Disaster-Relief Training System Using Augmented Reality and Voice Input Triage

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Abstract - When a large disaster happens, health care workers need to determine the priority of medical treatment and perform triage. In order to carry out emergency lifesaving activities at an actual disaster site quickly and accurately, frequent training is very important. However, current training has issues such as cost, many time and effort to prepare, as well as not being able to consider changes of patient's vital signs. In addition, they cannot use any hands while writing paper tags or using PDAs, so it is difficult to perform necessary medical treatment in parallel. In this study, we propose triage training system where health care workers get patient information through a monocular HMD (Head Mount Display) and perform triage via voice input, so their hands are free to conduct necessary treatment even while doing triage. Moreover our system can reproduce the situation through the HMD by superimpose dynamic information about patients onto real space, and allow sharing the training status. The evaluation shows that our system enables to perform triage quickly and accurately with health care workers' hands free and make disaster-relief trainings more meaningful.

Keywords: Triage, Disaster-Relief Training, Monocular HMD, Voice Input, Augmented Reality

1 INTRODUCTION

When a large-scale disaster occurs, a large number of people are injured at the same time, so medical workers first need to do triage in order to decide the priority for treatment depending on their severity of injury and the urgency of treatment. The purpose of triage is to save more lives through efficient use of a limited medical resource.

Currently, paper triage tags are often used to indicate the condition of patients and to record information of their injuries. However, in a confused situation, it may be difficult to record information due to loss of paper tags attached to the patients and it may be impossible to respond and adjust quickly to fast changing conditions. In addition, writing something on paper tags is also one of the factors that disturb diagnostic actions from busy health care worker's hands.

Therefore, in recent years, electronic triage systems have been researched in order to support lifesaving emergency activities. We have been developing an electronic triage system where patients information is sensed by electronic tags and is presented to PDA (Personal Digital Assistance) terminals which health care workers hold [1].

Frequent training is very important for health care workers to be accustomed with real disaster situations and to master the method of triage by performing tasks such as decision of tag color and transportation of patients, however, current training has issues such as cost and human resource for preparing and conducting the training. In addition, while patients' vital sign in training is static and does not change because a healthy person plays the patient. Furthermore, writing on triage tags or using PDAs requires use of the hands, hampering immediate medical treatment.

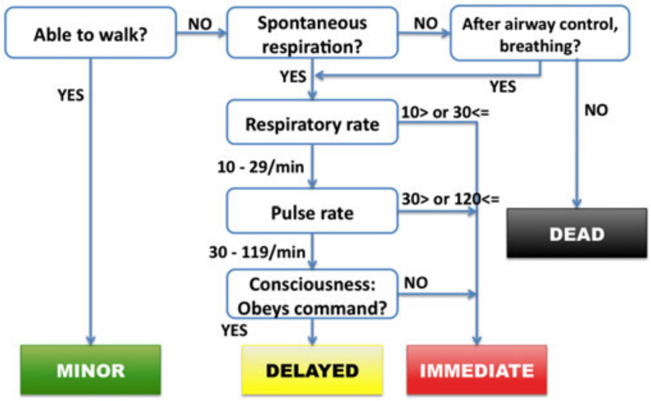

Figure 1: START method

In this study, we propose triage training system where health care workers can get information such as patient's vital signs through a monocular HMD and can perform triage via voice input. Our system can reproduce realistic situations through monocular HMDs, change patients' biological information such as vital signs dynamically and allow sharing the training status among participants.

In Section 2, we provide outline and discuss issues. In Section 3, we show our proposal of solving the issues. Section 4 explains the implementation of our system. Section 5 discusses the assessment of our system and Section 6 discusses future work of our system. Finally, Section 7 presents our conclusion.

2 LIFE SAVING ACTIVITIES AT DISASTER SITE

2.1 Medical Services Based on Triage

In Japan, health care workers perform the triage based on START (Simple Triage and Rapid Treatment) method shown in Fig. 1 at a triage post [2]. The purpose of the triage is to classify patients according to their vital signs such as respiratory rate and pulse rate, so health care workers only perform eastriction' and eairway control' as immediate medical treatment. patients are categorized for their treatment priority into the following four: Red (immediate) → Yellow (delayed) → Green (minor) → Black (dead). After each triage, a health care worker writes necessary information, such as person's name, age, blood type, transportation, organization and the name of the health care worker in charge, on a paper tag shown in Fig. 2, removes unnecessary colors, and attaches it

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Figure 2: Paper triage tag

to the patient [3].

