WARHORSE: A NEW APPROACH TO MANNED/UNMANNED TEAMING

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This paper presents a multi-human/multi-vehicle control and integration concept called Warhorse. Warhorse is a control paradigm that is applied to all vehicles (air or ground) that are used in conducting operations. The Warhorse concept aids humans in developing operational plans, enacting a plan using single or multiple vehicles (manned and/or unmanned), and individually controlling a single vehicle (i.e., one-on-one). It synergistically integrates the human with the machine so that the warfighter can bring all their skills and experience to bear on accomplishing the mission.

Introduction

The warfighter of the future will be called upon to command several manned or unmanned vehicles of differing types at the same time to complete a mission. It may be the case that the warfighter himself occupies one of these vehicles. It is a goal of the Army's Synergistic Unmanned Manned Intelligent Teaming (SUMIT) program to develop onboard and remote interfaces that will enable collaboration and/or control of multiple air and/or ground vehicles. These vehicles will, by definition, have different and unique capabilities in the form of payload, range, speed, stealth, and versatility. In addition, these vehicles are likely to be in a dynamic, hostile environment where the enemy, weather, and terrain may inflict restrictions and/or harm on them. It is important to provide robustness and adaptability, and allow for performing the mission with degraded or inoperable equipment (including the automation itself) on multiple vehicles. Vehicles and assets may not always be present or may be disabled during the mission, causing the warfighter to swiftly replan and reconfigure for the mission.

This paper presents a multi-human/multi-vehicle control and integration concept called Warhorse. Warhorse is a control paradigm that is applied to all vehicles (air or ground) that are used in conducting operations. The Warhorse concept aids humans in developing operational plans, enacting a plan using single or multiple vehicles (manned and/or unmanned), and individually controlling a single vehicle (i.e., one-on-one). It synergistically integrates the human with the machine so that the warfighter can bring all their skills and experience to bear on accomplishing the mission. Using the Warhorse concept, the warfighter can quickly command vehicles as part of an operation, even if the warfighter does not have a great deal of experience with some vehicles. This is accomplished through the use of common command paradigm used for all vehicles so that they all seem familiar. The command paradigm uses a hierarchical set of behaviors – plays, missions, and maneuvers. It is important to note that this is not a common interface – inceptors and actual control devices may vary greatly in order to best accommodate and enable the vehicle being commanded. The warfighter can command behaviors on any vehicle in a similar manner, just as most computer programs offer the "File, Edit, View, Format, Help, etc." interface paradigm; the programs themselves may be very different, but the user already has a sense of where certain commands are located and how to interact with the program. This allows the warfighter to bring their human capabilities, experiences, and training to bear on the mission rather than being relegated to managing and monitoring the automation.

The human being has a number of unique and valuable capabilities that are difficult to encode in a machine, and yet often provide a significant advantage over the enemy. These are flexibility, adaptability, comprehension of overall goals and the 'big picture', and an 'all-purpose' nature that allows one individual to perform a wide variety of disparate tasks (serially). The human can manually control a vehicle or conduct communications or replan a mission or troubleshoot and repair a damaged system. No single automation agent can be this versatile. Indeed, even multiple automation agents rarely work together to form a notional single agent that can perform all of these tasks as well as a human. The human being is creative, innovative, and brings a poorly understood and yet extremely valuable trait called intuition to the mission. Rather than attempting to imbue these attributes (many of which are extremely difficult and risky) into machines, the Warhorse concept allows both human and machine to do what they do best using a process called complementary automation or Complemation (Schutte, 1999). This design approach runs counter to the philosophy of automating as much as possible and then relegating the remaining tasks and functions to the human.

Warhorse combines two metaphor-based command and control interaction concepts. The first is the Playbook concept (Miller, 2004). The Playbook concept uses the metaphor of a sports team's playbook, similar to those used extensively by American football teams. They represent strategies or behavioral patterns that lay out what each member of the team will do on the play. Each play is generally named and practiced so that in the game, the quarterback or team captain can just call out the name of the play and all of the team members will know what to do. A quarterback can quickly change the play based on the situation. The Playbook approach has been used to create a control system in which a warfighter with little or no knowledge about the operation of unmanned aerial vehicles (UAVs) can call for a play and count on the UAVs involved to perform that play. Examples of plays are tracking a target, area reconnaissance, and sustained surveillance of a target.

