Towards Agent-Based Modelling for Situation Awareness: modeling a ships Operations Room

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Abstract. An Agent-Based Model of a Maritime Operations Room is developed. Different versions of the model are run to compare the impact of team structure and information management on performance. The aim of the work is to model Situation Awareness in terms of information flow and team structure. From a description of information flow and operator activity in an Ops Room, we defined key roles, information use and communication for Agents in a model. The model allows us to define rules that reflect different modes of activity. Clear performances are found between structures and this is interpreted in terms of Situation Awareness.

Keywords. Situation Awareness, Communication, Agent-based-modelling, NetLogo

1. Introduction

The Operations Room (Ops Room) of a warship comprises a wide range of staff roles and different sensing systems. As sensing systems become capable of greater autonomy, so these systems have the potential to become team members rather than merely tools. This raises the need to understand the balance between Situation Awareness (SA) held by human operators and SA held by the systems with which they are interacting (Woods & Sarter, 2010). In order to consider this, we develop Agent-Based Models which can be reconfigured to create different team structures. In Ergonomics, the Awareness of people (be they pilots, power station operators, or car drivers) to the Situation that they are observing has long been a subject of study. Gorman et al. (2006) argue that it is essential to understand team coordination (in response to changes in the situation) and how team dynamics change in response to the situation. Team Mental Models (TMM), consisting of distributed 'taskwork knowledge' and overlapping 'teamwork knowledge' could lead to improved performance (Mohammed et al. (2010). However, they note that "empirical work is needed to test these hypotheses".

This call for 'empirical work' highlights a key challenge for Ergonomics, which is how best to capture SA in teams. We assume that this requires understanding of Distributed Situation Awareness (Stanton et al., 2006). We could approach this problem through a well-controlled series of laboratory experiments, but this raises a further problem of recruiting participants, training them as teams and ensuring consistency across all runs of the experiment. While we would not dismiss the value in such an approach, we have been exploring ways in which multiple runs of a situation, involving minor changes in dynamics, could be run using Agent-based Models (ABM) in order to explore team activity and system SA.

1.1 Agent-Based Modelling and Situation Awareness

In this paper an Agent-Based Modelling approach was employed (through the use of NetLogo) as it allows the modeler to allocate instructions to many independent agents who are carrying out tasks based on those instructions simultaneously (Allan, 2010).

The notion that an essentially cognitive process can be amenable to Agent-Based Modelling requires some justification. An argument against this approach is that internal cognitive processes cannot be reduced to a simple set of algorithms. We recognize that reductionism is a potential shortfall of the approach, but feel that this is true of any form of simulation of cognitive activity (from Artificial Intelligence to Cognitive Architectures). This makes it possible to explore the connection between the micro-level behaviour of individuals and the macro-level patterns that emerge from the interaction of many individuals. Although many tasks take place within an Ops Room, the activity of detecting and engaging with a threat is the focus of this paper, as it involves numerous operators, information and communications to complete a specific task. For the models developed in this paper, we assume that the Principle Warfare Officer (PWO) makes the final decision as to whether to deal with a target or not (in a real life scenario, this decision may be undertaken by another officer, depending on the mission objectives). The manner in which the PWO is able to make this decision depends on how information is processed by the rest of the system. Each Agent in the network performs specific functions, drawn on those observed in an Ops Room (Stanton et al., 2006). To this end, it is proposed that the Situation Awareness of each Agent can be defined by the information available to them at a given moment and how much of this available information they store (as knowledge). This is intended to be analogous to the manner in which SA-probe techniques, such as the Situation Awareness Global Assessment technique (SAGAT) (Endsley ,1988), reflect knowledge. We appreciate that SAGAT captures more than the small number of information items in our model but the intention is to produce a model which reflects aspects of Ops Room activity.

Agent-Based Modelling provides an opportunity to operationalise Op Rooms activity in ways which are amenable to experimentation and testing. In particular, we can define independent variables which reflect the manner in which information is processed or distributed and dependent variables which reflect when ‘awareness’ arises (at least in terms of the relationship between available information and specific responses).

