Development of a software to identify and analyse marine traffic situations

Conference Paper · September 2015

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DEVELOPMENT OF A SOFTWARE TO IDENTIFY AND ANALYSE MARINE TRAFFIC SITUATIONS

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AVOIDING COLLISIONS IS ONE OF THE MAIN TASKS FOR A DECK OFFICER ONBOARD A VESSEL. TRAFFIC SITUATIONS WITH TWO OR MORE VESSELS ARE VERY COMMON AND HAS TO BE HANDLED REGULARLY AND ACCORDING TO ANTI-COLLISION REGULATION (COLREG). BY DEVELOPING A SOFTWARE THAT USE AIS DATA, IDENTIFY AND ANALYSE TRAFFIC SITUATIONS, WE WOULD LIKE TO MEASURE MARINE TRAFFIC IN SPECIFIC AREAS. THE PURPOSE IS TO DEVELOP THE TRAINING AND EDUCATION FOR NEW OFFICERS AND TO VALIDATE INCREASED SAFETY IN AREAS WITH NEW REGULATIONS, I.E. NEW TRAFFIC SEPARATION SCHEMES AND SEA TRAFFIC MANAGEMENT. THE SOFTWARE IDENTIFIES AND ANALYSE TRAFFIC SITUATIONS AND MANOEUVERS BASED ON DIFFERENT PARAMETERS, I.E. BEARINGS, DISTANCES, SPEED, COURSE, TARGETS IN VICINITY AND OBSTRUCTIONS AROUND THE VESSEL, SHOWING RESULT FOR INDIVIDUAL TRAFFIC SITUATIONS AND FIND STATISTICS FOR THE AREA SELECTED. THE RESULT IS VALIDATED BY USE OF A NAVIGATIONAL SIMULATOR AND MEASURES OF REAL TRAFFIC DATA FROM BORNHOLMSGAT. THE DEVELOPMENT OF THE SOFTWARE IS STILL IN PROGRESS.

KEYWORDS: MARINE TRAFFIC, ANTI-COLLISION, COLREG, AVOIDING MANOEUVERS

INTRODUCTION

Although the technical standard onboard modern merchant vessels increase, there are still collisions between vessels at sea. When the world fleet increases in size and the navigable areas are reduced, for example by wind farms, the number of complex traffic situations will increase and the risk of collisions remains. Collisions at sea could result in major environmental damage and are often very expensive for insurance companies, ship owners and cargo owners. By analysing marine traffic and study how traffic situations are solved, an understanding of difficult situations could be found, and the education for deck officers developed to better prepare new officers for the demands.

One way to analyse marine traffic is through collision investigations, but it can also be done by analysing marine traffic, and the individual situations that occur, by analysing data from radar or Automatic Identification System (AIS). AIS is a transponder system used by all merchant vessels of more than 300 gross tonnage due to the International Convention of Safety of Life at Sea, SOLAS. Smaller vessels and leisure boats could use AIS transponders on a voluntary basis. This means that AIS data could be used to analyse traffic situations, but the full coverage of the situation could not be clarified since there could be smaller vessels involved not using AIS.

Dynamic AIS data is sent frequently, in intervals of 2-180 seconds, depending of the vessels navigational status, speed and rate of turn. Faster speed and higher rate of turn results in more frequent transmission of messages. An AIS message consists of a timestamp, the vessels unique Maritime Mobile Service Identity (MMSI) number, current position, speed over ground, course over ground, heading, destination, estimated time of arrival, type of vessel and cargo, navigational status (under way using engine; not under command; restricted manoeuvrability; constrained by her draught; aground; engaging in fishing; under way sailing; at anchor; moored) and some technical information.

With frequent update of each vessel's position, marine traffic situations could be found and analysed. In this study, a traffic situation is defined to start when two vessels are within a specified assessment range from each other. When a situation occur, the officer of the watch (OOW) must identify if there is risk of collision, and in cases where there is a risk, identify the give-way and stand-on vessel according to the international collision avoidance regulations, Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 1972 as amended (IMO, 2003), and, if necessary, take avoiding actions.

