Adaptive Distributed Aviation Asset Optimization for Operational Effectiveness

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Abstract

The paper describes the use of an intelligent agent associate (IAA) for management of distributed aviation assets during man-in-the-loop experimentation and evaluation for warfighter net-centric operations. Bell Helicopter and Applied Systems Intelligence, Inc. are integrating a collaborative adaptive tasking system (CATS) into a full mission simulation evaluation environment in the Bell Helicopter Manned Unmanned Operations Capability Development Laboratory in Huntsville, Alabama. The IAA CATS serves to validate development and test activities which enable aviators to effectively manage distributed aviation assets, in this example - unmanned aircraft, without impairing their performance on other flight tasks. The IAA CATS enables enhanced aviator performance and mission safety and demonstrates the ability for the system to incorporate additional knowledge bases adapted to accommodate evolving Tactic's Techniques and Procedures (TTPs). Accelerated Adaptive Distributed Aviation Asset Optimization of Operational Effectiveness will show that even in complex situations, the decision aiding functions provided by CATS enhance aviator performance and mission safety. The CATS enables human-centered requirements analysis and refinement, and acts as an integrating layer that brings together situation assessment, dynamic planning and procedure execution assistance to the federated helicopter systems architecture. The CATS system reflects the task needs of the flight crew but does not interfere with or impede the ability of the pilot to perform whatever actions are required during mission execution and does not add task demands to pilot workload. The influence of the CATS is to reduce net task demands on the aircrew while insuring mission success and flight safety that results in aviation asset management from a combat helicopter cockpit environment. The development of additional operational scenarios to drive requirements specification will be evaluated over time for other applications associated with Parapublic and Commercial aviation asset management. Operational effectiveness and situational awareness requirements consider data and user interfaces, space, power and weight, real-time performance and human interaction issues. These defined requirements aid in defining and documenting the evaluation criteria for the IAA CATS. Evaluation criteria consider collection and analysis of the measurements for both a simulator-based environment and for full flight environments.

Introduction

This paper describes the use of an intelligent agent associate (IAA) for management of distributed aviation assets during man-in-the-loop experimentation and evaluation for warfighter net-centric operations funded under a SBIR phase I program. Bell Helicopter and Veloxiti are integrating a collaborative adaptive tasking system (CATS) into a man-in-the-loop mission simulation evaluation environment in the Bell Helicopter Manned Unmanned Operations (MUMO) Capability Development Laboratory in Huntsville, Alabama. The IAA CATS serves to validate development and test activities which enable aviators to effectively manage distributed aviation assets, in this example - unmanned aircraft, without impairing their performance on other flight tasks. The IAA CATS enables enhanced aviator performance and mission safety and demonstrates the ability for the system to incorporate additional knowledge bases adapted to accommodate evolving Tactics Techniques and Procedures (TTPs).

Discussion

Under the Army's Aviation Applied Technology Directorate (AATD) in Fort Eustis, VA, the Manned-Unmanned (MUM) System Technology program is addressing the challenges of teaming Unmanned Aerial Vehicles (UAVs) and manned helicopters. To perform MUM operations safely and effectively, the Army needs an innovative and effective way to dynamically task distributed unmanned assets without overloading the aviator. Typical Unmanned Aerial System (UAS) control implementations require intensive user inputs to specify the desired mission behaviors. In the cockpit, this presents a high cognitive demand that pulls attention away from the flight situation and is inherently error prone.

As Army Aviation transitions to enhanced glass cockpits with advent of the continued Safety Enhancement Program (SEPs) with OH-58D Kiowa Warrior and AH-64E, the Army has recognized the opportunity to control UAS from the cockpit of its manned aircraft. The combined MUM team has the potential to provide the Army aviator with more situational awareness of the combat environment and to multiply his effectiveness. With this new initiative brings more challenges and demands on the aircrew, specifically MUM operations between Crew and UAVs.

OH-58Ds operate in teams of 2-4 A/C in direct support of ground forces. In that type of operating environment timeliness and accuracy of information to the Aviation crew is critical. This has always been and continues to be a challenge. Additionally, OH-58Ds operate with uncertainty and in a bandwidth restricted environment creating more demands on tasking.

