Developing Collective Training for Small Unmanned Aerial Systems Employment

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Abstract: The projected use of small unmanned aerial systems (SUAS) in military operations will produce training requirements which go beyond current capabilities. The paper describes the development of prototype training procedures and accompanying research simulations to address this need. We initially constructed a testbed to develop simulation-based training for an SUAS operator equipped with a simulated vertical-lift and land SUAS. However, the required training will go beyond merely training an operator how to pilot an SUAS. In addition to tactics, techniques, and procedures for employment of SUASs, collective training methods must be trained. Moreover, the leader of a unit equipped with SUAS will need to learn how to plan missions which incorporate the SUAS, and take into account air space and frequency management considerations. The demands of the task require the leader to allocate personnel to the SUAS mission, communicate and coordinate with those personnel during the mission, and make use of the information provided. To help address these training issues, we expanded our research testbed to include a command and control node (C2 node), to enable communications between a leader and the SUAS operator. In addition, we added a virtual environment in which dismounted infantry missions can be conducted. This virtual environment provides the opportunity for interactions among human-controlled avatars and non-player characters (NPCs), plus authoring tools to construct scenarios. Using these NPCs, a collective exercise involving friendly, enemy, and civilian personnel can be conducted without the need for a human role-player for every entity. We will describe the results of our first experiment, which examined the ability of players to negotiate use of the C2 node and the virtual environment at the same time, in order to see if this is a feasible combination of tools for training development.

1. INTRODUCTION

The demonstrated usefulness of unmanned aerial systems (UASs) has led to a steady increase in their employment for reconnaissance and surveillance over the last decade. One area of research and development concerns the employment of small UASs (SUASs). If SUASs can be made light enough to be man-portable and easy enough for almost any Soldier to operate, they could provide unprecedented situation awareness at the small military unit level. Several types of SUASs are already in use by the military, and the U. S. Army is currently evaluating an SUAS with vertical take-off and land, and hover capability. If the evaluation is positive this system will be deployed. This will create a large training demand, which will require both virtual and live simulation. System operators will require training on systems operation and maintenance, and their leaders will require training on system management and a means to conduct team-level mission exercises [1]. Anticipating this training demand, we developed a research simulation testbed to explore how simulation could best be used for these purposes. By analogy with the successful use of simulation for pilot training, we initially focused on developing simulation-based operator training exercises and evaluating the usefulness of various performance measures for their ability to contribute to a standards-based simulation training curriculum [2], [3], [4]. We have subsequently expanded the testbed to allow for team-level mission exercises. This paper will describe the evolution of the testbed.

2. OPERATOR TRAINING SIMULATION

Considering the extensive use of simulation-based training in manned aviation [5], it seems natural to extend the use of simulation training to unmanned aviation systems. As such, in collaboration with the Institute for Simulation and Training at the University of Central Florida, the U.S. Army Research Institute began by developing a research testbed to develop and test simulation-based training exercises as well as performance measures which would be appropriate to use for training standards.

2.1 The simulated SUAS

The characteristics of the simulated SUAS (SSUAS) were loosely based on a prototype Micro-Aerial Vehicle (t-MAV) developed under the Defense Analysis Research Project Agency's MAV Technology Demonstration. The t-MAV was a ducted-fan vertical lift vehicle which could hover, rotate in place, and travel at an airspeed of up to six knots under manual control, and over 25 knots under waypoint navigation. We incorporated these characteristics into the SSUAS. We developed a flight model, which, similar to the t-MAV, caused the vehicle to tilt forward one degree for every knot of forward speed, and which gave it some inertial properties (e.g., when in forward movement, it took time to actually stop and assume a hover after the hover command was issued). Like the t-MAV, the SSUAS was equipped with two cameras, one facing forward, and one facing downward. The tilt produced by forward movement of the SUAS tilted camera angles (e.g. while moving forward, the downward camera pointed somewhat behind the vehicle). Some features of the SSUAS were configurable, so that the effect of various aspects on operator performance could be investigated. For example, the cameras could be fixed or have the ability to pan and zoom.

2.2 The operator control unit

The operator control unit (OCU) was designed to be reconfigurable, so that the effect of OCU design on operator performance could be investigated. For example, the OCU display could be configured to show one camera view at a time or both camera views simultaneously. Figure 1 shows one particular OCU configuration, and illustrates several of the potential features. In particular, an altimeter on the left edge, the camera view with a heading tape, an overhead map showing the SSUAS position, and flight controls. Icons on the tool bar controlled functions such as switching camera views and taking still photographs. Though not illustrated here, the OCU could also provide the operator the opportunity to program automated flight paths based on preset waypoints, and launch or interrupt these automated missions. In manual mode, the OCU could be controlled by a mouse or by a two-thumb stick game controller.