In this project a software for analysing AIS data has been developed. The aim is to identify and analyse marine traffic situations and how they relate to COLREG to get a picture of the actual marine traffic in an area. The result could be used to exemplify or improve education of maritime officers, for example by exporting interesting situations to navigation simulators but also to better understand how COLREGs are practiced and shaped in real traffic situations, how they are adapted to the contextual demands. The effect of Sea Traffic Management, new traffic separation schemes (TSS) and other regulations developed to reduce risk for collisions, could also be measured by analysing marine traffic before and after the introduction. The development of the software is still in progress and the software will be extended and adapted to future studies.

BACKGROUND

The main tasks during a navigational watch are to avoid grounding and avoid collision, taking the vessel towards the destination. The vessel will be in a lot of different traffic situations during the voyage. Traffic situations, and the behaviour of maritime officers in traffic situations, has been analysed by researchers for decades, mainly by radar observations [1-3], onboard observations [3, 4], or simulator studies [5, 6]. Those methods are time consuming and expensive ways of collecting data. AIS data is cheap and could be received from wide areas in real time, the drawbacks are loss in coverage due to the fact that all vessels do not use AIS and the possibility of incorrect data sent. For statistical measurements, in areas without extensive leisure boat or small fishing boat traffic, the AIS data could be good enough.

To identify risk of collision, the concept of ship domains has been used since the early 1970s, introduced by Fuji and Tanaka, 1971 [7]. A ship domain is an area around own vessel where the OOW do not want any other vessel to be. If the other vessels track leads to an entrance to the domain, there is a risk of collision and the OOW will in normal case take early avoiding action, or in case of being the stand-on vessel according to COLREG, hope that the other vessel will follow the rules or act in a later stage. The size and shape of the ship domain has been discussed and developed during the past 40 years, but could be grouped in three main categories; circular [8-10], elliptical [7, 11, 12], and polygonal [13-15] ship domains.

The behaviour of OOW in different marine traffic situations have been studied by several researchers. Zhao et al [4] used cadets to gather information from different situations, measuring the closest point of approach (CPA), actual passing distance, course alteration of avoiding manoeuver and the time the manoeuver commenced. Kobayashi [16] used data from simulator exercises to find parameters affecting the mariner´s behaviour in different situations. Belcher [3] measured the rule following behaviour in Dover Straits. Chauvin and Lardjane [17] analysed crossing situations with ferries in the Dover Straits.

During the last years, a lot of researchers and companies have used AIS data to analyse marine traffic, but no specific research has been found where AIS data is used to analyse individual traffic situations in the context of the COLREGs. Pan et al [18] created a visualization model for assessing marine traffic situations by use of AIS data. Silveira et al [19] studied the traffic pattern off the Coast of Portugal and Kujala et al [20] analysed the marine traffic from a safety perspective in the Gulf of Finland. Aarsaether and Moan [21] used AIS data to analyse manoeuvers in the Risavika harbour in Norway. One reason why research connected to COLREGs is not found could be the problems still found in the AIS with messages partly missing or wrong information. Last et al [22] found that 0.25% of all received messages in their study were corrupt and that the availability of position data was good but the information about the vessel´s heading was missing for 25-30% of all vessels.

A TRAFFIC SITUATION

A marine traffic situation is defined, in this study, to exist if two vessels are within a specific range of each other. The first task for the officer of the watch (OOW) on each vessel is to determine if there is risk of collision or not in a situation. Risk of collision is present if the other vessel will pass within a safety domain around own ship. The size and form of this safety domain varies (see figure 1).

