Prototyping of a Situation Awareness System in the Maritime Surveillance

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Abstract. This paper discusses about the design of a Situation Awareness (SA) system to support vessel crews and control room operators in improving the decision making process. The architecture of the system is ontology based. The vessel crews and control room operators may face a loss of SA. They may have limited cognitive abilities which make it difficult to make a decision in a high stress level, short time availability and continuously evolving situation with incomplete information. In this work, we describe the application of Semantic Web Rule Language to represent corresponding knowledge in the maritime surveillance domain. The result of this research will demonstrate that an ontology based system can be used to remodel the information into a meaningful and valuable form to predict the future states of SA and improve the decision making process.

1. Introduction

Decision making is a crucial part in performing maritime surveillance. Decision is made in various conditions, from threatening to normal situations. Vessel crews and control room operators need to fuse information from diverse sources to observe and analyze the situation before making a decision.

Experience, training, intelligence and a healthy physical condition will influence the process of interpreting information. Although the incoming information is the same, different people may have different interpretations (1).

This research proposes an SA system to improve the vessel crew and control room operator in analyzing the incoming information to provide an understanding of the situation to assist in making a good decision in a threatening situation. For the purpose of this research, the Semantic Web Rule Language (SWRL) will be employed to represent the knowledge and model the threatening scenario to support the vessel crew and control room operator in the decision making process.

This paper is organized as follows. Section two discusses the SA in the decision making process. In section three, we describe the proposed architecture of system for the analysis of threatening vessel

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behavior. Meanwhile, section four discusses about the R-Scene prototype and case study whereas Section five presents the ontology based SA. Finally, the conclusion will be presented in section six.

2. SA in the decision making process

As cited in (2) Endsley defined SA as "*The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future*".

This research proposes a method to extend the concept of SA using ontology and inference to make projections of the future. Figure 1 illustrates four layers describing the different levels of abstraction.

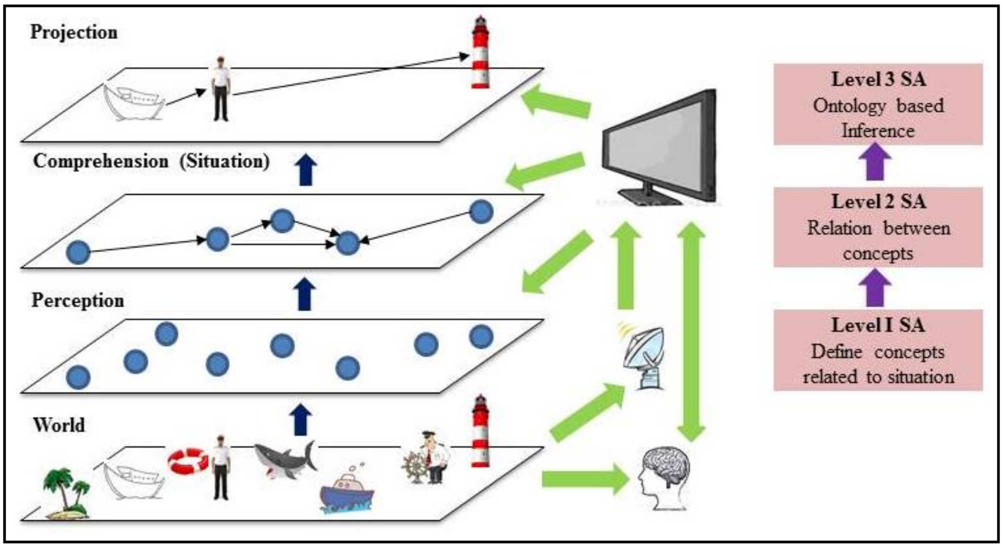

Figure 1. Ontology based SA, adopted and extended from (1,3)

The bottom layer is the "World". It is a symbol for physical or conceptual things, or both that may be the object of situation. On the right side of the World layer is a human head that shows that the SA actually takes place in the human's brain. Hence, the human observes the information of the world and human gets input from the computer, as displayed in Figure 1.

The second layer is the "Perception" layer. The dots in this layer represent the objects from the World layer that are obtained from sensors and represented in the computer memory. The arrow from the World layer to the radar image represents the sensory process, providing data to the computer. This layer is compatible with the output of the Perception process in the Endsley's model.