To meet this challenge, VELOXITI has developed an Intelligent Associate (IA) system technology for use in aircraft such as the OH-58D. An Intelligent Associate system is an architecture built on a knowledge base that includes procedural information, operational data, and a current picture of the world state. The OH-58D associate enables an air crew to control individual/multiple UAVs and other air assets. Critical challenges that were addressed include:

1) Maintaining aviator awareness of distributed asset mission status in flight.

2) Supporting the coordination of multiple unmanned assets in a variety of simultaneous activities.

3) Providing efficient control capabilities to the Army Aviator while minimizing the impact on workload.

The decision aiding functions provided by CATS enhance aviator performance and mission safety. CATS enables human-centered requirements analysis and refinement, and acts as an integrating layer that brings together situation assessment, dynamic planning and procedure execution assistance to the federated helicopter systems architecture. The CATS system reflects the task needs of the flight crew but does not interfere with or impede the ability of the pilot to perform whatever actions are required during mission execution and does not add task demands to pilot workload.

The CATS reduces net task demands on the aircrew while insuring mission success and flight safety. The development of additional operational scenarios to drive requirements specification will be evaluated over time for other applications associated with Para-public and Commercial aviation asset management. Operational effectiveness and situational awareness requirements consider data and user interfaces, space, power and weight, real-time performance and human interaction issues. These defined requirements aid in defining and documenting the evaluation criteria for the IAA CATS. Evaluation criteria consider collection and analysis of the measurements for both a simulator-based environment and for full flight environments. Most current battlefield systems, including helicopters, can only interact with UAVs in an indirect manner. Sensor information from a UAV is disseminated through intelligence channels to the Tactical Operation Center (TOC), the battlefield commander, and/or the reconnaissance crew.

Command and control of UAVs is limited to line-of-sight from the ground. Any deviations from the planned mission parameters by the reconnaissance crew must be requested through communications to the Ground Control Station (GCS). This process has many drawbacks including time delays for re-planning or re-tasking approval, latencies in communications due to the flow of large volumes of other information, limited range of the operation or mission, differences in perspective of the battlefield situation and reduced survivability of the helicopter.

Previous Technology Base

The development of the CATS system has not occurred in isolation, but instead in the context of a rich technology base that has evolved over many projects and products over a 24 year period. VELOXITI has been a leader in the evolution of this technology base, participating in the design and development of most of the human-centered intelligent aiding systems made in that period. The development of human-centered intelligent aiding systems began with the DARPA Pilot's Associate, the visionary program that launched VELOXITI as a company in 1990. Since then, VELOXITI has played a central role in the evolution of this technology base. This section highlights just a few of the important historical contributions to the technology base that formed the starting point for the CATS system.

DARPA/USAF Pilot's Associate (1987-1992)

The Pilot's Associate Program created a new model for human-centered intelligent systems, built from the start to cooperate and support their human user. All such systems are now known as "Associates". The program was sponsored by DARPA under the Strategic Computing Program. The goal of this program was to investigate the applicability of emerging Artificial Intelligence capabilities in military applications. The PA was administered by the USAF Avionics Laboratory at Wright-Patterson Air Force Base in Dayton, Ohio and was originally conceived as a set of 4 collaborating expert systems: Systems Status reporting the ability of the aircraft to perform its mission; Situation Assessment determining the external environment; Mission Planning with a long-term strategic view of the mission; and Tactics Planning with a short-term, reactive view. Three more expert systems were later added: Pilot-Vehicle Interface (PVI) managing the presentation of information to the pilot and interpreting pilot actions; Mission Management maintaining a consistent view of the mission parameters and organizing the communications between systems; and Mission Support Tool to allow pilots to tailor the behavior of the systems before each mission.

VELOXITI was founded at the start of Phase II of the Lockheed Pilot's Associate. VELOXITI led the test and integration efforts for the software until its successful completion in 1992.

Army Rotorcraft Pilot's Associate (1994-1998)

VELOXITI participated in the system design, software development and testing of the RPA, and supplied the Crew Intent Model for use within the intelligent Crew Interface Manager.

The Rotorcraft Pilot's Associate (RPA), was an advanced mission/cockpit management system developed by the Army and McDonnell Douglas Helicopter to assist the pilot with complex combat tasks. The architecture and performance of the RPA was based directly on the earlier DARPA Lockheed Pilot's Associate. The target mission for the RPA was Scout-Attack, and it was developed on the Apache Longbow platform. Although RPA was designed to initiate time critical activities such as actions on contact, it always kept the pilot in charge of the aircraft. In battle situations, RPA identified and prioritized targets, selected battle positions, coordinated target handoffs among available teammates and provided safety areas for the pilot.

