Extracting rules from expert operators to support situation awareness in maritime surveillance

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Abstract – In maritime surveillance, supporting operators' situation awareness is a very important issue for enabling the possibility to detect anomalous behaviour. We present a user study which conceptualises knowledge to be implemented in a rule-based application aiming at supporting situation awareness. Participatory observations were used as a method for extracting operators' knowledge. The result of the user study is in the form of a number of identified rules emerging from organisational factors, group thinking and individual experience. A description of the rule-based prototype is presented a long with the result from the user study. This is also discussed together with the applicability of rule based systems and how to support situation awareness.

Keywords: information fusion, situation awareness, maritime surveillance, knowledge elicitation, expert systems

1 Introduction

A typical maritime surveillance task performed along the Swedish coast line is to track and identify objects at sea. To aid this task, video cameras, radars, and AIS (automatic identification system) track data can be used. Often, this information is fused and summarised into an overview display (i.e., situational picture) which operators use to obtain situation awareness, cf. Figure 1. To be continuously aware of what is going on and able to notice suspicious behaviour in such displays is difficult for operators mainly due to three aspects. First, operators have limited cognitive abilities which make it difficult to be attentive to an overview display that only shows small changes in each time step [1]. Second, the interpretation of the overview display is typically very individual, i.e., people have different knowledge and experience which makes them notice different issues in the display, and hence they are able to maintain SA differently [2]. Third, today, when interpreting the display, suspicious behaviours are less obvious compared to during the cold war when the activities

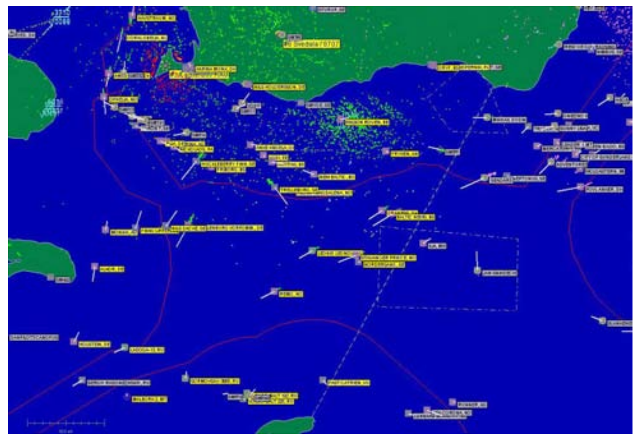

Figure 1. An overview display providing users with information about current vessels near the southern Swedish coast line

outside the Swedish cost were characterised by known surveillance ships from mainly Russia, Germany and the UK. Today, the enemy is characterised by other activities such as smuggling which may be difficult to notice. Fortunately, as technology advances, we have new possibilities to support operators' interpretations of these types of displays used in maritime surveillance activities. For instance, there are different kinds of technologies [3-5] which from data (e.g. sensor data) automatically find anomalies. This helps users to detect unusual activities in maritime surveillance scenarios. In general, this kind of technique could be referred to as "bottom-up" approaches, i.e., from the available data one automatically identifies anomalies. In contrast, a more top-down approach can be used where, for instance, existing knowledge about suspicious behaviour is used to identify unusual activities. These systems most often utilise rules extracted from experts [6].

This paper presents a case study which identifies and extracts knowledge of expert operators to inform the ongoing development of a rule-based application [7] aiming at supporting situation awareness. The method for capturing knowledge from experts that we apply here is participatory observations [8]. In the following sections, a brief description of the current version of the developed prototype is presented. Next, the results of the user study intended to inform the ongoing development of the tool are presented and discussed.

2 Background

2.1 Using expert systems as support

Expert systems originated in the mid 1960s [9] and have since then been used in many different domains such as finance, data processing, marketing, human resources, manufacturing [10]. Such systems typically uses symbolic knowledge representation and logical reasoning techniques (e.g. case-based reasoning, fuzzy logic, etc.), sometimes, in combination with non-symbolic techniques (e.g., neural networks).

One particular category of expert systems is rule-based expert systems. These are systems which “contain information from human experts, and represent that information in the form of rules, such as IF-THEN” [9, p. 94]. Rule based expert systems were popular during the 80s and have lately gained increasing recognition. For instance, [9] reports on a wide range of applications developed during the twenty-first century such as Tutoring systems, Geosciences, Biochemical nanotechnology, agriculture planning, Apiculture, probabilistic fault diagnostic, indicating the applicability of rule based systems today.

