and Gray.M shows that egocentric is better for co-operation than third person[12].

There are several kinds of technologies for multi-view visualization. The glasses with stereoscopy technology could present two images separately to left and right eye of the viewer. Based on this technology, many technologies of multi-view systems have been developed. Nagono et al[13] proposed the new polarized glasses: One user wears the glasses with two left lenses of original glasses; the other one's glasses have two right lenses of original glasses. Therefore, two users could have the representation independent in 2D.

Mistry[14] made the other technology, called ThirdEye for getting a different point of view. Each eyeglass of shutter glasses is made by a single pixel LCD screen. The LCD screen could be transparent or opaque if we change the voltage on it. ThirdEye switches the state of LCD of two users alternatively at a high frequency (at least 120Hz). The displayed content on the screen is synchronized with glasses. When the first user's LCD is transparent and the second user's LCD is opaque, the screen presents content correspondingly of first user and vice versa. With this technology, it is possible to generate more than two points of view if we increase the frequency of LCD and screen. Roman et al[15] contributed a multi-view tabletop, called Permulin which supports both co-located collaboration work and individual work.

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They proved that in co-located collaboration work, multi-view technology could provide better interaction than traditional tabletop.

3. PROPOSITION OF MULTI-VIEW SYSTEM FOR COLLABORATION

Our multi-view can provide two independent 3D points of view of the two users. The interaction and visualization technique is used to share information about two views on coordination. By using this system, users can work collaboratively and interactively with each other using domain-specific representations of DMU. The implementation of the system utilizes High Brightness digital video projectors. Each projector is controlled by a computer and can provide an individual 3D representation due to its refresh rate of 120Hz. Meanwhile, the user wears the shutter glasses with LCD eye lens which is synchronized with the projector by the radio frequency 3D emitter. The light emitted by the two projectors will be separated by a polarized filter for getting certain polarized light. Therefore, with the matched polarized filters on shutter glasses, users will only see the image issued by the projector that corresponds to them. Users' movements are represented by one of the glasses. The glasses' movements are captured by the tracking system and send to the computers. After that, the two computers process the data and generate the image corresponding to the user's position (Figure2).

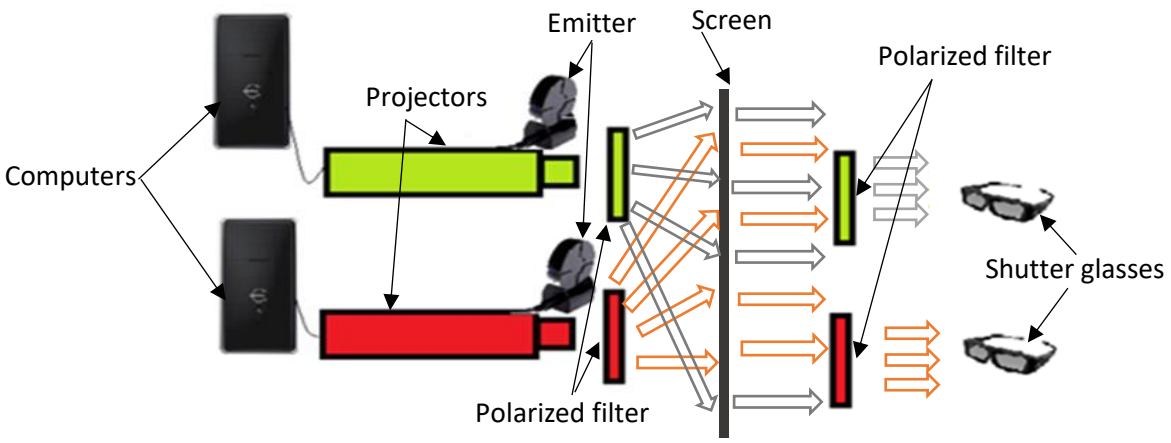

Figure 2: each shutter glasses can only be synchronized with the emitter and receive the light from the 3D projector correspond with it. So that users could have individual representations.

4. EXPERIMENT

The experimental study is designed to explore the advantage of collaborative work in the virtual environment by using the multi-view system we introduced earlier. To simulate the collaborative work during industrial design and optimization work using DMU, a game is designed through three characteristics: First, the collaboration task must be completed by collaboration work of both of the two users. Second, this collaboration task must be co-located and be conducted in real time working condition. Third, each user in collaboration task must have independent perspective.

4.1 Description of the game

We proposed a collaborative game for two participants with two different roles: "player" and "helper". They must work together for going through a labyrinth.

Player role: The player's objective is to move in the labyrinth and to find the exit. The player can see and collect golden coins. At meanwhile the player should avoid the bombs that are not visible to him/her (Figure 3).

Helper role: The helper oversees guiding the player to find the exit of the Labyrinth and to avoid the bombs. At an intersection of the labyrinth, the helper can identify the correct way to take due to its highlighted appearance. In addition the helper can also see the bombs that are not visible to the player. In summary, the helper should tell the player which way to take and where is the bomb (Figure 3).