After the triage, patients are taken to each tag color's post and health care workers perform the second-triage in order to determine priority with transportation to hospitals. In this paper, we focus only on the triage.

2.2 Current State of Disaster-Relief Training

After the Hanshin-Awaji Great Earthquake in 1995, residents of the surrounding area have had more opportunities to participate in disaster training with health care workers. Furthermore, since JR Fukuchiyama Line derailment accident, the concept of triage in lifesaving emergency activities has been widely recognized, and triage training has become essential in order to perform actual triage quickly and accurately in a real situation [4]. Triage training process and its procedure may differ by medical centers, but the basic procedure is as follows. People who play patient role have a piece of paper describing their imitating symptoms and biological information. They need to pretend the written symptoms to health care workers. Then, health care workers determine the priority for treatment by observing the behavior of a patient role and information on the paper. After that, health care workers writes necessary information on a paper tag and makes an order to transport patient role to the corresponding tent.

For example, Fuji city has conducted a training of doing triage, conducting treatment, recording information and transporting patients depending on the result of triage [5]. Yamanashi School of Medicine has also conducted an experiment of an electronic triage system, TRACY, where FeliCa IC cards are used [6]. The system aims to share widespread disaster information. In addition, the Emergo Train System, which is a disaster training system with desktop simulation, has also been employed in recent years [7]. Using this training system, health care workers can study proper arrangement of personnel by moving magnets instead of patients and health care workers on a whiteboard which represents a disaster site and hospitals.

2.3 Related Work and Issues

In recent years, systems based on RFID (Radio Frequency Identification) tags and sensors have been researched to be used for emergency lifesaving in disasters [8]. In the CodeBlue Project [9], vital signs obtained from sensors are collected through an ad hoc wireless network. MEDiSN [10] is a sensor network platform for automating physiological monitoring of patients in hospitals and in mass disasters. Furthermore, studies that collect patient's vital signs using mobile information terminals, such as PDA (Personal Digital Assistance), have been conducted [11], [12].

However, in order to check information and to enter information, health care workers have to hold the PDA on their hand. Therefore, they cannot use any hands prohibiting them from performing necessary immediate medical treatment in parallel. In addition, there are other problems in current training systems. In the case of current training systems, biological information of patients does not change as an actual disaster situation, because health care workers make diagnosis based on written paper. Moreover, health care workers perform treatment action and transportation action according to the given manual. An additional problem is that frequent training is impractical, because it requires participation of many health care workers and people acting patients, and also requires considerable time and effort to create a scenario of the training and setting up the equipment. The Emergo Train System allows for frequent training because it does not need any actors to play patients, but it does not reproduce a real disaster site or gives a sense of reality. Moreover, the existing training systems cannot utilize triage records or action histories.

3 DISASTER-RELIEF TRAINING SYSTEM USING AUGMENTED REALITY AND VOICE INPUT TRIAGE

Disaster-relief trainings need to be done frequently in order to make effective use of the developed system in real disaster situations and carry out emergency lifesaving activities at an actual disaster site quickly and accurately. However in the current training patient's vital signs does not change actually so it is less of a reality. Moreover reproducing a real disaster site is difficult and sharing the status of training is insufficient. Also writing paper tags or using PDA hinders the necessary immediate medical treatment that they must conduct in parallel, and slows down the speed of triage.

Therefore we need to develop disaster-relief training system where health care workers can perform triage with their hands free and conduct training in consideration of biological information without imposing time and effort.

3.1 Reproducing Disaster Situation

In triage based on the START method (Fig. 1), vital signs such as respiratory rate, pulse rate and SpO_2 (oxygen density in blood) become the key element to determine the priority. Therefore, it is necessary to prepare those patient information upon conducting a training. However, it is difficult to ask persons who are actually injured to participate in a training. Although vital signs can be gathered from healthy participants, their values are normal and cannot be used for the training to detect any abnormality. In a current training, abnormal values of vital signs are written on a piece of paper and triage is performed by referring to those static information. However, actual vital signs changes constantly. It is sometimes necessary that some play a role of indicating a sudden change to symptoms. Therefore, training system is desirable which can reproduce dynamic patient information that constantly changes.

