COLLABORATIVE VIRTUAL ENVIRONMENT TO SIMULATE ON-THE-JOB AIRCRAFT INSPECTION TRAINING AIDED BY HAND POINTING.

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ABSTRACT

The human inspector performing visual inspection of an aircraft is the backbone of the aircraft inspection process, a vital element in assuring safety and reliability of an air transportation system. Training is an effective strategy for improving their inspection performance. A drawback of present-day on-the-job (OJT) training provided to aircraft inspectors is the limited exposure to different defect types. Previous studies have shown offline feedback training using virtual reality (VR) simulators to be effective in improving visual inspection performance. This research aims at combining the advantages of VR technology that includes exposure to a wide variety of defects and the one-on-one tutoring approach of OJT by implementing a collaborative virtual training environment. In an immersive collaborative virtual environment (CVE), avatars are used to represent the co-participants. In a CVE, information of where the trainer is pointing can be provided to a trainee as visual deictic reference (VDR). This study evaluates the effectiveness of simulating on-the-job training in a CVE for aircraft inspection training, providing VDR slaved to a 3D mouse used by the trainer for pointing. The results of this study show that the training was effective in improving inspection performance.

INTRODUCTION

Sound aircraft inspection and maintenance are an essential part of safe and reliable air transportation. In the aircraft industry, ninety percent of all aircraft inspection is visual in nature, conducted by human inspectors. Thus, it is critical that a high level of inspection performance is achieved. Human inspection is not completely reliable. Strategies must be deployed that will reduce human error and improve human performance. Training has been identified as the primary intervention strategy to improve the quality and reliability of aircraft inspection (Gramopadhye et. al. 1997).

Traditionally, on-the-job training (OJT) has been a popular method of instruction for performing aviation inspection. However, the drawbacks of this approach have been well documented. In an OJT environment, feedback is scarce and not systematic, and on the occasions that the inspector receives it (e.g., as the result of an audit), it is delayed. Also, although it is desirable to provide feedback on the job, there are instances where this is economically infeasible and in some cases impossible due to time and logistical constraints. In such cases, alternate schemes, such as periodic off-line training and feedback may be utilized.

OJT also does not allow for regularity in the application of learning principles. OJT is restricted to exposing trainees to a limited number of different aircraft structures, especially in the case of wide-bodied aircraft. Often, wide-bodied aircraft are difficult to obtain for inspection training purposes and are only available to the trainee during actual maintenance situations. With such limited exposure to different aircraft, the trainee's familiarization with these aircraft and their individual weaknesses is limited. Likewise, by having a limited array of aircraft to learn from, the trainee also remains unfamiliar with uncommon defects.

A virtual reality aircraft inspection simulator provides a flexible and controlled training environment (Vora et. al. 2001). A collaborative virtual environment (CVE) also allows the co-immersion of the trainer and the trainee in the virtual replica of the aircraft inspection environment. The CVE allows the fabrication of controlled training scenarios that would be infeasible in the physical environment. Of particular importance to collaborative training experiences are deictic references. Deictic references are associated with pointing and verbal expressions such as "look at this". By enabling deictic reference in a CVE, effective communication might be established in the immersive virtual environment. The most common form of deictic reference used in meetings or training in day-to-day life is pointing by hand and representing this visually like in the case of using a laser pointer could be effective in improving communication in a CVE. Thus, OJT may be effectively simulated.

It is hypothesized that a CVE is an effective training medium that would enhance the process of search strategy training for novice inspectors. This paper describes a study conducted at Clemson University evaluating the effectiveness of using CVE as a training medium for an aircraft inspection task aided by a hand-slaved visual deictic reference (VDR).

