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Tsunami Evacuation Drill System Using Smart Glasses

Junya Kawai[a]*, Hiroyuki Mitsuhara[a], Masami Shishibori[a]

[a]*Tokushima University, 2-1, Minami-josanjima, Tokushima, 770-8506, Japan*

Abstract

Evacuation drills are commonly conducted as traditional disaster education to reduce damages from natural disasters. However participants are not always interested in or committed to such drills. To improve this situation, we focused on Edutainment and proposed game-based evacuation drill (GBED) using the Real-World Edutainment (RWE) program. There are two types of GBED systems, i.e. the Tablet-based GBED (T-GBED) and the AR and HMD-based GBED (AH-GBED). We conducted GBED at several schools and determined that it can improve student motivation for disaster prevention. Subduction-zone earthquakes frequently generate tsunamis and can cause catastrophic damage especially to coastal areas. Thus people in coastal areas must move very quickly to evacuation sites when a massive earthquake occurs. Both GBED systems cannot be used directly for tsunami evacuation drills because the participants will not want to sprint while holding a tablet or wearing a HMD and have time to stop to view the digital materials. In this study, we propose a tsunami evacuation drill (TED) and have developed a TED system. The TED system uses smart glasses (a lightweight optical see-through HMD) which allows participants to view digital materials while moving quickly.

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Keywords: smart glasses; wearable devices; tsunami evacuation drill; disaster education

1. Introduction

Large-scale natural disasters cause enormous damage. In Japan, for example, the Tohoku Region Pacific Coast Earthquake and the resulting tsunami (seismic sea waves) caused the death of many people. Each time a natural disaster occurs, many people subsequently recognize the importance of disaster prevention. A promising approach to disaster prevention is disaster education. Nowadays, ICT (Information Communication Technology) plays an important role in disaster education. A Japanese

* Corresponding author.
E-mail address: c501537010@tokushima-u.ac.jp .

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ministry reported that ICT-based disaster education has improved student awareness of disaster prevention [1]. There are many types of ICT-based disaster education. In particular, digital game-based disaster education has been a typical focus. Ericson [2] developed a fun virtual reality game that improves student fire safety skills. Tsai et al. [3] developed a tower defence game for learning flood protection and reported that it motivated students to learn more about flooding.

In addition, evacuation drills are commonly conducted as traditional disaster education in schools, companies and communities. However, participants are not always interested in or committed to such drills because they simply follow instructions and do not reflect upon and discuss their evacuations. As a result, such drills become monotonous and ineffective. In schools, for example, students must move from their classroom to the school yard in an orderly manner along a predetermined route with a teacher as a guide.

To improve this situation, we focused on Edutainment, which is the integration of education and entertainment (e.g. digital games), for increasing learning motivation and effect. Even though Edutainment is often conducted in virtual worlds, we believe that it is more effective to employ Edutainment in the real world because learning through the five physical senses is highly effective. Therefore, we previously proposed a game-based evacuation drill (GBED) using the Real-World Edutainment (RWE) program [4][5][6], which is a location-based educational game (similar to role-playing or adventure games) that provides game-based learning in the real world. The RWE system, which works on a tablet computer with a GPS receiver and other sensors, presents digital materials based primarily on a learner's current situations (e.g. location) and a branched learning scenario (game storyline). When reaching a particular location designated by the learning scenario, the learner observes and interacts with the digital materials that correspond to that location. Thus, users can learn from the virtual (digital game) and real worlds.

Our primary idea for the GBED is that the interactivity and fun provided by a digital game can increase participant interest in evacuation drills. In the GBED, the learning scenario is designed as an evacuation scenario that begins at a certain location and ends at a designated evacuation site within a time limit. The digital materials represent serious disaster situations that correspond to locations. In other words, participants experience pseudo disaster situations in both the virtual and real worlds. For example, when digital material that represents an encounter with an injured person is presented at a given location, the participant must answer a yes-no question, 'Will you help the injured person?' If the answer is 'yes', the participant must give first aid to the injured person played by a real human actor while referencing digital material about first-aid methods.

We conducted the GBED at several schools and determined through a questionnaire survey that the GBED can improve student motivation for disaster prevention. We also found that the auditory-visual reality of the digital materials was insufficient. To improve the reality of these materials, we developed a new GBED using marker-based augmented reality (AR) and a binocular opaque head-mounted display (HMD) [7]. Then, an experiment with the new GBED revealed that it was difficult to use the HMD for evacuation drills that focus on prompt evacuation (e.g. tsunami evacuation).

