Joining humans and robots at the hip, transitioning from command and control to teaming and trust

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Abstract — Combinations of Unmanned Maritime Systems (UMS) are being deployed by Navies to collect data from remote regions of the Oceans. These systems are being required to operate for long periods of time in co-operation with manned operations, often in communication limited environments where information must be delivered in a prioritised and compact manner. The successful interaction and co-operation between UMS and manned systems requires advances in Human-Machine-Interactions (HMI) over current approaches typically employed with autonomy systems. This paper describes several novel approaches to the audience around information extraction and sharing, offering an improved user experience that enables operators to trust and team more effectively with their UMS to achieve the objectives of their missions. These approaches are a result of lessons learnt from the recent multi-national exercises of Unmanned Warrior'16 and Autonomous Warrior'18, offering opportunities for operators to interact, control and monitor their UMS in a more intuitive and natural manner. This paper will discuss how these information extraction models and multimodal interfaces can be exploited in an operational environment to reduce uncertainty and cognitive load of mission progress, increase situational awareness and trust from operators, and enable collaboration between platforms and humans. Ultimately this transitions the human from being an observer to an active participant in the mission.

1 Introduction

The most recent advances in maritime autonomy have enabled Unmanned Maritime Systems to be deployed unattended for long periods of time, operating cooperatively to achieve mission objectives more efficiently. These missions can be complex in nature, requiring the on-board autonomy to dynamically adapt in-mission to changes in the environment. Unexplained deviations from the original planned mission can result in operators incorrectly believing that the mission has failed in an unknown and unpredicted manner, leading to low operator trust in the on-board autonomy system and unnecessary mission aborts.

These platforms also now carry a wide variety of sensors that collect high volumes of diverse data. However, communication links at sea remain limited, sporadic, and poor quality requiring information to be prioritised and transmitted intelligently if the operator is to maintain any type of situational awareness of the mission. Furthermore, the storage and endurance resources of those platforms are limited. As a consequence, human operators are struggling to remain situationally aware as the duration, complexity and data management requirements of these missions increase, while the monitoring of these tasks increases cognitive load.

Current human-machine interaction limitations are having a negative impact on UMS mission performance and slowing down fleet adoption of autonomous systems. Unmanned Warrior '16 successfully demonstrated large numbers of UMS collaboratively carrying out a mission, highlighting the ability for Mission-level Autonomy to direct multiple assets. However, standard GIS Command and Control stations quickly become cluttered when tracking large numbers of assets, highlighting the requirement for improved HMI to match improvements in Autonomy.

This paper will present a number of novel HMI improvements that SeeByte have been integrating with their autonomy and sensor processing capabilities to improve operator situational awareness and interactions with the UMS. The SeeByte vision is that an operator should have the tool to be able to control, monitor and interact with multiple UMS concurrently, while recognising this will be dependent on a large number of parameters such as mission profile, operator skill level and required levels of operator input. This paper will first present methods to reduce the data acquisition and transmission process for UMS assets through the use of intelligent modelling techniques for the sampling and exfiltration of data. Secondly, we will present multi-modal human-machine interfaces, using a combination of visual displays, acoustic dialogs, and augmented reality devices to present mission data in real time, explain decisions and summarise results. The aim for these technologies is to allow fluid interaction between the operators and UMS and enable effective teaming between unmanned and manned teams. Example interactions could include operators rapidly re-tasking unmanned assets based on new information, or the insertion of manned assets into the mission (e.g. launch and recovery). These emerging technologies are aimed to make the operators feel like active participants in the mission, capable of making decisions and interacting with the UMS as quickly and accurately as if they were co-located with the assets.

2 Model-based Communication

The maritime environment is particularly difficult to achieve reliable communication bandwidth. Weather and sea-state can adversely affect surface communications. Sub-surface operations present an even greater challenge with communication bandwidths being reminiscent of 1980's dial-up modems resulting in the need for intelligent communications able to prioritise and package information up smartly. One area of research that has proven very effective in reducing the amount of communication required between two participants is the use of shared models, so that only key details are transmitted.