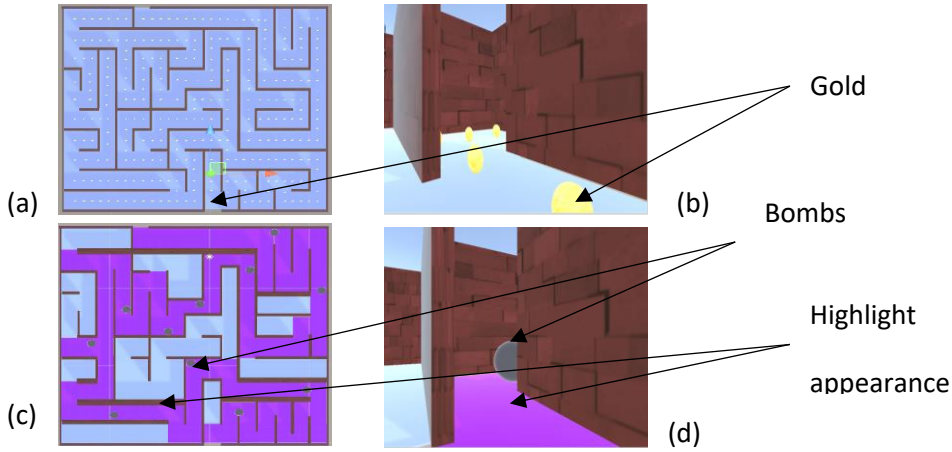

Figure 3: The player's top view of the labyrinth is shown in (a). The player's perspective is shown in (b); the helper's top view of the labyrinth is shown in (c). The helper's perspective is shown in (d).

4.2 Visualization conditions

This experiment is carried out by a group of two users under two viewing conditions (Figure 4):

Separated view system: Two screens of separated views and one view for each user. For example the player can see the labyrinth with golden coins (fig.5.a) whereas the helper can see the highlighted way (fig.5.b).

Multi-view system: A screen of multiple overlapping views (Multiview) for each user (fig.5.c).

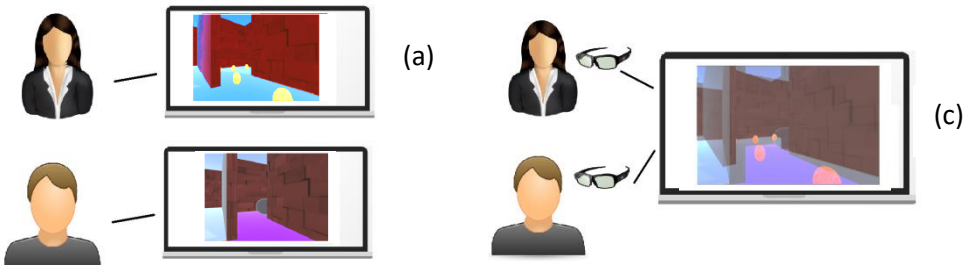

Figure 4: two device conditions, right: separated view conditions; left: multi-view conditions

4.3 Experimental hypothesis

The various aspects (effectiveness of collaboration, awareness, usability, involvement, collaboration satisfaction) related to the user's experience will be investigated. These aspects are used to prove the following hypothesis.

H1*: Our multi-view system provides greater collaboration efficiency. In other words, compared to the traditional ways of collaboration, users reach the collaborative task by using the multi-view system more efficient. Three following sub-hypothesizes express this hypothesis:*

H1.1*: Participants will finish the task more quickly with multi-view system than with separated view system.*

***H1.2**: Participants spend less communication time with each other with multi-view system than with separated view system.*

***H1.3**: The percentage of the time for communication is smaller with multi-view system than with separated view system.*

***H2:** Multi-view system provides better user experience than separated view system for people.*

4.4 Experimental protocol

The duration of the experiment ranged from 40 minutes to 90 minutes. Before the real test, participants must undergo a preliminary training. The purpose of this preliminary training is to make participants understand the process of experimentation. Participants are served as "player" and "helper" separately and crossed a small labyrinth with the rules presented previous. The "player" is positioned before a projector screen and the "helper" plays the game with a computer screen (separated views). Both participants move in the labyrinth by the mouse. For starting experiments, Participants must finish the training without the problems of movement and hit no bombs at the same time.

In the experiment, each group of participants will do 4 tests of 2 view conditions we mentioned in 4.2. Four labyrinth maps in similarly difficulty will be used in our experiment. In the first and second test, players and helpers plays in separated views (like the preliminary training). After two tests, both participants must complete a questionnaire before passing the following tests. Then, participants play the game in a virtual environment with the multi-view system and complete a questionnaire in the same manner as before at the end.