The Playbook approach focuses on a minimally trained operator, but there are times where unique human capabilities are necessary, such as flexibility and opportunistic reactions to changes on the battlefield. There are times when the warfighter needs to make dynamic changes in the play and even times when he or she wants to take a more direct control of a vehicle or its payload. In the Playbook metaphor, the warfighter might want to "pass" to a player who is unexpectedly "open" or may want to "run the ball" his or her self. In these cases, another metaphor is needed – the Horse metaphor (Flemisch, 2003). In the Horse metaphor, the vehicle is assumed to have a certain level of intelligence that is strictly limited to transportation. It responds to the rider's commands, but if the rider offers no command, the horse will stay on its current path. The horse can respond to changes in the environment and it can respond automatically to certain threats. But the horse has no higher level sense of the mission – that is left to the rider. The horse has a number of behaviors or maneuvers that it can perform on its own, such as trot, jump, and gallop. For horses used in work or sport, there are more complex behaviors such as following a calf so the rider can rope it in ranching or maintaining safety and safe distances in polo while the player concentrates on the ball. The Horse metaphor has been applied to aviation (Schutte, et al, 2007; Schutte, Goodrich, & Williams, 2017) and automobiles (Altendorf, E., et al, 2015). Examples of Horse-metaphor maneuvers for a helicopter are takeoff, climb (direction, rate), level off (altitude), cruise (destination, speed), hover (destination), pop-up (altitude), laze (target), and mask (altitude). The warfighter can take more detailed control of a particular asset in a play and utilize the unique capabilities of that asset. As mentioned earlier, the warfighter might be in an aircraft during the mission and the warfighter might need to take 'manual' control of his or her vehicle (due to loss of vehicle automation or to perform more detailed maneuvers commensurate for the current situation). The Horse-metaphor allows for varying levels of automation assisted 'manual' control (see Schutte, et al, 2007 and Schutte, Goodrich, & Williams, 2017 for more detail).

In the Warhorse concept, the warfighter can play three roles: Planner, Commander, and Player. Each of these will be described below. The Warhorse concept is defined in relation to the warfighter as opposed to describing it solely as the system.

Planning Using Warhorse

German military strategist Helmuth Von Moltke once said, "No battle plan survives first contact with the enemy." The battlefield is highly dynamic and unpredictable: for example, the enemy can change tactics or have assets in locations not detected by intelligence; the weather and ground conditions can change; and systems and machinery can fail. That said, it is still important to have a robust plan before going into battle. The warfighter needs to be able to quickly plan using the best intelligence available; but perhaps more importantly, the warfighter needs to be able to replan as the situation changes. In the Warhorse concept, each and every vehicle (ground/air, manned/unmanned) is treated as a semi-autonomous agent that can be commanded in a common manner. Each vehicle has a list of maneuvers that it can perform. These maneuvers are meaningful, high-level descriptions of scripted maneuvers such as takeoff, max climb, hover, orbit, or fly Nap-Of-The-Earth (NOE). Maneuvers will vary from vehicle to vehicle based on their capabilities; however, the manner in which the warfighter assigns maneuvers to each vehicle is the same. Maneuvers can be temporally and spatially linked together to create simple Plays. A surveillance Unmanned Air Vehicle (UAV) can be given a string of maneuvers to execute autonomously in a Play. As the warfighter creates these simple plays, the performance characteristics of the vehicle are automatically represented in the play. For example, assigning a climb maneuver to an attack helicopter will graphically represent the performance angles and speeds associated with that helicopter. Assigning a climb maneuver to a UAV will present a much different range of climb profiles than those of the attack helicopter. This allows the warfighter to quickly assess the capabilities of the vehicle.