TECHNICAL DETAILS

The virtual environments are driven by a 1.5 GHz dual-CPU PC with 1GB RAM and an NVidia GeForceFX 5950 graphics card running Red Hat Linux (v8.0 Kernel 2.4.20). Multimodal devices in the lab include V8 Virtual Research head mounted displays (HMD) (Figure 1) that offer 640x480 pixel resolution for each eye, with separate video feeds for the left and right eyes and a 75.3º x 58.4º visual angle. HMD position and orientation is measured using an Ascension Technologies 6-degree of freedom (DOF) Flock of Birds electromagnetic tracker, mounted on the top of the HMD. A binocular eye-tracker is integrated within one of the HMD's. The eye tracking unit is a video based, corneal reflection unit, built by ISCAN. A 6DOF mouse (Figure 1) is used either as a virtual wand for pointing in the CVE or for selecting defects in an inspection task scenario.

Figure 1. HMD and 6-DOF mouse

Vspec, Inspect and Inspector are the software components used in this study, custom developed by Clemson University researchers (Duchowski et. al. 2001). The Inspector program displays the VR scenario to the participants while recording their eye movements. Vspec performs offline analysis of the participant's point of regard (POR) data. The CVE is enabled by Inspect. No data is recorded in the CVE.

Our CVE was implemented by extending a single-user virtual environment to two or more participants. Our shared state repository model is realized by a client-server architecture (star topology), where many clients can connect to the central server. The server contains the only truly valid copy of the world and all world logic runs on the server. Clients enqueue user/world input, and then send these input requests to the server. The server then processes each input, and pushes a new

Figure 2. Avatar of trainee and trainer in CVE with a representation of VDR

world state to each client. To compensate for the delay between sending new input to the server and receiving an updated world state, each client attempts to predict future world states. Multithreaded clients manage the head position and orientation and eye tracking devices only when these devices are active. The client can be thought of as a specialized dumb terminal, since the only processing it performs (other than marshaling user input) concerns representation of the world to the user.

Avatars are used in our CVE are based on MD3 models (model format courtesy of Id Software). Each avatar's eye direction is mapped from the tracked point of regard (POR) of the avatar's human counterpart (Duchowski et. al. 2004). Furthermore, since our eye tracker returns (0, 0) during blinks, we model the avatar's eye blinks by texture mapping a closed eyelid during blinks. Other than the eye movements, the avatars are capable of head rotation and torso movements which follow predefined animation sequences based on the position of the HMD tracker.

Visual deictic reference for the novice is slaved to the orientation of a 3DOF mouse held by the expert and is implemented by displaying a small red dot (Figure 2) at the point of intersection of a ray cast by the 3D mouse and the virtual scenario. The expert gets real time feedback of where he is pointing, i.e. the VDR he provides to the novice, in the form of a blue dot. Head-slaved deictic reference conveys the orientation of the novice's gaze to the expert. Thus, both of the participants in the CVE are provided information regarding what the other person is looking at and it allows for the expert to make sure that he is communicating effectively.

METHODOLOGY

Sixteen Clemson University students screened for visual acuity and color vision participated in this study. It has been demonstrated (Gallwey, and Drury, 1986) that students can be used in place of industrial inspectors for experimental studies of visual inspection. A Pretest-Posttest Control Group Design (Campbell, and Stanley, 1966) was used for this experiment. The participants were randomly assigned to two groups: treatment and control. The treatment group received feedforward search strategy training wherein they observed an expert inspector perform an inspection task while being co-immersed in the CVE. The control group did not receive the CVE training.

Figure 3. Virtual reality model of aft cargo bay

Scenarios used in this study were variations of a texture mapped virtual reality model of an aircraft aft cargo bay (Figure 3) simulating the cargo bay of the Lockheed L1011 aircraft. Five scenarios were used for this study. To familiarize trainees with virtual reality and to allow them to become accustomed to the cargo bay environment, a familiarization scenario with the different types of defects highlighted was used. The defect types were crack, corrosion, abrasion, broken electrical conduit, and hole. Two multiple defect inspection scenarios were developed for the trainees to perform inspection tasks before and after the training session (pre-test and post-test). These scenarios were constructed to be equivalent in task difficulty and contained twenty-two defects of the above-mentioned types. The two multiple defect inspection scenarios were counter-balanced to assure that both groups receive the same number of orderings of the two scenarios. The task involved the participants searching for defects in the virtual inspection scenario. Once they found a defect, they marked it by pointing and clicking using the 3D mouse. The fourth scenario was the training scenario displayed in the CVE to the participants in the treatment group with an expert inspector present. A fifth scenario was one identical to the fourth, except that the control group participants were immersed in it alone, with no training provided so as to isolate the effect of the CVE training.

