

USING HAPTIC TOOLS TO EXPLORE FUTURE COMBAT SYSTEMS DESIGN ISSUES

Piotr Windyga, Adam Schmidt, Allison Griffin, Gary Green

Institute for Simulation and Training (IST)
University of Central Florida
Orlando, FL

pwindyga@ist.ucf.edu, x32932@usma.edu, ist.ucf.edu, agriffin@ist.ucf.edu, ggreen@ist.ucf.edu

Chris Metevier

Simulation, Training and Instrumentation Command (STRICOM)
Orlando, FL

Chris_Metevier@stricom.army.mil

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ABSTRACT

The planned integration of a Future Combat Systems (FCS) Virtual Crew Station with haptic peripherals is a major step forward for the development of training systems for the United States Army. This paper reports on a new approach for defining the way soldiers train. The system will allow soldiers to train faster and more effectively than ever before. The key steps in developing such a design are high level architecture design, equipment elicitation and selection, concrete configuration, software installation, interface development, and testing.

The intent of this effort is to conduct experiments involving Future Combat Systems concepts in support of FCS and the Objective Force. Essentially, STRICOM and IST are attempting to create solutions to potential problems. An example of a potential experimental effort would be the study of how to train a soldier to process the massive flow of information or inputs that he/she receives during combat operation of the Future Combat Systems.

The project is still in its initial stage of development, but tremendous progress has been made. At completion of Phase 1 this fall, the human-machine interface will be used to conduct experiments under Phase 2.

ABOUT THE AUTHOR

Piotr Windyga is a Senior Computer Research Scientist at the Institute for Simulation and Training at the University of Central Florida. Currently, Dr. Windyga is the PI of the FCS virtual reality test bed project. He has recently participated in simulation interoperability projects involving DIS and HLA, as well as modeling distributed simulation behaviors.

Adam Schmidt is a 2nd Class Cadet at the United States Military Academy. In his third year of study for Electrical and Computer Engineering, he is currently training at the Institute for Simulation and Training, Orlando, Florida. Affiliations include the IEEE computer society.

Allison Griffin is an Associate in Simulation at the Institute for Simulation and Training, University of Central Florida. Ms. Griffin serves as project engineer on the haptics project, and has been working in the field of simulation for four years. Currently, she is the project lead on the Support to the Simulation Interoperability Standards Organization (SISO).

Gary Green is an operations research analyst and research associate at the Institute for Simulation and Training, University of Central Florida. He has over 18 years documented success in management and analysis of programs and projects. His recent experience includes five years in managing and participating in simulation research projects. He also has experience in studies management, systems analysis and functional design of software and data base applications. His background includes extensive application of rigorous operations research techniques to planning, management, resource allocation and other issues. He received his MS in Operations Research/System Analysis from the US Naval Postgraduate School.

Christopher Metevier is the Lead Principal Investigator for Objective Force Experimentation with the US Army's Simulation, Training & Instrumentation Command (STRICOM). He received his Bachelor of Science degree in Electrical Engineering from the University of Central Florida, and has been employed both by the Navy and Army in the modeling & simulation field. His experience includes development, adaptation, and integration of numerous distributed simulation efforts in support of the training, research, advanced concepts, and simulation-based acquisition areas. He is the government's principal investigator for the FCS Haptic Virtual Crew Station Simulator effort.

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Piotr Windyga, Adam Schmidt, Allison Griffin, Gary Green

Institute for Simulation and Training (IST)
University of Central Florida
Orlando, FL

Christopher J. Metevier

Simulation, Training and Instrumentation Command (STRICOM)
Orlando, FL

INTRODUCTION

The end of the Cold War has emphasized the need for the US to develop and maintain a quick and decisive response package to potential crises and conflicts across the broad spectrum of warfare. Tomorrow's military force must be capable of providing our national leaders with a variety of response options. This is a daunting task, as the diversity of conflicts and the ever-changing nature of warfare demand the highest levels of proficiency from our military forces. To meet these requirements, the US Army intends to leverage emerging 21st Century technology to produce the tools it needs to accomplish its changing mission.

The Army is developing the Future Combat Systems (FCS) concept to provide the necessary weapons systems and platforms. The research presented here concentrates on crew station aspects of manned FCS platforms and the use of virtual reality visual and haptic systems to represent them. Through these tools, the Army will be better able to develop effective crew station designs and training solutions to prepare soldiers to operate these potentially complex Future Combat Systems. The end result will be the creation of a responsive force, capable of meeting a variety of threats quickly and decisively.

