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HUMAN EFFECTIVENESS ISSUES IN SIMULATED UNINHABITED COMBAT AERIAL VEHICLES

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ABSTRACT

The advancement in technology has brought a new revolution in the military domain. The success of the two unmanned reconnaissance prototypes Predator and Hunter had paved the way to the development of more challenging remotely operated vehicles (ROVs), such as uninhabited combat aerial vehicles (UCAVs), used for locating, identifying, and destroying the enemy targets. As these semi-autonomous systems become more and more complex, the use of automation tools become inevitable. Although automation is introduced to reduce operator workload, increase in the automation features also increases the complexity of the system. The complexity of the system is increased by factors like situational awareness, trust, biases, workload, skill degradation as well as many other human factors issues. The purpose of this paper is to describe the research and development of a UCAV interfaces and simulation that can support human factors issues for controlling multiple UCAVs.

1 INTRODUCTION

The military has been using remotely operated vehicles (ROV) for reconnaissance missions for many decades. ROVs have been and continue to be used in decoys, scouts, reconnaissance platforms, surveillance platforms, and in transports (Christner 1991). Some of the more impressive factors associated with ROVs involve potential performance characteristics. Based on current research trends the New World Vistas (1995) provided several points of discussion involving future ROVs. Some of the advantages that a UCAV has over a conventional inhabited combat aerial aircraft are operational persistence, potentially lower life-cycle cost, no hazard to crew, and more maneuverability.

Compared to manned aircraft, UCAVs are cost effective and versatile systems, hence, make significant contributions to the war fighting capability of the operational forces. Timeliness of battlefield information is greatly improved while reducing the risk of capture or loss of manned assets. Mariani (1996) advocates that the highly autonomous remotely controlled UCAVs are the best and perhaps the only candidates for this specific military mission. Mariani also suggests that the automation of basic mission functions such as automatic route planning and execution, automatic target recognition, identifying, prioritizing, cueing, and automatic weapons loading are necessary to guarantee the success of military combat mission.

Human operators of complex systems, such as the control system for UCAVs in a suppression of enemy air defenses (SEAD) mission, have many responsibilities such as multiple UCAV coordination, handling multiple targets and/or target areas, detecting targets, identifying targets, planning routes, destroying targets, and timely returning UCAVs to base. Such responsibilities include supervisory control during normal operations, making minor adjustments when necessary, and overriding automated systems when abnormal situations occur. Successful completion of the mission depends on an operator's ability to perform the manual task(s) as well as maintain awareness of the automated task(s).

Incorporating uninhabited combat aerial vehicles into military missions possesses a real challenge for designing command and control stations and also the simulation architecture that can support or address these design challenges.

2 BACKGROUND

Automation is defined as a method in which operations are done automatically at some level. The dynamic and complex nature of systems and the overwhelming amount of data that must be handled by these systems are making automation a critical part in planning, decision-making and execution. However automation can fail in many ways (Bainbridge, 1983). First, an automation aid can fail to produce a response or a signal message. Second, an automation aid may have a low accuracy as the technology themselves are limited in their capabilities due to over simplification of the underlying decision making models. Third, the automation aid may work perfectly but fails to respond at the right time. Thus, the concept of human-centered automation arose in which the human is seen as an important element in the system to monitor the subsystems and to make decisions. There are many levels of control within automation. Sheridan (1980,1987) listed 10 levels of automation (LOA) depending up on the role of the human in the human-centered automation.

The taxonomy of 10 levels of automation that were developed by Sheridan clearly states that any automated system will allow the user some form of control over the automation. Even though the human operator is removed from direct control in these automated systems, human operators from remote locations will perform supervisory control tasks such as monitoring, command, control and co-ordination. Mosier and Skitka (1996) observed that too little as well as too much human intervention leads to problems. Wiener and Curry (1980) reported that the advent of automation brings new problems associated with human computer interaction. The problems associated with automation are vigilance decrements (Frankmann and Adams, 1962; Heilman, 1995), out-of-the-loop performance problems (Endsley and Kiris, 1995; Thackray and Touchtone, 1989), complacency (Mosier and Skitka, 1994; Mosier and Skitka, 1996), and skill degradation (Wiener and Curry, 1980; Hopkin, 1995). Some of the other factors that affect the overall efficiency, and performance of the system as well as human error are workload (Riley, Lyall, and Wiener, 1993), situational awareness (SA) (Billings, 1991), and reliability (Parasuraman, Molloy, and Singh, 1993).