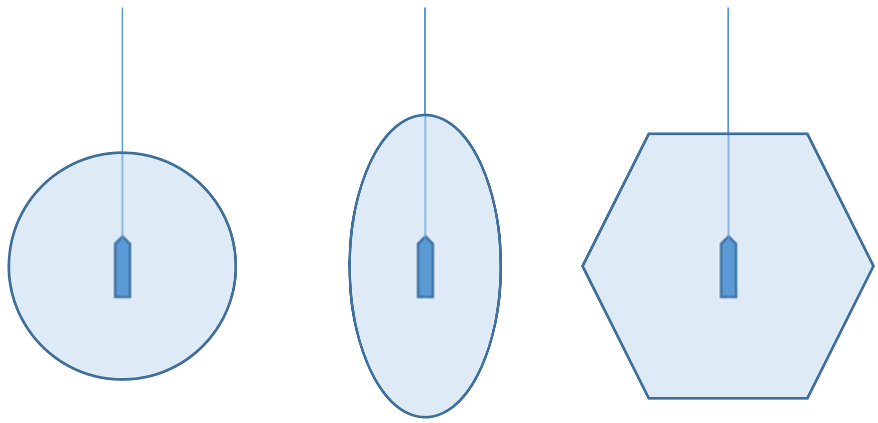

FIGURE 1 - SAFETY DOMAIN FORMS

The International Convention on Preventing Collisions at Sea (COLREG) regulates how different traffic situations should be handled in open seas, traffic separation schemes and narrow channels when vessels are in sight of each other and when there is restricted visibility. Normally, one of the vessels are the give-way vessel and the other the stand-on vessel. In some cases, i.e. in restricted visibility or when two power-driven vessels meets head-on, none of the vessels have right of way, both are give-way vessels.

The vessels could meet in one of three different situations; head-on, crossing or overtaking situation (see figure 2). A head-on situation is defined as a situation where both vessels are meeting with risk of collision on reciprocal or nearly reciprocal courses. Normally this is interpreted to be in an interval of relative bearing of +/- 10 degrees from ahead. Overtaking situation is defined as a situation where the overtaking vessel is approaching the other vessel from a relative bearing of 112.5° or more on each side. Crossing situations are all other situations with risk of collision.

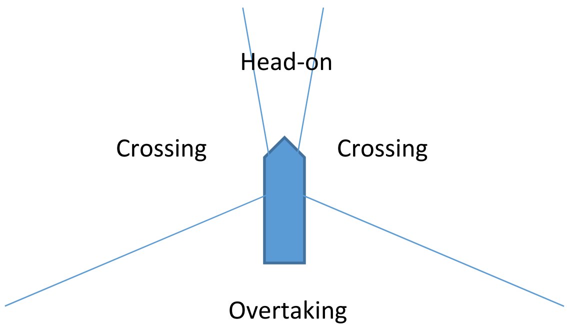

FIGURE 2 - TYPE OF SITUATION

When identifying the traffic situation, the officer of the watch on each vessel tries to find out the navigational status of the other vessel (power-driven, sailing, engaged in fishing, constrained by draught, restricted manoeuvrability, not under command), aspect to define type of situation (head-on, crossing or overtaking), and to determine risk of collision the distance and time to the closest point of approach (CPA) and the range and time for bow crossing (BCR and BCT) (see figure 3).

