Using Virtual Reality Technology to Support Job Aiding and Training

Sittichai Kaewkuekool, Mohammad T. Khasawneh, Shannon R. Bowling, Anand K. Gramopadhye, Andrew T. Duchowski, and Brian J. Melloy

Department of Industrial Engineering
Clemson University
Clemson, South Carolina 29634-0920

Abstract

The aircraft inspection/maintenance system, which is influenced by based operators and regulated by the FAA, consists of several interrelated human and machine components. In this process, visual inspection plays a significant role in ensuring aircraft safety. To improve the quality and reliability of aircraft inspection, training and job aiding have been identified as the two most important intervention strategies. Both of these have the potential to be improved using new advances in computer technology, especially virtual reality (VR) technology, which is becoming increasingly more affordable and prevalent. As a result, this study will investigate the use of VR technology as a support of job aiding and training in the improvement of aircraft inspection performance.

1. Introduction

The aircraft inspection/maintenance system is a complex one (Drury, Prabhu, and Gramopadhye, 1990; FAA, 1991). There are consisting of several interrelated human and machine components. This system has been affected by the based operators associated with general aviation. Inspection is regulated by the Federal Aviation Administration (FAA) as is maintenance. Moreover, almost all inspection of aircraft maintenance tends to be visual in nature and is conducted by inspectors. Therefore, it is significant that this visual inspection is performed effectively, efficiently, and consistently over time.

Training has been identified as the primary intervention strategy to improve the quality and reliability of aircraft inspection. Moreover, training has shown a powerful effect on inspection performance (Wiener, 1975; Drury and Gramopadhye, 1990;) when applied to both novice and experienced inspectors. If training is to be successful, it is essential that the appropriate training tools and environment be provided to aircraft inspectors. However, training for improving the visual inspection skills is general lacking at aircraft repair centers and maintenance facilities even though its impact on visual inspection skills has been well documented in both the aircraft and manufacturing industries (Moll, 1980; FAA, 1991; FAA, 1993). In particular, the success of off-line training/retraining with feedback suggests that this method can play an important role in aircraft inspection training.

Existing training for inspectors in the aircraft maintenance environment tends to be almost on-the-job-training (OJT) (Latorella et al., 1992). This method may however not be the best method because feedback may be infrequent, unmethodical, and cause delay. In addition, feedback is economically prohibitive or impractical because of the nature of the task. Since the benefits of feedback in training have been well documented (Weiner, 1975; Gramopadhye et al 1997), alternatives to OJT are sought. One of the most viable approaches in the aircraft maintenance environment is computer-based training that offers several advantages over traditional training approaches, which is more efficient while facilitating standardization and supporting distance learning at the same time.

2. Using Computer for Training

With the computer technology becoming cheaper, the future will bring an increase application of advanced technology to training. In the domain of visual inspection, the earliest efforts using off-line inspection training were reported by Czaja and Drury (1981), who used keyboard characters to develop a computer simulation of a visual inspection task. To study inspection performance in laboratory setting, other researches have used similar simulations. Latorella et al (1992) and Gramopadhye, Drury and Sharit (1994) have used low fidelity inspection simulators with computer-generated images to develop off-line inspection training programs for inspection tasks. Similarly, Drury and Chi-Fen (1995) studied human performance using a high fidelity computer simulation of a PCB inspection task. The use of computer-based simulators for aircraft inspection training has a short but rich history (Latorella et al., 1992; Gramopadhye et al., 1994; Gramopadhye et al., 1996; Blackmon et al., 1996 Nickles et al., 2001). The most advanced and recent example being the Automated System of Self Inspection for Specialized Training (ASSIST), a training program developed using task analytic methodology and featuring s PC-based aircraft inspection simulator where an image of a task an airframe is presented to the user for inspection (Gramopadhye et al., 2000). All system users interact through a user-friendly interface, which capitalizes on graphical user interface technologies and human factor research on information presentation, ease of use, and information utilization.

The results of a follow-up study conducted to evaluate the usefulness and transfer effects of ASSIST were encouraging as to the effectiveness of computer-based inspection training, specifically in improving performance indicated by high scores on various usability measures (FAA, 2000; Gramopadhye et al., 2000). The advantages of ASSIST have been seen through usability evaluation, performance evaluation, and post training evaluation. Even though there were some advantages, the simulator is limited by its personal computer (PC) based technology. It lacks realism as it uses only two-dimensional section images of airframe structures and does not provide a holistic view of the aircraft cargo bay. Moreover, the inspectors are not immersed in the environment, and, therefore, they do not perceive the same look and feel of conducting an actual inspection. To address these limitations, virtual reality (VR) technology has been proposed as a solution, and in response a high fidelity virtual reality based inspection simulator has been developed (Duchowski et al., 2000).

