HUMAN MACHINE INTERFACE DESIGN FOR CONTROL OF ROBOTIC SYSTEMS

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ABSTRACT

The objective force is intended to provide the U.S. military with a fighting capability that far exceeds potential adversaries. It consists of a highly mobile unit of action (UA) consisting of a variety of platforms and dismounts that will have advanced situational awareness on the battlefield thus enabling the UA or its elements to see first, understand first, and act decisively before the enemy has time to react.

The UA is structured to use unmanned systems (air, ground, and sensors) to support manned operations in a variety of ways. All of these include control of unmanned systems in both single task and cooperative employments (kill-chains) to improve force projection and mission capabilities.

Anticipating these requirements, the U.S. Army Research Laboratory started Collaborative Technology Alliances (CTAs) focused in five areas: Advanced Sensors, Advanced Decision Architectures, Communications and Networks, Power and Energy, and Robotics. These collaborative alliances between government, academia and industry are intended to advance the state of the art in technologies needed to support the new concepts of the objective force.

This paper focuses on the human-centered research and design being conducted under the Robotics CTA.

1. INTRODUCTION

New military operational requirements have been established to use unmanned vehicles and unattended assets to improve the warfighting capability of the objective force. Unmanned vehicles are well suited to support military missions that needlessly place our military personnel in harms way or to perform jobs and tasks that are monotonous or well suited to procedural applications. However, employments of these assets add new tasks with very high attentional demands to the operational requirements of the individual warfighting elements.

To answer these new challenges, the U.S. Army Research Laboratory established a long-term research and development program to advance the state of robotic technologies under the Robotics Collaborative Technology Alliance (CTA). The Robotics CTA is composed of a number of different commercial, educational, and government participants working research issues for near and far term robotic challenges.

A great deal of research is dedicated to improving the autonomous capability of unmanned systems, but use of robotics in the near term will be through soldier-robot teams. Improvements in autonomous robotic capabilities coupled with the variability of the operational environments create new mixed-initiative control paradigms for soldier-robot teams. The range of human tasks for robotic control may range from simple line-of-sight remote control to supervisory control requiring varying levels of man-in-the-loop operations.

2. DEVELOPMENT APPROACH

Our focus is on research and development being conducted for the Human-Machine Interface (HMI) technical area within the Robotics CTA to address the human interactions and control mechanisms for the soldier-robot teams. Supervisory control, semi-autonomous direct control, and robotic teleoperation and remote control in multiple asset environments is characterized by high attentional human demand. Accordingly, research into multi-modal control systems and new display concepts are being investigated to help mitigate simultaneous demands imposed on the controllers. In addition, the CTA provides technology transition opportunities to transfer concepts and technologies to other government robotic programs, and this paper is intended to address this broader goal.

With the introduction of the Future Combat Systems (FCS) and Objective Force Warrior (OFW) requirements, the need to develop deployable systems of unmanned ground vehicles, unattended ground sensors, and micro air vehicles is now advancing at an accelerated pace. This entails, in part, merging technologies and supporting language from various disciplines. A "consistency" (e.g., of language, displays, timelines, task sequence, expectations) objective is paramount to success.

We present an analysis and HMI development approach in use to develop an interface for an integrated crew station in a direct fire combat vehicle with robotic control requirements, a separate single display control system to support scout missions, and concepts for dismounted control of unmanned ground vehicles. A primary component of this approach will be the development of human performance models of operators interacting with proposed hardware and interfaces. Modeling efforts are used to establish the attentional and cognitive workload demands of the proposed systems with respect to their desired capabilities.

For each of the three types of operator control units (OCUs) we will define the research space by describing previous systems upon which each system is originally based, and operational requirements for the system. We will then describe our strategy for how we plan to integrate the system requirements with human factors design considerations. Finally we present the current state of our implementation with a screen mockup and some of the details surrounding the design.

3. INTERFACE DESIGNS

The Robotics CTA has focused on supporting three different crewstation configurations to support three distinct mission areas under various environmental conditions. The first is an advanced warfighter crewstation intended to support a Command Vehicle with command & control responsibilities, a Mobile Gun System platform that has both command & control and LOS engagement responsibilities, a Scout mission that can be accomplished from a HMMWV or new Reconnaissance & Surveillance vehicle platform, and dismounted operations. In each of these configurations we have introduced advanced interface control technologies to improve the soldier's ability to perform the basic mission as well as plan, manage, and employ unmanned assets.