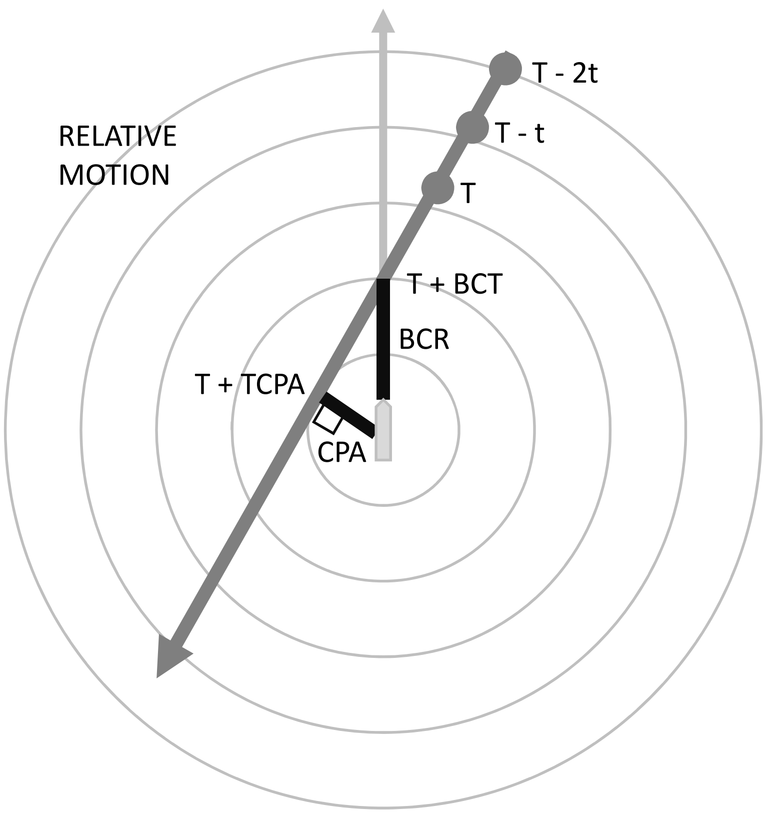

FIGURE 3 - CALCULATION OF CPA, TCPA, BCR AND BCT (AT TIME T)

During a situation the vessels could change course or speed. This change is called a manoeuver and could be an avoiding manoeuver or a non-avoiding manoeuver. Avoiding manoeuvers should be performed in accordance with the COLREG. When navigating the vessel, the OOW has to avoid some areas, i.e. shallow water and land, or change course to follow a TSS for example. This means that there are several occasions where the vessel change course, in presence of other vessel or not. These areas are, in this study, called “normal turning areas” and the manoeuver is defined as a non-avoiding manoeuver.

The situation could be divided into four different phases. The first phase, assessment of the situation, occur when the other vessel is sighted (visually or by radar) at long distance. When the action range is reached, the next phase starts, called “before action” phase. When one of the vessels do an avoiding manoeuver, the next phase starts, called “after action” phase. When there is no risk of collision, the phase “safe situation” starts (see figure 4).

In some cases, the give-way vessel could have limited possibilities to change course due to different type of obstructions, i.e. land and other vessels in the vicinity. In those cases planning in advance is necessary for the OOW to make a proper avoiding manoeuver. Obstructions are measured by closest distance to the object and bearings (see figure 5)