On top of maneuvers are missions. Missions are goal-directed behaviors. Missions use maneuvers but also use sensor data and other additional information. A mission is generally performed by a single vehicle. For example, a mission could be to track an enemy asset. The mission is highly dependent upon the enemy's movements. Another mission would be to guard a perimeter. Again, each vehicle has its own unique capabilities and therefore its own available missions. An unarmed UAV is not capable of performing a “Guard the perimeter” mission. It may be that different vehicles have similar missions that are conducted in very different ways. For example, a stealth approach mission for a helicopter may be flying NOE, whereas a stealth approach for a ground vehicle may mean keeping out of the line-of-sight of a particular position.

Missions and maneuvers can be used in conjunction with additional information to run plays. Plays are the scripted behaviors of assets mentioned earlier, usually for several vehicles in a coordinated fashion. Plays can have timelines where the warfighter can set events such as time elapsed events, trigger events, or synchronization events. Thus, early arriving assets might hold their position until all assets have assembled and then proceed to the threat zone to perform the rest of the play. Plays can be highly developed, and are usually created by the warfighter well ahead of their performance. This does not preclude the use of previously created (templated) plays that a warfighter can suddenly call.

When creating a plan, the warfighter has a map display, a timeline, and available assets (vehicles). The timeline contains a ‘play head’ that can be scrubbed through time, showing the positions of all assets at different stages of the plan. These positions are based on the performance characteristics of each vehicle. The warfighter is given the objective, gathers the necessary assets, and locates them at their desired locations on the map. They can then assign behaviors to the assets. When a behavior is assigned, it is given a start time and then projects its progress on the timeline. For example, if an aircraft is assigned a climb maneuver, as the warfighter advances through the time line, the aircraft will move on the map based on its predicted performance characteristics. This assists the warfighter in creating and coordinating the plan. These predictive characteristics can be propagated backwards in time as well. For example, the warfighter may want a surveillance UAV to be in position at a particular time. They can place the UAV there at the time on the timeline and the system will project backwards when the UAV should be dispatched. Not all behaviors (e.g., goal directed missions) can be accurately placed on the timeline. However events can still be used to set start or stop times. Timeless events such as trigger and synchronization events can be created on the timeline without anchoring to a specific time.

Commanding/Replanning Using Warhorse

After the plan has been created using the timeline, the warfighter moves to a mission commander role. Here is where the flexibility of behaviors comes into play. As the warfighter watches the plan unfold in real-time, they can monitor it using whatever sensor information and intelligence available. If something in the plan needs to be changed or modified, the warfighter can simply select an asset or group of assets and apply maneuvers, missions, or plays to those assets. The warfighter can preview these changes to see the outcome before they are implemented. However, if something needs to be done immediately, for example, the need to clear assets out of the area, the warfighter can quickly assign and command maneuvers or missions without waiting to review. The warfighter could call on a vehicle to execute a maximum climb to escape an area that contains newly discovered hostiles. For another example, a new threat may pop up and the mission commander can basically pick one of the available assets, assign an attack mission to the asset and specify the target, and then return to monitoring the battle.

Recall that assets may be manned, unmanned (remotely controlled), or unmanned autonomous. The same behavior command structure (maneuvers, missions, and plays) still applies regardless of asset type. The exact protocol and procedure for these assets will vary based on the capability of the asset. For example, an unmanned armed fixed-wing UAV will likely have fewer options for attack patterns available due to its trajectory and missile launch capability (e.g., a fixed wing UAV must launch a missile in the direction of its flight and may not be able to launch a missile at a target in time).