RESULTS

The collected data was analyzed using Microsoft Excel 2003. The results measured the effect of training provided to novice inspectors in terms of accuracy (the number of defects detected) and efficiency (speed; time taken for the task in seconds). For the control group, the difference between the post-test and the pre-test represents the effect of practice while, for the treatment group, the difference represents the effect of the training coupled with the effect of practice. The effect of training can be isolated by comparing the post-test - pre-test difference for the treatment group with the difference for the control group. The inherent ability of the participants to perform the search task varies. Hence the absolute difference between the post-test and pre-test measures does not represent the actual effect of the training for each individual. This variability is accounted for by transforming the absolute difference to a relative difference. Relative difference was calculated by representing the difference (post-test - pre-test) as a percentage of the pre-test scores for each participant, thus focusing on the improvement of the participant's abilities relative to his or her initial ability.

Once transformed, the relative gains in accuracy and efficiency were analyzed using the t-test. The t-test of the relative difference in accuracy shows that the improvement for participants who received training in the CVE was significantly higher than that of the participants in the control group ($p < 0.01$). Figure 4 presents this result graphically. Using a t-test of the relative difference

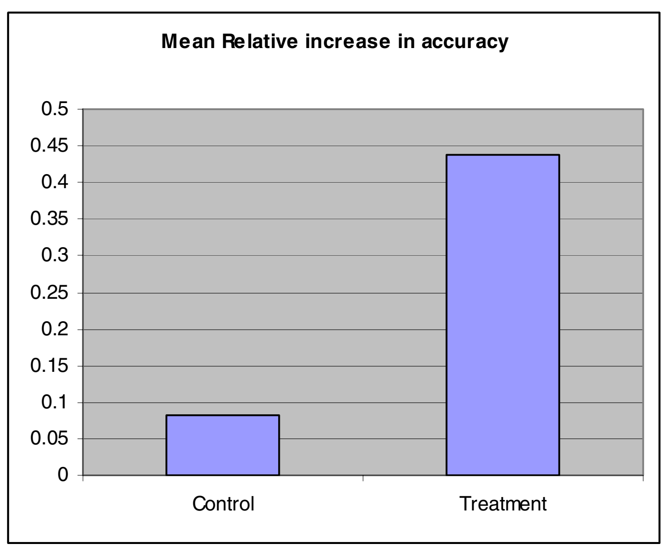

Figure 4. Relative gain in accuracy for the control group and the treatment group.

in time taken to complete the inspection task, no significant difference was found between the treatment group and control group ($p > 0.05$).

DISCUSSION

The objective of this study was to determine if search strategy can be taught using simulated on-the-job training using the collaborative virtual aircraft inspection environment aided by displaying visual deictic reference slaved to the 3D mouse used by the trainer for pointing. The effectiveness of this training was evaluated by comparing the inspection performance of a group of participants who were administered this training to that of a group of participants who did not receive the training.

The results show that CVE training aided by hand slaved VDR was effective in improving the accuracy of novice inspectors in detecting defects. There was no significant difference in the time taken to complete the task for the participants in the treatment and control group. We can be infer that the participants receiving training adopted a more systematic search strategy similar to that of the trainer resulting in them achieving better accuracy in the same amount of time.

CONCLUSION

Thus we see that feedforward search strategy training in a CVE is effective in improving inspection performance. The VDR display technique developed was found to be effective in aiding communication between the expert and the novice in the simulated OJT scenario. We can conclude that search strategy can be taught and can lead to improved aircraft inspection performance.

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