Augmented Reality Systems for Immediate-Action Commander Training During Disasters

Hiroyuki MITSUHARA[a*], Keisuke IGUCHI[b], Junya KAWAI[b], & Masami SHISHIBORI[a]
[a] *Graduate School of Science and Technology, Tokushima University, Japan*
[b] *Graduate School of Advanced Technology and Science, Tokushima University, Japan*
*mituhara@is.tokushima-u.ac.jp

Abstract: Disaster education focusing on how we should take immediate actions after disasters strike is essential to protect our lives. We proposed Immediate-Action Commanders (IACers) training and prototyped three IACers training systems using augmented reality (AR) and head-mounted displays (HMDs). The systems superimpose interactive virtual objects onto HMDs' real-time vision or a trainee's actual view.

Keywords: Augmented reality, head-mounted display, digital game, disaster education

1. Introduction

Disaster education focusing on the execution of planned immediate actions against disasters, which has been conducted in various ways and scenes, is essential to protect our lives. Nowadays, disasters are diversified and we must acquire sufficient knowledge through disaster education. However, the occurrence of a disaster is frequently regarded as someone else's problem. We do not always apply knowledge to immediate actions against a real disaster. Compared to adults, children find it difficult in applying knowledge to a real disaster—children may panic and feel incapacitated by fear. Therefore, adults should appropriately instruct children to take immediate actions in the event of a disaster. We refer to such adults as Immediate-Action Commanders (IACers). However, few satisfactory training programs are currently available, and majority of adults have not been trained yet. In this context, we must develop multiple IACer training programs.

IACer training programs must represent disasters realistically because trainees (e.g., school teachers) find it difficult to imagine disaster situations as they do not have a prior experience of such an event. In other words, the programs need situational and audio-visual realities. An approach to the realistic representation is to integrate digital games into the programs, i.e., game-based IACer training programs. Digital games with high interactivity and audio-visual effects, which aim at improving situational and audio-visual realities by scenarios and virtual worlds (computer sounds and graphics) respectively, have gathered significant attention in disaster education (Tsai et al., 2014).

Game-based IACer training programs should involve the real world to further improve the situational and audio-visual realities. In particular, we focus on visual reality because virtual worlds may not encourage trainees to feel a sense of tension due to representational limitation in computer graphics (CG). For high visual reality, we considered implementing augmented reality (AR) that superimposes interactive virtual objects (e.g., 3DCG characters) on a real-time vision.

2. Prototype Systems

To save lives of numerous children, majority of the adults should be trained to become IACers. For the ideal program as a game-based IACer training program, we adopted AR-based interactive virtual children (i.e., 3DCG characters) who exhibit reactions and take immediate actions against disasters. This means that an AR system is necessary to superimpose the virtual children on a real-time vision (i.e., a trainee's view). As a game element, we adopted a simple interactive fiction (IF). We defined the following requirements for the AR system.

(1) Working on portable computers

Although recent AR systems can work on various computers (e.g., desktops, laptops, tablets, and smartphones), the ideal AR system should work on computers that are not fixed stations, i.e., using desktop computers should be avoided.

(2) Having visual consistencies and interactivity optimized for head-mounted display

General AR systems aim at improving visual reality in terms of visual consistencies (e.g., geometric and photometric consistencies) while being optimized for visual output devices (i.e., displays). Head-mounted displays (HMDs) will be most suitable to maximize visual reality because HMDs can provide high immersion.

The interactions (i.e., changes in reactions), which are controlled according to branched IF scenarios, can be regarded as the game element. We think that the virtual children should change their reactions according to a trainee's vocal commands because the system users (the HMD wearers) have difficulties in visual and touch operations.

2.1 System Overview

To prototype AR-based IACers training systems, we adopted a binocular opaque HMD (Oculus Rift), a smartphone-based binocular opaque HMD (Google Cardboard), and an optical see-through HMD (Epson Moverio). We refer to the AR systems developed for Oculus Rift, Google Cardboard, and Moverio as System-1, System-2, and System-3, respectively. System-1 and System-2 superimpose virtual objects (interactive virtual children and visual effects) onto the real-time vision. System-3 superimposes virtual objects semi-transparently onto a trainee's (i.e., wearer's) actual view. Figure 1 is a schematic of the overall design of the AR systems.

