A Unified Situation Analysis Model for Human and Machine Situation Awareness

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Abstract: The use of technology to assist human decision making is not a novel idea. However, we argue that there is a need for a unified model which synthesizes and extends existing models. In this paper, we give two perspectives on situation analysis: a technological perspective and a human perspective. These two perspectives are merged into a unified situation analysis model for semi-automatic, automatic and manual decision support (SAM)².

1 Introduction

At a high level of abstraction decision making can be seen part of an iterative process. Before a decision maker can decide what to do, the relevant information needs to be observed and analyzed in order for the decision maker to become aware of how the observations relate to each other and influence potential decisions. This part of the process is often referred to as situation analysis which results in situation awareness (e.g., Roy [1]), in the following termed SA and SAW respectively. When a decision maker is aware of the current situation or its future implications it can be quite straightforward to actually decide on which action to take. After an action is performed, the situation is analyzed to evaluate if the chosen action had the desired effect.

The result from this analysis process, which depending on the task can range from single entity identification to prioritized lists of available actions, is reported to the decision maker as decision support. For most complex tasks fully automated SA is not possible with today’s technology. Instead, integration between machine and human analysis is needed. The literature does not supply a unified model for SA, integrating both technical and human analysis. Nor is SAW fully incorporated into models commonly used for constructing technical systems. In this paper, we present a unified SA model for generating human and machine SAW. We call this model (SAM)² (Situation Analysis Model for Semi-automatic, Automatic and Manual decision support) as it can be applied to automatic and manual SA as well as to analysis integrating both of these, referred to as semi-automatic analysis. This latter type of SA is important since it will allow exploitation of both human and machine strengths.
2 The technological and human views of SA

The ability of machines to collect and fuse large amounts of data to find “interesting” objects, situations or threats is used for decision support in many domains. Within the military domain, the standard model for providing an automated support for SA is the JDL model for data fusion, [2]. In general terms, the JDL model focuses on the technological aspects of SA. It accounts for functions to assess objects, situations, impacts, and the fusion process itself. For some tasks, the result of this analysis could be sufficient for automated decision making. For most other tasks the result is used by a human decision maker. The inclusion of an additional level for cognitive refinement (cf. [3,4]), is an important step to facilitate this. However, we argue that it is not enough.

Endsley [5] argues that achieving (human) SAW involves combining, interpreting, storing, and retaining information. In Endsley’s model SAW is the result of processing at three distinct levels: perception, comprehension and projection. At the perceptual level, attributes and dynamics of the elements in the environment are perceived. At the comprehension level, multiple pieces of information are integrated and their relevance to the decision maker’s goals is determined. At the projection level, future events are predicted. Hone, et. al, [6] extends this view by arguing that at least one process must occur before perception takes place. This process allows connection to the external world (sensing the environment). Endsley’s model of SAW is purely cognitive and does not include technological aspects. The JDL model provides a technological view on the data fusion process. Although the JDL model provides a functional model of the fusion process, it does not model this process from a human perspective. Many complex tasks require integration of both human and machine analysis.

3 A unified SA model

Automatic and manual systems are both extremes, rarely found in real world applications. Most systems are in fact a combination of human and technology, which are commonly referred to as semi-automatic systems. Hence, there is a need for a unified model integrating manual and automatic SA. We therefore propose the combined model, depicted in Figure 1. It acknowledges the difference between analysis processes and the results that they produce. It is also supports interaction at various levels. At one level the SA can be automatic, while at another it could be manual and again automatic at the next level. Naturally, interaction between humans and machines is possible at all individual levels. This means that the SA truly becomes semi-automatic.