This paper describes the FCS concept, the FCS virtual reality test bed and the haptic interface toolset. We begin with a background on the FCS, haptic and VR test bed. This is followed by a specific discussion on the conceptual crew station and test bed design, followed by potential applications and future use of the technology. Finally, we present the applications and future uses as we envision them.

Future Combat Systems

The Future Combat Systems (FCS) program is a revolutionary initiative designed to augment the US Army's current fleet of weapons system platforms such as M1 tanks and M2/M3 fighting vehicles. The goal is to field an ensemble of manned and potentially unmanned combat systems capable of increased operational and tactical mobility, lethality, survivability, and sustainability. The systems are designed to ensure that the future Objective Force is strategically responsive and dominant at every point on the spectrum of operations from non-lethal to full-scale conflict. It achieves such awareness by employing a common relevant operating picture.

The Desert Storm experience raised questions about the speed at which the present day US Army can be deployed. Technology can play a part in developing a more rapidly deployable force and FCS development is a priority of the Army Science and Technology community. The FCS concept envisions an overriding need for high data-rate and low-latency communications to support real-time fire control and robotic missions [1]. The objective of the system is to develop and field a generation of rapidly deployable combat systems that will blur current distinctions between heavy and light forces. FCS will provide a rapidly deployable force for mounted tactical operations by conducting direct combat, delivering both line-of-sight (LOS) and beyond-line-of-sight (BLOS) precision munitions, providing variable lethal effects (non-lethal to lethal), performing reconnaissance, and transporting troops. Technology increases in such areas as surveillance, remote control and reconnaissance are among those under evaluation for inclusion in this complex system of systems. Overall, FCS will allow the army to maintain its persuasive presence among the global

community, and continue its dominance in military technological development.

The research and design of the effort described in this paper are specific to one part of the FCS, the manned FCS platform's combat crew station. The crew station is that central piece of the FCS system that provides the critical link between man and machine. The following sections describe work being done in modeling & simulation (M&S) to help optimize FCS crew station design and soldier use.

Virtual Reality Test Bed

A virtual reality (VR) test bed is a simulation of a system, such as a cockpit, console, or building, which is used to test, evaluate, or refine design ideas and concepts. A virtual reality test bed would use equipment such as Head Mounted Displays (HMDs), haptic and/or tracking gloves, and other VR devices to immerse the evaluator into the simulation. Essentially, it facilitates rapid prototype development in the virtual world. The user is immersed into the VR test bed to view/operate the equipment that is modeled. Because he/she can reach out and virtually touch switches, knobs, gauges, or screens, he/she can provide feedback on design layout, switch position, lighting, and many associated human factors issues. Since the models are virtual, changes can rapidly be made in the development environment for re-evaluation.

Haptics and the Human-Machine Interface

Haptics involves the modality of touch and the sensation of shape and texture an observer feels when exploring a virtual object, such as a three-dimensional model of a porcelain vase from a museum, a tactile map, or a graphic designer's rendering of an imaginary object. [2] Haptics will play a major role within the FCS crew station discussed earlier.

Most defense systems of today require some form of "human in the loop," and the design of that system's man-machine interface can be critical to its effectiveness. Haptic M&S technology allows the user to "feel" a human-machine interface within a Virtual Environment (VE) as he/she works within one. Fundamentally, haptic M&S systems are manipulators that are used to provide force or tactile feedback to humans interacting with virtual or remote environments. Haptic tools provide the link needed for realism in the interaction between the physical human and virtual machine.

Haptics can be used in various interfaces. Virtually any movement and interaction of the human body in a VE can be tracked and then displayed or felt within a simulation. This is accomplished by using hardware specifically designed for a given part of the human body. Many times, the device itself will be configured similarly to the layout of the human part with which it is attempting to interact.

Special care must be exercised during development of each interface to not only create a sense of object position, but also of shape, texture and slip. Should these crucial aspects be ignored, the interface would be of little value since, even though the user senses the object, he or she would be unable to identify its most obvious qualities by touch.

Crew Station Concept

STRICOM's embedded simulation program is developing and demonstrating technologies necessary to move embedded simulation from the laboratory into the hands of soldiers. The program office also has begun to consider how embedded simulation could be used to train crews of Future Combat Systems.

The objective of this effort is to produce an FCS crew station simulation test bed that will provide the ability to effectively and quantitatively address operator-interface issues concerning the enormous information processing and associated training challenges facing FCS crews. The FCS crew station used in this project was developed from general knowledge of the FCS crew station and is not based on a final design.