The RPA modified cockpit featured three multifunction, full-color liquid crystal display panels which provide targeting information, two- and three-dimensional virtual reality maps of the battle scene and control access to all aircraft systems, such as communications, countermeasures, propulsion, fuel and weapon systems.

Data fusion, which was a key element of RPA, provided the spatial and temporal adjustments that allowed the system to take information from global positioning satellites, off- and on-board sensors, communications channels and aircrew input. RPA continuously re-assessed information to inform the pilot and provide mission plans based on any new impacts to the current route or mission plans. The RPA was flight tested at Yuma Proving Grounds on the Apache Longbow, accumulating over 100 flights in a 12 month period. This technology has direct application for today's current CATS as an intelligent decision making system to be incorporated into a rotorcraft cockpit environments, C2 vehicle/platforms, and other existing technologies.

The agent developed for the CATS prototype extends capabilities that were originally developed for the Warfighter Associate system. The system's knowledge base is organized to support OODA loop problem solving. First defined by Col. John Boyd, OODA loops (Observe-Orient, Decide, Act) provide a means for continuously responding to continuously changing situations.

What can CATS reason about?

As configured for the Phase I CATS prototype, the system handles six commonly occurring battlefield events: Troops in Contact, Downed Aircraft, Probable IED, Confirmed IED, Insurgent Leader, and Demonstration. Some of these events are more important than others; for example, Downed Aircraft events almost always have priority over Demonstrations. The knowledge base associates an importance value with each event type.

- All normal doctrinal operations
- Troops in Contact
- Personnel Recovery/ downed aircraft
- MEDEVAC (Medical Evacuation)
- IED (Improvised Explosive Device), VBIED (Vehicle Borne IED), SVIED (Suicide Vest IED) , P-IED (Possible IED) /Predictive Analysis
- CASEVAC (Casualty Evacuation)
- POO/POI (Point of Origin / Point of Impact)
- Airspace ROZ (Restricted Operating Zone)
- HVT (High Value Target)
- ISR (Intelligence, Surveillance, Reconnaissance) asset and management
- Unit boundaries
- Joint and coalition coordination
- Minefields
- Demonstrations
- Air Threats

Based on the nature of an event and currently available assets, the agent recommends the top three most suitable ISR assets. The resource allocation algorithm considers both the nature of the event and the characteristics of available ISR assets. The agent considers seventeen different platform attributes including:

- Average speed
- Coverage radius
- Current altitude
- Current location (lat, long)
- Echelon
- Equipment can travel to event
- IMINT capable (Imagery Intelligence)
- Is manned or unmanned
- MASINT capable (Measure and Signature Intelligence)
- Max seconds until arrival
- Max wind speed
- NTISR capable (Non-traditional ISR)
- Required offset from target
- Sensor fidelity rating max
- Sensor fidelity rating min
- SIGINT capable (Signals Intelligence)
- Stealth rating
- Survivability rating
- Task org to Battalion

An advantage of an Intelligent Associate system is that it can control individual and multiple types of UAVs and other air assets to complete the mission. UAVs can provide video surveillance and reconnaissance, target laser designation, battle damage indication, communications relays, and even alternative weapons platforms - all under the watch of the crew in the Kiowa Warrior that is safely under cover. Teaming UAVs with manned vehicles has the potential to greatly increase the mission effectiveness and the survivability of the manned assets. UAVs can act as an extended sensor network for the manned vehicles, allowing them to extend their influence over a much larger battle space. Whether the Kiowa Warrior is executing an attack sequence or conducting a reconnaissance mission, the Intelligent Associate will have the knowledge necessary to construct an appropriate plan for crew support with UAVs.

Another advantage of associate systems is the efficiency of the knowledge structures. Because VELOXITI's technology is a knowledge-driven system versus data, our footprint is small compared to traditional database systems.

VELOXITI has demonstrated in a desktop prototype that Intelligent Associate technology can provide the necessary functionality to the Apache and Blackhawk for commanding and controlling multiple UAVs based on Intelligent Associate knowledge. There were several conclusions to be drawn from the current body of work for this effort at VELOXITI.