The next layer is "Comprehension". The layer illustrates the lines that represent the relation of each point. The process of filtering irrelevant information in order to obtain useful data by integrating some relevant information occurs in this layer. This layer represents also the Comprehension stage in the Endsley's model of SA.

The top layer is "Projection". This layer has a direct relationship with the Endsley's model in which projection is defined as the capability to predict future state situation based on the events of comprehension.

3. The Proposed Architecture System of R-Scene

In the analysis of threatening vessel behavior, we proposed for a system that consists of four main processes as demonstrated in figure 3.

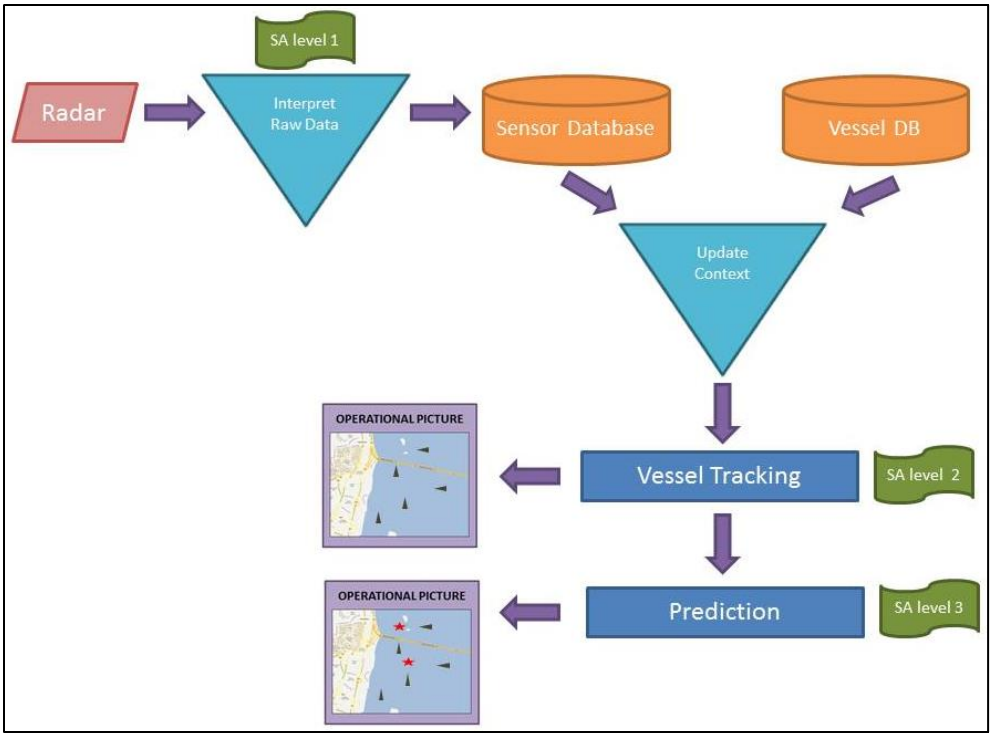

Figure 3. Architecture of system for the analysis of threatening vessel behaviour

Generally, the four processes will include:

1. The process of interpreting raw data into readable form to obtain the pattern from previous scenarios. The obtained pattern will be used to predict the future state.

2. The process of merging sensors and vessel database. Data from sensors and vessel database will be fed back to the ontology processing engine to update the context ontology. This step is compatible with the SA level 1

3. The tracking process. In this process, the system will filter all related data to model the situation. This step is compatible with the SA level 2.

4. The process of predicting possible future states of the current situation. In this stage, the inference engine will process all new information using the predefined SWRL rules and characterize the behavior of the vessel. This step is compatible with the SA level 3.

4. R-Scene Prototype and Case Study

Our prototype system, the R-Scene Prototype, is illustrated in figure 4. As depicted, it shows the digital map of Penang island with the latitude of 5.354632^{o} and longitude of 100.348349^{o}.