The OCU is written in Linux using freely available software (Open Scene Graph for rendering and OpenAL for audio) and requires no additional licenses to be purchased. The SSUAS and a base station are transmitted using the DIS protocol so that both can be displayed in other systems. Any modem PC and video card can satisfactorily run the OCU.

Figure 1: Example OCU Interface

2.3 The synthetic environment

The SSUAS could be operated in one of two synthetic environments, each based on an actual Military Operations in Urban Terrain (MOUT) training areas. Both simulated small towns, but differed in their specific features. Any OpenFlight database can be loaded although the overhead map feature requires an additional image file. The map can be an actual map image or an aerial view depending on the need. In addition to features inherent in these environments, other entities could be imported through Distributed Interactive Simulation (DIS) communication protocol (we used OneSAF Testbed Baseline v2.5). This allowed for the display and routing of various types of vehicles and dismounted personnel.

2.4 Research findings

We developed operator training missions intended to train manual flight control, concentrating on two types of missions. One focused on flight skill. To conduct these we set up obstacle courses delineated by poles placed in various configurations. Trainees had to learn to manually maneuver the SSUAS along a designated path around the poles. The other type of mission focused on using the SSUAS for reconnaissance. In these missions, trainees maneuvered freely around the environment in order to find and photograph targets (both dismounted personnel and vehicles).

Participants were given an initial introduction to the OCU, and the opportunity to practice simple maneuvers and functions. They were subsequently asked to complete a series of missions during which performance measures were collected. Different trainees were given different OCU configurations, and performance effects of these configurations were examined in order to investigate the sensitivity of various measures (e.g., number of collisions, number of targets detected, time to complete mission). Our aim was to determine which performance measures were sensitive enough to be useful for future standards-based simulation training. Our results suggest that temporal measures (time to complete mission) is the most sensitive measure we assessed, and therefore likely the most useful for setting standards (e.g., must be able to complete mission within a set time with no collisions). For further details on this research, the reader is referred to [2], [3], [4].

3. TEAM-LEVEL MISSION SIMULATION

Like individual pilot training, team training in aviation has benefited from simulation [6], [7]. For SUSAs, the makeup of the team may depend on the specific system, but in the context of a small Army unit, it will likely consist of at least the operator and a robotics noncommissioned officer (NCO), and/or the unit commander. Effective team performance will require team members to coordinate, communicate, and hold a shared understanding of the task, their equipment, and their teammates [7]. Thus, it is not sufficient to merely train an operator how to operate a system. The leaders in a unit equipped with an SUAS will need to learn how to plan missions that integrate the SUAS, and take into account air space and frequency management considerations. The leader will need to allocate personnel to the SUAS mission, communicate and coordinate with those personnel during the mission, and make use of the information provided by those personnel [1]. The unit will need to learn tactics, techniques, and procedures associated with the employment of the SUAS, and collective training methods will be required to accomplish this. To help address these training issues, we expanded our research testbed to include a command and control node (C2 node), to enable communications and information exchange between a leader and the SUAS operator. In addition, we added a virtual environment in which dismounted infantry missions incorporating use of the SSUAS can be conducted.

Specifically, the system was expanded to include three separate elements: 1) GDIS: a virtual immersive environment that replicates one of the synthetic MOUT sites and can be populated with human-controlled avatars and semi-intelligent computer generated forces (non-player characters or NPCs). 2) C2 node: a command and control node enabling communications between the commander and SSUAS operator, and 3) the OCU: the pre-existing OCU was modified to allow for interaction with the C2 node. As a whole, this system offers a great deal of flexibility in that participants may operate avatars in GDIS, and/or may operate the C2 node or the OCU, thus simulating an entire small unit equipped with an SUAS. The SSUAS is visible to characters in GDIS and can "sense" the GDIS environment and transmit these sensor images to the OCU and/or C2 node.