The FCS crew station display (see Figure 1) is made up of the following:

- Three Out the Window (OTW) displays
- Two Remote Sensor Displays (RSD)
- One Multi-Function Display (MFD)
- One Plan View Display (PVD)

The three monitors across the top represent an out-the-window view of the area immediately surrounding the vehicle. In the center, the middle display is multi-functional and the bottom center display is a plan view (Situational Awareness) display that shows the disposition of friendly and enemy entities on the battlefield. On each side are additional displays that represent views from other manned or unmanned friendly systems or sensors under the control of the crew station. These views could be from an Unmanned Aerial Vehicle (UAV),

Unmanned Ground Sensor (UGS), a robotic gun, or some other sensor or weapon system. Since the crew will not generally have visibility of the sensors or robotic vehicles under its control, this is a perfect opportunity to use simulation to train the operators in employment and management of unmanned systems.

Images and information are moved between displays using touch screen technology. Moving images into the multi-function display (MFD) (see figure 1) allows the user to take command of a remote sensor, an unmanned aerial vehicle, etc. The user can then lase, designate targets, fire weapons, or relocate the entity. The view presented in the MFD has the appropriate menu for the sensor or robotic vehicle, such pertinent information about the vehicle as weapons on board, ammunition available, fuel or battery life remaining, and, if appropriate, a heads up display. The robotic vehicle can be moved or directed to a target with the use of a joystick.

Embedded simulation technology soon will be available to support the sophisticated operational and training needs of a digitized force. STRICOM's embedded simulation program is preparing the way to equip Objective Force systems with this rapidly evolving capability.

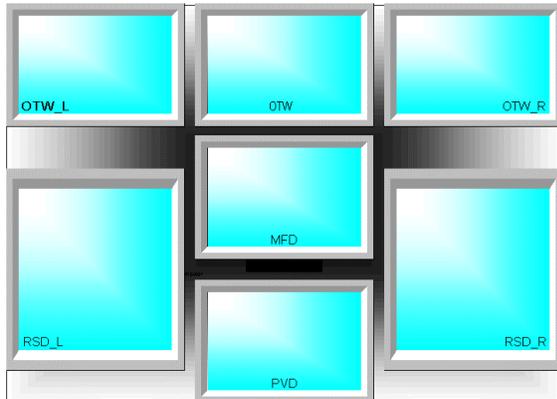


Figure 1 FCS Crew Station Display

Virtual Model of the Crew Station

Figure 2 shows a three dimensional virtual view of the crew station. This view was created using commercial CAD software. The seven major components of the station discussed prior can be seen in the three main panels; center, left and right.

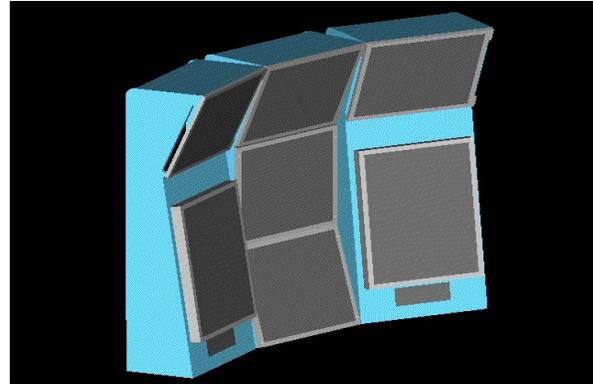


Figure 2 FCS Operator Crew Station

Methodology

The key steps in developing the haptic test bed are:

- **High-level architecture design:** The general concept and purpose are developed, along with a temporary design.
- **Equipment elicitation and selection:** Commercially available equipment is thoroughly researched. Equipment determined to be the most effective and efficient is selected for the initial design. Critical pieces include the HMD, and the Haptic glove.
- **Concrete configuration:** The final configuration, to include equipment, is conceptualized and developed.
- **Software development:** The software needed to operate the crew station is developed. Each part of the crew station requires specific software to perform its individual function.
- **Interface development:** The human-machine connection, a major part of this concept, is developed and implemented. The Haptic equipment is the main portion of this.
- **Preliminary Evaluation and Testing:** The crew station, now developed and constructed must be evaluated and tested for its performance. It is imperative that the new technology function to the high standards its trainees will demand. Preliminary testing must include all hardware and software. Hardware such as the HMD and Haptic glove must be pushed to their limit. Such things as quick movement and touch accuracy must be evaluated during testing. Software such as the interface and touch screen system must also be thoroughly evaluated.