3.1 Integrated Crewstation

The Vetronics Technology Integration (VTI) program from the Tank Automotive Research, Development and Engineering Center (TARDEC) and the U.S. Army Tank-automotive and Armaments Command (TACOM) is currently developing an integrated crew station intended for platforms such as the Command Vehicle, Mobile Gun, Beyond Line of Sight (BLOS) and Non-Line of Sight (NLOS) vehicles. The overall program is advancing the application of autonomous mobility developments to help aid in driving both manned and unmanned vehicles in a variety of element configurations.

Specifically, for the integrated crewstation the Robotics CTA has developed interface standards for the variety of displays presented to the soldier. These standards address such factors as: consistency among displays, increased operator situation awareness of the current state of the displays, operation in a moving vehicle using protective gear, and presentation of the material in a useful and appropriate manner. The primary tools used to accomplish these objectives include careful interface design, integrated intelligent aiding of soldier tasks and a robust speech-recognition interface.

3.1.1 Previous Systems

The VTI program is a fairly direct continuation of TARDEC's Vetronics Technology Testbed (VTT) program and TARDEC's Crewman's Associate prior to that. The primary goal of these programs was to reduce the crew size of a direct fires vehicle through computer assistance. The VTT program expanded the development of the vetronics or vehicle electronics, through the addition of vehicular drive by wire and indirect driving sensors. The indirect driving sensors were a series of cameras outside the test vehicle which the crew station operator used for driving from inside the back of the vehicle.

In VTT, two identical crewstations were placed in the vehicle, with two operators responsible for all of the driving and target acquisition duties normally assigned to three or four man crews. The system was configured so that either operator could perform any function as needed, from driving to preparing reports.

Each of these systems used color displays for the maps and the video feeds (both driving and targeting), but the other operator displays, such as reporting, system setup, and others were primarily single bit monochrome displays with occasional color for alerts and a few other indicators. In VTT, two of the three computer screens were operator reconfigurable multifunction displays (MFDs) and a fixed position map, while the indirect driving screens were dedicated video monitors above the MFDs. Other inputs to the operator included tonal warnings and a 3D audio system was initially designed to aid operator situation awareness.

Both systems also used a combination of the touch-screen and programmable display push buttons. VTT used a variety of operator inputs to interact with the displays. Operators could touch either the virtual screen buttons or the hard buttons surrounding each screen. For driving and target acquisition functions, they had a control yoke similar to the control yoke for an M1A2 tank. They also had a keyboard and limited speech recognition capabilities. Finally, the operators could navigate among the buttons using a "bump cursor", a small thumb operated cursor on the control yoke. Two primary purposes for the bump cursor are 1) allow the operator to control the displays without removing their hands from the yoke, and 2) allow a means for interacting with the touch screens in a bumpy environment, such as when the vehicle is on the move. This on-the-move requirement was a major driving force in the design of the VTT crew station and will be discussed in more detail below.

3.1.2 System Requirements

VTT was originally designed to be a testing platform and VTI expanded upon that concept through the desired capabilities of the multifunction displays. In VTI, the decision was made to allow any display to be put on any

Figure 1. Layout of displays for robotic control using the VTI control station A control station comprises six displays (A). Each 20 inch monitor screen (B) comprises two half-screen displays or one full screen display. Each display has a viewing/interaction area (C) and one or two fixed columns of seven 1" x 1.5" buttons (D). The displays shown are the RSTA viewer /browser (left screen), mission planning (top center), mapping (bottom center), situation awareness camera (top right), and asset control (bottom right). The control yoke is located under the center screen.

computer monitor. This would allow for various means of operator testing, including fixing the displays, allowing complete operator freedom in assigning displays and intentionally loading the operator to determine operator overload.

The requirements for on-the-move control and indirect driving and targeting were maintained and so was the utilization of the bump cursor and other input modalities as a result. In addition to operating on the move, the operator also needs to be able to operate the system using Mission Oriented Protective Posture (MOPP) gloves, 14 or 25 mil lined butyl rubber gloves, which greatly reduce an operator's tactile sensitivity.