3.1 C2 Node

The C2 node was created to simulate a nominal command and control station. Like the OCU, the interface is reconfigurable. For example, the experimenter can choose to have blue force tracking displayed on an overhead map or not. Or the experimenter can choose to allow the C2 to receive streaming video from the SSUAS or not. Figure 2 shows one particular C2 node configuration and shows many of the features available, including an interactive map grid that shows the location of the SSUAS, NPCs, and players within the GDIS environment, a window for receiving pictures and/or streaming video from the SSUAS/OCU, text windows for sending and receiving messages, and menus for mission planning. Mission planning includes inserting routes, no fly zones, and flagging entities, as well as sending and receiving information (e.g., mission plans, texts).

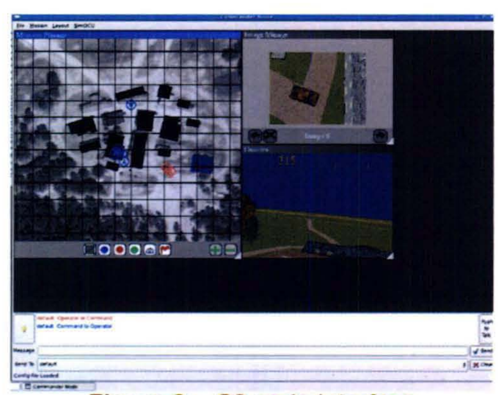

Figure 2: C2 node Interface

3.2 Modified OCU

The OCU was modified to include features and functionality that enable communication and coordination with the C2 node. Figure 3 shows a specific modified OCU configuration, including some of the new features. These include a new window to display still photos, which can be labeled and sent to the C2 node, and a window for exchanging text messages with the C2 node. The OCU can also receive mission plans from the C2 node. Similar to the C2 node, blue force tracking can be enabled or disabled, so that the effect of having this capability on mission performance can be investigated. All of the information exchanged between the OCU and C2 node is time stamped and saved to a text file for subsequent analysis.

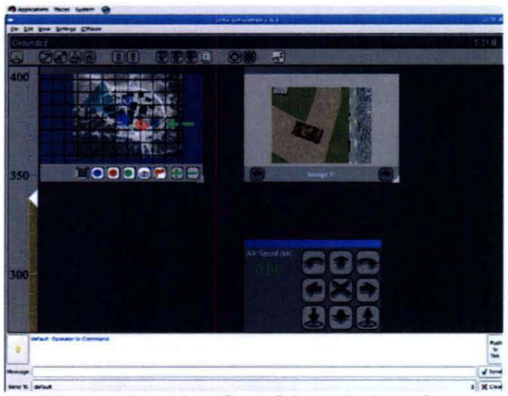

Figure 3: Modified C2 node interface

3.3 GDIS Virtual Environment

The GDIS virtual environment (developed by Research Network Inc.) has the ability to function alone, allowing multiple distributed human players to control avatars, which can maneuver, shoot, emote, and communicate with other players. We have integrated GDIS with the OCU and C2 node, such that the SSUAS is an entity that appears in GDIS, but is controlled from the OCU. In addition, we have added substantial artificial intelligence capabilities (AI) to allow for semi-automated NPCs. This allows a multi-person scenario to be conducted without requiring a human role-player for every character. Figure 4 shows a screenshot from GDIS with NPCs and the SSUAS visible. The system is user-friendly with regard to the development of scenarios, having relatively sophisticated AI specified by menu-based authoring. Scenario authors can add NPCs, assign them to teams, and assign individuals or teams to waypoint-based routes. Authors can also add operational vehicles and a range of objects, including improvised explosive devices (IEDs).

NPCs in GDIS have a number of settings, including team membership, weaponry, competency (i.e., novice, expert fighter), and rules of engagement (ROEs). Routes can be created using waypoints, and specific behaviors can be assigned to waypoints. NPCs can then be assigned to the routes and will act out the behaviors that are associated with each waypoint when they are reached. For example, "patrol" can be assigned to a waypoint, and an NPC arriving there will engage in patrolling behavior according to a selected amount of time and a selected radius of the waypoint. Behavioral characteristics can also be altered at waypoints. For example, ROEs can be changed so that they are different inside vs. outside of a town. Moreover, in order to make scenario branching more sophisticated, contingencies can be set up at waypoints. This allows behavior to change according to context. For example, the waypoint may direct the NPC (or NPC team) to go to the next waypoint only if another NPC team has reached another specific location. These if/then contingencies are specified through the menu-based authoring system in the same manner as the more simple waypoint-associated options.