- **Screen:** The screen represents a screen in the array of crew station displays that will be used to display the platform.

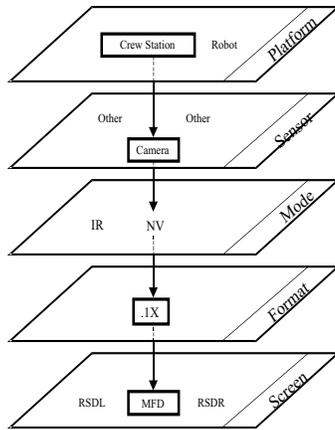


Figure 4 FCS Crew Station Modeling User Interactions

State diagrams are being developed to outline all proposed actions and events associated with the crew station model. This following provides an overview of the crew station, an outline of the events or levels in the crew station, and state diagrams detailing events.

The objects that make up a user interface must be coordinated to work together as a whole. Figure 5 provides a state diagram of the general haptic interface with the FCS, and the following provides explanation of the terms used.

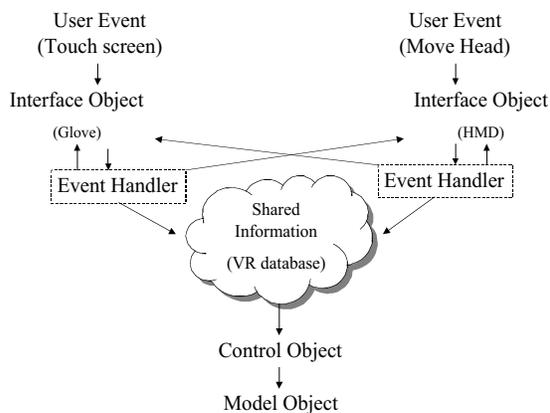


Figure 5 State Diagrams

- **Interface object:** This is the link between man and machine. In our case, the haptic glove and the Head mounted display (see Figure 6) are the interface objects.
 - **Event Handler:** These determine the context in which the event occurred to determine which actions should be executed.
 - **Shared Information:** Information that a number of handlers can access and modify
 - **Control object:** The control object maintains the state of the user interface as a whole, as the shared information is modified
 - **Model Object:** A Model Object maintains the long-term information held by the system, which survives executions of the application. [4]



Figure 6 Main Interface Devices

Future Use and Applications

The first phase if this project ends September 2001 with a fully operational test bed. Current plans for the second phase of this effort are to show the utility of the tool in evaluating training concepts. Since haptic technology is well suited for studying operator interface issues, an alternative under consideration would examine such issues as control station layout and data visualization dynamics. Potentially, this test bed could be linked with a more sophisticated HMD (developed at UCF's Center for Research and Education in Optics and Lasers (CREOL)) that includes a laser-based eye-tracker. Adding this eye tracker would allow precise tracking of an operator's area of interest, permitting evaluation of the operator's interactions with multiple information displays. This would show the location of the operator's attention over time, patterns in viewing information and whether or not they are seeing critical information at the right time in a given scenario.

Future efforts also will consider upgrading the vibrato-tactile interface to a more sophisticated haptic interface that will provide full force feedback. This interface allows users to feel the resistance of objects as well as their weight.

This versatility will be realized through an open architecture system concept, with an easily upgradeable and “tailorable” design approach to accommodate system use. [4]

Conclusion:

The FCS will be the centerpiece of the Army’s Objective Force and play a dominant role on the battlefield. FCS command and control will be exercised by manned platforms, such as an FCS Crew Station described here. As such, it must be designed to optimize the interaction between man and machine. VR has proven to be an important tool in research and development (R&D) and should prove to be a valuable tool in the optimization of the design of the FCS Crew Station. The addition of touch in VR as used in the Haptics VR test bed should provide yet another data point that engineers can use to optimize the design of the FCS crew station. The Haptics VR Testbed will provide the first glimpse into the design of the crew station and its effect on Human Factors.

One other area that will be evaluated is the use of haptics in VR in the fields of training. VR is currently used in training in many areas of the military, as well as other fields, and is a valuable tool. The Haptics VR Testbed will provide insight into how important the role of haptics will be in the VR training environment.

Training to use haptic technology effectively will demand time and dedication from soldiers and trainers alike. Haptics has the potential to make a valuable contribution toward system design, evaluation, and overall training of tomorrow’s force.

Acknowledgement

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