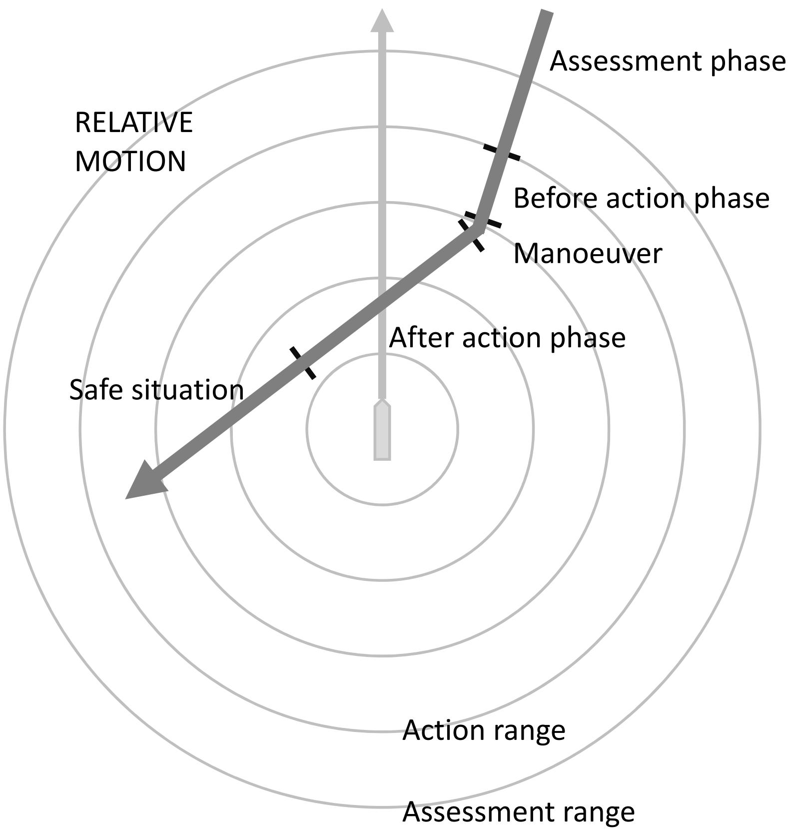

FIGURE 4 - SITUATION PHASES

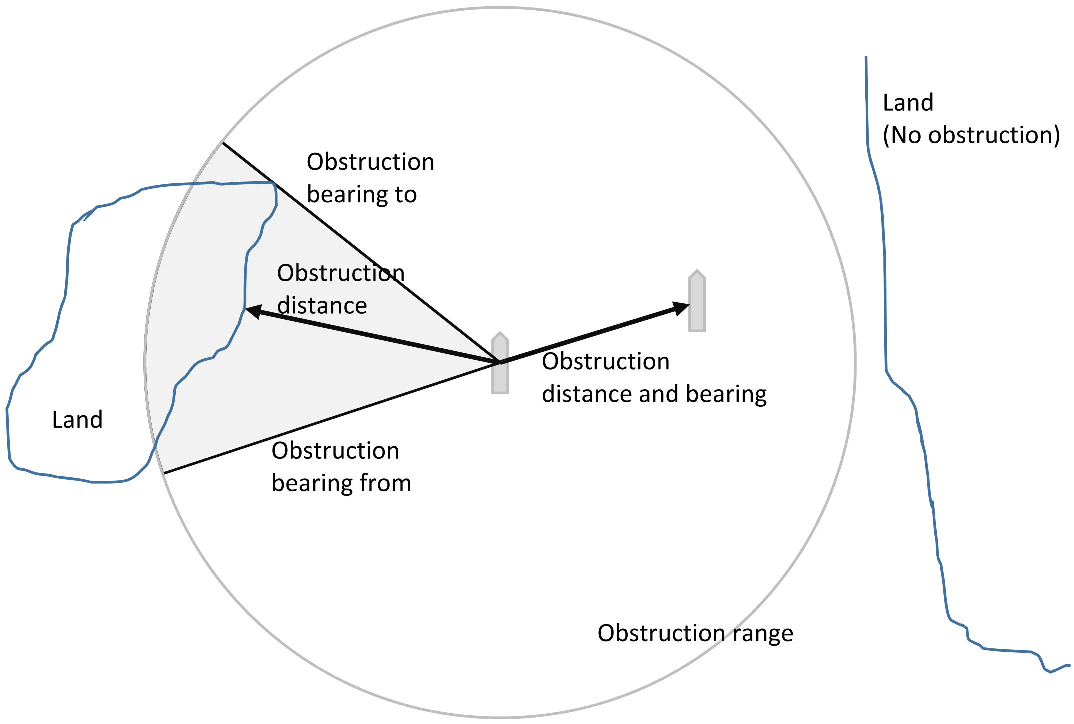

FIGURE 5 - MEASUREMENT OF OBSTRUCTION DISTANCE AND BEARING

THE SOFTWARE

The software developed in this project is called "Marine Traffic Analyser".

PURPOSE

The main purpose of the software is to find marine traffic situations and analyse those according to COLREG. The result could be used to learn more about the observance of regulations, to improve the education of deck officers regarding anti-collision, to find real traffic situations as base for navigational simulator exercises or to compare traffic before and after introduction of new regulations such as traffic separation schemes, sea traffic management areas etc.

FUNCTIONALITY

The software uses position data to analyse marine traffic from different perspective. The most advanced analyse is the one described in this paper, analyse of marine traffic situations and their connection to the COLREG.