Figure 3: Monocular HMD and Wi-Fi camera

In addition, it is important in a real diagnosis to see the positional relationship between a patient and a health care worker. A health care worker approaches a patient, touches the body directly and checks the detail of injury. In order to make a diagnosis correctly, a health care worker needs to see the body closely. Therefore, we need to reproduce the state changes associated with the positional relationship in the training system. In our system, the distance between a health care worker and a patient and the direction are used to change how much patient information is shown.

3.2 The Voice Input in the Triage

It is desirable to conduct triage in less than one minute per patient. However, in a chaotic situation, there is a possibility that health care workers may make a mistake to determine the priority, or may forget the detail of the START method. Furthermore, they cannot use any hands while writing paper tags or using PDA, and cannot fully perform treatment actions allowed for the triage, such as 'astriction' and 'airway control'. As a result, the triage may take more time.

We have designed voice input function with which health care workers can perform triage quickly and accurately while keeping their hands free. In addition, we use Vuzix's TacEyeLT as our monocular HMD, Ai-Ball's Trek as our Wi-Fi camera to recognize AR (Augmented Reality) markers attached to patients, and Apple's iPhone4S as our terminal for screen output to the HMD (Fig. 3). Health care workers operate our system by answering questions displayed on the HMD screen. The questions are also offered as sounds through the earphone so that they can operate without relying wholly on the screen. Answers to the questions are either two choices such as 'Yes' or 'No' or simple choices which they can answer easily. Moreover, the questions are customized according to each patient's vital signs such as respiratory rate and pulse rate. These functionalities reduce the burden of the thinking of the health care workers and their mistakes of triage.

3.3 Sharing of Training Result

One of the important things in training is to repeat basic trainings [13]. Especially, it is important that health care workers can find their weak points by themselves after each training is done. However reviewing the result of training is really hard because current training systems use a whiteboard to share training logs such as progress of triage, patients' biological information, health care workers' actions, and so on.

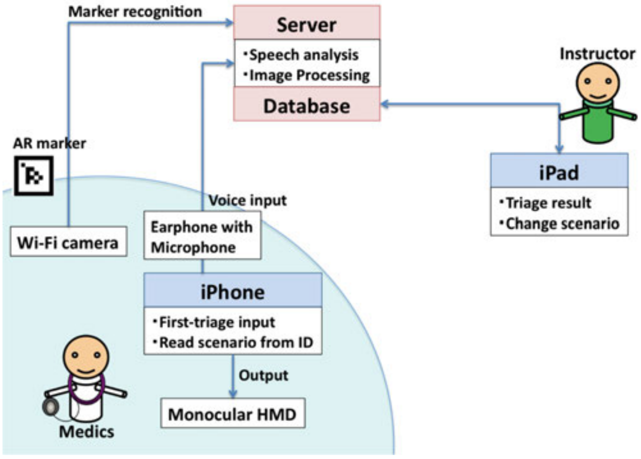

Figure 4: Configuration of the system

Only those who wrote texts on the whiteboard may understand them. The training is more effective when it is carried out with a group of people. After the training, it is important to review the training logs as well as to understand the situation of other participants. Reviewing the action history after the training enables to analyze mistakes of triage.

4 IMPLEMENTATION

4.1 System Configuration

Figure 4 shows the overall configuration of the system. A health care worker and an instructor use the system as a pair. The health care worker who performs triage is equipped with an iPhone and a monocular HMD to which an earphone-mike and a Wi-Fi camera are attached. Sight of user's one eye is not always be completely blocked, and users can see the HMD screen by looking at the upper part of the glasses. The instructor evaluates health care worker's training using an iPad.