Chatzimichailidou et al. (2015) reviewed SA measurement in complex socio-technical systems and argue that existing SA measurement techniques tend to provide qualitative data. An Agent-Based Modelling approach to SA potentially allows for quantitative results and data analysis, where other factors such as workload or decision making can be incorporated. Agent-Based Modelling also allows for any aspects of the system to be added with all the characteristics of the agents involved in the system. Using the Agent-Based Modelling approach, concepts and designs of a system can be measured and analysed as early as the concept phase of planning. When modelling team SA it is important that simulations represent realistic or human-like responses, especially when working on time stressed tasks (Fan, Sun, & Yen, 2005). As such, Agent-Based Modelling can be designed to provide such human-like response (Bosse & Mogles, 2014) and can provide a way of developing concept maps to gain an understanding of what the individuals and teams know.

2. Models Description

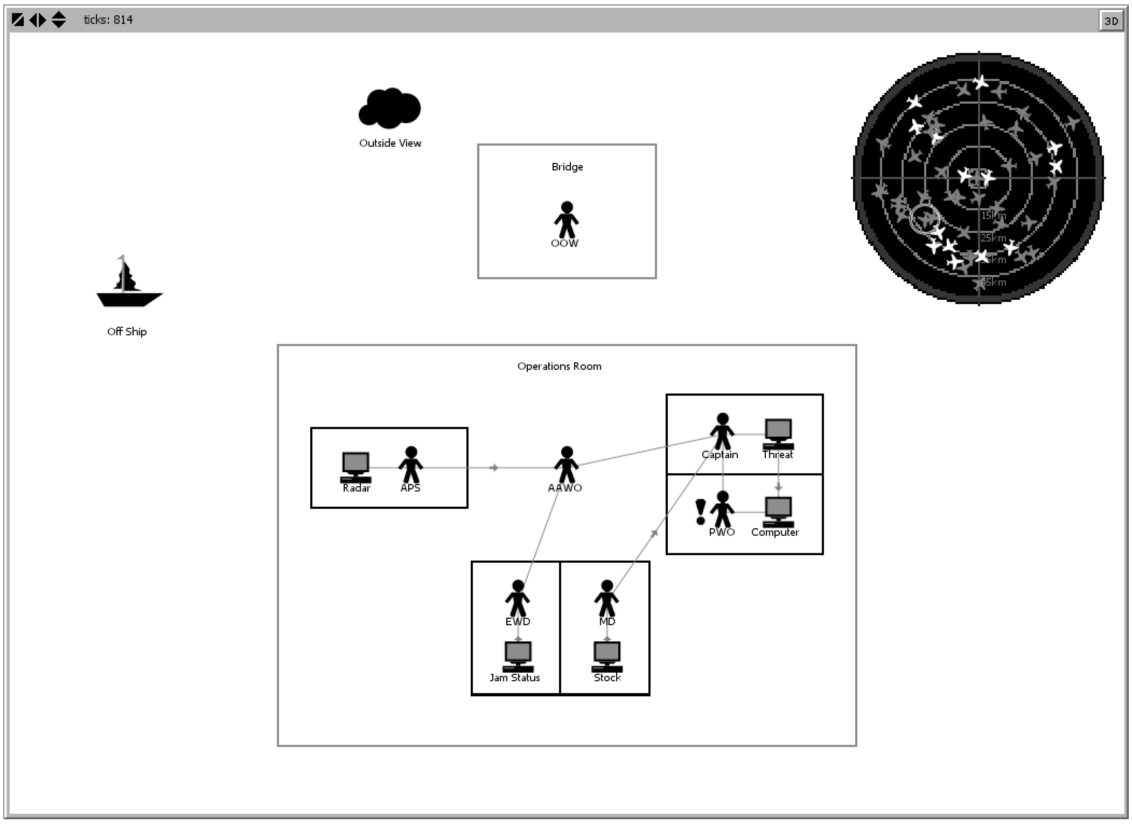

Figure 1: A screenshot of Model 1 during a simulation

NetLogo was used to create two models which simulate a part of the operations room within a Type 23 Frigate naval vessel. The agents and their positioning were placed in such a way that represents that of the operations room outlined in the training session at Her Majesties Ship (HMS) Dryad in the article by (Stanton et al., 2006). The model consists of agents (humans and computers), a radar screen with airplanes randomly situated and randomly moving, and arrows which transfer information from one agent to another. The agents in the model are the Air Picture Supervisor (APS), Anti-Air Warfare Officer (AAWO), Principle Warfare Officer (PWO), Electronic Warfare Officer (EWD), Missile Director (MD) and Captain with the rules in which they work to being based on those on HMS Dryad caste study.

Information about an airplane is detected randomly by the radar, which consists of the colour of the airplane, the proximity to the "ops room" or "ship" and the airplane ID and stored in its short term memory. An arrow is sent with this information in the direction to the APS agent (human) and the information at the Radar agent (hardware) is updated with the new information about the airplane. Each agent has six "slots" which can store information, in both of the models there are 6 bits of information being transferred around the system; airplane ID, airplane colour, airplane proximity to ship, electronic signal strength, missile stock level and threat level.

2.1 Agent Tasks

In Model 1 (figure 1), when a bit of information is received, the agent will send on that information to **one other agent** once it has been stored. The PWO will make a decision when it has received all the relevant information required about the airplane being monitored.

In Model 2 when a bit of information is received, the agent will send on that information to **all other agents** once it has been stored. The PWO will make a decision when it has received all the relevant information required **and** when all human agents have stored or "know" the airplane ID of the airplane being monitored. As an example, figure 1 shows the information transfer and communication links in Model 1. The task of storing information has a time limit associated to it and therefore means that any bits of information arriving at an agent during this time will be ignored until the task (of storing information) is complete. Both models also recorded the 'information' stored by each Agent which can then be used to build concept maps of the operations room.