Other functionality includes:

- measuring all traffic passing a specified line in the area to calculate the distribution along the line, the number of vessels passing etc
- traffic density plot to identify traffic patterns in an area
- speed distribution for vessels in an area

LIMITATIONS

All vessels at sea do not have AIS installed, which means that the full coverage of the situation is missing. To cover all movements at sea the AIS data must be complemented by radar data, which is not possible for larger areas but could be implemented for smaller areas such as Vessel Traffic Service (VTS) areas.

The heading is not known for all vessels, due to the fact that the heading is not included in there AIS messages. In those cases the heading has been replaced by course over ground in analyses. For vessels with relatively high speed in waters without strong current, tidal stream or heavy wind, the difference between heading and course over ground is normally small and should not influence the result much.

Today, the actual visibility in a specific position at analyse time is not considered. The obligations for the vessels according to COLREG differ if the vessels are in sight of each other (rules 11-18) or if the other vessel is detected by radar alone (rule 19). In some areas and some time periods, data of visibility could be found in databases from metrological institutes, but has not yet been implemented in the software.

The vessels' position for different times are known, manoeuvers could be identified, but the thoughts of the officer of the watch in a specific situation could never be known by using AIS data only. Particularly in complex situations with multiple vessels involved, the work on each vessel's bridge would be of importance to understand the situation in full.

ALGORITHM FOR TRAFFIC ANALYSE

The traffic situation analyse is performed in an eight step algorithm:

1. Read data
2. Preparation of data
3. Selection and filtering
4. Time step to find all situations were vessels are within assessment range
5. Merge situations
6. Check fulfilment of situation type
7. Show result
8. Find statistics

STEP 1: READ DATA

The most important values, for identification and analyse of traffic situations, are the vessels' unique identifier (normally MMSI), time of the message, position in latitude and longitude, speed, course over ground and heading.

STEP 2: PREPARATION OF DATA

When all messages for the specific area and time period are saved, the movement of each vessel is analysed.

In preparation, there is also an identification of manoeuvers, i.e. changes in course or speed, for each vessel. To find manoeuvers, and not only a sudden change in course due to wind, waves and swell, the manoeuver is identified and stored when the difference between a steady heading and speed and a moving average of the heading and speed from the last messages (default 5 latest) are larger than a specified threshold value (default two degrees change in heading respectively two knots change in speed).

STEP 3: SELECTION AND FILTERING

Before analysing traffic situations, the user specifies some parameters:

- AIS datasets to be used in the algorithm
- Situation types to search for
- Collision risk assessment method
- Specific areas to use (i.e. traffic separation schemes, narrow channels, normal turning points etc.)

By using more than one AIS dataset, a comparison between traffic situations in different areas or different time periods could be done. Several datasets could also be used as one, if there are multiple sources.

The user could specify which type of situations to search for by giving search parameters. The search parameters are divided in four groups; general (i.e. latitude and longitude range), measurements (i.e. CPA, TCPA, minimum distance and minimum course change), Boolean parameters (i.e. type of situation or within TSS), and string values (i.e. navigational status and ship type). The search parameters could be included or excluded, for example searching for all situations with a minimum passing distance of less than 0.8 nautical miles (included) but not if the ship type is a pilot boat (excluded).

To identify if there is risk of collision or not, the concept of safety domain is used and the user could specify which collision risk assessment method to be used, i.e. Fuji and Tanaka or Goodwin.

By specifying specific areas to be used in the algorithm, manoeuvers could be better identified as normal turning points or avoiding manoeuvers in a traffic situation, but at the cost of computational power and time.

STEP 4: TIME STEP TO FIND ALL SITUATIONS WERE VESSELS ARE WITHIN ASSESSMENT RANGE

At this step in the algorithm, the software starts to analyse at the specified start time and loop through all vessels to find if the vessel is within specified analyse area and to find other vessels at a distance less than the assessment range. The position of each vessel has to be adjusted to the actual analyse time by interpolation from the positions read from the AIS messages closest to analyse time. For each vessel within assessment range, the situation is measured regarding distance, true and relative bearing, CPA, TCPA, BCR, BCT, risk of collision, course difference, speed difference, aspect, if the vessel is within a specific area, targets, and obstructions.