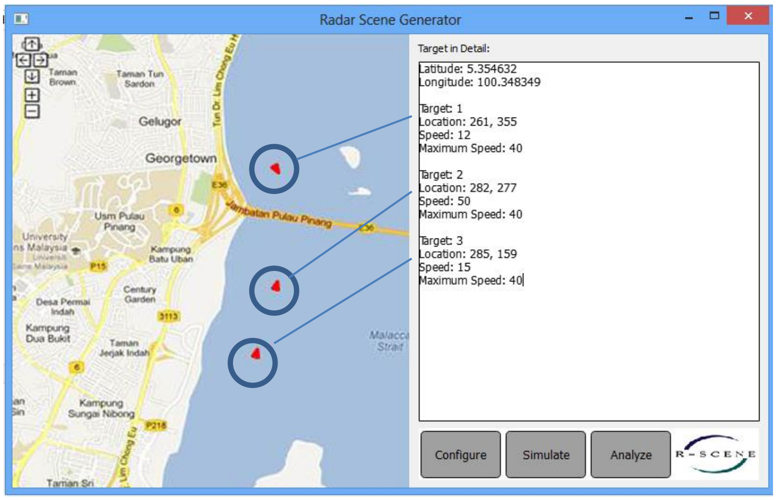

Figure 4. Screenshot of the prototype R-Scene.

QT 4.7.2 was chosen to create the Graphical User Interface front end. Figure 4 demonstrates our preliminary results. The figure consists of two main parts. The left side indicates the digital image. As shown, three targets are displayed in the current scenario. The right side consists of a window for displaying details of targets and three buttons to activate the tasks 'Configure', 'Simulate' and 'Analyze'. The display window indicates the coordinates of the digital map and detailed information of each target. In our preliminary results, we have detected 3 targets in three different positions with various speeds. Speed and maximum speed are needed for the scenario of high speed vessel. The speeds of targets are 12 knots for the first target, 40 knots for the second target and 15 knots for the third target, respectively. Knowing that the maximum speed allowed in that area is 40 knots, the alert class will give the warning message and point out the second target as a suspicious target.

5. Ontology-Based SA

Vandecasteele & Napoli (4) mentioned that to understand the phenomenon, it is necessary to reflect the information in a simple way. In order to be able to discriminate between normal and threatening situation, the use of context is inevitable. For the purpose of our research, we will utilize the ontology to reach our objectives. This section will briefly describe the terms ontology, knowledge base and rule base.

5.1 Ontology

This paper will discuss the ontology approach from the artificial intelligence (AI) perspective. The ontology developed in this research is used as a tool to automatically integrate the knowledge and information part. Previous study by (5) emphasized on the importance for one to bear in mind that ontology merely serves as a specification of a conceptualization. For the AI systems, ontology is defined as representational vocabulary for a researcher who needs to share information in a domain, what exists is that which can be represented (5,6).

5.2 The knowledge base

To implement the ontology we first need to translate the expert knowledge in such a way that it can be applied in our system. We plan to conduct interviews with expert to obtain knowledge about the threatening situations, how to identify it and how to solve the corresponding problems. The Protégé 4.2.0 software is employed to process the information gathered. Figure 5 presents an example of ontology for maritime surveillance.