4.5 Measuring

Participants' activities are analyzed by subjective measures and objective measures. In objective measure, we measure the time to complete the task and the communication time for each participant during the task:

Finish time: The length of the completion time during a collaborative task;

Communication time: how much time participants spend to communicate with their partners;

Error committed*:* An error occurred when players touch a bomb in our experiment. The number of bombs touched by the player during the task is recorded.

A questionnaire is used to measure the subjective variable which is described below:

Involvement*:* participation level of the participants in their activity[16];

Usability*:* Ease of learning[17];

Collaboration Satisfaction*:* User's acceptance of the performance of tool or system[18]

5. ANALYSIS OF RESULTS

10 groups of participants have attended the experiment. In this chapter, we will compare and discuss the performance of each group of participants in two device conditions.

5.1 Subjective measures

Involvement, usability, and collaboration satisfaction is investigated by questionnaire with a scale of 1 to 5 points. Since the distribution of data compliance with nonparametric

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test conditions and the frequency of data is small, we use the chi-square test to specify the difference between groups is significant or not.

Involvement: The result of questionnaire shows that the average of the involvement of separated view condition is 3.95, while for the multi-view system condition it is 4.53. Chi-square test proves that there is the significant difference between 2 device conditions (p=0.032). With multi-view system, participants could feel **more involved** in an experiment and feel more concentrated.

Usability: For the separated view condition, the average of usability is 3.26. This value is 3.70 for multi-view system condition. Chi-square test proves the significant difference between 2 device conditions (p=0.030<0.05). Compare with separated view system, the multi-view system is **easier** to use.

Collaboration Satisfaction: Chi-square test shows no difference in this measure (p=0.854>>0.05, 3.81 for separated view condition and 3.95 for multi-view condition. This indicates that under both conditions, participants are positive in their collaboration effects, even though from the result of statistical analysis, the difference is **not significant**.

5.2 Objective measures

The sum of helper's communication time, the sum of player's communication time and finish time of each test are measured during the experiment. The ratio of participants' communication time to finish time is calculated after that. The number of touched bombs is analyzed at the end. Since the distribution of data compliance with nonparametric test conditions and two groups of data are dependent, we use Wilcoxon test to prove the significance of the measurement result.

Finish time: Finish time can be used to represent the collaboration efficiency. A significant difference between two device conditions (p value = 0.008) is analyzed with Wilcoxon test. The average finish time for separated view condition is 563.74s and it is 451.4s for multi-view condition. The player could finish the task more quickly by using the multi-view system.

Player's and helper's communication time: Players spend an average of 39.94s to communicate with helpers in separated view condition, which is 8.82% of finish time. However, the average of communication time of multi-view condition is 10.67s. It is 2.51% of finish time. Wilcoxon test shows a significant difference between two conditions. (p=0.009 for communication time, p=0.007 for ratio of play's communication time to finish time.)

Helper's communication time: Helpers spend an average of 172.47s to communicate with players in separated view condition, which is 31.45% of finish time. The average of communication time of multi-view condition is 136.15s, 37.08% of the finish time. The result of Wilcoxon test shows a difference of communications between two conditions (p=0.028). However the Wilcoxon test shows no difference in ratio of communication time between two conditions. (p =0.074) So the difference between two kinds of communication time may be caused by the shortening of finish time.

Error committed: In separated view condition, player touches an average of 1.46 bombs each game. Meanwhile, player touches 0.8 bombs in multi-view condition. Wilcoxon test proves a significant difference between two conditions (p = 0.041). Therefore, the multi-view system could **reduce the error incidence rate**.

5.3 Discussion

Although the ratio of communication time of the finishing time of helpers is not significant (H1.3), the result of another variable: finish time (H1.1) and communication time (H1.2) are significant to represent the efficiency of collaboration. From our analysis results, these dependent variables have the differences between two working conditions. On the other hand, the difference between helpers' communication time is not significant. From these

objective data analysis above, we found that users achieve the collaborative task more efficiently with the multi-view system than without it. Users can finish the collaborative task with less communications with the use of multi-view device.

From the analysis of involvement in participants and usability of the system, the significant difference between both conditions indicated that participants have better user experience with multi-view system than without it (H2). There is no significant difference in terms of collaboration satisfaction for the both conditions; however, the collaboration satisfaction level may depend on the participants themselves.

6 CONCLUSIONS

In this paper, we describe a multi-view system for co-located collaboration work in a virtual environment. An experiment was carried out to examine the efficiency of the system. The result showed that compared with separated view system, our multi-view system has better collaboration efficiency and a better user experience. In the future, we will apply this multi-view system in industry collaboration design work with DMU. An example of how to apply this multi-view system in industrial design is presented in Figure 5. Two people can work together to design a cup. The user, show in left picture, test the usage of the mug in driving situation. The designer, showed in the right picture, could change the design parameters of the cup through the buttons.

Figure 5: An example of using multi-view system in the product (mug) design. Left picture: the scenario of utilization in a car. Right picture: the panel of tools available for the designer.

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