When all situations are measured, analyse time is increased by a specified number of minutes (default three minutes) and a new loop through all vessels are performed to measure situations.

STEP 5: MERGE SITUATIONS

The situations are found and measured for each vessel, which means that each traffic situation appears twice, from both vessels' perspective. At this step the situation data is merged into one situation. After the data is merged;

- the type of situation is identified (head on, crossing or overtaking) from the aspect,
- the give-way and stand on vessel according to COLREG are identified depending of the type of situation and the navigational status of both vessels,
- the minimum distance between the vessels are calculated (the minimum distance will probably occur between two of the measurements),
- avoiding manoeuvers are identified, and
- situation phases are identified

To distinguish between avoiding manoeuvers and non-avoiding manoeuvers the following criteria are used to identify an avoiding manoeuver for a specific situation:

1. Risk of collision exist between the vessels
2. The manoeuver is performed within the specified action range for the type of situation
3. The manoeuver is performed when TCPA is positive
4. The CPA should increase due to the manoeuver
5. The manoeuver is not performed in a normal turning area to a new course within its normal turning range
6. There is no other target with higher risk of collision, defined as lower TCPA

STEP 6: CHECK FULFILMENT OF SITUATION TYPE

All situations are merged and measured, at this step in the algorithm each situation is compared to the search parameters given.

STEP 7: SHOW RESULT

The search result is shown in a list, showing main parameters such as involved vessels, minimum distance, type of situation, avoiding manoeuver etc. The user could select one of the situations in the list to see a graphical view of the situation (based on Google Maps) and all measures from that particular situation (see figure 6).

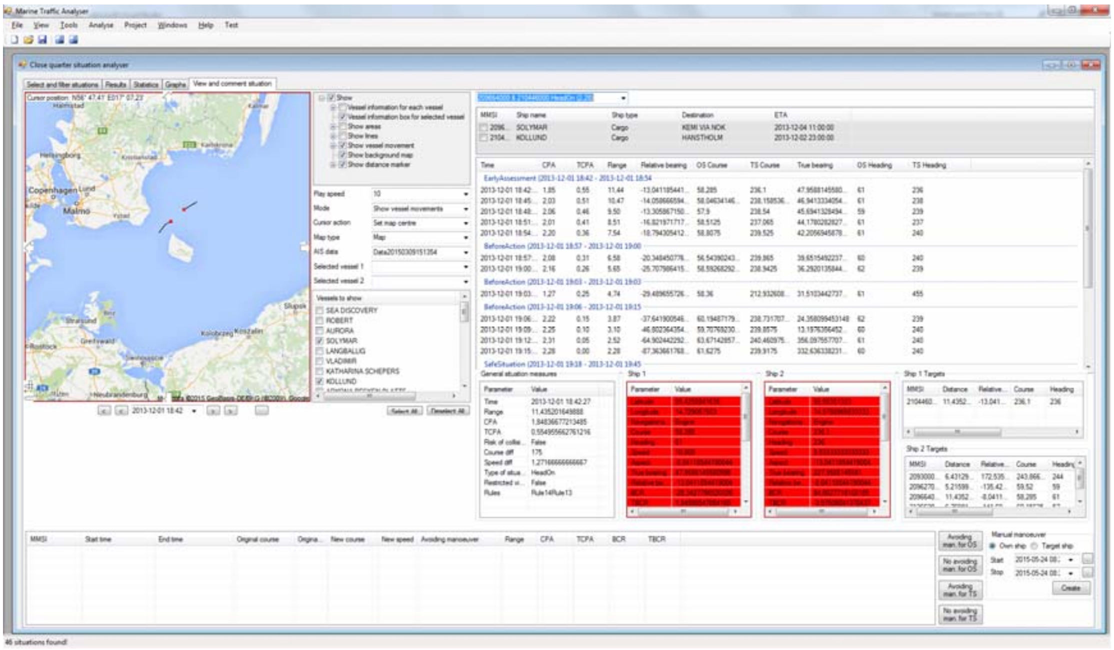

FIGURE 5 - DATA FOR ONE TRAFFIC SITUATION (THE RED FIELDS INDICATE THAT NONE OF THE VESSELS HAVE RIGHT OF WAY IN THIS HEAD ON SITUATION)