A common problem for all expert systems is, according to [11], the ‘knowledge acquisition bottleneck’. This refers to the difficulties computer specialists often encounter when extracting knowledge from domain experts to be transferred into expert system applications. It is estimated that only approximately two to five units of knowledge can be extracted during one day [11]. There are a number of different methods developed for this purpose, i.e., capturing users knowledge and experience to develop expert systems [10, 11]. Amongst others, case analysis, critical incident analysis, commentaries, conceptual graphs and models, brainstorming, prototyping, performance reviews, are all examples of methods used for such occasions. Although interview transcripts are, by far, the most common source to inform such systems, it is well known that how you think you go about to do a task may not be how you actually do it, cf. [10,11]. Another possible technique is the capturing of knowledge as a side effect when automating a work process. In other words, in order to extract knowledge users answer questions as they interact with the system.

2.2 Supporting situation awareness

Expert systems can be used to support situation awareness [12]. Looking specifically at situation awareness (SA) research, Endsley [1] who is one of the founders of the concept, developed a model where SA was divided into three distinct levels, i.e., Level 1: perception of current elements in situation; Level 2: Comprehension of current situation; Level 3: Projection of future status. As the model is outlined, the three levels of situation awareness are a prerequisite for making a decision which can result in an action. Also, it could be argued that the focus is much on what cues to provide in order to achieve an accurate mental model. Furthermore, according to the model, it is important to not just have a comprehension of the current situation but also of future events. Endsley [13] identifies different elements which need to be supported for achieving situation awareness in the aviation domain, i.e., geographical SA, spatial/temporal SA, system SA, environmental SA, and tactical SA. On the other hand, SA has been considered as the interaction among different entities [14]. In paper [14], a distributed cognition perspective is used for understanding the creation and distributedness of situation awareness, i.e., how multiple operators and the tools/artefacts they use collectively maintain SA [14]. The implication is that there is not as strong a focus on mental models inside a person’s head compared to Endsley’s model of SA.

3 Implementation: a rule based expert system prototype

A prototype of a rule based expert system application has been developed and published in 2006, see [7] for an extended description of the tool. As the authors point out [7]: “The basic idea behind the prototype is that in order to achieve greater situation awareness it is necessary to identify relations between individual entities and their immediate surroundings, neighbouring entities and important landmarks” (this is also in line with Endsley’s model of SA). Hence, a rule based situation assessment system that utilises both COTS and in-house software was developed. The basic idea is that long-term intentions and situations can be identified by patterns of more rudimentary behaviour, in essence situations formed by combinations of different basic relationships.

“It is built upon an agent framework that speeds up development times, since it takes care of many of the infrastructural issues of such a communication intense application as this is, and a rule based reasoner that can reason about situations that develop over time. The situation assessment system is developed to be simple, but structurally close to an operational system, with connections to outside data sources and graphical editors and data displays” [7].

For providing an easy way for operators to add rules a rule editor has been created, cf. figure 2. As can be seen in Figure 2, the focus is on time based reasoning. To illustrate the potential of the tool, a smuggling scenario was implemented, cf. Figure 2 and 3.

