Interactive Haptic Virtual Collaborative Training Simulator to Retain CPR Skills

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Abstract. This paper provides a novel approach for training in collaborative environment by integrating collaborative virtual environment (CVE) and haptic joystick. Active World is used as the CVE and Novint Falcon is the preferred haptic device to send force back to the user(s). As our test scenario, we consider cardiopulmonary resuscitation (CPR) skills training simulator for re-training purpose. CPR is not just a compress-and-release procedure - it is a collaborative work and is affected by the performance of each team member. This study also explains the transferability of the CPR skills from this system to the real world case. The data collected from 12 participants verify that this simulator helps users to improve the accuracy of compression rate, and also to retain the skill afterwards.

Keywords: Collaborative Virtual Environment, CVE, Haptics and CVE, Medical education, Collaborative Haptics Training Simulator, CSCW and Haptics.

1 Introduction

Computer Supported Cooperative Work (CSCW) has been a rapidly growing research field after the invention of the Internet. According to Baecker [1], CSCW is an activity, which is performed by groups of collaborating individuals in a computer-assisted environment. He also visualizes CSCW in a form of 2 X 2 matrix of location (local site, different sites) and time (synchronous, asynchronous). Most of the time, CSCW is considered to be a work done by the users located at different sites [2].

Collaborative Virtual Environment (CVE) is generally considered as the combination of CSCW and Virtual Reality (VR) [6]. According to [2], in CVEs, participants share a common virtual environment and are connected to it through a computer network. Participants have their own avatar(s) to represent their identity, location, actions, and gestures. Participants are also able to communicate with each other from within the environment. CVEs are best suited for education as they are capable of providing group discussion (plain text, audio, and/or video), and can also support different media (text, audio, video) to display information about particular topics to the participants. Dickey [5] mentions that a CVE consists of three major components: (a) 3D space illusion; (b) a character to represent real user, called as "avatar"; and (c) an interactive communication environment.

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Medical education is, however, slightly different from traditional form of education. Apart from cognitive part of the education, developing psycho-motor skills is also equally important. So far, most of the research on education using CVEs is based on disseminating information to the participants in audio-visual media format. There have been numerous virtual reality based simulators that help the participants learn psycho-motor skills in addition to cognitive skills. However, most of these simulators are standalone and only one participant can access the system. In real world emergency cases, there is a team and each team member has his/her own task to perform. They switch their role back and forth during the same emergency care session. Clearly, this approach of educating medical professionals or medical students is not suited for medical education because not only are the participants communicating with each other, but are also performing psycho-motor activities at the same time.

In this paper, we attempt to solve the issue of collaborative medical education by providing a novel approach of integrating CVE with haptic joystick. This work is a part of advanced cardiac life support (ACLS) procedure, which is a collaborative task, where CPR is one of the most important procedures. In this paper, we focus on the chest compression part of the CPR to re-train the users who have basic idea on how to perform CPR but haven't practiced it for some time. This kind of scenario might occur when clinicians are preparing for continuing medical education although they are not actively performing CPR on patients. Simulators of this kind will be helpful to provide hands on experience in addition to theoretical learning. A participant, who has access to the haptic device, must maintain the rate of 100 compressions per minute while performing CPR on the haptic device. The participant is provided with haptic feedback at real time. Based on his/her performance s/he is given visual feedback in the CVE, so that s/he can improve his/her performance. His/her performance can also be seen by other users who are logged into the system at the same time. This study also intends to check whether the participants retain the CPR skills afterwards.

The paper is organized as follows: we outline related work in Section [2]. The overall system design, methodology, and implementation of the simulator are explained in Section [3]. The experimental design, setup, and participants are described in Section [4]. The results obtain from the simulator are presented in Section [5]. Finally, Section [6] concludes the paper.

2 Related Work

Although CVEs are being used in gaming, socializing, educational as well as working environments [9], only a few selected CVEs can be used in the field of collaborative education. [9], [10] outline different functionalities that should be present in a CVE in order to be suitable for educational purpose.

Boulos, Hetherington, and Wheeler [3] described the potential use of Second Life in medical and health education. They discussed about the use of Healthinfo Island in Second Life for education that is run by a team of information professionals and medical/consumer health librarians. The authors also gave example of virtual neurological education centre (VNEC, www.vnec.co.uk) in Second Life. According to the authors, users were able to learn about neurological disorders by selecting various neurological symptoms in VNEC. The result would be shown by animating their avatars with restriction on their movement and coordination.

Creutzfeldt et. al designed a procedural CPR training system in a virtual world. The authors focused on providing training on various diagnostic steps required during medical emergency. The participants were given questionnaire to get information about the qualitative experience. Based on the response to the questionnaire, the authors mentioned that the training in virtual world offers several advantages.