Riding the Warhorse

It may be the case that the warfighter will actually be controlling their own Warhorse vehicle or may have to take over direct control of another Warhorse vehicle. The warfighter may be in a ground control station operating an unmanned asset remotely. In these cases, the warfighter is considered to be 'riding' the Warhorse vehicle. The interface for one-to-one vehicle control in this ownship is unique because it is based on the manual inceptors unique to that vehicle. In the case of an aircraft, the warfighter becomes the pilot. These inceptors are not necessarily linked directly to associated effectors, but will likely have an intermediate level of automation between the inceptor and effector. As such, the pilot is still commanding the automation, rather than flying 'manually. For example, if the pilot has to do a climb in a fixed wing aircraft, they pull back on the stick. This sends a signal to the automation of the pilot's intent to climb. The automation initiates a climb based on the pilot's inputs but also presents options for climb maneuvers on a screen or through some tactile interface. The pilot selects one of these options, and then commands the aircraft to climb. At this point, the automation will control the aircraft and climb according to the parameters previously selected by the pilot. Virtually all Warhorse maneuvers are engaged through the use of manual inceptors. Warhorse missions and plays are engaged using selections on a multifunction map display. Again, the pilot selects the mission or play, designates the parameters (e.g., the target, the role in the playbook) and then engages the automation. This control paradigm is consistent across all Warhorse vehicles.

There are several reasons that manual inceptors are used for maneuvers (as opposed to touch screens or voice). The primary reason is the robustness of operation in the case of automation failure or some other system failure. The automation cannot be guaranteed foolproof nor invulnerable to programming errors, system anomalies, spoofed data, enemy fire, etc. There will be cases (especially when a human is on-board) where the operator will need to become a pilot and 'manually' fly the vehicle with degraded or no automation. Additionally, the pilot may want to take control because they see a tactical opportunity that does not allow for setting up a behavior. In the Warhorse concept, the pilot already has their hands on the controls. There is no need to revert to a completely different interface (e.g., from touch screens back to physical inceptors). The added benefit is that the warfighter's mental model requires less modification. A second reason for having the manual inceptors used for commanding the automation is to reduce skill loss due to constant use of automation. A third reason is to engage the warfighter in the battle in a meaningful way without creating extremes in workload. This helps the warfighter fight complacency and loss of situational awareness. A fourth reason is to promote a synergistic relationship between the warfighter and the Warhorse in order to achieve Complemation – optimal performance in human/automation teaming.

Summary

The Warhorse concept is designed to offer the trained warfighter a decisive advantage by capitalizing on the unique skills of the human being and using the automation to do what it does best. It allows for strategic planning and provides the ability to tailor and modify the mission as it is underway (i.e., tactical execution). It is important to note that the Warhorse concept is not designed for an individual with minimal training although the automation may be capable of adapting to less experienced users. It is designed to make the best use of human expertise and experience while minimizing the training required to learn system specific information. This allows the warfighter to spend valuable training time learning how to successfully complete the mission instead of learning how to operate the system.

References

Altendorf, E.; Baltzer, M.; Heesen, M.; Kienle, M.; Weißgerber, T.; Flemisch, F.: H-Mode, a Haptic-Multimodal Interaction Concept for Cooperative Guidance and Control of Partially and Highly Automated Vehicles; Winner et. al. Eds.: Handbook of Driver Assistance Systems; Springer, 2015

Flemisch, F. O., Adams, C. A., Conway, S. R., Goodrich, K. H., Palmer, M. T., & Schutte, M. C. (2003). The H-Metaphor as a Guideline for Vehicle Automation and Interaction. Report No. NASA/TM-2003-212672. NASA Langley, Langley.

Miller, C., Goldman, R., Funk, H., Wu, P., & Pate, B. (2004, June). A playbook approach to variable autonomy control: Application for control of multiple, heterogeneous unmanned air vehicles. In Proceedings of FORUM 60, the Annual Meeting of the American Helicopter Society (pp. 7-10). Baltimore: American Helicopter Society International, Inc.

Schutte, P. (1999). Complemation: An alternative to automation. Journal of Information Technology Impact, 1(3), 113-118.

Schutte, P. C., Goodrich, K. H., Cox, D. E., Jackson, B., Palmer, M. T., Pope, A. T., ... & Kinney, J. B. (2007). The naturalistic flight deck system: An integrated system concept for improved single-pilot operations. Report No. NASA/TM-2007-215090. NASA Langley, Langley.

Schutte, P., Goodrich, K., & Williams, R. (2017). Synergistic Allocation of Flight Expertise on the Flight Deck (SAFEdeck): A design concept to combat mode confusion, complacency, and skill loss in the flight deck. In Advances in Human Aspects of Transportation (pp. 899-911). Springer International Publishing.