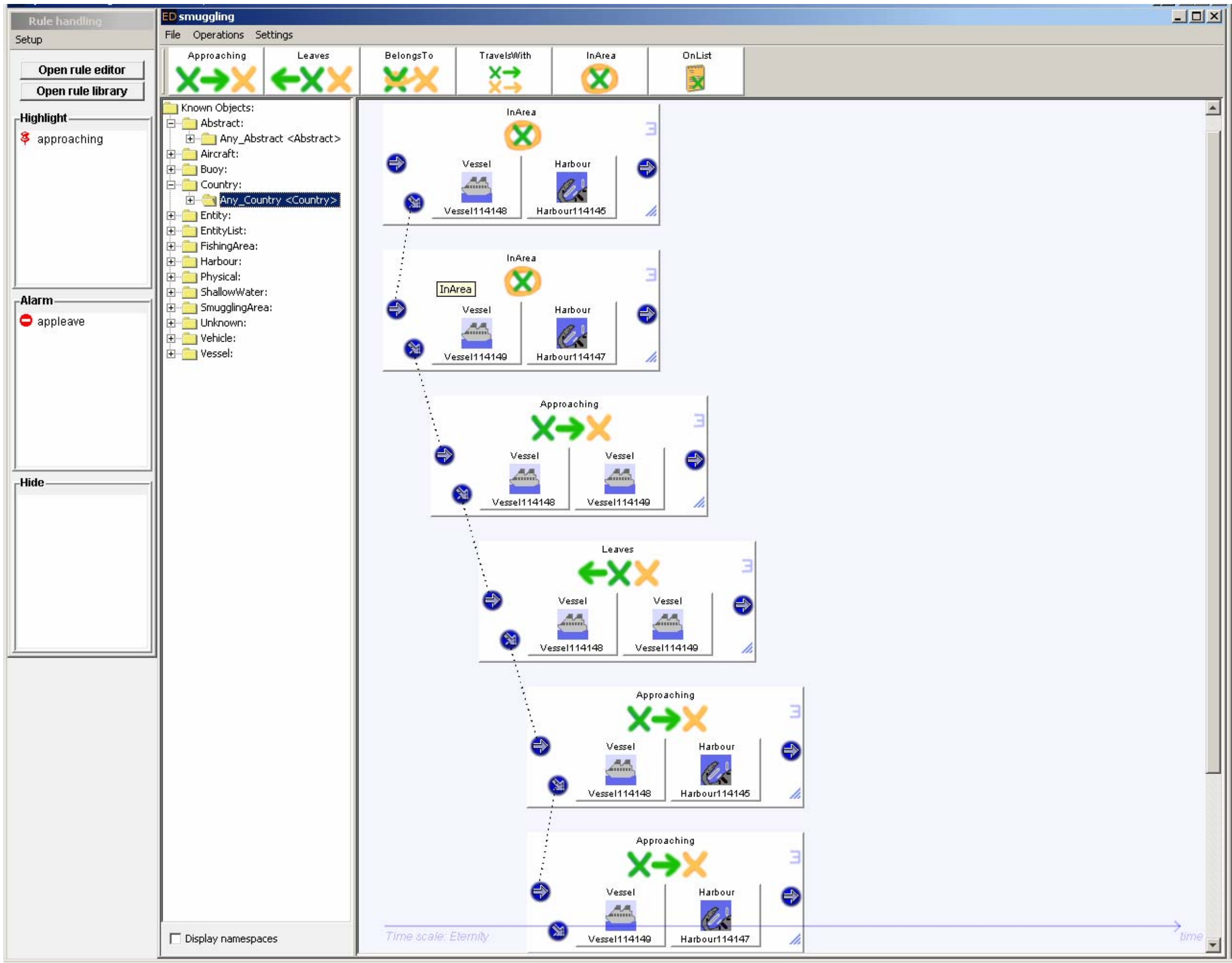

Figure 2. Rule editor displaying the rule of smuggling. At the top, components which the rule can be built from are displayed: approaching, leaves, belong to, travel with, In area, On list. To the left, users can choose to what degree they want to be notified by highlights or an explicit alarm. To the right, a graphical interface is provided where the user can create rules through "drag and drop".

The scenario (i.e., the suspicious behaviour to be identified), displayed in Figure 2, "… can be described as: two vessels, having departed from ports in different countries, meet up and stay together for some time, and then they split up and return to the ports from which they departed" [7]. This rule is implemented in the system, and if the rule finds a relationship, an alarm is triggered, hence, enhancing situation awareness and enables operators to take action.

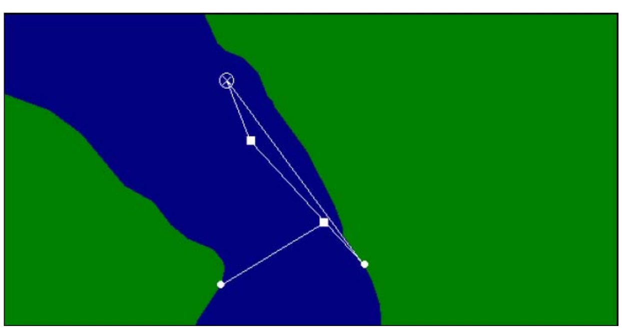

Figure 3. Display of smuggling scenario, i.e., visualisation of identified suspicious behaviour.