Figure 1 shows this approach within the context of transmitting sonar data snippets for Mine Counter Measure operations. The top section of the image shows the conventional transmission approach where both the raw data (often compressed) and the model used to de-code the information are transmitted. Assuming a COTS acoustic modem, capable of sending 20-30 bytes for each cycle, the transmission of a full snippet will require many cycles which is costly in terms of time. The semantic modelling approach developed by SeeByte requires that only the model is transmitted and assumes that the topside software has the information a priori to reconstruct the data. This is analogous to building flat pack furniture where the material is delivered beforehand and only the instructions need be provided online, reducing delivery costs. This model-based approach has the further advantage of allowing incremental detail to be sent as required. This method of encoding allows vital information, at the required resolution, to be transmitted back to the operator to aid decision making and determine if dynamic re-tasking of the UMS is required.

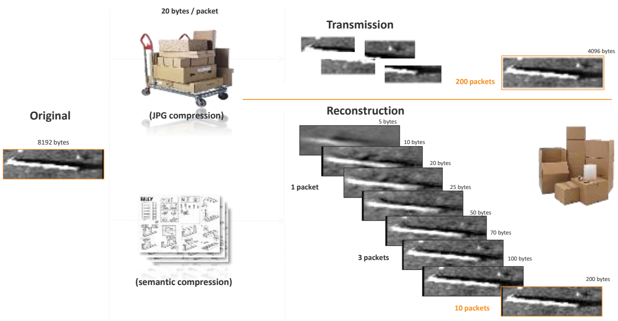

Fig. 1. Example encoding of sonar images using shared models versus JPEG. JPEG requires approximately 20 times more data to achieve the same result.

The one significant downside with this model-based communication approach for sub-sampling is the dependence on accurately identifying the model type. If the original sonar image is wrongly identified then the transmission will simply re-inforce this error.

3 Multi-modal Communication

A second important aspect of multi-domain missions using unmanned maritime systems is their focus on traditional command and control solutions. This typically involves a GIS, centred on the control station, which is used to visualise a representation of the operating area, along with additional useful data (e.g. images or video) displayed in small windows. Real-estate on the User Interface can be limited with the addition of multiple UMS, all controlled and monitored via the same interface, making the operator's job even more difficult. While a complete understanding of the operating area clearly requires the ability to know the location of all assets at any given time, using a map display as the primary method of interaction with the UMS limits interaction options and the sophistication of information that can be shared. Current HMI research suggests a multi-modal form of interaction improves operator situational awareness with two modes currently beings investigated by SeeByte including a

chat-bot text communication and augmented reality visualisation.

3.1 Chat-based Communication

Maintaining situational awareness, or trust that a mission is being executed correctly, is difficult when the robot or asset is not co-located with the operator. The interface between the operator and autonomous systems is key to maintaining situational awareness and understanding between the system and the human operator. Chat bot technology allows the human operator to interact with the UMS in a manner similar to how they would work with a work colleague, with the underlying technology allowing personalisation to ensure the autonomy communicates the most useful information in the manner (and depth) that the operator requires.

The approach aims to align the operator's mental model, in terms of explaining both what the system can do and why it is doing certain behaviours. This type of explainability increases trust and will therefore ease adoption of remote autonomous and unmanned systems.

Using technology from SeeByte and Heriot-Watt University, an initial evaluation of an intelligent, interactive chat-bot, referred to as MIRIAM (Multimodal Intelligent inteRactIon for Autonomous systeMs) was conducted. Integration of this AI technology was designed to enable seamless manned and unmanned teaming, and provide capability within the constraints imposed by acoustic communications; provide a clear audit trail for the on-board AI, enhancing trust and understanding of autonomous systems.