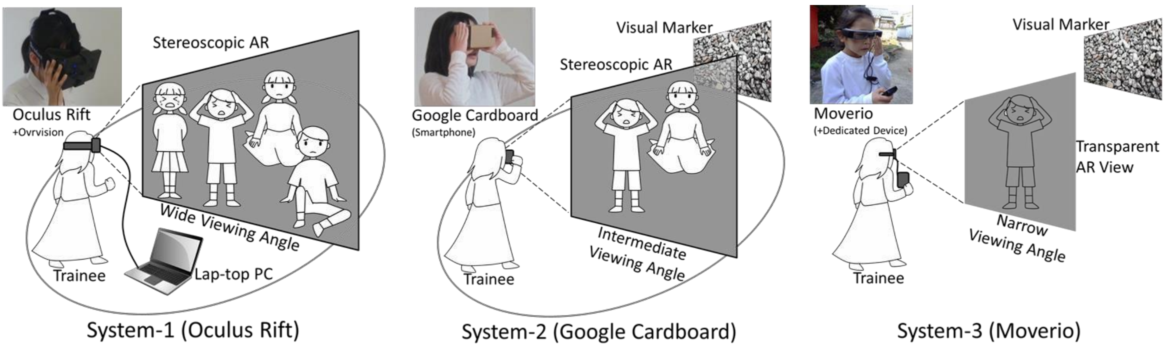


Figure 1. Three AR systems for IACer training.

(1) System-1

Oculus Rift provides high immersion (110° viewing angle and sensitive head motion tracking using acceleration, gyro, and geomagnetic sensors); however, it requires a high-performance computer and an external camera. For System-1, the authors considered using laptops (e.g., Intel Core i5, 8GB memory, Intel HD Graphics 4600, and Microsoft Windows 8) and a stereoscopic camera (Ovrvision).

System-1 realizes a markerless stereoscopic AR that adjusts the positions of the superimposed virtual objects according to the feedback from the head tracking functions. System-1 superimposes not only virtual children (up to 16 children) but also other virtual objects (e.g., desks) on the real-time vision, taking the advantages of Oculus Rift's high immersion. Figure 2 shows screenshots of System-1 that represent the situations after an emergency earthquake warning sounds in class. The left picture shows the superimposition of the virtual students seated in a classroom and a fixed message, whereas the right picture shows that nearly all students have huddled under the desks (i.e., they took the proper immediate action). However, in the right picture, there are some students who are still standing (i.e., they did not take the necessary actions). In such a situation, a trainee must repeat the appropriate command again.

(2) System-2

System-2 works on standard smartphones that are placed into a cardboard frame with two lenses. For System-2, the authors considered using Android smartphones (e.g., 2.5 GHz quad-core processor, 2GB + 16GB memory, and Android 4.4).

System-2 realizes a visual marker-based stereoscopic AR that divides the real-time vision into two visions (for left and right eyes) and adjusts the positions of the superimposed virtual objects, even when the visual markers are lost in the real-time vision, by using the tracking function of a visual marker-based AR library (Vuforia). Basically, System-2 superimposes not only virtual children (up to 8 children) but also other small virtual objects (e.g., fragments of broken glass) on the real-time vision because regular smartphones' cameras do not have a considerably wide viewing angle. Figure 3 shows screenshots of System-2. In the left picture (divided for the stereoscopic view), two students have huddled under the table that is not a virtual but a real object.

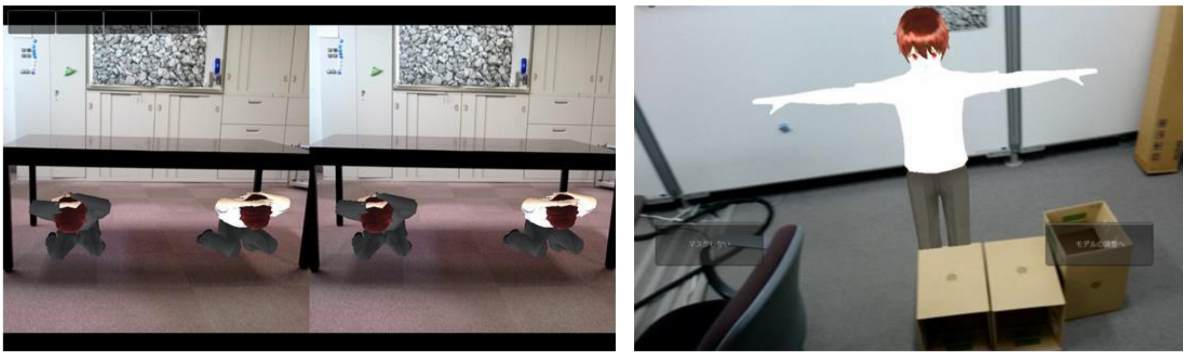
(3) System-3

System-3 works on a dedicated Android device (dual-core processor 1.2 GHz, 1GB + 8GB memory, and Android 4.0) with its connectivity solely restricted to Moverio.