1. A definite need exists to enhance the user crew's experience to support multiple UAVs and other air assets from the cockpit.
2. Current sensor and UAV technologies will expand the capabilities of current aircraft well beyond present operating limitations.
3. The intelligent system's knowledge base needs verification from pilots and other SMEs. Despite program approval and validation during Phase I, the knowledge should be thoroughly examined and expanded to meet the needs of the program.
4. Building the complete OH-58 prototype and integrating it into a Bell Helicopter simulation will happen later this year.

The Team has carefully constructed a work plan for Phase II SBIR that accomplishes substantial progress towards the introduction of the CATS II system onto the OH-58 Kiowa Warrior and lays the foundation for commercialization for both Army aviation and for use in the general aviation fleet. The plan uses Agile Test-Driven Development to validate requirements and refine the design and implementation of CATS II. At the completion of Phase II, the CATS II system will have demonstrated its robustness and mission value in flight worthy hardware, and we will have a well-defined deliverable prototype fully ready for flight evaluation, production readiness and system certification in Phase III.

The ATDD methodology we have proposed for Phase II is divided into five main development spirals, each with several small sprints within them. The first four of the major spirals culminate in manned simulation test (MST) periods in mission OH-58 flight simulators, while the final spiral applies the results of the MST 4 to the final requirements, design and implementation in Bell's high fidelity flight simulator. Each sprint within a spiral is typically 30 days long and includes refinements of requirements, test cases, design, and implementation, all focused on the goals of the major spiral and the tests defined for the MST event.

Our work for Phase II will involve the use of human subjects during the major MST events. While VELOXITI and Bell Helicopter both have employees with OH-58 flight experience, we strongly desire to include Army flight personnel in these tests as well. Our Team has extensive experience in planning, conducting and analyzing manned simulation tests and flight tests.

Manned Helicopter Experimentation Environment

Current battlefield helicopter systems interact with UAVs in an indirect manner. Sensor information from a UAV is disseminated through intelligence channels via GCS to TOC, battlefield commanders, and/or the helicopter crew. Coordination, transmission, and receipt of UAV sensor imagery and UAV control is predicated on numerous interoperability protocols that tend to increase crew work load. Army efforts to develop, organize and employ UAS aviation assets across the full spectrum of operations are well underway and the need for rapid technology assessment and insertion that reduces aircrew work load is required. To support this need and the long term viability of the armed scout helicopter mission, Bell Helicopter, in collaboration with AAI Corporation (a Textron Systems Company), developed a MUMO CDL to enable rapid technology experimentation specific to manned unmanned teaming.

The CDL, as shown in Figure 1, is located in Huntsville, Alabama, an area rich in aerospace and military technology development. The CDL is physically located adjacent to the Textron Systems Integration Collaboration Laboratory (TICL) containing AAI unmanned aircraft platforms, command and control solutions and training and simulation equipment. (See Figure 2). The TICL also contains technologies providing for real-time collaboration

Figure 1: Capability Development Laboratory

using live data feeds from Shadow unmanned aircraft flown at nearby Redstone Arsenal. The connectivity between these laboratories provides the engineer, analyst, and pilot with an immersive environment for MUM technology experimentation and operational strategy development.

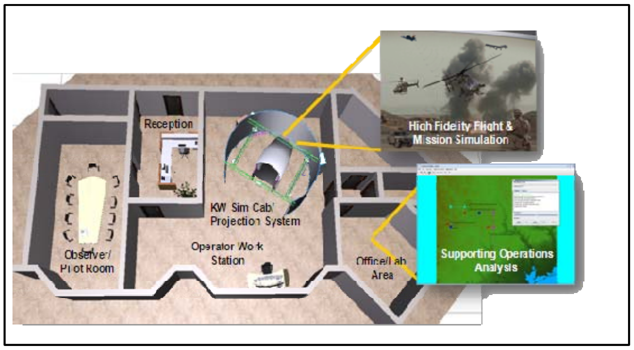

Figure 2: MUMO CDL

The man-in-the-loop portion of the laboratory uses tailorable, rapidly-reconfigurable cockpit hardware and displays. The MUMO CDL contains the OH-58D Kiowa Warrior cockpit simulator (Figure 2) which is a fully interactive man-in-the-loop device that provides a rapid prototyping environment for quick development.