Many people have experienced the fear of tsunami from the past (e.g. Indian Ocean Earthquake and Tohoku Region Pacific Coast Earthquake). However, they did not necessarily learn how to survive a tsunami. Depending on an earthquake's situation (e.g. epicentre and magnitude), a tsunami may reach coastal areas in only a few minutes. Therefore, people in coastal areas must move very quickly to evacuation sites when a massive earthquake occurs. We believe that tsunami evacuation drills should require participants to move very quickly while imagining tsunami approaching.

In this study, we aim to realize the GBED focusing on tsunami evacuation. To achieve this, we adopt smart glasses (a lightweight optical see-through HMD) as an alternative device for digital material presentation and a panoramic animation of tsunami approaching as the digital material.

2. Game-based Evacuation Drill System

There are two types of GBED systems, i.e. the Tablet-based GBED (T-GBED) and the AR and HMD-based GBED (AH-GBED).

2.1. T-GBED system

The T-GBED system, which works on a tablet computer that has a GPS receiver, an RFID (Radio Frequency Identification) reader, an electronic compass and a small camera, recognizes a learner's current situation (location and direction) and presents the corresponding digital material based on the recognized situations and an evacuation scenario. The evacuation scenario (described in XML) is composed of scenes (locations) and cuts (digital materials). The digital materials include images, sounds, videos and single-choice questions, as well as markerless AR [6]. For AR material, the T-GBED system superimposes a background-transparent image (including animated GIFs) onto the real-time vision captured by the tablet computer's camera. The superimposing is processed based on the brightness similarity between each frame of the real-time vision and a previously shot image. The superimposed image is synchronized according to the direction of the camera. Figure 1 shows screenshots of the AR material and a snapshot of participants viewing AR material.

In the T-GBED system, the visual reality of the AR material was insufficient. In particular, an image was not superimposed accurately due to low robustness of the markerless AR processing (i.e. similarity calculation and synchronization). In addition, the AR material (superimposed images) was only two-dimensional, and the tablet computer's screen was too small to view the details of the AR material.

2.2. AH-GBED system

To improve the visual reality, we focused on a HMD. Research into the combination of AR and HMDs has a long history. In the latter half of the 1990s, Feiner et al. [8] developed a guide system that provides users with information about university campuses using text-based AR and an optical see-through HMD.

We also developed the AH-GBED system [7], which works on a laptop computer with a binocular opaque HMD (Oculus Rift) and a stereo camera (Ovrvision). This system superimposes 3DCG (Unity3D) onto the real-time vision more accurately and realistically by recognizing a learner's direction using marker-based AR (ArUco library).

We conducted a small-scale GBED using the AH-GBED system. The evacuation scenario involved an earthquake, and the participants (high school students) had to evacuate from the fifth floor of a building (the current floor) to the outside of the building within 15 minutes. Figure 2 shows screenshots of the AR material and snapshots of a participant viewing AR material. Through the questionnaire survey, we found that the AH-GBED system improved visual reality and participant awareness of disaster prevention.

However, nearly all of the participants suffered from 3D sickness and felt that the HMD was too heavy to move in the evacuation drill.