3. Virtual Reality (VR)

Virtual reality, described by several researchers (Kalawsky, R.S, 1993; Burdea et al., 1994; Durlach et al., 1995; Heim M., 1998), is most applicably defined as immersive, interactive, multi-sensory, viewer-centered, three-dimensional computer-generated environments and the combination of technologies required building them (Cruz-Neira, 1993). As these definitions suggest, creating a virtual environment (VE) requires immersing humans into a world completely generated by a computer. The human user becomes a real participate in the real world, interacting and manipulating virtual objects. Therefore, human performance is one of the most important considerations in defining the requirements for a virtual environment. During human-computer interaction, abstract values such as ease of use, ease of learning, presence and user comfort become significant (Roy, S.K., 1993). For virtual environments presence, the subjective experience of being in one place or environment even when one is physically situated in another (Singer et al., 1996), becomes the most important measure.

This concept of experiencing "presence" as a normal awareness of attention phenomenon is based on the interaction between external stimuli and immersion factors. Fully immersed observers perceive that they are interacting directly or remotely with the environment. Thus, presence become a subjective sensation or mental manifestation that is not easily amenable to objective physiological definition and measurement, with its strength varying both as a function of individual differences, traits, and abilities and the characteristics of VE. The success of using VR as a tool for training and job aiding, therefore, is highly dependent on the degree of presence experienced by the users of the virtual reality environment. In this essence, it is critical to measures the degree of presence of the VR simulator to support training. If the VR simulator is to be proposed as a solution for off-line training, it is essential that this environment accurately mimic the real world as perceived by the user or trainee. Only then can the effects of training be expected to transfer from the VR environment to the real world.

The results of using VR to perform experiments at Clemson University indicated that the inspectors performance were improved and successful. Analysis of the correlation revealed that the subjects who experienced a sense of involvement in real world experiences also felt involved in the VR experienced. In addition, the subjects who experienced high involvement in the simulator felt that their experiences were as natural as the real world ones. The interface quality and the naturalness of the environment were also significantly correlated, indicating a high level of interface quality in the simulator. Also, the mental and physical state of the person and the tendency to avoid distractions while performing a particular task, that is, "being focused", did not affect the performance of the subjects on the assigned inspection task. Figure 1 shows the physical features of the real aircraft cargo bay.

Figure 1. Aircraft cargo bay physical environment

The performance measures (search time, stopping time, defect detection accuracy and incremental stooping time) and process measures (number of fixations, percentage area covered and fixation times) were analyzed. The results showed improvement in inspection performance by improving speed and accuracy after training. The performance group after receiving outcome information during the training session improved inspection performance by reducing search time and stopping time, and increasing detection accuracy. This reinforces the finding from other studies (Parkes and Rennocks, 1971; Czaja and Drury, 1981; Micalizzi and Goldbegr, 1989) that outcome or performance feedback enhances performance.

The cognitive feedback group received task information in visual and statistical form. This change in search strategy helped subjects in the cognitive feedback group to reduce the search time but increased the stopping time and there was a considerable improvement in the accuracy with an increase in detection accuracy. Higher stopping times and a larger number of fixations showed that to compensate for the lack of performance feedback information and its potential for influencing the effectiveness and efficiency of their search strategy. Without the performance feedback, subjects were not completely able to realize the impact of strategy changes on inspection performance, thus degradation in search efficiency with higher stopping times improved search accuracy.

As a result, it can be concluded that the use of the VR system provided crucial information to training. Moreover, it was favored over the existing PC based ASSIST system. Therefore, it seems that the VR system has the potential to be used as an off-line training tool for aircraft visual inspection tasks. The use of the VR based inspection environments will facilitate conducting controlled studies off-line, and aid in understanding human performance in aircraft inspection.