Simulation of the aircraft's dynamic flight performance characteristics is accomplished using a real-time implementation of the Bell proprietary COmprehensive Program for Theoretical Evaluation of Rotorcraft (COPTER) analysis and design tool. Simulated software such as the Mission Equipment Package (MEP) and other avionics systems and hardware (e.g. Multi-Function Display (MFD) bezels, etc.) was selected for the CDL as opposed to integrating actual aircraft components. The primary reason behind this decision was to prevent the integrator from being hindered by the constraints that using aircraft equipment would bring. In this way, the integrator is allowed full flexibility in developing software and hardware in an effort to increase situational awareness while simultaneously lowering operator workload. Secondarily, while there is a cost associated with correctly emulating the aircraft's software and hardware, by doing so the developer is allowed to make changes, create "what ifs", and adapt much quicker than would be possible with aircraft components. While no actual aircraft components were used during lab development, there is no reason to preclude insertion of avionics equipment or prototypes into use. Using a simulated host can actually ease the integration process. L2 MUM software currently fielded in operational units is integrated in the CDL simulator and allows operator interaction with simulated UAV systems in the TICL.

A battlefield environment provides the ability to build and control dynamic scenarios for various engagement and testing conditions. While this environment is typically run as a standalone system, it can also be used in distributed simulations as well. In an effort to be current with other facilities, a MetaVR Image Generator (IG) was selected to provide "out-the-window" and sensor visual presentation. The IG, along with five Christie projectors in a rear projection setup, provides a 245˚x63˚ field of view, with individual channels providing a 16:10 screen aspect ratio and a display resolution of 1920x1200 pixels using Widescreen Ultra Extend Graphics Array (WUXGA). The IG allows a variety of environmental conditions to increase realism during system evaluation. All application software is hosted on off-the-shelf style personal computers running either Debian Linux or Microsoft Windows operating systems.

In order to properly conduct and manage an evaluative environment, an Instructor Operator Station (IOS) was placed in close proximity to the manned simulator (See Figure 3). The IOS allows the test director dynamic control over the battlefield scenario the operators are facing and weather and other external visual cueing, while providing a secondary view of all in-cockpit displays and communication capability to both the KW operators as well as the Shadow (or other) UAS operators located elsewhere.

The KW simulation device provides a man-in-the-loop test bed to rapidly prototype, integrate and evaluate various technologies in the development and concept exploration of MUMO and TTPs. The IOS provides the test director all of the data and tools necessary to interactively work with the KW device as well as any other integrated system(s) being evaluated for MUMO and TTP development.

Supporting Technology Insertion and Test

The collaborative laboratory environment enables small business and contractors the ability to insert and demonstrate relevant and applicable technology onto the MUMO CDL simulation environment for development test. The laboratory allows early integration and test with Kiowa Warrior, Shadow, aircrew

Figure 3: Instructor Operator Station (IOS)

training hardware and simulated devices. Additionally, the lab enables next generation aviation system growth and technology insertion focused on operator workload reduction.

Conclusions

The first product will be a CATS intelligent agent that compliments the Army's Kiowa Warrior OH-58F growth strategy for manned unmanned operations (MUMO) to enable Level 3, Level 4 and potentially Level V Level of Interoperability (LOI). This product and associated growth strategy will enable Next Generation Aviation systems growth required for emerging Future Vertical Lift systems and the associated operator workload reduction. The CATS capability supports and enables satisfaction of emerging requirements for MUMO fielding and deployment in full spectrum MUM operations capability. Full Kiowa Warrior OH-58 product insertion will require the support, authorization and acceptance by Armed Scout Helicopter (ASH) Program Management (PM). ASI Inc., working with Bell Helicopter Textron Inc. and AAI Corporation, intends to coordinate with ASH PM to obtain this authorization and acceptance.

CATS will support anticipated Control and Display Subsystem (CDS) growth objectives in a spiral improvement to the current and emerging CDS systems that addresses component obsolescence and MEP capability approaching true Armed Aerial Scout objective requirements as defined in the AAS Analysis of Alternatives Phase I Exec Summary from December 2010 for MUM Teaming at CAV Squadron Level.

We envision that the CATS improvements can be incorporated into CDS growth objectives via a single block modification or by a series of smaller scope local Modification Work Orders (MWOs) or by depot modification for the more complex and labor-intensive installations required to achieve broader UAS LOI capabilities. As a first step towards migration from LOI 2 to LOI 3, the Bell-VELOXITI team will address issues such as pilot interactions with the aircraft and the associated MEP. CATS will add an intelligent agent associate (IAA) allows slew-to-cue sighting capability.

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