A Tactical Picture Accuracy Assessment Tool for ComTET

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ABSTRACT

Generating and maintaining an accurate tactical picture is challenging for submarine command teams due to uncertainty and task complexity inherent in the submarine control room sociotechnical system. Changes proposed for next-generation control rooms should improve, or at least maintain, the command team's ability to maintain an accurate tactical picture. This work introduces a tool developed to automate the analysis of tactical picture accuracy from scenarios conducted as part of the Command Team Experimental Testbed project to understand the effect of proposed changes. Developed to process output from multiple scenario engines, the tool processes each into a common abstracted format. This format can then be used to understand tactical picture accuracy throughout a scenario, and to explore contributory factors when combined with other data, such as verbal communications or task completion metrics. The paper describes planned analyses using the outputted data, with potential uses in a training environment discussed. It is our ambition that output from the tool, especially when combined with other data, can facilitate an understanding of factors affecting tactical picture accuracy, ensuring recommendations are robust and not detrimental to control room performance.

KEYWORDS

Submarine Control Room, Tactical Picture Accuracy, Objective Data

Introduction

The Command Team Experimental Testbed (ComTET) project aims to make recommendations to stakeholders about the design of submarine control rooms, ranging from contemporary optimisation to future designs. These recommendations are to ensure that future control rooms remain capable of meeting projected challenges, including: processing more data from new and improved sensors; an improved understanding of the complex global maritime environment; and a drive to maintain, or reduce, crew sizes. Current control rooms are advanced and capable of meeting all requirements, although this does not preclude further improvements (Stanton, 2014). While an evolutionary approach has been successfully used for control room design thus far, step changes for future designs could ensure maximal use of current capabilities, such as using Ecological Interface Design to redesign operator interfaces (Fay et al., 2019).

A key aspect of ComTET recommendations is the supporting evidence base, which originates from repeatable experiments that are scientifically and statistically robust. Providing sufficient evidence helps to mitigate the risk associated with making changes to 'tried and tested' designs, allowing stakeholders to be confident in doing so. To date, several methods have been used as appropriate, including Social Network Analysis (SNA), Event Analysis of Systemic Teamwork (EAST), Cognitive Work Analysis (CWA), and Hierarchical Task Analysis (HTA). Application of these methods has yielded results including, but not limited to, the validation of fidelity in ComTET (Fay et al., 2018), an understanding of contemporary operations (Roberts et al., 2017; Stanton et al., 2017), the examination of configuration changes (co-location and reduced crewing; (Roberts et al., 2019)), and Human-Machine Interface (HMI) design recommendations (Fay et al., 2019).

To provide more evidence and further explore previous results, a requirement has been identified to understand the objective accuracy of the command team's tactical picture throughout completed scenarios. This will provide objective evidence to support any recommendations, in addition to revealing any common factors that affect accuracy. The tactical picture is a representation of ownship's (the submarine) current environment, with solutions for contacts represented as icons. Contacts are entities that the command team is aware of, and solutions are the contact's perceived bearing, course, range, and speed parameters (Mansell et al., 2004; Genç, 2010). Combined, these parameters specify the contact's current location in relation to ownship, and where it will move over time. Representing the perceived current and future position estimates for all contacts, the tactical picture acts as a representation of the command team's Situation Awareness. This representation is used by the command team to make key tactical decisions, such as navigation or ensuring vessels are a safe distance away.

Ensuring that tactical picture accuracy is improved, or at least maintained, assures that any recommendations made would not be to the detriment of remaining safe, remaining undetected, and completing the mission, which are core tactical priorities (Mack, 2003). Of these, safety is the most important. All solutions must be as close as practically possible to the actual parameters of the contact (truth) they represent; this is vital, as an inaccurate tactical picture can result in accidents (National Transportation Safety Board, 2001; Marine Accident Investigation Branch, 2016) or result in counter-detection. By aligning other data to a timeline of tactical picture accuracy, it becomes possible to confirm that observed benefits from other changes did not degrade accuracy, and to attribute improved accuracy to specific factors.

As submarine control rooms are complex sociotechnical systems, understanding contributory factors for improved tactical picture accuracy is vital to providing optimal recommendations with successful implementation(s). A key factor is uncertainty. Generating a tactical picture and maintaining its accuracy can be challenging for submarine command teams, due to uncertainty, and errors arising from this uncertainty or task complexity (Hautamaki et al., 2005). Uncertainty is an inherent aspect of submarine control room operation and can arise directly from sensor information or multiple solution possibilities. To ensure tactical picture accuracy, and therefore ownship safety, it is vital that uncertainty is properly represented and minimised as far as possible.

As contacts cannot be directly observed, information about them must be gathered via sensors. Each sensor provides information on contacts, but this information might be uncertain, or provide one component of information required to make a solution with certainty. This is prevalent when using passive sonar, which is a submarine's primary sensor (Ince et al., 2009). It can be used to determine bearing, Signal-Noise-Ratio (SNR), classification, speed, and direction of travel. However, as range is not certain, it is feasible that the contact could be located at many ranges along the bearing. Thus, there are a multitude of solution possibilities that must be narrowed down. This narrowing down is performed by Target Motion Analysis (TMA) operators and the Operations Officer (OpsO), who seek to engineer solutions for contacts, building the tactical picture. Information is received from multiple operators and sensors to remove uncertainty regarding positioning, progressively constraining solutions until a highly likely candidate emerges. This allows the solution to be placed on the tactical picture with confidence that the truth position is not significantly different. Crucially, this process relies on accurate information. There is a possibility that erroneous information may be inadvertently used, such as a miscommunicated speed, leading to an incorrect solution. Furthermore, uncertainty is still possible with accurate combined information if enough data has not been received to sufficiently constrain the solution; without sufficient information, solutions may have to be input as informed approximations.