A significant new requirement of the VTI program was the addition of robotic follower control. While originally envisioned as robotic control primarily at the convoy level, it quickly expanded in scope to include detailed control of multiple autonomous robotic vehicles with various mission payloads, primarily direct fires, indirect fires and reconnaissance, surveillance and target acquisition (RSTA) sensor packages. These improvements are direct technology advancement feeds from the robotics CTA program, primarily in the form of the asset planning and RSTA management interfaces.

3.1.3 Strategy

The plan to reduce crew size in VTT and Crewman's Associate was successful as a crew of two operators was theoretically capable of performing the function of three or four operators using conventional systems. An increased level of responsibility and workload was observed, however. We realized that the addition of robotic asset control would increase the level of workload even higher, perhaps to unmanageable levels. Our first strategy was to design a common interface modality on all interface components to allow for increased operator familiarity and recognition of the displays and how to interact with them.

We used existing military standards and guidelines documents (Military Standard 1472f, Human Engineering Design Criteria Standard, 1999; the Aviation Human Computer Interface (AHCI), 1998; the Handbook for Human Engineering Design Guidelines, MIL-HDBK-759C, 1998; and the U.S. Army Weapon Systems Human-Computer Interface (WSHCI) Style Guide, 1999) to generate minimum requirements and then included other human factors research considerations to address the complications imposed by on-the-move control and MOPP gloves.

The next design issue was to reduce workload through intelligent aiding and multimodal interfaces. The rationale was that if the operator could have certain decisions made by an intelligent agent, either during mission planning or mission execution, it would reduce the operator workload. Also, multi-modal inputs such as speech recognition would also reduce the workload by allowing the operator to use another means of input (i.e. voice) for commands when the other primary means of input (the hands) were already tasked.

While these improvements should reduce workload, there may be circumstances where the operator is unwilling or unable to use these technologies. To account for this another design principle was that no operator function could rely *solely* on either speech input or intelligent aiding. Thus interfaces were designed to include the option but not the necessity of these improvements for full display functionality.

For the various displays needed, we used the VTT displays as a guideline for developing the driving, target acquisition and system setup displays. We used the

DemoIII robotic control OCU (described in section 3.2) for the interface principle involved in control of multiple robotic assets. We also examined the Force XXI Battle Command, Brigade and Below (FBCB2) system to provide additional command and control functionality. From all three systems, the best and most appropriate mapping and map interaction concepts were combined to create the mapping interface. From these, we developed a functionality requirements document containing all of the design considerations and requirements from the three systems as well as the new requirements for the program.

Finally, to support a rapid development approach and allow for the identification of problems or issues early in the design process, we held weekly teleconferences and frequent sub-team meetings to cover the displays as they were developed.

3.1.4 Implementation

One of the requirements of the VTI program is greater flexibility in the placement of the displays on the screens. Closely tied to this requirement was the desire to allow an operator to use the screens normally dedicated to indirect vision driving for other tasks. The possibility of using the crewstation in this capacity is increased by the design of the crewstation integrated automation testbed (CAT) vehicle to be capable of autonomous mobility as well as the unmanned robotic vehicles. To do this, we employed a modular design strategy so that interface control components may be placed in any one of six positions on the three screens. The new crew station design comprises three 20 inch touch screens (Figure 1B), with each screen capable of two half-screen displays, or one full screen display (Figure 1A).

The operator is provided with a bank of hard buttons above the display which facilitates easy placement of displays. Also provided are a series of six "suite" buttons which will allow an operator to quickly switch among different tasks by pressing a suite button. The suite button will bring up a certain set of displays appropriate for that task; for example, the operator does not need to manually switch each display to change from driving to robotic asset control,. The plan is that the user won't configure which displays will appear for each suite button, but rather will use the suite to get as close as possible to the needed displays to perform the function. The fixed nature of the suites is also helpful to insure the exact positions of displays for human performance testing of the system.

Table 1
Displays of the integrated crewstation

CAT vehicle operations	System setup
	Indirect driving view
	Driving console
	Target acquisition
	Target queue
	Vehicle and system status
	Situation awareness sensor
Robotic Asset Operations	Robotic asset status
	Robotic asset mission planning
	Robotic asset RSTA imagery control
	Robotic asset direct and/or indirect fires
	Semi-autonomous direct control
C2 Operations	Incoming and outgoing reports
	Interactive map control
	Electronic order receipt and processing
	Battlefield visualization (simulated fly-over)
	Immediate response warnings and cautions & queue

Our first step in the detailed interface design was to determine the framework for the display. Due to the high cost and unreliability of the programmable display push buttons, it was decided to make all display interaction buttons soft buttons. These buttons would be accessible though the touch screen, the bump cursor and voice activation. MIL-STD-1472f (1999) specifies that buttons must be a minimum size of 0.65 inches and a maximum size of 1.5 inches. Ideally we wanted the buttons to be the maximum size as we had two core requirements: operation with MOPP gloves and cross-country on-the-move control. Either one of which degrades the operator's ability to accurately interact with the display in a timely fashion, thus suggesting a larger button size.