Pascale, Mulatto, and Prattichizzo [8] proposed and implemented a new idea of using haptic device in a CVE. The idea behind the research was to help blind people to navigate around Second Life with the help of joystick. Instead of visual cues, auditory signals were provided to the users.

To the best of our knowledge, no existing training simulator has been developed for CPR training by integrating haptic device and virtual world, together with the capability of evaluating the performance of the participants.

3 System Design

The design consists of two major components: a CVE, and a haptic device. We used Active Worlds (AW, www.activeworlds.com), which is a CVE and provides its own API that makes it easier for developers to design customized virtual environments. AW allows 30 users to login simultaneously, which provides a platform to perform collaborative work. The haptic device that we used in our system is Novint Falcon haptic device (www.novint.com). The device comes with its own HDAL haptic API that provides different control mechanisms to communicate with the Falcon haptic device. We integrated these two components using their APIs. How the system is developed is explained in sub-section 3.1.

Figure (1) shows the overall design of the system. The direction of the line indicates the information flow.

3.1 Methodology

This research is part of ACLS training simulator in which people work in a collaborative environment. The major objective of this system is to re-train users to perform CPR skills, who already know how to do it, but haven't practiced for some time. Each user's performance is displayed in the CVE (active world). To achieve our goal, we divide the objectives into a set of subtasks.

The first subtask is to calculate force. When participants perform compression, force is calculated and is applied in the opposite direction. The handle of the haptic joystick moves back to the original position, thus simulating 'recoiling'. Mass-spring model is used for its simplicity and efficiency in our system for force calculation. In the proposed system, the force feedback is independent of the visual feedback – it is not necessary to detect collision between the objects in the CVE. This is very important for a collaborative work like CPR because not all members in a team

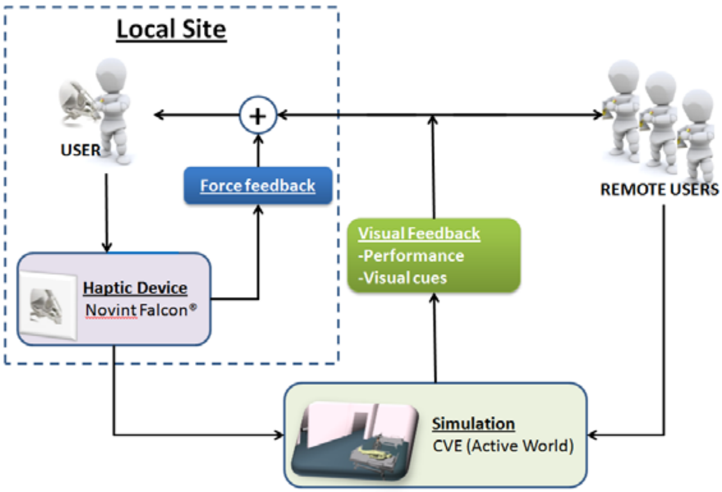

Fig. 1. System Design

perform the same task simultaneously; however, the members switch roles every now and then.

After calculating the force, the number and the rate of compressions are calculated and stored in the local computer, which can be used for the validation of the proposed system.

Once the number and the rate of compressions are calculated, different callback functions, event handlers and attributes provided by Active World SDK are used to visualize the data in the CVE. These data can be seen by all the users who are available at the virtual training location. The output(s) of the system is shown in Figure (2).

Fig. 2. Screenshots from the system: a) Green board for correct compression-rate, b) Red board for lower compression-rate

4 Experimental Design

Each participant has to perform 3 CPR trials. In the first trial, the participants have to perform CPR without any feedback. They have to maintain the rate of 100 compressions per minute. The second trial provides visual cues and feedback. Participants have to synchronize their rhythm of compression with the visual cues provided on the screen. A 'Press' button is used as a visual cue and it becomes visible and invisible maintaining the rate of 100 per minute. Participants have to perform compression whenever the button appears on the screen, and recoil when it disappears. In addition to the visual instructions, the participants are given feedback on their performance. They are shown their compression-rate, number of compressions and a message (if needed). If their compression-rate is less than 90, then the message "Go Faster!" is displayed, and the participants must increase the rate of compressions. Similarly, when the compression-rate is more than 110 "Go Slower!" message is displayed. These two messages are shown in red background, representing that they are deviant to the actual rate. If their performance is between 97 and 103 compressions per minute, the current compression-rate and the number of compressions are shown on a green background. The third trial is similar to the first one; no visual cues and feedback are provided.

For each trial, the number of compressions, time taken for each compressions (in seconds), and the rate of compression is stored. Our hypothesis is that participants perform better when they are provided feedback (second trial) than when they are not (first trial).

Experiment Setup: 12 participants (3 female, 9 male) participated in the experiment. All participants had basic idea about CPR skills and had already performed CPR before. All of them already knew that they had to maintain the rate of 100 compressions per minute. However, they haven't performed it for 2 months. Only 5 participants had experience on using the haptic device before the study, all others were using the haptic device for the first time.

