Multiplayer collaborative training system based on Mobile AR innovative interaction technology

Liao Yangguang
School of Optoelectronics
Beijing Institute of Technology
Liaoyg620@163.com

Liu Yue
School of Optoelectronics
Beijing Institute of Technology
liuyue@bit.edu.cn

Wei Xiaodong
School of Computer Science
Beijing Institute of Technology
wxd1633@163.com

Abstract*— The applications of Augmented Reality (AR) in such mobile devices as phones and pads can enhance the users' experiences both in virtual and real world. In this paper the design and implementation of a Multiplayer Collaborative Training System (MCTS) is presented. It is a combination of virtual and physical reality, which builds virtual worlds with changeable scenes, brings authentic user experience and records process for analyzing and evaluation. Players are trained in a closed environment, which is composed of projectors, multimedia devices and physical scene. The application of mobile AR device guides the entire training process, and users make effective interaction with mobile devices to start and finish training mission. In the proposed system five innovative methods are implemented to improve interaction quality. An experiment case is devised with a series of tasks and conundrums for players, experimental results show that the MCTS can contribute more effective educations on team consciousness through the use of mobile AR technology and multimodal interaction to integrate virtual and real experience.

Keywords-Mobile Human-Computer Interaction; Augmented Reality; Mixed Reality; Collaborative Education

1. Introduction

The appearance of AR technology creates more possibilities between real environment and virtual scenes. Since mobile phone satisfied the hardware requirement of computing and rendering, AR technology is gradually applied in many apps. People have more chances to using their mobile phones for virtual experience based on real environment. The popularization of mobile AR encourage this technology to be applied in more fields. Because of this new way to connect virtual world and real physical objects, people would like to accept this interaction more easily than other virtual reality techniques. More and more phone applications of education and entertainment adopt AR and MR to enhance interactive effectiveness[1].

Traditional virtual reality focus on authentic 3-D modeling and rendering, the human-computer interaction is limited by regular input device, for example mouse and keyboard. Mobile AR could utilize its own advantage of hardware to enrich the human-computer interaction process, which plays a significant roles to improve user experience. In this paper, a systematic research is made for the mobile AR interaction in mixed reality environment, studying its significance of application effectiveness improvement especially in education and entertainment fields.

Since personal ability is limited, individual heroism is no longer admired by public. Teamwork is becoming a more effective way for problem-solutions. People stress the importance of teamwork and start to create training system for it. However, most of the training systems are based on face to face conversation[2] and limited physical environment, such as table-top model simulations[3], which provide resources for practical case study. There are also many training softwares building virtual world for team cooperation learning, but most of them are based on virtual environment which is unable to construct an authentic collaborative situation. What's more, the relationship of virtual team lacks familiarity and stability[4] during the training process, which results the trainings don't achieve expected aim.

We use mobile AR technology to create a training system[1,8], and conduct different interaction to encourage users' communication and cooperation. Current 3D rendering technology allows virtual worlds to bring rich user experience[5] by lavish resources and expansive space. The system could create different virtual characters to promote more human-computer interaction. People can co-work with more persons even they were strangers in remote places. Comparing with traditional training pattern, people can build a larger interaction network and reach extensive training content.

In this paper, firstly, we introduce several innovative interaction technology of mobile AR device applied in entertainment and education fields to enhance efficiency

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of human-computer interaction. Then, we design the Multiplayer Collaborative Training System (MCTS), which interprete applications of mobile AR technology and other multimedia device like immersive projection, multi-touch screen and automated mechanical device. At last, we design an experiment to test and verify the specific effect of mobile AR interaction of MCTS on team building and collaboration education, including the experiment solution and implementation method. Then, we present and evaluate the data and results from the experiments and makes some conclusions.

2. Human-Computer Interaction in mobile AR and Mixed Reality

In MCTS, we design five effective interaction of mobile AR device and mixed reality environment to promote collaboration and team education, like the Fig.1 shows.

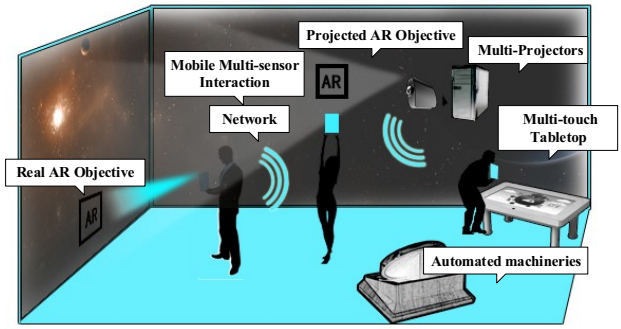

Fig.1: Interaction technology in Mixed Reality

2.1 Basic Human-Computer interaction of mobile AR.

We use appearance of training tools as AR markers and also add specific AR markers on some positions of rooms. By utilizing maker tracking, registering and 3D rendering, we change their virtual forms and conceal information of puzzle tasks. The interface and interactive display of mobile device can demonstrate real and virtual objectives by real-time rendering. Users can use touch operation to communicate with virtual avatars.