From the AHCI (1998) "Where vibration is of concern or when crewmembers must operate the touch screen while wearing gloves, the target size should be at least 1 inch square." An initial Fitt's law - Welford variant (Welford, 1960) analysis:

$$t = 0.1 * \log_2\left(\frac{d}{s - v} + 0.5\right) \tag{1}$$

(where t is the time in seconds, d is the distance to travel in inches, s is the size of the shortest dimension of the button in inches and v is the root mean square vibration in inches) of an operator interacting with a three screen system (Figure 1B) indicated that with a 1.5 inch button, the operator would take 0.44 seconds to move his hand from a position on the yoke to the furthest button (top left for the right hand or top right for the left hand). With a 0.5 inch vibration, (a conservative estimate of vehicle motion at best), the time increases to 0.5 seconds. Unfortunately, an analysis of the buttons required for each display indicated that in order to maintain the desired similarity among displays, approximately 14 buttons are needed (seven on each side of the display, Figure 1D). With a 20 inch screen (Figure 1B) and two displays per screen (Figure 1A), this necessitates one inch high buttons. One inch high buttons with no vibration have a Fitt's law time to contact of 0.5 seconds. With a 0.5 inch vibration that increases however to 0.6 seconds.

We developed two approaches to deal with the increased difficulty. The first is to have the height at 1 inch but allow the width to remain 1.5 inches. Since the touch screen is designed to use a "release position" strategy, where the touch is considered to be the position the touch is released and the operator will have a visual feedback of the button changing its visual appearance, the extra 0.5 inch width may help the operator orient on the correct button. Testing the accuracy and times for pressing various button sizes in a moving vehicular environment has been recently proposed and approved as a research topic for ARL/HRED (Chris Smyth, personal communication).

The second approach is to keep the buttons as close to the edge as possible and provide a physical means for grasping the bezel between screens. The bezel becomes an anchor point, reducing the Fitt's law distance traveled, thus reducing the time to contact.

The large number of displays (Table 1) and operating options available to the operator present the potential problem of a loss of situation awareness when switching from one task to another. In order to help maintain this situation awareness, and also provide easy access to commands in a reliable fashion, we favored a "flat" sub-menu and sub-function layout. Specifically, no function of any display is presented as a moveable "pop-up" window, which has the potential for obscuring needed buttons or commands. All menus and the results of menu selections always appear in the same place. The only exception to this rule is the menu that pops up when selecting a map entity. Here, however, the pop-up menu would only appear in the viewer/interaction area (Figure 1C) and not overlap the buttons (Figure 1D). Also the menu will not be moveable but will appear in a position of close proximity to the selected entity while staying within the viewer/interaction area.

Finally we wanted to provide the operator with operationally appropriate groupings of functions in the displays. Here we tried to strike a careful balance between keeping the information on a given display easily accessible without overcrowding or confusing the operator with too much functionality, and overwhelming the operator with too much switching among displays to perform a specific task. There are three primary kinds of tasks the integrated crewstation operator will perform: 1) CAT vehicle operations, 2) Robotic asset operations and 3) Command and Control (C2) operations (Table 1). Many of the displays are usually associated with other displays (such as target acquisition and target queue) but are kept as separate displays to individual placement on the screens. For example some operators may prefer the target queue next the target acquisition display and others may prefer it below. Similarly, both the indirect driving views and the driving console are necessary for driving, but the non-driver may choose to observe either display as desired.

The groupings of the displays also clearly suggest the previously mentioned suites. For example the driving suite may have indirect driving in the top half of all three screens , the driving console in the center bottom, and vehicle/system status in one of the lower corners and the warnings & cautions queue (from C2 operations) in the other corner. Similarly, a robotic asset suite may have the same displays as shown in Figure 1, but with an unmanned vehicle camera view instead of the crewstation's situation awareness camera view.