4. Aiding Tools

Even though VR has shown significance in improving inspection performance, training programs are still one of many considerations in any attempt to improve inspectors' performance. Training for inspection has been found to be universally beneficial in improving inspection performance both for experienced and novice inspectors. However, the use of analytically based training strategies in the aircraft maintenance industry is limited. Although a wealth of laboratory data has been gathered on training and learning, the application of this knowledge to inspection in the aircraft maintenance domain is an expectation rather than a rule. Researchers still do not know how the various training methods can be integrated into a well-designed training program to improve inspection performance. The

questions arise on what kind of training is appropriate to improve inspection performance. The VR environment will help us in conducting studies that investigate the effect of using job-aiding tools during training. Figure 2 shows the use of a virtual flashlight in virtual environment of the aircraft cargo bay that has been developed at the VR lab at Clemson University.
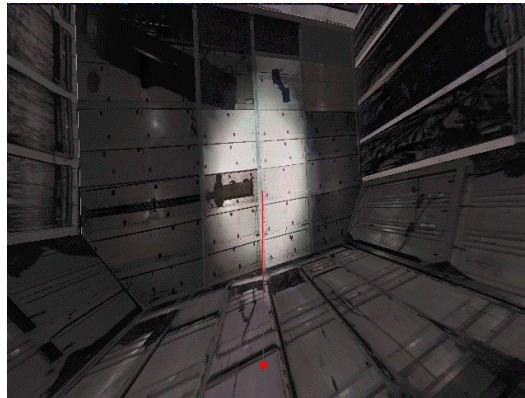

Figure 2. The virtual environment of the aircraft cargo bay.

In the real world, inspectors have to perform tasks under several conditions (e.g. dark area, narrow area or angle of aircraft cargo bay). Under these situations, aiding tools become of great importance for inspectors to better perform their tasks. Moreover, a large but critical component of inspector's work is extremely procedural (e.g. includes the use of tools, writing up non-routine card, looking up information in manuals and following procedures, etc). Although some of these activities are extremely procedural in nature, evidence exists to lack of adherence to those procedures when conducting inspection. This has often resulted in incorrect maintenance actions, incidences and accidents. The performance on this activity can be improved through training and through the use of job-aids. The VR environment will help us in conducting studies to identifying the appropriate mix of training strategies and job aids to improvement performance on procedural tasks, which will be the focus of our research.

5. Conclusion

Training has been identified as the primary intervention strategy to improve the quality and reliability of aircraft inspection. Therefore, the main objective of this paper is to review and evaluate the use of virtual reality technology as a job-aiding and training tool in the aircraft maintenance industry. The paper discusses the use of computer based tools for training, and describes how virtual reality technology can be used to support training and improve inspection performance.

Biographical Sketch

Sittichai Kaewkuekool is a PhD student in the Department of Industrial Engineering at Clemson University. He received his B.S. in Production Technology Education from King Mongkut's Institute of Technology, Thonbui, Thailand, and M.S. in Industrial Engineering from the University of Miami, FL. His research focus is in the use of advanced technology systems for improving human performance in quality control systems.

Mohammad T. Khasawneh is a PhD student in the Department of Industrial Engineering at Clemson University. He received his B.S. and M.S. in Mechanical Engineering from Jordan University of Science and Technology, Jordan. His research interests are in the development of advanced technology to solve interesting human-machine systems design problems, and modeling humans in process and quality control systems. He is a member of the Institute of Industrial Engineers and the Human Factors and Ergonomics Society.

Shannon R. Bowling is a PhD student in the Department of Industrial Engineering at Clemson University. He received his B.S. in Electrical Engineering Technology from Bluefield State College, WV, and M.S. in Quality Management from East Tennessee State University. His research focus is in the use of advanced technology systems for improving human performance in the aircraft maintenance industry.

Dr. Anand K. Gramopadhye is professor of Industrial Engineering at Clemson University, South Carolina and associate editor of the International Journal of Industrial Ergonomics. His research is focused in the areas of modeling humans in quality and process control systems, inspection, aviation human factors and issues related to the use of advanced technology in solving human-machine systems design problems in aviation and manufacturing systems. He has published over 100 papers on the above topical areas and his research has been funded by various private and federal sources. He is a member of IIE, ASQ and HFES.

Dr. Andrew T. Duchowski is an assistant professor in the Department of Computer Science at Clemson University, South Carolina. He received his B.Sc. and Ph.D. degree in computer science from Simon Fraser University, Burnaby, Canada, and Texas A&M University, College Station, TX, respectively. His research and teaching interests include visual attention and perception, eye movements, computer vision, graphics, and virtual environments.

Dr. Brian J. Melloy is an Associate Professor in the Department of Industrial Engineering at Clemson University and a registered Professional Engineer. His area of specialization is applied operations research, with a research emphasis in visual inspection. He is currently developing mathematical models for the purpose of predicting visual search outcomes in the inspection of commercial aircraft and reusable space vehicles. Both this research, and his prior research in visual inspection, have been disseminated in numerous publications and have been supported by the government and private sectors. He is a member of the American Society for Quality, the Institute of Industrial Engineers and the Institute for Operations Research and the Management Sciences.

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