First, in the training site the instructor places AR markers which are used instead of patients. When the health care worker looks at an AR marker via the Wi-Fi camera, the scenario of the patient corresponding to its ID number can be read. Beforehand, the instructor sets up each patient's biological information such as vital signs and the tag color, as that person's scenario. During the training, the vital signs simulating a real patient is generated depending on the tag color, and the information management server keeps updating the information at regular intervals. When viewing the AR marker, the health care worker can carry out triage with voice input by referring patient's information in the monocular HMD. After the triage result is stored, health care workers can check the tag color by looking at the AR marker again. Via the network, the database stores scenario information created by the instructor, the voice inputs from the health care worker, the result of triage, the result of marker detection and the result of monocular HMD output. This database enables output of the training result in real time.

4.2 Training System by Reproducing Disaster Situation Through the Monocular HMD

In our training system, patients are represented by AR markers in a training space. Therefore, the preparation is easy:

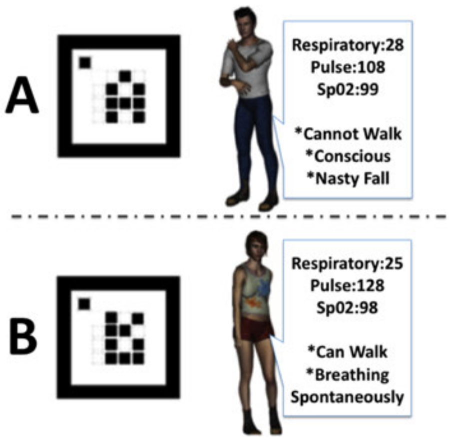

Figure 5: Different scenario depending on ID numbers

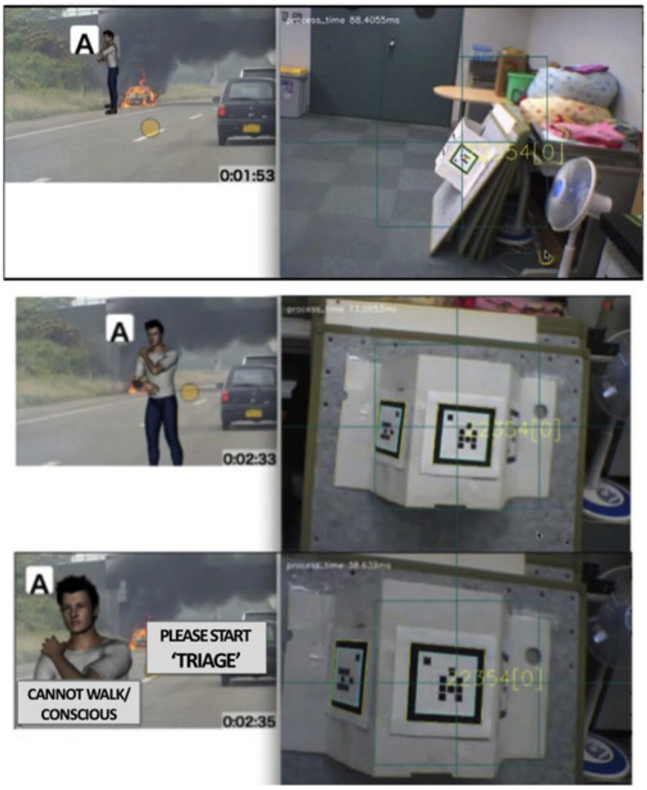

Figure 6: Difference by distance and orientation from markers

placing AR markers in the training space. When a marker is recognized by a Wi-Fi camera, the patient's scenario can be read according to its ID number (Fig. 5). The reasons why we use AR markers are: anyone can create them easily, and they prevent from misreading ID numbers. We use AR markers looking like alphabets.

The presentation of patient's information changes according to distance and direction of markers. When performing triage, a health care worker should face the patient. Therefore, we reproduced the difference of face-to-face state and side state by the orientation of markers (Fig. 6). The left images are displayed on the health care workers' monocular HMD and the right images represent the direction and the distance of AR markers.