3.1 Initial concept evaluation

An informal evaluation of the prototype was performed spring of 2007 by two of the authors (MN and JE). The aim with the concept test was to get initial user feedback of the tool and evaluate the usefulness of the tool for maritime surveillance.

Location. The test was conducted at a Swedish marine surveillance control centre in Malmö.

Participants. Two former operators participated in the test. They had both long experience of working in the control room. One of them has been responsible for introducing new technology in the surveillance control room; hence, there is a strong technological interest. Former operators were used due to their availability.

Scenario. A smuggling scenario involving two vessels departing from two different harbours was presented to illustrate the potential of the tool. The scenario took a couple of minutes to run.

Procedure. The evaluation was performed as a concept test where the tool was presented to the participating operators. After the presentation the operators were asked to brainstorm around the prototype.

Their opinions were noted with pen and paper. The evaluation lasted for about 30 minutes.

Results. The evaluation indicated that the tool could be useful in the surveillance control room supporting operators' daily work. One of the major benefits put forward was that the tool provides the opportunity to track evolving events. Typically, today, operators work in shifts which make it difficult to notice incidents evolving over longer periods of time. For instance, it is difficult to notice if one vessel is located for five days in the same spot (because the operators responsible for the area are constantly changing). Furthermore, the evaluation identified some suggestions for improvements. For instance, it was suggested that it would be beneficial to explain why a rule was added in order to limit the risk for deleting a rule just because the operator does not understand why the rule exists. It was also suggested that rules in the system should be able to be personalised. The operators argued that some people may want to have many alerts and others may want fewer alerts. Moreover, the evaluation indicated that the rules need to be adapted towards the activities of the operators. The presented rule of smuggling is very sophisticated; however, it does not reflect the daily work of the operators. Thus, for the operators to see the full potential of the tool, more knowledge of the work domain is needed; consequently, there is a need for further user studies which could inform future development of the tool.

4 User study

In addition to the initial concept study, a user study has been performed as part of the ongoing development process of the rule based situation assessment tool for sea-surveillance, cf. [7]. In its current state, the tool is equipped with rules based on fictitious scenarios. The aim with this study has been to identify relevant rules for sea surveillance in South Sweden, which could, then, be implemented in the tool and further evaluations could be performed.

Method. Participatory observations [8] were chosen as a method to extract knowledge from the operators. Participatory observation is a method which observes users by including the observer in the work environment. The method allows the observer to ask questions and to be instructed by the users as they perform their work. Hence, participatory observations allow users to explain the action while they are performed (i.e., focus is not only on what they know, but how they actually use that knowledge which they might not necessary be able to verbalise themselves).

Location. The observations were conducted at a Swedish marine surveillance control room in Malmö (the same centre as the initial concept test)

Participants. Seven operators with an average of three years experience participated in the user study (these were not the same people as the ones participating in the initial concept test).

Procedure. The observations were conducted during four occasions (including pilot test) distributed evenly round the clock to allow for different conditions, for a total of 16 hours. About 70 vessels were identified and tracked during the observations by the team of operators. During the observations, when needed, operators were asked to explain the reason for making a specific action. Field notes (pen and paper) were used to capture work procedures and events which could later be formalised into rules. A summary of the rules has been verified by two of the operators for validity. The underlying focus of the observations was on the following question:

- How do operators in a maritime surveillance control room classify/interpret suspicious behaviour when interacting with the overview display (cf. Figure 1), i.e., when and what triggers users to make a decision and/or to take action?

Case site: maritime surveillance

The presented case study was performed in a marine surveillance control room responsible for the security of an area outside the Swedish coastline. The main task of operators located in the surveillance control room is to identify vessels and continuously analyse the situation being aware of the current state at sea, thus, involving identification of possible suspicious behaviour.

In general, there are five users working in the control room, i.e., *one* operator responsible for incoming intelligence reports, *two* operators responsible for manually identifying vessels, and *two* operators keeping track of the overall situational picture of the current situation. The participatory observations focused on the two operators in charge of keeping track of the current situation. To help they had an overview display which showed the output of the identification and tracking process of vessels, cf. Figure 1. They also had access to a number of additional technologies (e.g., radio, ships, airplanes, optic camera etc.) which, when needed, could provide additional information.