2.2 Interaction of multi-sensor in mobile device.

The gyroscope of mobile device can ameliorate interactive mode: accelerometer and gyroscope could detect device in its specific angle; Electronic compass could monitor the direction of device. We calculate device pose by the data of these sensors, then users can use device as somatosensory controller to finish tasks in mixed reality. Moreover, we use marker position and camera pose to perform 3D virtual reconstruction on realistic foundation.

2.3 Interaction of immersive virtual environment.

We design one room of MCTS as an immersive environment. Several projectors project virtual background on the walls of room. Some feedback of interaction can be expressed by the variation of virtual environment. We choose mobile phone or pad device instead of mouse and keyboard to communicate information. The projections can also be markers for AR recognition and users' operation can be sent to background management system via mobile device. The multi-projectors could change room's virtual scene during the process.

2.4 Interaction between mobile AR device and multimedia equipment.

In MCTS, we design some interactive application in Multi-touch Tabletop and Automated machineries to enrich education process[3]. They can correspond with the system by AR technology or serial port communication. These interaction could expand physical collaborative training.

2.5 Interactive multiplayers education based on wireless network.

In some training tasks, trainees are divided into two group, and they can't meet each other. They need communicate with their virtual avatars and cooperate through mobile AR device to finish tasks. All of their information can only exchange by the network of their Mobile AR device. What's more, network also connect the mobile device and MCTS.

3. Implementation of MCTS

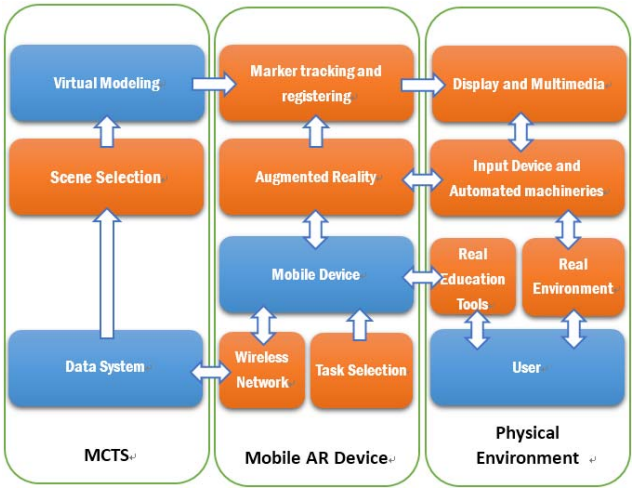

Fig.2: Information flow of MCTS

MCTS is a system that can conduct situational education and virtual tasks involved in various fields, such as history, literature, mathematics and physicsni. The mobile AR device plays a crucial role in the interaction between players and training scenes[7]. Various interactions and sensors provided by AR device enrich the training content and overcome geographical limitation to augment players' thinking expansibility. Mobile AR device can communicate with backstage processor by wireless network. The whole training procedure is controlled by MCTS and responded by virtual projections based on physical environment. The system records finishing time, tasks attempts number, task finishing order, teams' predilection of work mode, and team work efficiency in different background. Then, MCTS analyses the data to evaluate team capability.

During these training process, people in a closed space not only work with teammate, but also make clear division of labor and recognize their own positions of team to maximize teamwork effectiveness. MCTS can create large scale 3-D space by virtual immersive system, every scene has its own background. Players will be provided enough chances to communicate with team members or virtual characters. In most situations, without any outside factors, players are expected to work as united team naturally and make adjustments according to more in-depth understanding of each other. This training process of MCTS helps team members recognize their merits and how to co-work with others.