The Robotics CTA has successfully transitioned a robust speech recognition system that is gender-independent, robust in noisy environments and requires no prior training to the VTI program. Incorporating the speech interface in the design from early in the design process allows for the designer to solve potential problems that may appear only or primarily when using a speech interface with a given display. One example is the use of redundant words. If the word "Cancel" appears in two different parts of the display, it is immediately obvious from a physical operator interaction which button has been pressed, while saying the word "Cancel" is ambiguous unless additional information is provided. Another potential problem involves words which sound similar. One example which occurred in the reports display was the auditory similarity between the send and save commands, increasing the potential for misinterpretation. To alleviate this problem, the word report was added after the word send on the button, so the proper spoken command to send a report became "Send Report", differentiating it from the simpler "Save" on the same display.

The intelligent aiding system was designed to primarily address two main areas of operator overload and confusion: incoming warnings and cautions and the robotic asset planning process. Since there are a fixed number of warning and cautions and their text is predetermined (i.e. they are not free-text messages), an intelligent aiding system is well suited to deal with these messages and prepare a response for the operator to accept or reject.

The electronic orders display was designed primarily to assist the intelligent aiding of asset planning. Ideally, the operator would receive an order as an electronic report. The operator would then manually parse the order into a specific series of commands that the intelligent agent would interpret and use to present a proposed plan for robotic asset movement. The operator could then accept, reject or modify the plans as desired.

3.2 Standalone Crewstation

The Robotics CTA is emphasizing operations in a mounted and dismounted scout mission environment. Concepts range from a vehicle mounted Operator Control Unit (OCU) to dismounted hand-held units that utilize advanced sensor and autonomous mobility capabilities of unmanned ground vehicles and cooperative support from micro air vehicles and unattended ground sensors.

With the advanced sensor and autonomous mobility capabilities built into the unmanned vehicles, a thrust for the research is to maximize the number of heterogeneous unmanned assets a single warfighter can control. Human interventions will occur for target confirmations and the occasional orientation of mobile platforms, but the interventions are supplemented by intelligent control architectures that aid the warfighter in the performance of the human intervention tasks.

For the scout mission single-screen autonomous control vehicle, efforts here focus on reducing the confusion and cognitive load of controlling not only a large number of robotic assets (up to ten), but also controlling three fundamentally different types of assets: ground vehicles, air vehicles (micro or larger), and ground sensors. This utilizes the same set of tools described for the crew station of interface design, intelligent aiding, and speech control.

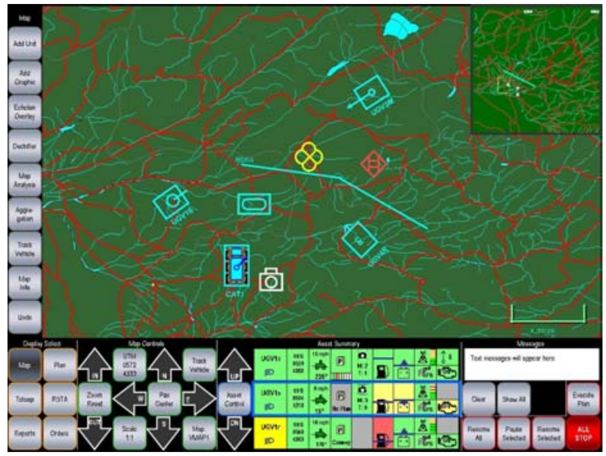
3.2.1 Previous Systems

The standalone crewstation being designed for the Robotics CTA OCU is based primarily on concepts in the Demo III OCU, used for the experimental unmanned vehicle (XUV) demonstrations from GDRS and ARL. The Demo III OCU was a single-screen monitor with keyboard and trackpad inputs, designed to control up to four identical XUVs with RSTA capabilities. It utilized a custom made map for use by the route planning software to determine XUV routes and a simple SPOT reporting capability.

3.2.2 System Requirements

The additional requirements of the Robotics CTA OCU are to primarily provide greater flexibility in the utilization of the OCU, and provide a testbed for the multimodal inputs and intelligent aiding technologies discussed for the integrated crewstation. Specifically, the new OCU will not be limited in the number of assets the operator may control (although the Robotics CTA only specifies up to ten), nor the types, expanding to include unmanned air vehicles (UAVs) and unattended ground sensors. The control of these assets will be aided and augmented by the same enabling technologies of speech recognition and intelligent aiding as described for the integrated crewstation.