Every task has a fixed amount of workload associated with it (Hart and Bortolussi, 1984). In a flight simulator experiment, Riley (1996) observed workload as a major factor in the pilot's choice of automation. High workload also causes stress and fatigue in human controllers, which enhances the possibilities of human error. In air traffic control experiment Hilburn, Molloy, Wong, and Parasuraman (1993) demonstrated that increase in air traffic density also increased workload of the operators.

Bainbridge (1983), pointed out that automation, designed to help reduce controller's workload, sometimes increases it. Hancock, Chignell, and Lowenthal (1985) suggested that adaptive automation could be used to allocate tasks to the user or system based on user workload in order to keep the user's workload within an optimal level.

The human operator and the automated portion of the human-computer system must be capable of communicating information and commands to each other (Billings, 1991). This is possible if there exists awareness between the two modes. The three levels of SA as described by Endsley (1988) are as follows:

1. Level 1 SA user's awareness of elements within the system
2. Level 2 SA user's understanding of elements on the complete system
3. Level 3 SA important factors that influence the user's performance.

Factors that impact SA are over-reliance on automation, passive role of human operator, and out-of-the-loop performance. A study conducted by Riley (1996) showed that when automation was found to be highly reliable subjects did not respond quickly to initial indications of failure. Endsley (1995) demonstrated that when operators are passive monitors of others input, as opposed to active suppliers of input, it becomes more difficult to understand, learn, and remember consequences of the inputs

A change in the system feedback or a complete loss of feedback results in associated problems with automation. Due to the lack of feedback it becomes very difficult to judge the performance of the human operators or controllers. Controllers may not know if their actions are received, if the actions are being performed, or if problems are occurring. Without feedback people are said to be out-of-the-loop of the system. Research shows that feedback received during manual control helped operators performance better than automated control. During failure modes operators who have been removed from system control may not know what corrective actions need to be taken to stabilize the system and bring it into control due to their required absence from the loop.

Many of these problems created are due to the fact that the user is not up to date on what the automation has done, what the automation is doing at present and what automation is going to do in future. Over reliance can be expressed as a function of a person's trust in, reliance on, and confidence in automation. Hence, reliabilty can increase or decrease efficiency and performance of the human controllers which in turn affects system performance.

Trust in automation causes the controllers to neglect automated systems and the system parameters completely. The questions to be answered before relying on automation are how often the user relies on automation, how often an error occurs because the user did or did not rely on the automation. User's can rely on automation if proper feedback is given to the user by the automation aids on what of it is doing.

When we refer to trust we are referring to the user's confidence and acceptance in the automation. When the operator relies on the automation too much, this is referred to as the complacency problem. The accuracy of the automation is referred to as the automation's reliability (Moiser and Skitka, 1996). The user's perception of that reliability may be higher or lower than the automation's actual reliability and this is due to mental model mismatches or a combination of several human biases (anchoring effect, immediate occurrence dominance, authority/power bias, stereotype bias, media bias, etc.). This perception is often referred to as simply 'trust.' Because this definition of trust is difficult to measure many researchers measure trust through related measures such as how often the user relies on the automation, how often an error occurs because the user did or did not rely on the automation, or they compare automation performance to user performance. The key is to help the user rely on the automation when the automation is making decisions as well as or better than the user, and to help the user to intervene otherwise. However when the user is overworked, perhaps the user should also rely on the automation when the performance of the system will not be critically affected (Mosier and Skitka, 1996). Based on a user's perception of his or her performance accuracy a user will develop a certain confidence in his/her own skill. Given the current circumstances, the user then may compare his or her skills to his or her trust in the automation, and then weigh his or her acceptance in the automation based on this comparison. However, this may lead to other problems (e.g., the user is out-of-the-loop when unique or critical decisions have to be made).