Before the trials, each participant was explained about the system, the experimental design, and what they had to do in the experiment. Each participant was provided a minute to get used to with the simulator. When they were ready, the first trial was performed. An interval of approximately 0.5 minute separated the trials. Figure (3) shows how the system was set up for the experiment.

5 Results and Discussion

Figure (4) displays the number of compressions in each trial performed by each participant. The safe range (90-100 compressions per minute) is highlighted in the figure. For each trial, performance metrics of each participant, like number of compression, time, and rate of compression, were recorded. Almost 60% of the participants could not maintain their rate within the range of 90-110 compressions per minute. The outcome shows that people who know about CPR, but do not practice it often, tend to make mistake in maintaining the required compression-rate. The

Fig. 3. Experiment Setup: CVE shown at the left and haptic device at the right

compression-rate varied from 76 to 126 per minute.The second trial was performed in presence of visual cues and performance feedback. All participants were able to maintain the compression-rate between 90 and 110. The range of number of compressions per minute varied from 95 to 104 in the second trial. Participants performed better in the third trial as compared to the first one. All of them were able to maintain the compression between 90 and 100. The compression-rate varied from 90 to 110.

We, initially, hypothesized that the participants should maintain the rate between 90 and 110, and providing them the visual cues and feedback would improve their performance. In the visual cues, we displayed their compression-rate, and whether they are going fast or slow, in real time, so that even if they were maintaining the

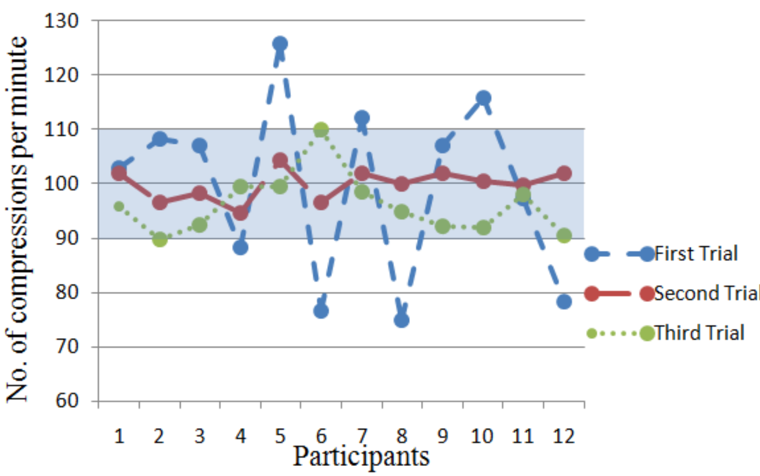

Fig. 4. Performance of 12 participants on each trial (safe-range is highlighted)

required rate, they can improve to maintain it at 100 compressions per minute. Our hypothesis was verified; when they were provided the cues, they performed much better than when they were not given feedback on their performance. The compression-rate varied from 95 to 104, which was more than that we expected.

In the third trial, we wanted to check whether the participants could retain the skill or not if visual cues are not provided. From the outcome of the experiment, we can say that they could retain the skills. All participants could maintain within the range 90-110.

The important thing to mention here is that the participants did not practice on this simulator for a long period of time. Based on the results, even in that short period of time they spent with the simulator, they could retain the skills. It is possible only because they already knew how to perform CPR. This proves that this simulator helps the people, who already know about CPR skills, to perform better by providing feedback on their performance and to retain the skills.

5 Conclusion and Future Work

This paper focused mainly on interactive collaborative CPR skills training simulator for the purpose of re-training the users, who already know how to perform CPR but had not practiced for some time. To achieve our main objective, we also presented a novel approach of integrating haptics and CVE by localizing haptic feedback.

The challenges to design this kind of simulator include the integration of the haptic device to the CVE. As most of the CVEs do not provide application programming interface (API), it is very difficult to integrate with haptics API. Once the haptic device is integrated, it requires very high bandwidth to transmit haptic signals over the internet, which is virtually impossible. This is the main reason to localize haptic feedback.

This opens up different possibilities that we can do with the integration of haptics and CVE. Apart from re-training skilled CPR practitiners, this system can be a part of a virtual mock code training simulator where participants perform different tasks during emergency, and they also need to switch tasks in-between. The participants can log in from different locations, and can interactively practice the mock code in the virtual environment.This can also be used as virtual assessment tool for CPR skills. Participants can log in from a remote site to perform CPR. His/her performance will be stored in a server, where only authorized user can login and evaluate the performance.

The future work includes validation of the learning of CPR skills using the simulator for users who do not have prior CPR experience. As this study was pre-validation of the virtual CPR training simulator, we restricted the number of participants to 12; however, for the validation for unexperienced users, the number of participants will be increased.

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