Fig. 1. AR materials in T-GBED system

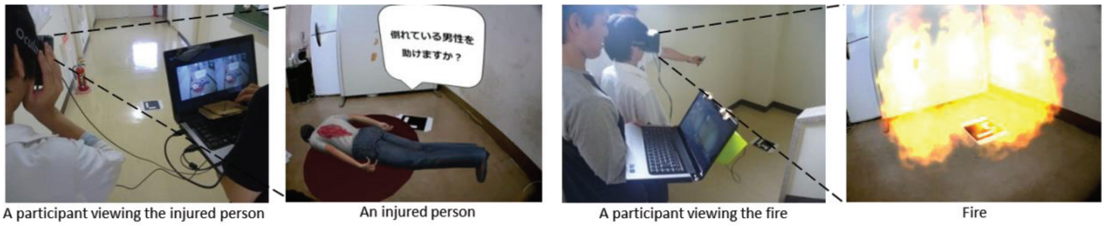

Fig. 2. AR materials in AH-GBED system and snapshots of the system

2.3. T-GBED and AH-GBED for tsunami evacuation drill

Subduction-zone earthquakes frequently generate tsunamis and can cause catastrophic damage, especially to coastal areas. Therefore, people in coastal areas should be sufficiently trained to survive a tsunami through appropriate evacuation drills. In most tsunami evacuation drills, participants must quickly move to an evacuation site within a certain time limit. During the drills, the participants should imagine a tsunami approaching to have a sense of tension (danger). However, some participants will have difficulty imaging this—it will be difficult to imagine a tsunami approaching even if the fact that tsunami's speed is approximately 40km/h at a 10-metre-deep harbour is given. In this situation, the participants may not develop a sense of tension. Thus, they may not adequately consider how quickly they should move.

The T-GBED and AH-GBED systems can help this imagination by presenting digital materials that represent a tsunami approaching. However, the participants will not want to sprint while holding a tablet or wearing a HMD. In addition, they will not have time to stop to view the digital materials. Therefore, both systems cannot be used directly for tsunami evacuation drills.

3. Tsunami Evacuation Drill System

In the GBED, digital materials are presented and participants are required to reach an evacuation site within a given time limit. We consider that these characteristics can be used for effective tsunami evacuation drills. In addition, the digital materials should not prevent participants from moving quickly (prompt evacuation) but should represent an approaching tsunami. Therefore, we propose a tsunami evacuation drill (TED) based on these characteristics. We have developed a TED system that allows participants to view digital materials while moving quickly. The TED adopts time-based competition. The participants must get to an evacuation site (e.g. higher elevation) no later than a tsunami event. Note that the TED does not focus on fun and interactivity (i.e. the game elements of competition).

3.1. System overview

The TED system requires lightweight devices for digital material presentation so that the participants can view the digital materials while moving quickly. Therefore, we employed smart glasses (an optical see-through HMD) and adopted 'Moverio' [9]. Moverio (BT-200) weighs 88 g (headset) and is connected to a GPS- and Internet-enabled terminal device (Android OS) such as a smartphone. Figure 3 shows snapshots of a user wearing Moverio.

We are developing the TED system as a web application (cross-platform) which works with standard web browsers. Figure 4 shows the system composition with a participant wearing Moverio and a subjective Moverio viewing field.

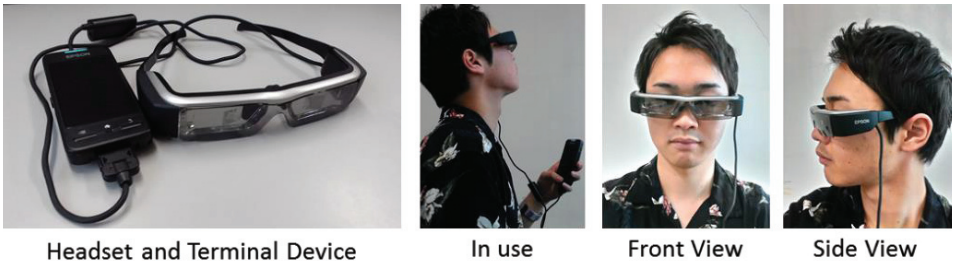

Fig. 3. Moverio (headset and terminal device)

On the server, a PHP program simulates a virtual tsunami and sends the simulated data to the terminal device (client). On the terminal device, a JavaScript program receives the participant's current location data (latitude and longitude) from GPS at a regular interval. Simultaneously, the JavaScript program visualizes how far the virtual tsunami has approached and determines whether the virtual tsunami has reached the participant. We have adopted a simplified tsunami estimation (linearly approximated tsunami wave propagation) rather than a sophisticated tsunami simulation. Evacuation site location data are stored manually in the database on the server. In some cases, the location data of official evacuation sites can be collected from open data servers for disaster prevention.

3.2. Digital materials

The TED system does not present videos, single-choice questions and AR because participants may stop to view these materials. In other words, the TED system does not attach importance to the visual reality and interactivity. Rather, the TED system presents the following types of digital material to help imagine an approaching tsunami (i.e. it helps build a sense of tension).