Due to false conceptions of reliability, humans tend to show biases in situations where the system is highly machine oriented, like power plants or aircraft, rather than less machine oriented such as stock market analysis (Mosier and Skitka, 1996). Moiser, Skitka, and Korte (1994) in analyzing aviation accident reports give evidence of over reliance on autopilot and flight management systems. This problem of complacency may be exacerbated with highly reliable automation (e.g., Three-Mile Island) (Parasuraman, Mouloua, Molloy, and Hilburn, 1996). Fault is partly due to the fact that it becomes more difficult to predict the behavior of the automation as it becomes more complex and mysterious. Efforts must be made to make automation more transparent (Norman, 1990, 1998), so as not to generate mistrust.

3 INTERFACE AND SIMULATION

The interface and simulation design was context driven rather than technology driven. Since the SEAD mission, and war in general, is so unpredictable we attempted to design a mechanism to prepare the human operator for unanticipated variability. The focus of the current project is on navigation, flight paths, UCAV updates, target tracking, target identification, target destruction, and elements that aid the UCAVs. The interface software was developed in VEGA and the simulation software was developed in Java on a Windows PC platform. The communication between the interface and simulation was facilitated by sockets. The interface is displayed on a 21 inch monitor, with input via mouse, keyboard, and voice.

In the SEAD mission, UCAVs are remotely flown over the enemy territory with the capability to detect, identify and destroy enemy targets. The UCAVs travel along individual predetermined routes. The routes are made up of waypoints, connected by lines. Each UCAV moves from one waypoint to the next waypoint along the lines connecting the waypoints. Waypoints can be moved, added, and/or deleted at any time during the mission. Associated with the waypoints are the UCAV's speed and fuel level. The UCAV speed can also be manipulated at any time during the mission time (Figure 1).

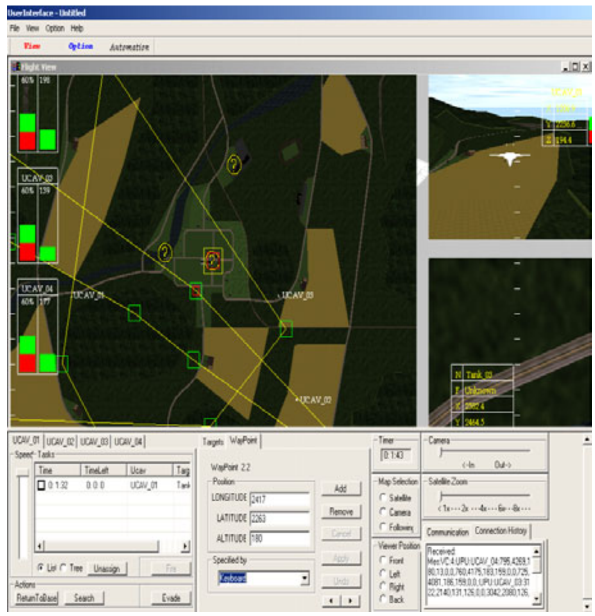

Figure 1: Screenshot Showing the Human Controller Interface

As the UCAVs fly along their individual routes, the human operator monitors and controls the UCAVs to identify and destroy the enemy targets and return to base safely. Targets appear on the map only when they are in range of the UCAVs as the UCAVs fly along the routes. Targets can be friendly, enemy, and/or unknown. The targets are detected and identified by sensors onboard the UCAVs.

Onboard each UCAV there are two types of simulated sensors for detecting and identifying the targets. One is long range sensor and the other is short range sensor. The long range sensor detects the targets when the UCAV is in range of the targets, whereas the short range sensor identifies and confirms the target type. Each UCAV can detect and identify four types of targets. The four types of targets include (1) A long range missile, (2) Medium range missile, (3) A short range missile, and (4) Tank.