Also Figure 6 shows the states depending on the distance

Figure 7: Interface of the triage input during training

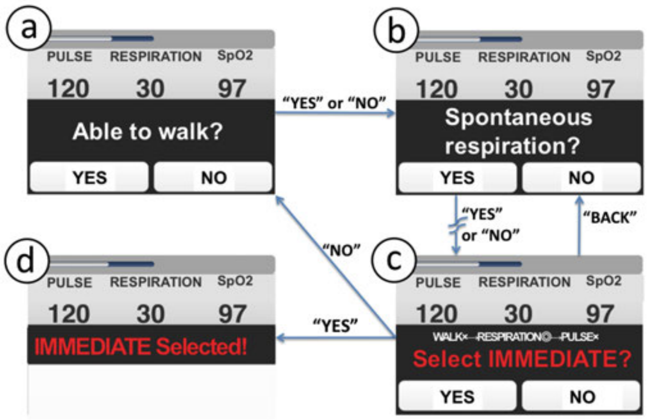

Figure 8: Triage input flow

from markers. For example, triage can be done only when the distance is less than one meter. According to the distance, the displayed patient's information changes as follows:

- One marker within one meter:
  Can perform triage and can see all the patient's information.
- More than one marker or one marker beyond one meter:
  Cannot perform triage and can see only some information of patients. The scene is displayed from afar and a diagnosis cannot be made.
- Marker outside of view:
  Cannot triage and cannot see patient information.

If the health care worker says "start" in the bottom screen of Fig. 6, interface of the triage input is displayed at the right side of the screen (Fig. 7).

4.3 Input Interface of the Triage

Figure 8 shows the input interface flow of the triage. The bar on the top of the screen shows the best timing of voice input. Underneath the bar, health care workers can see respiratory rate, pulse rate and SpO_2. The questions for determining the medical treatment priority based on the START method are displayed in the middle of the screen, and health care workers can answer the questions using voice input. We have designed each item so that it can be recognizable on a small display of monocular HMD.

If the camera recognizes an AR marker, it will move to the state where triage can be started. If the health care worker

Table 1: Vital sign parameters

Triage color	Consciousness	Parameter		
		Respiratory	Pulse	SpO_2
Red	Yes or No (Pattern I)	under 10 or over 30	50–180	90–99%
Red	Yes or No (Pattern II)	1–50	under 50 or over 120	90–99%
Red	No (Pattern III)	1–50	20–180	90–99%
Yellow	Yes	10–30	50–120	90–99%
Green	Yes	10–30	50–120	90–99%
Black	No	0	0	0%

says "start", it changes the screen as is shown in (a), and the health care worker can answer questions one by one. The system judges automatically the value of vital signs acquired from the patient, and the next question is selected as is shown in (b) and (C). After selecting the priority as is shown in (d), the triage result is sent to the database. If the health care worker makes a mistake, he/she can say "back" and the triage can be redone from the beginning. Thus, the health care worker can conduct triage without using any hands, and necessary immediate medical treatments can be performed in parallel.

4.4 Generation of Simulated Vital Signs

Our system generates simulated vital signs such as respiratory rate, pulse rate, and SpO_2 dynamically as Table 1 according to each tag color. The values have been determined from the discussion with emergency medical specialists at Juntendo University School of Medicine.

The vital signs are generated at random by our system. We set the upper limit of respiratory rate to 50 breaths per minute and pulse rate to 180 beats per minute. We also set the delta per unit time. Breathing rate's delta is less than 10 breaths per minute, pulse rate's delta is less than 20 beats per minute and SpO_2's delta is less than 1 percent per minute. This is to eliminate the impractical values and changes in a real situation. We have three patterns which generate vital signs depending on patients' condition in a case that the triage color is red. Pattern I is when the breathing rate is abnormal and pattern II is when the pulse rate is abnormal. Pattern III is when patients are unconscious. This provides health care workers with criteria by means of biological information to decide who need to be given priority for treatment and transportation among multiple numbers of casualties with red tag. In our system, when patient's condition changes from green or yellow tag to red tag, it is defined as 'sudden change'. If there is sudden change to somebody, health care workers can recognize it via the monocular HMD.