In Figure 1, human SA is seen on the right side and the machine SA on the left side. The inter-level interaction channels communicate SAW between levels and are needed in order to allow internal communication between non-adjacent levels. This allows for instance impact assessment on target tracks. In order to avoid clutter, some simplifications have been done in Figure 1. The output (SAW) from the SA processes is implicit in the interaction channels. SAW can also be input to other SA processes. The interaction between human and machine is illustrated by the central Human Computer Interaction (HCI) channel. It allows for SAW to be exchanged between human and
machine, for assessment at various levels. This exchange is not as straightforward as the figure might be taken to imply. It demands similar information models within the interacting systems, a research field in its own right. This problem is, however, not unique to the field of human-computer interaction. It is the same problem when machines, or even humans, exchange information. Different information models might result in loss of information.

Figure 1: The unified model for Situation Analysis. The SAW (i.e., the short arrows coming out of the Inter Level Interaction channels) supports decision making. It connects the Observe (sensing) and Orient (the different assessments) with the Decision making and Action of the OODA loop.

The model can also account for level 4 (process refinement), and level 5 (cognitive refinement) of the JDL model. Process refinement would be to modify an assessment process at some level, or the interaction between some levels. This process might be initiated by internal demand (e.g. awareness of the situation that some sensor is not focused at the right area) or external feedback (e.g. feedback from a decision maker that the situation awareness has some flaws). Cognitive refinement is the equivalent of process refinement, but at the human side. It should, however, be noted that process and cognitive refinement overlap in the HCI interaction channel. Both of these aspects need to be taken into account when refining HCI processes.

The SAW is delivered to the decision maker via the machine or human interaction channels. One could imagine a situation where the machine and a human come to different SAW. This inconsistency can be solved in several ways. One way is to leave it to the decision maker to solve the problem. Another way is to utilize the process refinement to solve it internally within the system. A third option is to add a unification layer on top of the system, to solve the inconsistency.
4 A common situation awareness?

Within the military domain, it is not only the case that a commander should utilize decision support systems to achieve correct SAW before making strategic, operational, or tactical decisions. Equally important is to disseminate this awareness (often also referred to as situation understanding) to the subordinate commanders so that they can relate his orders to the right context, often referred to as Common Operational Picture (COP). In order to facilitate this ability, the model needs to be extended to include multiple humans and interaction possibilities between them. This extension is also necessary to allow for cooperation between humans during the SA process. In a similar fashion, the model needs to be extended with multiple machines and interaction between them to allow usage of multiple sources of machine SAW, see Figure 2.

![Figure 2: SA involving multiple machines interacting with multiple humans.](image)

The leftmost interaction channel (CCI) allows for computer-computer interaction. The key enabler of this type of interaction is interoperability. Important tools are protocols and standards, e.g. the use of common information exchange models such as the Joint Consultation Command & Control Information Exchange Data Model (JC3IEDM). The rightmost interaction channel (HHI) allows for human-human interaction. Important aspects here are for instance methods and culture. The HCI (in the middle) allows for interaction between multiple computers and multiple users.

The figure also clearly illustrates the problem of achieving COP, which, as Lambert [7] points out, results from the union of technology, psychology and interaction. Even though the extended model would allow exchange of SAW between humans and machines, it deserves to be highlighted that there is no guarantee that a human, or machine for that matter, actually interprets the information in the intended way. It depends on many aspects that are outside the model, e.g., experience and alertness. This would imply that it is impossible to guarantee COP. However, one could possibly get
sufficiently close by for instance using the same information models within cooperating technical systems, standardized ways to visualize information and training.

7 Conclusion

This paper argues for a unified model for SA. The need for such a unified model is apparent when considering that many tasks require exchange of analyses for improved decision support. Correctly utilized, this integration between humans and computers would enhance the overall capability of the decision process, in the sense that more complex problems can be handled in a shorter period of time by integrating the strength of humans and machines. We therefore propose the unified SA model (SAM)\(^2\) which can model SA systems with any degree of automation, ranging from manual to fully automatic. An extension of the (SAM)\(^2\) model is also suggested, which allows for concepts such as common SAW and COP to be discussed. The extended model encompasses the interaction between machines (e.g. protocols, architectures), between humans (e.g. doctrines, culture, organization) and between humans and machines (e.g. user modeling, visualization).

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References