Therefore, recommendations made must consider the effect they have on tactical picture accuracy, aiming to improve performance without detriment and address the challenges posed by uncertainty, errors, and task complexity. While assessing objective tactical picture accuracy in isolation will enable an understanding of performance, it could be combined with other data to further understand previous outcomes, and where improvements could be made. Due to the complexity and number of scenarios requiring analysis, it was decided to create a tool to automatically output metrics that quantify tactical picture accuracy across time and at key fixed points. This work introduces the initial version of this tool and describes its analysis use cases. The information generated by the tool can be used by itself, or with other data, such as verbal communications or task completion metrics, to understand command team performance and recommendation efficacy. Its functionality also presents opportunities to enhance training for command teams, in addition to the stringent training they currently receive.

Description of the Tool

The tool was designed to parse simulation engine output to enable multiple analysis and output combinations that could be used to understand tactical picture accuracy throughout a scenario and at key events, such as when a solution was updated. Flexibility was key throughout the development process, facilitating a variety of use cases. To achieve this, simulation engine output is transformed into a common abstracted format used for processing, analysis, and output. The tool currently only processes Dangerous Waters (DW) output, as this is the simulation engine used for most ComTET experiments. Each output is parsed, replicating the logic of the source simulation engine where necessary, to create the scenario within the tool. This representation is then abstracted to a simulation agnostic format to remove any idiosyncrasies and differences between simulation engines. Any processing is performed on this format, including accuracy calculations and data output. This creates the potential for comparisons of accuracy between multiple simulation engines.

When processing the common scenario format, absolute and percentage differences between the truth and solution parameters as computed as standard. A score can be computed from these values, or they could be compared to thresholds determined by Subject Matter Experts (SMEs), depending on the analytical requirements. This can be augmented by other values deemed pertinent by the analysts. For example, in a Return to Periscope Depth (RTPD; transit from a deep depth to shallower one at which periscope can be used) scenario, proximity contacts would be required to more rigorously updated as opposed to other maritime traffic several nautical miles away. This is because the submarine would be near the surface, and vulnerable to collision. As the tool has processed the scenario, dynamic rules can also be added, such as requiring contacts to have more accurate solutions when they cross a certain range threshold. Finally, time can be accounted for in the metrics, with overall tactical picture accuracy being degraded until the command team has entered a solution for all contacts, or if a solution has not been updated for a pre-defined period.

The flexibility of the tool allows for multiple different output formats, depending on analysis requirements. Currently, processed data is output in Comma Separated Values (CSV) format, consisting of entity and contact data across time. Entity information outputted comprises of sensor capabilities, positions, and velocities. Solution information comprises of known contacts, associated merges (multiple trackers known to relate to one entity are treated as one tracker), any solutions entered, and the accuracy of these solutions. This data, either by itself with the measures described above, or combined with other data, such as verbal communications or task completion metrics, can be used to analyse tactical picture accuracy for any given scenario.

Analysis Using the Tool

Identifying root causes affecting tactical picture accuracy can be difficult; the submarine control room is a complex sociotechnical system and, accordingly, performance is determined by a variety of interconnected factors. By combining tactical picture accuracy data from the tool with other scenario data, factors affecting accuracy across the control room can be understood and optimised. This has multiple areas of application.

Within ComTET, the tool will provide a comprehensive understanding of how proposed changes affect the control room and suggest areas of further research, as per the identified requirements. For example, Stanton and Roberts (2019) found that co-location of Sonar and TMA operators increased communication capacity and facilitated more efficient communication. If the tactical pictures generated by each team were also assessed for accuracy, it could be determined if the increased effectiveness also led to a more accurate tactical picture, strengthening the recommendation, or understanding specific areas for further research before implementation. The flexibility of the tool allows for different measures of accuracy to be used according to the scenario type. SME input will be used to create a series of rules for each scenario type currently used in ComTET, such as the various rules for a RTPD scenario described above. This will ensure that analysis sufficiently accounts for the varied and complex nature of a submarine's operations, which contextually affect the definition of an accurate tactical picture, depending on current objectives.

For training facilities, including ComTET, this information could be used to aid feedback to command teams and individual operators. At present, training is conducted by submariner and combat system SMEs, who provide feedback based on their experience. The tactical picture accuracy timeline output by this tool could enhance this. Trainers could emphasise epochs of interest for trainees, demonstrating the effect that procedures, choices, or tactics had on accuracy. For example, if a command team is being trained in a new procedure, trainers could demonstrate differences in accuracy between the old and new procedures. This could also be applied when designing new procedures. By analysing which strategies resulted in the most accurate tactical picture, an optimal solution can be identified, and enhanced by SME experience. Furthermore, as individual operators sometimes have task autonomy, such as choosing which TMA strategies to use (Hautamaki et al., 2005), they could also review the data to optimise their work based on observing objective evaluations of accuracy. This process could help maintain operators' skills on tasks they do not perform often, by enabling them to receive regular feedback without a trainer, utilising their time for complex procedures or assessment instead.

Conclusions

Ensuring tactical picture accuracy is vital for submarine command teams, as it ensures ownship safety. A requirement has been identified for the ComTET project to objectively assess tactical picture accuracy to ensure that recommendations provided improve, or at least maintain, accuracy. An initial version of the tool has been briefly described, along with the planned analysis it will facilitate. Future work for the tool will expand the simulation outputs that can be processed and add additional output formats, such as databases for future querying, or visualisations. This will facilitate the analysis possibilities described above and ensure that any recommendations made by the ComTET are based on a robust evidence base, accounting for the complex sociotechnical nature of submarine control rooms.

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