In order to increase compatibility and provide a similar platform for interaction with non-robotic systems, the new OCU will use a more robust JVMF based reporting system and standard NIMA maps and imagery products. Compressed arc digital raster graphics (CADRG) for planning information and navigation, and vector product format (VPF) maps for use in route planning of the ground robotic vehicles are the primary map types with digital orthorectified imagery (DOI) and



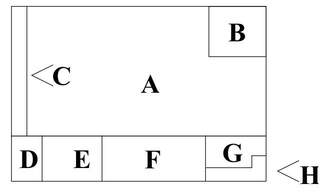


Figure 2
Layout of displays for robotic control using a Robotics CTA control station

The robotics CTA control station is a single screen operator control unit (OCU). The primary interface is through the map (A). Immediate map movement may be accomplished through the overview map (B). The buttons on the left side (C) change based on the display selected (D). Map navigation tools (E), Robotic asset status summary (F), incoming messaging (G) and robotic asset plan control (H) are always available.

digital terrain elevation data (DTED) for imagery and overlays.

3.2.3 Strategy

Our approach to the development is to design the new interface to enable the operator to successfully handle not only multiple assets, but multiple types of assets. Several of the lessons learned from the development of the VTI interface will be used and modified as appropriate to a single screen crewstation. While the Robotics CTA doesn't specifically call for on-the-move control or robotic fires, we will design the interface to be able to address these considerations as needed, due to the recent Unit of Action requirements for FCS.

Finally, we have observational data on the usage of the Demo III OCU to perform simulated missions, and the areas which caused frustration and high workload among the operators. We will pay particular attention to those areas to develop a better means for presenting information and reducing workload.

3.2.4 Implementation

The notional interface for the single-screen OCU was designed to provide as much information as possible that would be always available to the operator (Figure 2). In the single screen OCU, as with the DemoIII OCU, the map is the primary means of interaction with the display (Figure 2A and 2B). The map navigation tools, Robotic asset status summary, incoming messaging, and robotic asset plan control (Figure 2E - 2H) are always available.

Other functions are separated, as with the VTI OCU, into modular components which may be selected through the display selection buttons (Figure 2D). Selection of a different display will primarily change the functions of the buttons on the left side of the display Figure 2C, expanding out into the map as needed. A main difference in the implementation of display selection between the integrated crewstation and the standalone crewstation is the commonality of the map. The map provides an anchor, a frame of reference, for the OCU, as all functions of the OCU relate in some manner to the map. The display functions include general mapping functions, asset planning functions, RSTA capabilities, semi-autonomous direct control, reports and electronic orders. The asset planning functions will be further broken out into the specific planning functions for ground vehicles, air vehicles and ground sensors.

The primary area where the operators of the Demo III OCU had workload issues was during RSTA analysis. The operators were presented with a flat chronological list of images taken by the robotic assets. The operators spent time gaining situational awareness of the location and origin of the image. The operator then needed to analyze the image. This process takes time and the operator must dedicate a fair amount of time to the process. A side effect of this increased concentration is that the operator would lose situational awareness of the other assets, including their activities and their positions. To address this, we made the asset information more prominent. Changes in the state of the robotic asset will be indicated through a physical or text indicator (such as the number of images collected or the relative level of the fuel), a color indicator, and an auditory indicator. Additionally, as in VTI, we will minimize the use of moveable pop-up windows, so the asset summary and messaging areas (Figure 2F and 2G) will not be obscured.

Finally, we will incorporate the speech interface and intelligent aiding, as with the integrated crewstation, ensuring that the interface as designed is compatible with unambiguous speech recognition.

3.3 Dismount OCU

In the OFW vision of future combat, dismounted warfighters will be using an OCU to control unmanned assets, such as small ground vehicles. These ground vehicles will be designed to carry multiple mission payloads, such as machine guns, nuclear and chemical sensors and the Anti-Personnel Obstacle Breaching System (APOBS). For dismounted control of unmanned ground vehicles, this effort focuses on selecting the hardware platform and related interface design most suited to the needs and requirements of the dismounted soldier, such as simple deployment, ease of use, ruggedness, full vehicular control and payload delivery capabilities. Such technologies include glove-mounted controllers and arm-keypads for input, and monocle screens for information presentation.