STEP 8: FIND STATISTICS

When all situations fulfilling the search criteria are found, statistical measurements are calculated such as number of situations for each situation type, average passing distance when there is and where there is not an avoiding manoeuver and also minimum, maximum, average order and type of avoiding manoeuver.

VALIDATION

The validation of the software has been done at four levels, starting with basic functions and ending with comparison with known statistical traffic data for the Bornholmsgat area.

Level 1 – Basic functions. Validation of basic functions such as the calculation of distance and bearing between two positions has been done by comparison of calculated values and values from two ECDIS systems.

Level 2 – Situation measures. At the second level, validation of situation measures for a specific time has been done by comparison of known situations created in a navigational simulator, using Kongsberg Maritime's Polaris Ships Bridge Simulator, version 7.3.0. The scenarios were made to cover all types of situations (head on, crossing and overtaking) with two to six vessels involved. The parameters validated were the calculation of course and speed differences, CPA and TCPA, aspect and relative bearing, true bearing, BCR and BCT. Furthermore were the following parameters validated: risk of collision, type of situation, COLREG rules involved, minimum distance between vessels, manoeuvers and avoiding manoeuvers.

Level 3 – Find correct situations from search parameters. A more complicated traffic situation with six vessels involved, totally 15 different situations, were created and analysed in navigational simulator to find out the criteria for each situation. The search function were validated, by use of different search parameters and comparing the result with the 15 known situations.

Level 4 – Compare with known traffic situation. The final validation were made comparing the result and statistics measured for one day of traffic with known values for the traffic in Bornholmsgat on December 1, 2013 [23].

CONCLUSION AND DISCUSSION

The validation of the software shows that the result from analyses are correct and accurate.

The main purpose of the software is to find marine traffic situations and analyse those according to COLREG to learn more about in what way the rules are interpreted and followed by the officers on board merchant vessels. One interesting type of question is how officers perform there avoiding actions in difficult situations, for example in a situation in the boundary between crossing situation from starboard and overtaking situation. By doing an analyse of situations where the relative bearing is between 110-115°, we could learn more about which vessel doing an avoiding action, at what distance and if the "overtaking" vessel turn to starboard or port.

By learning more about the interpretation of the rules in real situations, the situations could be recreated as simulator exercises for improved education of new officers. It would also be interesting to compare the result from real situations with the result from simulator studies performed with experienced officers as participants. If the results correspond, the officers could be interviewed and their thoughts could be recorded to learn even more about the situations, and if the results do not correspond, the validity of simulator studies in anti-collision could be questioned.

AIS data is not the complete truth, but by looking at the data in a statistical perspective with hundreds or thousands of situations of a kind, single deviating situations could be overlooked.

The software could also be used to compare traffic before and after introduction of new regulations such as traffic separation schemes, sea traffic management areas etc. The number of difficult situations could be counted, the average passing distance could be monitored to find out if the new regulation reach the expected goals.

A third field of application for the software could be longitudinal studies where, for example, the average passing distance between vessels or the order of course change in different situations are measured. Many officers says that the passing distances have decreased during the years, but we have not found any scientific longitudinal study in this area.

The software is still under development and functionality will be improved when new studies require. Ideas for further development of the software includes:

- Improvement of use of specific areas to include measurement of crossing angle, entrance and leaving point, time in area etc.
- Possibility to read streams of real-time or historic AIS data from chosen area.
- Possibility to include meteorological data in analyses to calculate if the vessels are in sight of each other or not and find out which COLREG rule to follow.

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