4.5 Interface of Training Result

After a training, reflecting on one's own actions is very important. Figure 9 shows the display of the training history as seen on the iPad by the instructor. The instructor can see information such as patient's image according to its ID, when each patient was carried, when each patient was transported, when each patient got sudden change, when triage started, when it finished, how long it took, and how many mistakes were made. The instructor can look back on the flow of triage and the cause of mistakes based on this information. In addition, since the information will be updated in real time during the training, the instructor can continuously monitor how each

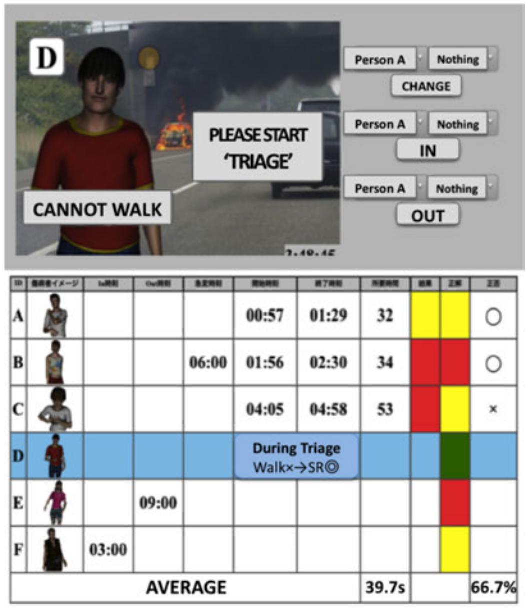

Figure 9: Interface of training result

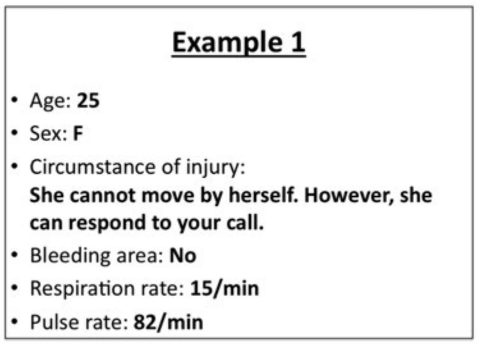

Figure 10: Example of a patient

health care worker is performing. The top left of Fig. 9 shows the monocular HMD display as seen by a health care worker. The top right shows buttons to change scenario during training. By using these buttons, the instructor can add other patients or delete current patients and make sudden change to arbitrary patients.

5 EVALUATION

5.1 Evaluation of the Triage Input Interface

5.1.1 Procedure

In the first evaluation, we compare our triage input system by voice and the current system of using paper based tags. Each examinee performs ten times of the triage based on the example of the patients shown in Fig. 10. In the experiment, person type sleeping-bags are used instead of patients. An examinee performs 'airway control' by raising the patient's head, and 'astriction' by connecting bleeding part with a string, and 'check of consciousness' by talking to the patient. A sheet of paper on which injury is written (i.e. Fig. 10) and an AR marker are attached to each patient (i.e. a sleeping bag). In the case of paper tag system, we asked to write the patient number, the start time, examinee's name, the tag

Table 2: Result of the triage input

	Paper Tag	Our System
Required Time (sec)	67.7 ± 17.4	32.7 ± 12.8
Correctness (%)	86 ± 35	97 ± 17

Table 3: Questionnaire result of the triage input

Question	Score
Was the triage input easy?	4.5
Were you able to perform medical treatment in parallel?	4.0
Was the screen on the monocular HMD easy to understand?	3.7
Did you feel tired?	3.8

color, and the diagnostic flow on the paper tag. In the case of using our system, the system records these items automatically. We selected ten students as examinees. Five of them started off with the paper tag system and then used our system, and the other five did in the reverse order. Because we wanted to compare the paper tag system with our system by the first evaluation, we did not consider the distance and the direction with the AR marker. We wanted evaluate whether examinees were able to perform triage using the monocular HMD with voice input.

5.1.2 Result

Table 2 shows the results. In the T-test, there are significant difference of 5 % levels of significance both in Required time and Correctness. Firstly, we focused on the 'required time' for input the triage. When our proposed system was used, the required time for triage per person was shortened for 35.0 seconds compared with the paper tag. In addition, it is desirable to conduct triage in less than one minute per patient. With our system the examinee was able to perform triage in 32.7 seconds. In the case of using paper tags, it was hard to carefully choose selection conditions of the START method and it also took time to record many things on paper tags. In the case of our system, examinees only needed to answer to given questions, and could perform the triage easily. In addition, they were able to perform medical treatment in parallel.