A trainee wearing Moverio (88g headset) can view the real world through the glasses. System-3 realizes a visual marker-based AR that superimposes virtual objects onto the trainee's actual view—it just presents the virtual objects whose peripheral area is filled with black. System-3 aims at improving the visual reality by a distinctive AR representation (i.e., semi-transparent AR). Figure 4 shows screenshots of System-3. The visual reality can be maximized toward the real world, but will decrease toward the virtual objects. Moverio cannot present virtual objects widely due to its 23° viewing angle. Therefore, System-3 can be used only to represent distant disaster situations, i.e., present small distant virtual objects.

AR View (Students Seated) AR View (Huddling or Standing Students)

Figure 2. Screenshots of System-1.



Screenshot (Stereoscopic AR View) in System-2 Occlusion Expression

Figure 3. Screenshots of System-2.

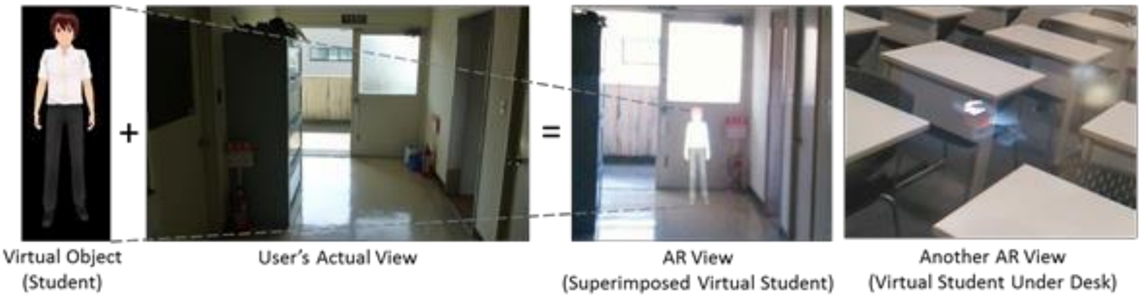


Figure 4. Screenshots of System-3.

2.2 Related Works

Nowadays, HMDs are rapidly being advanced, diversified, and commonly marketed. Reiners et al. (2014) use Oculus Rift so that workers can learn health and safety risks more realistically in the virtual environment. Suarez et al. (2015) use Google Glass so that learners can make instant inquiries with hands-free interaction (voice interaction). In disaster education, Wang et al. (2014) developed a 3D-simulator that allows HMD wearers to evacuate from a virtual building fire. We developed evacuation drill systems using AR and HMDs (Kawai et al., 2015; Mitsuhara et al., 2016). These systems superimpose virtual disaster situations represented by 2D/3DCGs or digital hazard maps onto the HMDs' real-time vision so that the participants feel a sense of tension in evacuation.

AR can be regarded as the integration of virtual worlds with the real world. AR systems for disaster education frequently realize this integration as a mixed reality game (MRG) or an alternate reality game (ARG) that works on portable computers (e.g., smartphones and tablets). For example, Fischer et al. (2012) developed a geo-fencing MRG, where field players can learn disaster response coordination by observing the virtual disaster situations (e.g., radioactive pollution areas) on a digital map. Meesters and Van de Walle (2013) developed an ARG, where field players can learn disaster information management (e.g., rescue operations) while carrying out missions presented on portable computers and interacting with volunteer actors who play roles (e.g., victims and police officers) in virtual disaster situations.

Virtual reality (VR) can be used for IACer training. Takahashi et al. (2015) developed a VR environment for training in initial earthquake responses. In this environment, trainees (school teachers) can vocally command virtual students to take immediate actions while observing virtual earthquake situations through large-size displays; an operator controls the virtual students according to disaster scenarios. Our prototype systems are similar to this environment; however, it differs in the following ways: (1) our IACer program can be conducted anywhere because the AR systems can work on portable computers and (2) it can further improve the visual reality using AR and HMDs.

3. Conclusions

IACers can protect children's lives. We prototyped three AR systems: System-1, System-2, and System-3 corresponding to a binocular opaque HMD, a smartphone-based binocular opaque HMD, and an optical see-through HMD, respectively. These systems aim at improving situational and audio-visual realities by superimposing virtual objects (e.g., 3DCG characters) onto a real-time vision or a trainee's actual view.

The game element in all the systems is voice-based interactions controlled according to a branched IF scenario, which provides multiple endings. However, we have not realized voice-based interactions and did not improve the visual reality in terms of photometric consistency, which means that the systems (i.e., the game-based IACer programs) are still in-progress. To make the systems available for more practical use, we must implement the voice-based interactions. In the future, we must evaluate the systems. In disaster education, it is particularly important to consider what to evaluate and how to evaluate it. The realities as well as the educational effectiveness of the systems should be evaluated through large-scale training practices.

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