5 Results

The participatory observations resulted in a collection of field notes on how the team of operators interacted in the control room in order to be aware of what was going on at sea. The result revealed a number of different interesting factors concerning situation awareness.

At the beginning of a shift, the operators need to quickly get an understating of the current situation. This is today supported by, for example, a formal debriefing by the previous work team, a specific daily report, and informal chat with colleagues. To be noted, more information than strictly the overview display is requested for getting awareness of the current situation, i.e., the cues provided by the overview display are not enough to get a accurate understanding of what is going on at the moment. That the overview display does not provided enough information is exemplified by the fact that different assessment of the information provided is made dependent on time (i.e., time of day/year). One of the operators explained that in July typically one sees a large number of boats/ships going from Germany towards Sweden cluttering the display. An automatic anomaly detector which identifies anomalities from data may trigger an alarm; however, the reason for the large amount of activities is that it is the start of the main holiday season in Germany. The limitations of the overview display are also reflected in debriefing where not only a snapshot of the overview display is provided but also actual photos of the vessels in the area. Operators reported that photos not only made their work more fun but they felt that they get a better feeling of what kind of vessels were in the area.

Furthermore, it was observed that each work team has to start their work from scratch, i.e., the knowledge of the current situation are just summaries in the form of a PowerPoint presentation. This presentation included the position and identity of vessels, not the achieved situation assessment. Also, this may lead to a lack of episodic reasoning (you do not transfer episodic reasoning between work teams).

The work is today divided between the different operators to be able to maintain situation awareness, i.e., the two operators responsible for identifying vessels alert the ones responsible for the overall situation if they see any suspicious behaviour. The operators had different ways for assessing the overview display (cf. Figure 1), i.e., to determine suspicious behaviour. A summary of factors affecting this assessment of suspicious detection (thus SA) is as follows:

- *Experience*. Dependent on experience one can see different information in the overview display, especially, a difference has been noted between the ones with less than a year experience compared to those that have been there longer. With experience, one is more likely to know what temporal and spatial patterns to look for.
- *Context*. The context of an event can classify it as a suspicious behaviour. It was emphasised that you need to be flexible in your interpretations of the overview display, one interesting pattern may not be interesting the other day.
- *Incoming reports*. Intelligence reports or other information from, for example, the coast guard or higher up in the hierarchy can provide information of interesting objects. The operators can be told to look for a specific pattern in the overview display.
- *Permits*. There are official documents describing what vessels have the right to be on Swedish water.

Furthermore, it was noted that differences exist between operators in what they identify as suspicious in the overview display. At one point, two of the operators were asked to make an individual assessment of the situation from the information provide by the overview display. The operators' assessments overlapped; however, there were individual differences between them in terms of what conclusion they drew from the overview display. Moreover, it was noticed that the operators had different working procedures, hence, there is a demand for personalisation of rules. Also, there was a difference in how aware the operators were of their knowledge and how well they could articulate it. In other words, some could express a specific reason for making an action or taking a decision, others could not express why they took a specific action (they just reacted to the information on the display). It also was noted in the observations that the users had difficulties to maintain situation awareness of the overview display as it presents a quite constant state. Often the two operators responsible of the overall situational picture were occupied with side tasks, and only, now and then, looked at the overview display.

Identified rules

The participatory observations resulted in a collection of field notes regarding causes of actions which could then be identified and formulated as different rules. It was noted when and why users decided to act upon the information provided by the overview display. Some of the identified activities were performed routinely, i.e. one could have standard rules implemented in the system. Others were instances of special occasions which would require the possibility to adopt and add new rules. Furthermore, the rules presented here have been confirmed by two of the operators for validity. The following are examples of situations which the users would like to be notified of are as follows.