Figure 4: GDIS system environment with NPCs and the SUAS

Finally, some team-level behaviors have been constructed (e.g., building search), so that an NPC team will perform the behavior in a coordinated way, without requiring the scenario author to script the behavior of each team member. Using this scenario authoring system, the interactions of NPCs with one another, with human-controlled avatars, and with the environment can be made to appear complex and realistic. Figure 5 shows a screen capture of some of the menus for scenario generation. Specifically, the screen shows the assignment of players and squads to specific routes.

In addition to specifying NPC behavior in pre-constructed scenarios, mission controllers can take over control of an NPC during scenario, manually manipulate its behavior, and subsequently return it to autonomous mode.

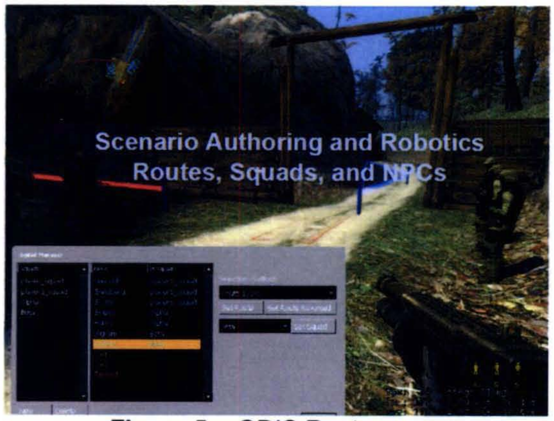

Figure 5: GDIS Route menu

GDIS was also created with an eye towards future compatibility with military systems and software. With the explosion of available game engines available to the Army, this research (and GDIS SimBridge) is being designed to leverage off these available technologies easily and allow for insertion of latest technologies as they become available. However, the military is currently using several different types of game-based applications, so there is no standard game engine being used as the basis of these applications. As a result, GDIS currently interfaces with the HL2 engine (Mod Type) and the GameBryo engine (Source Type).

3.4 Potential of the test bed for small unit missions with SSUAS

The integration of the OCU, C2 node and GDIS environment allows for the simulation of small unit level dismounted missions, which incorporate the use of an SSUAS. The operator of the OCU views the GDIS environment through the OCU video imagery, and can exchange information with the unit commander equipped with the C2 node. The unit commander can either be in a notional command center, or actually in the GDIS environment, by providing him or her with a computer running GDIS in addition to the C2 node.

In order to determine whether this latter configuration was feasible for a user, we conducted a pilot experiment to assess the ease or difficulty a person would have if assigned to use the C2 node and control an avatar in GDIS at the same time. We varied the workload demands of the C2 node (low or high) and the GDIS task (low or high), and each participant completed four missions representing the combination of these conditions. After some practice maneuvering their avatar in GDIS, and basic training on the C2 node, participants were given missions in which they were asked to visit specified buildings (in GDIS) and classify (on paper) the people they discovered as Soldiers, doctors, or refugees. In addition, they had to report (via text messaging using the C2 node) the presence or absence of specified targets in pictures sent to them through the C2 node. This represented the low-low workload condition. For the high C2 node workload condition, another C2 node task was added: on request, reporting the position of the SSUAS using the C2 node map grid. For the high GDIS workload condition, another GDIS task was added: on request, report (by text message) the location of a specific person in GDIS, using the GDIS interactive map. The order in which the missions were conducted was counterbalanced across participants. A metric that considered both accuracy and time to complete each mission was used to evaluate performance.

We found that our manipulation of workload had a far weaker impact on performance than simply the opportunity to practice. Regardless of the workload condition, performance improved over time from mission one to three, with performance on missions three and four roughly equivalent. Individual difference factors (e.g., video game experience and spatial ability) also influenced performance. Specifically, participants with higher spatial ability (as measured by the Cube-Comparison Test [8]) tended to perform better ($r = .39$, $p < .05$). Game-playing habits also affected performance. The time spent playing video games ($r = .71$, $p < .05$) and the frequency with which they played ($r = .68$, $p < .05$) correlated positively with the overall score which considered both accuracy and speed of mission.

4. CONCLUSION

Our initial research using all elements of the testbed indicate that it is feasible for a participant to work with the C2 node and control an avatar in GDIS at the same time. This research was conducted before we had the full AI functionality in the NPCs described above. Now that those capabilities are in place and we have established that people can work well with the systems, we can begin to craft more realistic scenarios. These will enable us to examine the coordination and communication issues that units will have in integrating use of an SUAS into a mission, as well as methods to overcome such issues through training, the use of standard operating procedures, and the development of tactics, techniques, and procedures.

5. REFERENCES

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