Secondly, if we focus on the 'percentage of correct answers', our system is 11 point better than the system using paper tags. The main reason of the improvement is that our system supports examinees to determine the priority by only judging patient's vital signs so that they may not need to remember the START method fully.

Furthermore, Table 3 shows the result of the questionnaire about usability. In the evaluation, five is best, one is worst in each item. The questionnaire result shows the triage input was easy and hands free was realized. For those reasons, we have confirmed the usefulness of our input interface for the triage.

5.2 Evaluation of Simulation Disaster-Relief Training

5.2.1 Procedure

We examined whether examinees were able to easily construct training environment and perform simulation training

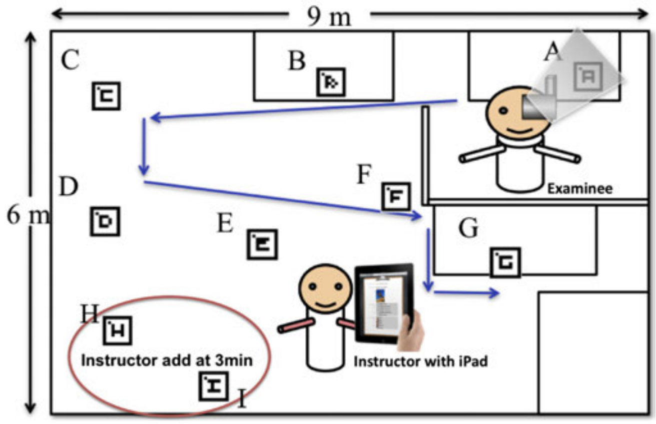

Figure 11: Evaluation of simulation disaster-relief training

while wearing the monocular HMD. Examinees were put into pairs consisting of a health care worker and an instructor, and carried out preparing a training environment, responding to sudden patient's condition changes, transporting patients, and performing triage. The disaster scenario used in the evaluation was a traffic accident involving two automobiles, and seven people were injured. There were two persons with red tag (Patient B and E), three persons with yellow tag (Patient A, C and F), two persons with green tag (Patient D and G), and none with black tag. These data are taken from a report of the triage training conducted at the Urayasu Hospital of Juntendo University School of Medicine.

Before training, the instructor prepares the training environment by placing AR markers according to Fig. 11 for the scenario prepared in advance (instructor's event 1). Once the training started, the health care worker perform voice input triage while looking at patients and their information displayed on the screen through AR marker recognition by the Wi-Fi camera attached the HMD (health care worker's event 1). At this time, the health care worker conducted triage in turn from Patient A to G along the blue arrow in Fig. 11. Also, the instructor produced/added the following events according to the scenario while confirming the triage officer's performance. As the notification of the added events were displayed on the triage officer's monocular HMD, he/she needs to stop conducting triage and respond to the events. For instance, if the instructor adds Patient H as the event, the notice "Patient H was newly added" is displayed on the triage officer's monocular HMD.

- At 3 min: The instructor adds Patient H with red tag and Patient I with yellow tag (instructor's event 2). The instructor place AR markers corresponding to the patients. The health care worker confirms new patients and accepts the event (health care worker's event 2).

- At 6 min: The instructor generates a sudden change to patient B's condition (instructor's event 3). The health care worker goes to the patient and handles accordingly (health care worker's event 3).

- At 9 min: patient can be transported out from the scene (instructor's event 4). The health care worker decides that two patients assigned red tags should be transported (health care worker's event 4).