The first thing operators looked for when a new vessel entered the overview display was if they were government-owned. Hence, the first rule is:

1. if a vessel is government owned then the operator needs to be notified

At one occasion, the operators got a notification regarding a Swedish military training operation which would be in operation for a couple of days. The notification said that a safety zone had been created where people were asked to not enter. The information was provided by a text file transmitted by fax. Therefore, every vessel which entered Swedish waters was relevant and needed to be identified. This situation would appear a number of times each day. Hence, the operator used the following rule:

2. if a vessel enters area X and has a name Y then the operator wants to be notified

At one point, a discussion among the team of operators was raised whether or not the speed of a vessel was interesting. The conclusion was that a vessel which had a high speed was interesting because most commonly people are aware of and obey the existing speed limit. Hence, the operator implicitly used the following rule:

3. if a vessel has a speed above X then the operator wants to be notified

In their daily work, operators routinely were provided with lists of suspicious vessels which need to be tracked. These lists were provided by email or fax. Hence, the operator used the following rule:

4. if a vessel has name X then the operator needs to be notified

On one occasion, an additional operator dropped by (this week he had other duties). When interpreting the overview display he asked about the name of a specific vessel. When told about it, he said that it should be checked out because “I think that vessel was there at that position last week also”. Also, it had been argued that a vessel making a sudden turn is interesting. Hence, the operator is interested in the following:

5. if a vessel is laying still and/or make a sudden turn then it is an interesting vessel and the operator wants to be notified
6. if a vessel is still during a longer period of time then the operator wants to be notified

One discussion among the team of operators was regarding what was hard to detect. One of the examples was to notice a change in speed. Hence, the following rule needs to be supported:

7. if a vessel abandons previous speed (i.e., high speed, low speed, high speed, etc.) then the operator needs to be notified

Quite often it was noticed by the operators that two vessels were going in parallel. This may have a natural explanation, e.g., two vessels changing crew, but it could also be a sign of an unwanted activity. Hence, the operators used the rules:

8. if two vessels going in parallel, in a certain range (x meters from each other) then further investigation was initiated
9. if two vessels are going towards each other, and upon encounter make a turn, then the operator wants to be notified
10. if one vessel encounters a smaller boat then the operator wants to be notified

It was noticed that operators often focused their attention towards specific areas of the overview display. For instance, the sea has specific paths where vessels usually travel (commonly referred to as E4/E6). Typically, vessels which do not want to be seen try to abandon the places where vessels typically travel, i.e., they take routes which vessels normally do not take. On the overview display this behaviour is easy to identify, i.e. operators use the following rule:

11. if vessels abandon a planned route or go beyond the specific area commonly referred to as E4/E6 then the operator wants to be notified

6 Discussion

The study focused around the question *“How do operators in a maritime surveillance control room identify suspicious behaviour when interacting with the overview display (cf. Figure 1), i.e., when and what triggers users to make a decision/action?”*. Looking at the identified rules, one can see that they consist of different components. Most often they consist of:

- relations (binary, unary)
- combination of future state and attributes
- combination of physical (border) and abstract (land) attributes
- describing situations evolving over time

In summary, the different rules emerge from both *organisational factors* (e.g. operators have a task to identify government owned vessels and are provided with lists of interesting objects and different permits), g*roup thinking* (operators collectively have knowledge which is used to identify suspicious behaviour) and their individual *experience* (some of the rules are created from operators experience).

In order to implement the rules, information from different sources is needed to alert the operator. For instance, AIS attributes, motion patterns of the vessels, local database of names of interesting ships, and so on. AIS attributes include time stamp, sensor ID, local track ID, ship location and velocity estimates, ship shape (length, width) estimates, ship type, ship name, navigation status. Moreover, when the actual rule should create an alarm need further evaluations. When creating the rules the operators may create the rules so they alert before the actual situation occurs or the rules can alert when the actual situation has occurred.

Notably, some of the rules identified in Section 4 cannot be implemented into the prototype in its current version. Hence, the next step in the development process is to identify what knowledge is possible to implement and perform more advanced user studies as well as develop the prototype further.

In addition, there are a number of different insights which we as researchers and developers of situation awareness applications can take with us from this study.

The usefulness of rule based systems using fusion techniques

The initial concept test identified the developed prototype as a useful concept. The tool could be used for managing problems operators commonly encounter today. For instance, there is a problem of identifying situations evolving over time due to the changing of shifts. There are also problems of maintaining awareness/attention towards an overview display which does not significantly change state often. A rule based prototype which takes into account the operators' knowledge could ease those problems by being able to operate over time and shifts alerting operators and directing attention towards interesting situations such as those exemplified by the previous identified rules.