(1)Text material

At a regular interval, the TED system calculates the distance between a participant and the simulated tsunami. It then presents the calculated distance and the estimated tsunami speed, elapsed time, remaining time and the distance to a designated evacuation site as text. Figure 5 shows an example of the text material together with an actual view on Moverio. While maintaining quick motion, the participant can view the presented information and imagine the approaching tsunami. The text material is somewhat abstract; however, it can help train participant imagination.

(2)Map material

The TED system calculates the text material and presents a panoramic animation of the simulated tsunami using Google Maps.

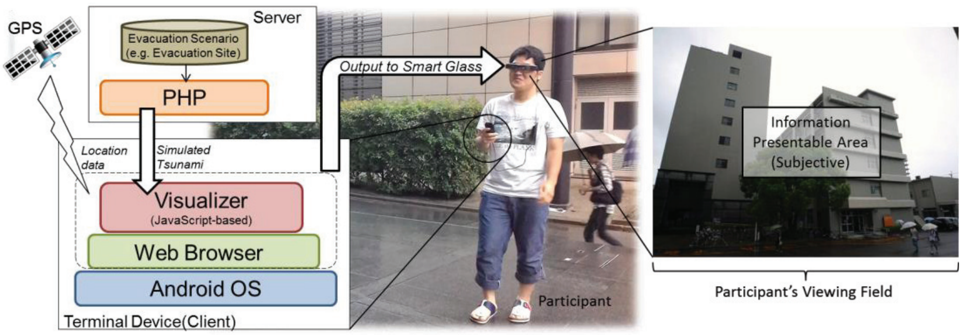

Fig. 4. TED system composition

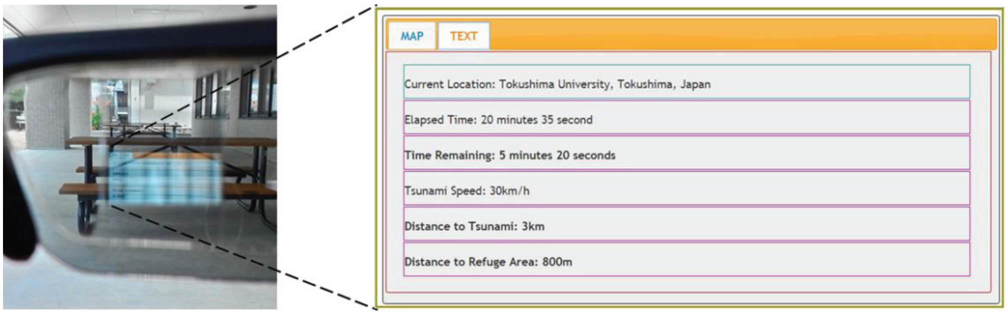

Fig. 5. Example text material in the TED system

A participant can view the map together with some information presented by the text. Figure 6 shows an example of the map material. The current location of the participant is shown by a circle, and the evacuation site is shown as a square. The area the virtual tsunami has reached is drawn by a semi-transparent blue mesh. As time passes, the blue area spreads. While moving quickly, the participant can overview the approaching tsunami. The map material helps participants understand distances as well as the speed of the tsunami.

3.3. Procedure

(1) Evacuation scenario composition

Composing an evacuation scenario for the TED is easier than that for the T-GBED and AH-GBED. Relative to an evacuation scenario (stored in the server), disaster prevention educators only need to input a scenario's ID, password, an earthquake epicentre (latitude and longitude), magnitude (numerical value) and evacuation site (latitude and longitude). The time limit is calculated automatically on the basis of the input data.

(2) Evacuation drill

First, a participant selects an evacuation scenario by sending the scenario's ID and password to the TED system (server) through a web browser using the Moverio. The participant must be in the area covered by the selected scenario while wearing the Moverio. After successful authentication, the participant can perform the evacuation drill (i.e. quickly move to the evacuation site) with the selected scenario. The participant can freely switch between text and map materials. If the participant arrives at the evacuation site within the time limit (i.e. no later than the simulated tsunami), the evacuation is successful; otherwise, the evacuation fails.