The work clearly demonstrated that MIRIAM provides increased situational awareness to end-users of unmanned systems allowing fluid text or speech driven interaction, including simple queries and improved understanding of autonomous functions and decision making. The ability of MIRIAM to explain autonomous actions in natural language promotes operator trust in unmanned systems, improving the efficiency of manned-unmanned teaming. It also reduced the risk of mission objectives not being met, and further reduced operational risks by enabling end-users to set alerts and reminders for post-mission reporting and maintenance.

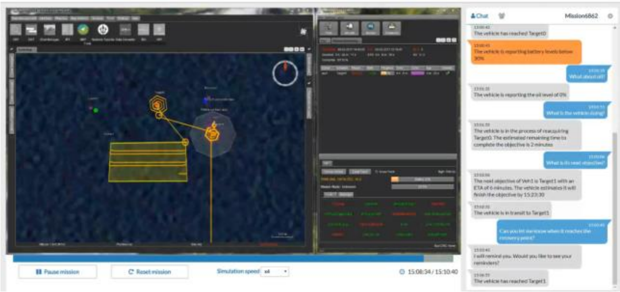

Fig. 2. Multi-vehicle MCM mission being executed, with chat-bot communication between human and machine participants.

3.2 Augmented Reality Visualisation

While top-down GIS displays are good at providing information about the position of objects relative to each other, they are poor at helping understand exactly where the objects are relative to the operator or building up a clearly understandable model of the changing world as the mission evolves. Augmented reality is a well proven solution in many military domains, with head-up displays and helmet mounted displays common-place technology for airforce pilots.

SeeByte has been conducting research to investigate how augmented reality displays may be able to improve the operator's awareness of multiple platforms while they are conducting collaborative missions. The current work has focused on displaying information about on-going collaborative UMS missions, so that the operator can see progress, tasking and location information within a single display. Figure 3 shows an example mission, with the key features labelled. The initial implementation has been on tablet computers for use by expeditionary forces but other layouts could be envisaged for other computer form factors.

The transition of the augmented reality from tablet implementation to a commercial head-mounted display, such as HoloLens, would probably bring further benefits. In particular a head-mounted display would free the operator from holding the tablet and allow use of their hands for other tasks. For example, this may offer exciting opportunities for intervention type tasks where the UMS may be equipped with manipulator arms. The next important next step in this development will be interaction with UMS operators to being to understand their requirements for using this technology.

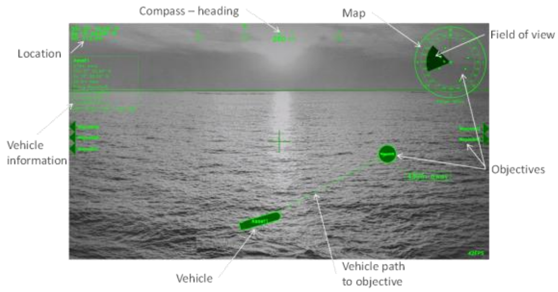

Fig. 3. Augmented Reality overlay, for use on either a tablet or an AR Headset for UMS.

4 Conclusions

This paper has presented the current limitations in human-machine interactions within the maritime robotics domain and provided an insight into emerging technology that SeeByte are supporting to enhance current UMS capabilities. As UMS are increasingly deployed on longer and more complex missions, it will become vital that operators are able to plan, re-plan, monitor, interact and command multiple UMS simultaneously. Multi-modal methods of interaction, using different forums to share information between the operator and UMS, offers the potential to hugely increase current operator situational awareness of what the UMS is doing, providing a platform for effective teaming. Intelligent use of the available communication bandwidth such as the outlined semantic encoding enables this capability through providing the option of sending data at different resolutions based on requirement.

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Author Biography

Dr. Scott Reed is the Head of Engineering at SeeByte, responsible for the delivery of SeeByte's engineering solutions for autonomy, command and control and signal processing for unmanned maritime systems. He ensures SeeByte's engineering group fulfils all their technical, sales, QA and training requirements. During his PhD, he specialized in automated detection and classification techniques in electro-optic and acoustic data.