There is an intricate mission system in MCTS, tasks of which ask every members participate in. These tasks depending on diversity of interaction methods involve a wide range of knowledge and require users' collaboration abilities. All the tasks are based on interesting background stories, which greatly improve the enthusiasm of players. The missions system contained the following types:

Table 1: mission types

Tools using ability	Useful information collecting
Observation	Decision-making ability
Logic and reasoning	Physics and mechanics
Literary and history	Mathematics and computing
Perspective-taking	Collaboration brainstorm

4. Structure and Content

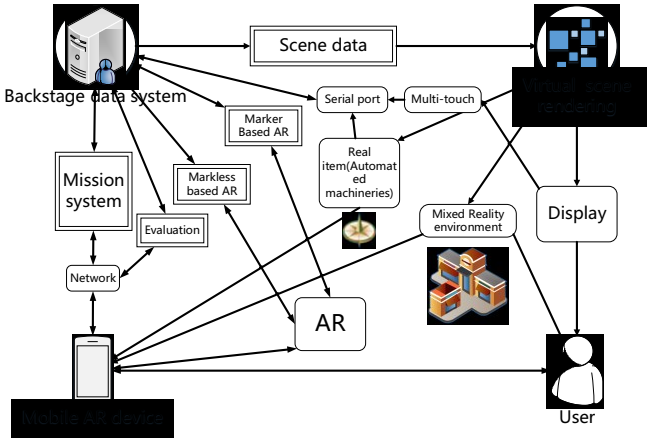

Fig.3. MCTS Structure

MCTS is divided into virtual and physical environments; the overall structure is presented in Fig.3. In this experiment, the system is built in the form of RoomBreak game which is a very popular game called TAKAGISM. Players are locked in a chamber, which forces them into a team and starts with a background story. They need crack all the puzzles and overcome difficulties to find way to escape. The Unity3D program supports to create immersive VR via projectors, record game process data, and make contract with mobile device. The physical part includes a closed chamber for players escaping, relative props and AR markers. Players are locked into closed room and their interactive tool is a mobile device such as iPad. The mobile device uses camera to track markers which is built by Qualcomm AR (QCAR[6]) unity editor, and then find out hidden information.

The iPad is regarded as main clue of whole game that hints players what is the next step. MCTS can construct multi-location and multi-temporal scene according to game process as situational teaching[7]. This system requires different capability and knowledge in various fields and it also record relative game data, then makes a result feedback and team evaluation.

5. User study

5.1 Example: collaborative game "Time Walker"

We make a sample of MCTS: a RoomBreak game "Time Walker". This game has 5 virtual scenes and several time dimensions. There will be 4 game lines about 4 celebrities or historical events, we regard them as "time lines", some need people work together, and some demands people divide their works. Each time line occurs

in different time and location, and cultivate team's different capabilities. For examples, Dante's time line requires common sense of literature; time line of Aristotle needs physics basic konwledge. The iPad used as a game prop called "Time machine", which can find hidden hints by AR or store cryptographic information. Players also need use iPad to make interaction with MCTS to move to next progress. When players use iPad to find key items by camera, iPad send message to MCTS, then system can make response, like changing scenes or hinting. After finishing 4 lines: The Greek Influence, Ancient Rome, Renaissance, and The British Empire, players finally go to the future universe built by virtual projection. The next missions require more effective teamwork, such as interaction game needs at least 3 persons to play. After cracking the password of every barrier, players can finally find the key to open the last door. After players escaped out, game is over and MCTS record all the game data and evaluation teamwork efficiency.

Fig.4: "Time Walker" Roombreak game

In the Fig.4, the first figure is physical props; the second one, player is using "Time machine" to communicate with MCTS; the third picture is projection room which bring virtual experience to players; the last figure show player is using AR to find hidden information.

5.2 Experiment

The experiment was designed to test players' efficiency of collaboration in MCTS by Time Walker example, and every participant should have enough knowledge reserve and capacity of multimedia device using.

5.3 Method

Experiment took place in Time Walker room. Participants was divided into two experiment environment, the first one was based on MCTS; the second was entire physical scene without mobile AR and virtual environment. Game difficulties and contents were same in both environments.

5.4 Participants

The participants of this experiment were divided into six groups, the group A & group B were mature teams in MCTS or Non-AR; the group C & group D were acquaintances or friends but never made any collaboration before; participants in group E & group F were totally strangers with disparate ages and fields. Every group has three teams. Before they came into game house, there were a short introduction for rules and using of tools in the house.

5.5 Procedure

The experiment lasted almost one hour, at the beginning, when participants entered game room, they need to crack each puzzle or task which can go to the next plot.