Table 4: Average time required for instructors

(event 1)	Time required to place AR markers	75.2 s
(event 2)	Time required to place AR markers for additional scenario	18.4 s
(event 3)	Time required to create scenario when sudden change occurs	7.6 s
(event 4)	Time required to create additional scenario of removing patients from scene	9.3 s

Table 5: Average time required for health care workers

(event 1)	Triage time per person	32.6 s
(event 2)	Time required to respond to notice new patients	8.4 s
(event 3)	Time required to take action in response to noticing sudden changes	47.1 s
(event 4)	Time required to decide on which patients to transport from scene	73.3 s

Table 6: Results of training questionnaire

	Question	Score
Health care worker	Was it easy to understand the presentation of patients information?	4.3
	Was it easy to see patient information on the HMD?	3.7
	Did voice recognition work satisfactorily?	3.1
	Was it easy to notice events?	4.6
	Did you see improvement in results?	4.1
	Did you work without feeling fatigue?	3.5
Instructor	Was it easy to understand the implementation status of triage?	4.3
	Was it easy to change the scenario?	4.5
	Did you feel like an active participant in training?	4.0
	Was it easy to find areas of improvement for the health care worker?	4.2
	Was it easy to implement training using this system?	4.1
	Did you work without feeling fatigue?	4.6

After the training, the instructor informs the health care worker of the elapsed time and the accuracy rate, and they exchange some comments. The examinees in this experiment were 10 pairs of students.

5.2.2 Result

Table 4 shows the average time required by the instructor for each event, and Table 5 shows the average time required by the health care worker for each event. The health care worker's event 1 represents the ten health care workers' average time required for conducting triage per one patient. The other event was only once occurred in each training and the average time of ten people, the instructors and the health care workers each, was calculated. The experimenter measured the time in a stopwatch. In the health care worker's event 2, the experimenter measured the time between when the notice of the added event was displayed and when he/she accepted.

For instructors, the results show that the required time for each event was very short. It was possible to construct a training environment around one minute, and to modify scenario less than 20 seconds during training. On the other hand, the required time of health care workers needed to determine tag colors was an average of 32.6 seconds per patient. Because triage is ideally performed in one minute per patient or less, we can say this is a useful result. Moreover, the results were similar to the experiment 1 and the trainees could make efforts in training without disturbing becoming skilled in triage even if the patients were virtualized. Health care worker's event 2, 3 and 4 show that health care workers completed correct actions in a short time when instructors added those events. These results show that health care workers responded quickly to various situations that occurred in triage. In addition, Table 6 shows the questionnaire results about the training. In the evaluation, five is best, one is worst in each item. The questionnaire results show high score for all items pertaining to both health care workers and instructors. Thus we have confirmed the usability of the training using our system.

However, according to the network crossing and the light quantity in the training environment, our system was hard to detect of AR markers. Furthermore, the pronunciation that was hard to be performed voice recognition depending on a user was found. The improvement of the system which is not influenced by the personality of user and training environment will be necessary.

6 FUTURE WORK

The problem of introducing this proposed system is how to recognize the patients and obtain biological information. The research and development of the electronic triage system are now carried out flourishingly and the small electronic tags that incorporated a biological sensor in the radio sensor network device equipped with a small CPU were developed as the substitute of the paper triage tags [14]. We consider that it is possible to use this proposed triage system in the real spot by sticking the AR markers on the electronic tags and attaching them to the patients. We would like to inspect whether our system can be introduced into the real spot with combining the electronic triage tags and the AR markers.

7 CONCLUSION

When a large number of people are injured at the same time, health care workers first need to perform triage in order to decide the priority for treatment depending on their severity of injury and the urgency of treatment. Nowadays, electronic triage systems that use PDA have been studied intensively. However, the operation of the devices may slow down the triage and become an obstacle for conducting necessary treatment in parallel. In addition, disaster-relief training is very important for health care workers to be accustomed with real disaster situations and to know how the electronic triage system works before it is actually used. In the case of current training systems, biological information of patients does not change as an actual disaster situation, and frequent training is impractical. Furthermore, there are many other problems in current training system.

In this study, we have developed disaster-relief training system with monocular HMD and AR markers and can control the system via voice input. In our training system, patients are represented by AR markers, so the preparation is easy, and enables to reduce cost and human resources. The presentation of patient's information changes according to distance and direction of markers and their vital signs are generated at random by the system. In addition, the training result can be shared after the training. We also enables to health care workers perform triage with their hands free to conduct necessary immediate medical treatment even while doing triage.

After conducting the experiments of triage input interface and simulation disaster-relief training, we have confirmed that it is possible to determine the priority faster and more accurately with voice input than the current paper tag system, and make disaster-relief trainings more meaningful.

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