In the participatory observation it was noticed that an application such as the one developed, would probably best work as a module in cooperation with other systems. Even though the system supports situation awareness, the users are dependent on other factors which cannot be transmitted by an overview display for achieving a certain level of situation awareness. Also, having the system as a module in cooperation with other systems would overcome the problem typically associated to expert systems (cf. Section2). This is in line with the system presented in [6]. However, this study highlighted that it is important to have a note where operators can explain why they have included a certain rule. This would not only improve the developed prototype but also the application of [6]. Furthermore, studying the actual rules, some of the rules need to be added "on the fly", i.e. a suspicious behaviour is identified and this knowledge needs to be implemented into the system (this rule may be valid during a limited time period). Other rules are more stable and will always exist in the system alerting operators. Also, some of the rules do not need to have an explicit alarm attached, instead, it is just needed to highlight the output of the rule, e.g., nr 7 (colour mark vessels which are going in parallel). In other words, the alerts the rules create need to be flexible and adjustable. These issues are accounted for in the developed prototype by the rule editor which enables users' flexibility and easy access to the rules.

Moreover, issues of *when* the rules should alert operators, i.e., the structure of the rule. For instance, one could create a rule which alerts the user of a situation, i.e., if vessel X is in area Y then alert the operator. Similarly, the rules could say: if vessel X is heading towards area Y, then it will put in at area Y. The first one could be interpreted as 'situation assessment' because it is an ongoing situation while the second rule could be interpreted as 'impact assessment' because it does not just alert the operator of an ongoing situation, it also makes a prediction of a future situation. This is a close trade-off between the different rules and they can be interpreted in different ways, further evaluations are needed.

It should also be noted that the rules identified mostly do not involve situations evolving over time and could be classified as "simplistic". This might be due the lack of support for such reasoning in their current work procedures. Also, the users might only use the identified rules because it would make such a difference for their current work environment. In other words, it is hard to imagine more advanced scenarios because they are not aware of the technological solutions which exist today. Also, the operators were often reluctant to specify a specific number (e.g., speed), instead they reasoned in terms of range.

Moreover, the initial concept evaluation highlighted the importance of matching the developed prototype to its intended use, i.e., to see the full potential of a rule based system it needs to be tested with real users under realistic circumstances (i.e., the very reason for the presented user study).

Finally, the participatory observations highlighted the fact that operators often reasoned using many different information sources when assessing the situation. More specifically, they used the overview display in combination with other technologies and colleagues as well as the rules combined with different attributes. This implies the need for *fusion techniques* when developing rule based systems.

Acquisition bottle neck problem

There have been many different methods developed to capture knowledge from experts, cf. [11]. The represented user study exemplifies the applicability of participatory observations for studying expert knowledge connected to situation awareness. The question is if participatory observation is a good alternative for capturing knowledge from users. The experience from the study presented in this paper is that the method is well suited for this purpose because you as a researcher are allowed to interact with the users at the same time as they use their knowledge. To identify knowledge while acting often triggers operators to recall more compared to a normal interview session. Hence, it is proposed that participatory observations can be used to minimise the acquisition bottle neck problem.

Supporting maritime situation awareness

The initial concept test of the prototype and participatory observations raised questions regarding how to support situation awareness. First of all, in the participatory observations it was noticed that situation awareness does not only involve knowledge about relations between individual entities and their immediate surroundings, neighbouring entities and important landmarks, but also, knowledge about *time* is an important factor for having an accurate understanding of the current situation. Time refers to, for example, what time of the day, year is it or how long time have the vessel been here. It can be argued that support of time is an important factor which needs to be accounted for. This is in contrast to situation awareness in the aviation domain [13] where, for example, spatial/temporal SA only refers to the planes' own position and projected landing time. Knowledge about the time of day or year is not explicitly acknowledged as a factor affecting pilots' situation awareness. The effect of time on SA goes beyond the typically knowledge of SA in the IF community which most often refers to Endsley's model of SA [1].

Furthermore, issues regarding when to alert the operator of an evolving situation emerged. In the initial concept test the question: should the rule initiate an alert when the event has happened or is about to happen were raised. Hence, there is an issue of whether or not supporting situation assessment (i.e., this situation has happened) or impact assessment (i.e., this situation is about to happen), here, more research is needed.