5.6 Results

This experiment mainly focused on two groups of data: task finishing and team collaboration. The first one included task numbers, finishing time; the second were familiarity degree, acceptance level, and game experience. Most data would be recorded in MCTS, the others obtained from questionnaire survey after experiment. The experiment data is following:

Table 2:The completion time of mission in two system

environment	Average Completion Time(min)						
	M1	M2	M3	M4	M5	M6	M7
MCTS	11	18	27	35	46	52	57
Non-AR	11	19	28	39	53	60	67

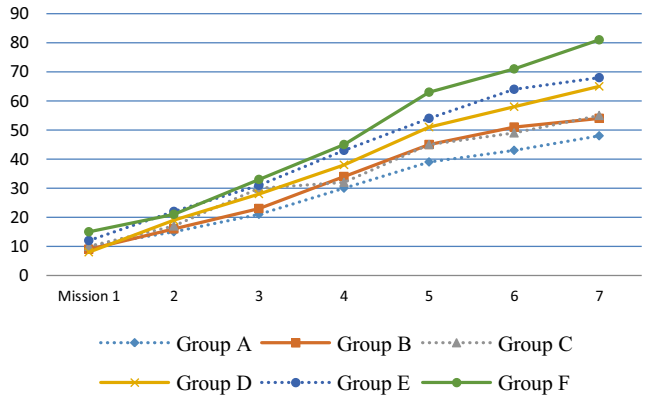

Fig.5: Every team's time points in mission system

We record teams' completion time of every mission. The experiment game is divided into 7 mission stage.

Compare with different environment, we found team using mobile AR device in MCTS could finish their missions more quickly, especially when they adapted to MCTS after several missions. The third group's team in

MCTS got more significantly improved than team's in real scene in spite that mature team can finish the experiment more quickly.

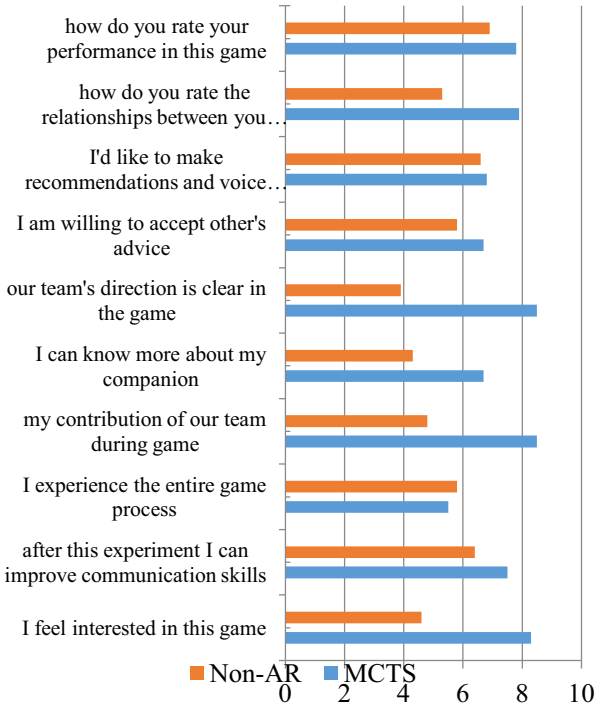

Fig.6 Questionnaire survey for players.

We make an investigation after experiment to evaluate players' sense of participation and team building training. In these questionnaires, players could choose from 0 to 10 points to rate their experience of the game. Then, we got Fig.6 according to the average scores of every question.

According to from question 1 to question 4, we can find MCTS can improve team members' degree of participation. From question 5 to question 7, MCTS can offer more effective process of team building. From question 8 to question 10, obviously such training system contains more entertainment.

6. Conclusion

Mobile AR technology provides more human-computer interactions for real and virtual worlds. MCTS can take advantage of this technology to create various scene in limited real training environment. The contrast experiment and questionnaire survey in this paper suggested that this innovative mobile interaction brought more authentic experience to trainees in diversified experiment backgrounds. MCTS encouraged trainees' self-study through tasks mode instead of traditional team building education[1,2]. According to the result of contrast experiment, we found that MCTS could be more effective to improve players' problem-solving ability and help them find answer faster. Comparing with traditional training system, the diversity of human-computer interaction of mobile AR enrich the education process. It makes mission system of MCTS more flexible for trainees to solve different types of problems, which was mostly changed by virtual mobile AR.

However, at present, MCTS can implement multiplayer collaborative training in LAN. The next work is to realize remote collaborative training by distributed technology and add navigation information in public open fields[8]. The interaction of MCTS can be optimized by more technology such as location technique and multi-players online collaborative training. In addition, it is expected that the mission system can change its mission according to real-time team situation and become more specific. It will be more effective if data recorded can be important reference for system artificial intellegence.

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