3.3.1 Previous Systems

A previous prototype dismount OCU control system (used by the Office of Naval research Gladiator program) was a teleoperation-only system without navigational tracking abilities. The layout of the OCU was basically a remote control unit, with several joysticks for mobility and camera tracking and several other dedicated control buttons.

3.3.2 System Requirements

Dismount OCUs for use in OFW will have increased functional requirements: 1) navigational tracking, through position information displayed on a map, 2) multiple payloads, described earlier and 3) the ability to control multiple robotic assets.

Operational considerations include requirements to operate the OCU with a single hand, wear MOPP gloves or cold weather gloves (providing even less sensation than MOPP gloves), and not have the OCU interfere with normal operations of the dismounted warfighter.

3.3.3 Strategy

These extra requirements and the open-ended nature of a flexible payload system argue against designing an OCU with fixed functions. In order to maintain simplicity we designed a system with a minimal reconfigurable button set that would provide all of the needed functionality. We can then design multiple input devices that are completely interchangeable with the OCU design as long as they have the minimum number of buttons.

Likewise, the actual display devices and even the number (one or two devices, such as a head mounted display and a PDA-style screen) are not critical for the design of the display portion of the OCU at this stage of development.

3.3.4 Implementation

A button set which should provide almost any small unmanned asset operation and payload delivery includes one primary set of navigational buttons, a function-specific action button, a small joystick for dedicated vehicular movement control, and three fixed buttons for display and control switching.

Various input systems that are being considered include a small pendant, a trigger-grip controller and a chest mounted input system. Because of the one-handed operation and the desire to keep the operator/interface interaction as smooth as possible, acknowledgement windows (e.g. “Did you mean to do this?”) are used only when personnel safety is critical, such as the arming of a weapons firing systems. Furthermore, menus are set up to cycle in a round-robin fashion and be easily selectable, one-handed operations, again in order to facilitate streamlined ease of use.

This simple menuing allows easy access to the necessary displays, which include vehicular movement control, RSTA camera control, a mapping interface with simple waypoint navigation, and multiple payload control.

Finally a simple set of auditory and visual iconic alerts will be used to indicate danger and warnings relevant to the unmanned asset.

4.0 HUMAN PERFORMANCE MODELING

The modeling effort for the Robotics CTA was two fold: Development of a baseline model which was an integration effort of several existing technologies and development models based on the designed integrated and standalone OCUs. The purpose of this multi-faceted approach was to provide initial workload measures from the baseline model and to compare baseline workload scores to predicted workload scores from the designed OCU model in order to see improvements in operator performance or identify areas where problems may arise using the new interface.

Operator workload was a key focus of this modeling effort, addressing the questions:

1) Where were instances of peak workload and how frequently did these instances occur?
2) Where were instances of operator overload and how many instances of overload occurred?
3) What mission demands caused these instances?
4) What tasks were being performed during these instances?

A baseline model was developed to support workload analysis of baseline technologies being transitioned into the new CTA system. Workload prediction was used to help mitigate the new interface design to reduce high workload interfaces that existed in the baseline technologies.

The next phase in the modeling effort involved the development of the model of the concept CTA interface. Development of the concept interface model followed a similar path as the baseline model. Task decomposition was performed on the concept interface to the button push level of detail. In addition, new goals were developed in the IMPRINT model in order to account for the enhanced task requirements from the concept interface.

The model was integrated with a scenario that simulates a mission involving the operator tasking of UGVs to scout two named areas of interest (NAI), evaluating RSTA reports received from the UGVs, and reporting the existence of targets detected at a specific NAI.

5.0 CONCLUSIONS

In each of these systems, we are developing the interface with attention paid to the unique requirements of each system while following both military and other human factors specifications. The use of consistent and well-accepted design principles will also provide for easier integration into both legacy and future systems at any level of robotic control. Results from this work are intended to transition to numerous Future Combat System platforms supporting a multitude of missions and operational environments. Detailed concurrent modeling efforts of human performance issues will allow the interface designer to see an improvement in operator performance utilizing the new interface or identify areas where problems may arise using the new interface.

ACKNOWLEDGEMENTS

We wish to thank Rene de Pontbriand for his counsel and advice regarding the advancing of human issues in unmanned vehicle control applications and Thad Wojcik for the discussion of the Human performance modeling.

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