In a continuous activity such as surveillance, it is especially important to be able to notice suspicious behaviour. To be able to notice suspicious behaviour is depended on knowledge and experience of users. As such, it should be noted that there is a limitation of rule based (expert) systems. These systems seem to best work for known recurring events. Therefore, in order to support situation awareness, these systems should be utilised in combination with other technological solutions as in [6].

7 Summary and Future work

The evaluated prototype has been presented at a previous conference [7], however, this paper reports on the latest user studies. First, an initial concept evaluation identifying the usefulness of the prototype was conducted. The result indicated that the application could be used for transferring knowledge between the different teams of operators. Also suggestions for improvements such as including a place where the user could explain why a rule exists were identified. A second user study was initiated to capture knowledge of users to be implemented in the prototype for future evaluations. The user study identified a set of rules to be implemented in the prototype as well as highlighted issues such as what to be supported. Moreover, the need for fusion techniques when developing rule based systems has been identified and the value of participatory observation as a methodology for capturing knowledge from experts was also demonstrated.

Future work will involve implementing the previous identified rules in the systems to allow for more advanced user studies concerning how to support situation awareness.

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References

[1] M. R. Endsley. Toward a theory of situation awareness in dynamic systems. *Human Factors* vol. 37, 32-64. 1995.

[2] M. R. Endsley and C. A. Bolstad. Individual Differences in Pilot Situation Awareness. *International Journal of Aviation Psychology*, vol. 4, 241-264. 1994.

[3] B. J. Rhodes, N. A. Bomberger, M. Seibert, and A. M. Waxman. Maritime situation monitoring and awareness using learning mechanisms. In *Proceedings of Military Communications Conference*, (MILCOM2005). 2005.

[4] J. B. Kraiman, S. L. Arouh, and M. L. Webb. Automated anomaly detection processor. In *Proceedings of SPIE Enabling Technologies for Simulation Science VI*, vol. 4716,128-137, 2002.

[5] N. A. Bomberger, B. J. Rhodes, M. Seibert, and A. M. Waxman. Associative Learning of Vessel Motion Patterns for Maritime Situation Awareness. In *Proceedings of International conference of Information Fusion*, Italy, Florence, 2006.

[6] M. Seibert, B. J. Rhodes, N. A. Bomberger, P. O. Beane, J. J. Sroka, W. Kogel, W. Kreamer, C. Stauffer, L. Kirschner, E. Chalom, M. Bosse, and R. Tillson. SeeCoast port surveillance. In *Proceedings of SPIE Photonics for Port and Harbor Security II*,, vol. 6204, 2006.

[7] J. Edlund, M. Grönkvist, A. Lingvall, and E. Sviestins. Rule based situation assessment for Sea-Surveillance. In *Proceedings of SPIE -Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications* vol. 6242, 2006.

[8] D. Waddington. Participant Observation. In *Essential Guide to Qualitative methods in organizational research*, C. Cassell and G. Symon, Eds. London: SAGE, 2004.

[9] S. H. Liao. Expert system methodologies and applications- a decade review from 1995 to 2004. *Expert Systems with Applications*, vol. 28, 93-103, 2005.

[10] E. Turban, J. E. Arson, and T.-P. Liang, *Decision Support Systems and Intelligent Systems.* (7th ed). USA: Pearson Prentice Hall, 2005.

[11] P. Jackson, *Introduction to expert systems.* (third edition). England: Addison-Wesley, 1999.

[12] Q. V. Do, A. Filippidis, L. C. Jain, and V. A. B. Hardikar. Fuzzy tracking expert system for enhancing situation awareness. In *Design and application of hybrid intelligent systems.* IOS Press, p. 448-457. 2003,

[13] M. R. Endsley. Situation awareness in aviation systems. In *Handbook of aviation human factors*. D. J. Garland, J. A. Wise, and V. D. Hopkin, Eds. Mahwah, NJ: Lawrence Erlbaum Associates, 1999.

[14] H. Artman and C. Garbis. Situation awareness as distributed cognition. *In Proceedings of European Conference on Cognitive Ergonomics*, Limerick, Ireland, 1998.