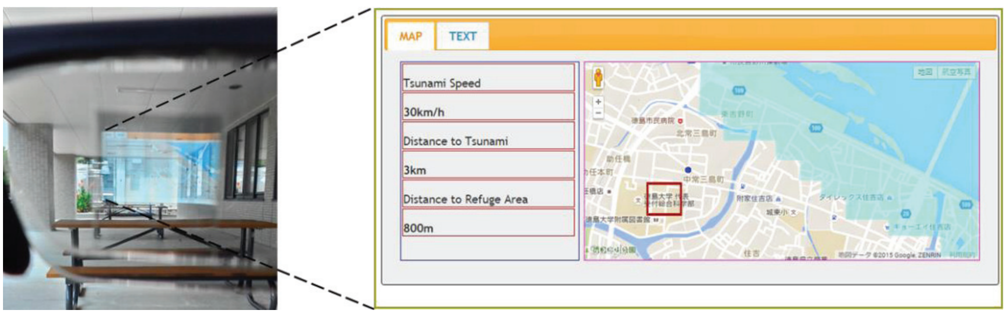

Fig. 6. Example map material in the TED system

4. Related Work

Recently, wearable technology such as high-performance smart glasses (e.g. Google Glass, HoloLense and Moverio) has attracted significant attention. Amft et al. [10] reported that smart glasses will be the best computing platform for sports and health, even though they currently have many problems relative to size, power consumption, etc. In addition, smart glass systems for education are emerging. For example, Mitsuhara et al. [11] prototyped a lecture support system that superimposes information about students (e.g. name, test score and attendance) onto a lecturer's view (smart glasses) to facilitate lectures. Suarez et al. [12] applied Google Glass to inquiry-based learning and proposed the Glassware Personal Inquiry Manager. This system provides hands-free interaction (voice interaction) anywhere due to its high portability and allows users (students) to make instant inquiries.

AR has been actively used for various types of education, and many learning systems use AR. For example, Redondo et al. [13] developed a handheld AR system (i.e. AR on a smartphone) that helps students understand architecture in field work and increase their motivation, commitment and academic performance. Tan et al. [14] developed a location-based mobile learning system that uses AR to identify learning objects and provide learning materials. Chang et al. [15] reported that educational guidance using AR is more effective than audio guidance and no-guidance in learning historical sites. As shown in these examples, AR is compatible with location-based learning.

The TED system can be regarded as a simple AR system that superimposes digital information onto a participant's vision using smart glasses. However, the superimposed information does not adapt to their vision. In addition, the TED system might be considered a location-based system because it uses GPS. However, the participant's current location is only used to calculate the distances and determine the end of their evacuation. In general, location-based learning is effective for learning issues related to locations (e.g. history of the region [16][17]). At present, we do not consider the TED system as an AR system or a location-based learning system.

5. Summary and Future Work

We have focused on the importance of tsunami evacuation drills (TED) and have proposed a TED system that uses smart glasses, which enables participants to view text and map materials while moving quickly. To represent an approaching virtual tsunami, text materials present numerical values (e.g. the distance between a participant and the tsunami), and the map materials present a panoramic view of the tsunami using Google Maps. These materials are effective in encouraging a sense of tension during the TED. Through the TED, the participants develop their imagination about tsunami and think more seriously about how to survive during a tsunami. Our primary future work is to complete the system. Furthermore, we must address the following problems. The first problem is system usability. The view angle of the Moverio is not very large (approximately 10–20% of the human view field). Some participants may feel that the information presented on the screen is too small. The map material may be insufficient to encourage a sense of tension in visual reality and ineffective for participants who have difficulty in map reading. To address these problems, we must change the information presentation methods in the TED system. For example, more visually-realistic AR should be implemented. In addition, the Moverio terminal device uses a touch panel that is difficult to operate. Therefore, the TED system should adopt voice instruction (e.g., directional guidance) and control. The second problem is the low accuracy of the tsunami simulation, which often generates more severe results than sophisticated tsunami simulations. Although such severe results may be accepted as assumptions for evacuation drills, our tsunami simulation should be based on accurate data (e.g. official open data about tsunami simulation). The third problem is participant safety. In most cases, the TED is conducted outside and requires participants to move very quickly. Participants wearing the smart glasses cannot always move quickly. In addition, the participants who have an excessive sense of tension may lose focus on the conditions around them. For example, traffic accidents are a biggest concern. Therefore, we must conduct the TED with sufficient preparation and attention to ensure participant safety. We believe that the TED is an effective disaster education tool to survive a tsunami. We want to conduct the TED in many schools, companies and communities especially in coastal areas and then clarify the effectiveness of the TED.

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