3. Concept Maps

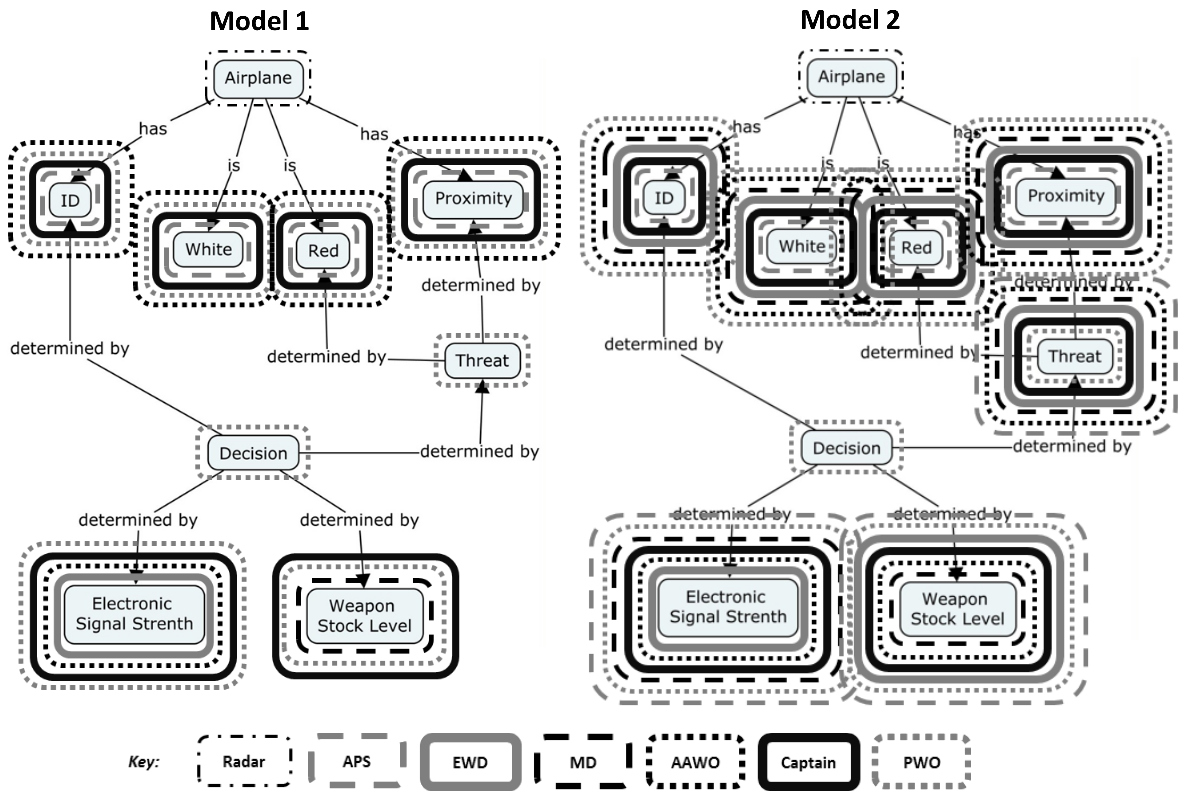

Figure 2: Concept Maps of information knowledge during the Model 1 and Model 2 simulations

At the end of the model trial a .csv file is exported which provides the information stored by each agent in the system. Figure 2 shows the concept map of the 'system' in model 1 and in model 2. The "concepts" in the map represent the information that is present the model (e.g. proximity or weapon stock level). Each concentric ring around a concept represents an agent in the system, some of which have several rings to indicate multiple agents using or "knowing" this information. From this, it is possible to determine key information and to see how this information is distributed throughout the system. For example it is clear to see that in model 1 only the PWO knows if the airplane is a threat or not and what decision is to be made; the ID of the airplane however is known by a number of agents: the APS, the AAWO, the captain and the PWO. Model 2 on the other hand shows us that apart from the airplane detection (executed by the radar) and the decision (known by the PWO) concepts, all agents have knowledge of all concepts.

4. Discussion

For this paper, we describe how Agent-Based Models operate and how this could reflect Situation Awareness through the use of concept maps. Each Agent receives information and, at each step in the model operation, the information held by each Agent can be displayed or saved to file. In this manner, it is possible to represent what each Agent 'knows' during the course of the model operation. As one or more model parameter increases, such as number of planes, proportion of threat planes etc., so the amount of information passing through the model increases. However, as each Agent has to perform a task before receiving more information, it is possible that the 'new' information can fail to be processed or that different Agents might be relying on different pieces of information to complete that task. This means that the models can become less efficient in terms of decision making, information processing and Situation Awareness.