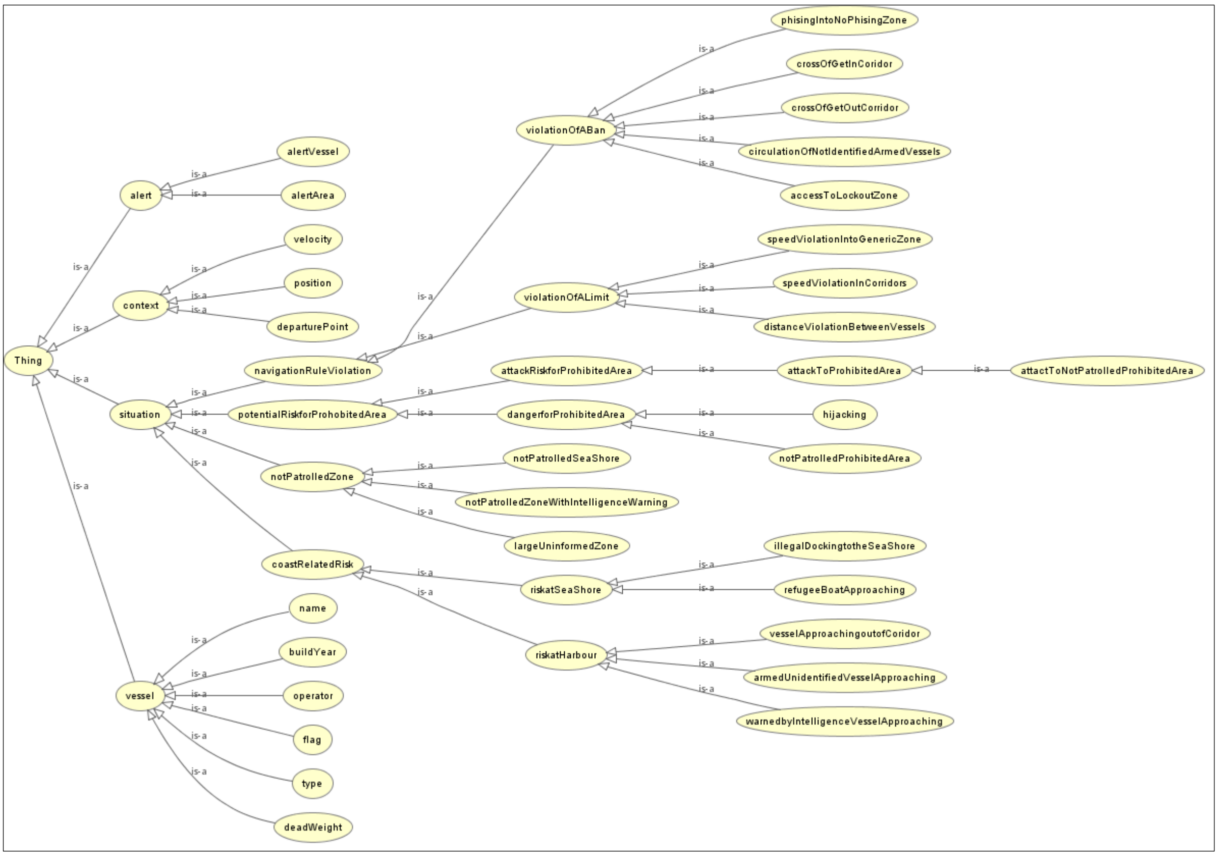

Figure 2. Maritime surveillance ontology, adopted and extended from (4,7)

The maritime ontology consists of 4 main classes:

- Vessel: this class consists of all basic information about a vessel. These include the vessel id, vessel name, type of vessel (fishing boat, cargo, etc.), maximum speed, deadweight, operator, flag and build year. Vessel class data will be derived from the vessel database.

- Situation: this class represents the possible interpretation of a situation in the maritime surveillance. The results from interviews will be used to generate the situation class.

- Alert: this class defines various alerts related to the maritime surveillance. The interview results will be utilized to generate the alert class.

- Context: the context class consists of elements that enrich alerts. It provides information related to vessel characteristics, its departure point, velocity and position. The context class data will be derived from radar data.

However, to make it more useful in the process of analysis, ontology requires for the addition of a rule base for the identification and characterization of threatening situations.

5.3. Rule based system

To represent and integrate rules into our ontology, we will utilize the Semantic Web Rule Language (SWRL), a combination of OWL-DL and RuleML (8), that will enrich the semantics of an ontology.

The rule was constructed by combining the experts knowledge and useful information from literature researches (9). Suppose the aim of the rule is to detect a ship moving at a speed that is excessive for its type. The request, translated into the SWRL is shown below and read as follows, "If a vessel (?vId) of an identified type (?vType) has a speed (?vSpeed) greater than (greaterThan) the maximum speed allowed for that type of vessel (?vMaxSpeed), then trigger an alert (Alert_Speed_HighSpeed)".

```
Vessel(?vId) ^ hasVesselType(?vId, ?vType) ^
hasSpeed(?vId, ?vSpeed) ^ hasSpeed(?vId, ?vTypeSpeed) ^
greaterThan(?vMaxSpeed, ?vSpeed)
hasAlert(?vId, Alert_Speed_HighSpeed)
```

In this example, we attempt to make comparison between the speed of the vessel and the maximum speed allowed for the vessel. If the vessel has a speed greater than the maximum speed, then the system will issue the alert of high speed.

6. Conclusion

This paper describes the development of a prototype for the detection of threatening vessel behaviour. The proposed prototype system R-Scene will integrate maritime surveillance and maritime SA. The prototype will provide maritime SA with a simple and easy user interface for maritime security and surveillance applications. The feature of the prototype will integrate vessel information database and radar data. The tracking process enables track analysis and target query by location, date and/or vessel specific information. In the prediction process, the analysis will denote the historical and prediction of the vessel movement. The example of scenario shows that the warning message will appear when the speed of target exceeds the specified maximum speed. For future works, some other scenarios will be tested to enrich the maritime ontology. Scenario of the maritime navigation in a prohibited area and prediction of collisions are planned to be completed in the next stages of our work.

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