Each UCAV has a supply of four types of ammunition to destroy the four different types of targets. The ammunitions used to destroy the enemy targets are named so as to reduce mental workload on human operators in selecting the right kind of ammunition. Once the enemy target is destroyed, the target is removed from the map so as to reduce clutter, errors, and mental workload and increase the performance of the human operator and the overall mission.

During the SEAD mission, the human operator should monitor and control the UCAVs for unanticipated variability. The human operator should make adjustments to the flight paths so that the UCAVs have enough fuel to reach the base safely. The human operator also monitors and makes amendments when necessary to other UCAVs flight paths in order to detect, identify and destroy enemy targets when a particular UCAV can/cannot detect, identify, and destroy the target due to fuel limitations or inability of the UCAV to fly over the region.

The interface can be used by the human controller to handle all the aspects of the mission operation. Figure 1 shows the snapshot of the controllers interface, used to command and control the UCAVs in a SEAD mission. The status panel and control panel are layered, and the UCAVs, targets, waypoints are all shown in the map display. The map display is further divided into panels to show the mission area in three different views. The three views include (1) Satellite view, (2) Camera view, and (3) Following view. This helps the human controllers to be situationally aware and to take appropriate actions as and when required.

The system also supports many interface/simulation capabilities. First, experimenters and operators have the ability to change the number of UCAVs needed to carry out the SEAD mission. Second, waypoints can be moved, added and deleted at any point during the mission time. Third, the fuel indicator of the UCAV not only displays the fuel consumption of each UCAV but also indicates the fuel level that is needed by the UCAV to return to base safely. Fourth, when identifying the targets, the human controller can zoom in and zoom out of the area to look at the target more closely. Fifth, enemy targets and the UCAV assigned to destroy the target are automatically queued in the control panel thus giving the direction of action that needs to be accomplished for the target. Sixth, the human controller has the ability to search and evade targets as and when required.

The communication between two or more human controllers controlling UCAVs is facilitated by the communication package called SimComm. The SimComm object handles all the network connections during the execution of the simulation model. A SimComm object is instantiated on the simulation server and also on the machines that are connected to the simulation server running the UCAV user interface as clients. The SimComm object instantiated on the simulation server stores the identity of the clients. The communication package thus sends and receives information back and forth to simulation server and updates the information on the user interface. Since, the simulation server was developed in Java users can connect to the simulation server platform independently.

The command and control of the UCAVs and targets was facilitated by physical, control, and information objects of the simulation. The physical class includes various actions the UCAVs take. For example, when a target is in the range of UCAV, the methods in the physical class specifies what action the UCAV has to take. The control class includes various decision making logic and the information class includes specific properties of the UCAVs like the airspeed, fuel level, etc. Figure 2 shows the relationship between the simulation and interface.

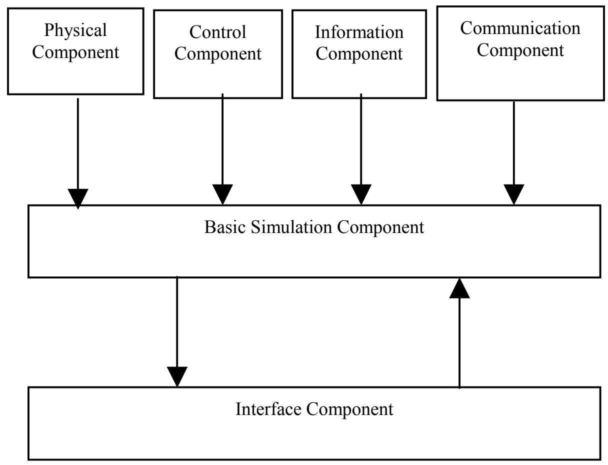

Figure 2. Communication Between the Simulation and Interface

4 CONCLUSIONS

The interface/simulation was designed such that experimental variables could be easily changed for future studies related to automation and evaluates the designs for the operator control of multiple UCAVs. It is also possible to construct the interface/simulation in the Cave Automatic Virtual Environment (CAVE) to test and evaluate the design for multimodal interactions.

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