By transferring what is known in the model to a visual representation via the use of concept maps, one can better understand how information is stored and transferred within a system during a task or activity. The models used in this paper, have no limits to information storage (i.e. memory) however this is not true to the real world. Under conditions where memory *is* limited, models such as this can provide insight into whether agents are becoming overloaded or overburdened with information. We can also detect whether the information that the agents are receiving, using and sharing is relevant to their own task at hand. This of course would be agent, system and task specific.

The purpose of this work is to show that it is possible to model human –like behavior through the use of agent-based modelling. We acknowledge that the agents themselves do not have human-like cognition; however they are able to mimic human-like behaviors. The authors also acknowledge that the behaviours modeled in this paper are limited and do not provide more optimized results due to the limitations of the model itself, for example there being zero degradation in the information transmitted. Modifications and development to the models could apply more human–like attributes to the agents which could provide more 'realistic' results and behaviors. These could include; the rate or speed of information transfer, a way of representing the effort or attention of an agent, the amount an agent can store in both short-term and long-term memory and how this information degrades over time, and the addition of extra tasks the agents must attend to.

The paper has hinted at the notions of Shared and Distributed Situation Awareness, simply through the model designs themselves. The authors are interested to explore if these models can provide insight into how these different approaches reflect performance and decision making under workload, or how the management of information can be reflected by differences in Distributed Situation Awareness in the team.

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