MONALISA 2.0 – Activity 4
Report on ICT tool to support bridge operations with early warning of grounding

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# Table of contents

1 Summary ........................................................................................................................................ 4

2 Normal behavior from historical AIS ............................................................................................. 5
    2.1 System description .................................................................................................................. 5
        2.1.1 Introduction .................................................................................................................... 5
        2.1.2 System flow diagram ....................................................................................................... 5
        2.1.3 AIS data as line segments ............................................................................................... 6
    2.2 Data Calculations ..................................................................................................................... 7
        2.2.1 Segment calculations ....................................................................................................... 9
    2.3 Warnings .................................................................................................................................. 10
    2.4 Interface .................................................................................................................................. 10
    2.5 Evaluation ................................................................................................................................ 11
    2.6 Discussion ............................................................................................................................... 14
    2.7 Future work ............................................................................................................................. 14
    2.8 References ............................................................................................................................... 14

3 Evaluation of the Dynamic Predictor ............................................................................................... 15
    3.1 Introduction ............................................................................................................................. 15
        3.1.1 Objective .......................................................................................................................... 15
        3.1.2 Method ............................................................................................................................ 15
        3.1.3 List of abbreviations ......................................................................................................... 16
        3.1.4 List of reference documents ............................................................................................. 16
    3.2 Results ..................................................................................................................................... 16
        3.2.1 Background ....................................................................................................................... 16
        3.2.2 Port manoeuvring ............................................................................................................. 16
        3.2.3 Open sea and anti-collision .............................................................................................. 17
        3.2.4 Controlled navigation in restricted waters ......................................................................... 17
        3.2.5 Emergency and mode awareness ....................................................................................... 18
        3.2.6 Training ............................................................................................................................. 18
        3.2.7 Improvement of model ...................................................................................................... 20
1 Summary

This report is a part of the MonaLisa 2.0 project. This report describes the technical and evaluation parts of “Sub activity. 4.3 – Extensive Risk Assessment” and covers the deliverables 4.3.3 “Report on bridge ICT support/Dynamic Predictor” and 4.3.4 “Report on risk assessment implementing and piloting” respectively, as part of the Milestone M11.

The first part of the report, chapter 2, is an analysis of an ICT tool for early warning of going aground by using historic and real time vessel data (AIS).

The second part of the report, chapter 3, covers the evaluation of a ICT tool for assisting in ship handling, Dynamic Predictor, to identify user needs and user aspects of the concept.
2 Normal behavior from historical AIS

2.1 System description

2.1.1 Introduction

Costa Concordia Investigative Body found that the Master’s unconventional behaviour represents the main cause of the shipwreck (Marine Casualties Investigative Body, 2013). Fortunately, there is usually a great imbalance between things that go right and things that go wrong (Hollnagel, 2014). By analysing what is normal behaviour, the unconventional behaviour will be a deviation from every day operations.

Historical AIS data is used in this study find what normal behaviour is. AIS (Automatic Identification System) is an automatic tracking system mandatory for all ships with gross tonnage (GT) of 300 or more and all passenger ships regardless of size, which is transmitted over VHF every 3 to 10 seconds. Each message, transmitted from each ship, is compared to stored, historical AIS data and by using different filters and calculations of the stored data, different deviation values is derived.

2.1.2 System flow diagram

The basic flow for the system is shown in figure 1. An incoming AIS message triggers the process where, based on the position, historical data is selected from the database and compared to the incoming message. The result of the comparison, i.e. the status, is written back to the database. A warning is generated if the status is outside of the pre-configured limits for several consecutive messages.
During the project the Swedish Maritime Administration (SMA) AIS stream was used, which covers Sweden’s coastal waters. The data traffic from the stream is approximately 80 AIS messages per second, which sums up to about 7 million AIS messages per 24 hours.

2.1.3 AIS data as line segments

AIS messages are stored pair wise as line segments and these segments are grouped into vessel tracks. All calculations of derived values, i.e. to determine if current vessel is behaving normal, are done in real time and the size of the area included in the calculations can be varied such that enough historical data is included. This method is described further in the data calculation chapter.

An advantage of not pre-calculating derived values is that the database can be seamlessly updated with the latest AIS data. Another advantage, using segments, is that even if the selection area is small intersecting segments are still included, whereas when storing points there might be too far distance between that they are not part of the selection, even though the vessel passed the selected area.

On the other hand, pre-calculating values is faster when the system is running, this due to faster lookup speed and the fact that some of the calculations are already performed.
2.2 Data Calculations

The data calculations below are done for each incoming AIS message, in relation to all adjacent historical AIS data segments that are part of the selection from the database.

In order to identify the two main directions of vessel traffic in a selection, the course over ground (COG) values are separated into two intervals of 180 degrees each. To get the most frequent COG direction, all the segments in the selection are grouped for each 10 degrees, where the largest group (containing the most segments) is chosen as the main direction.

Figure 2: Historic AIS data from 2014, turned into segments.
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Figure 3: Course division example.
2.2.1 Segment calculations

With the segment calculation method, an area around each vessel is selected from the database. The searched area used is a four-corner polygon, many times referred to as an envelope in geospatial applications.

The database search is filtered on vessel type (tanker, passenger and cargo) and speed over ground (SOG), which needs to be greater than 4 knots not to include anchored vessels.
2.3 Warnings

The average and standard deviation is calculated from the historical data and a warning is issued if the current value is outside of the second standard deviation. In this study the parameters COG and draught of the vessel were used. There is also a warning if the selected area contains too few segments, labeled as a “low data” warning.

2.4 Interface

Figure 5: Screenshot of html interface, with live AIS tracking.

Visualization of the calculated results is shown in a web interface, which contains a map layer, as well as a basic status and control section. The map layer is “Open Street Map”, a free web map service, with an added nautical layer that shows fairways and seamarks.

Figure 6: Screenshot of the control and status html interface.
Vessel information is listed in the status section along with several of the calculated values, taken from the results database. There are also controls for limiting the type of vessels to show on the map, i.e. Tanker, Cargo and Passenger ships.

The circle diagram in figure 9 show an example of the calculated standard deviations, i.e. normal behaviour.

Looking at the example in figure 9, the important numbers is the COG probability and draught probability. The COG probability is 0.599 and the draught probability is 0.619. These numbers represent the ratio in relation to the standard deviation, where the maximum value is 1.0 and the minimum is 0.0. The vessel in the example is within the second standard deviation value.

The segment count from the database is shown in the control area. In the example above there were 469 segments within the 180 degree interval and 31 segments within the opposite interval. The number of results from the database is limited to a maximum of 500 segments, in order to minimise search time and calculations.

2.5 Evaluation

Two grounding accidents that happened quite recently on the west coast of Sweden were used to evaluate the system. The first one was the vessel Ran on 2013-11-23 and the second was the vessel Victoria on 2015-09-19. When analysing Ran, showed in figure 11, the location is between the island Ven and the city of Landskrona, on the Swedish mainland. The first alarm from the behaviour system is at 07:26:49 UTC, and the grounding occur at 07:38:28 UTC. The system alerts about 12 min before the grounding.
Figure 8: Ran behavior analyze.
The other grounding accident, by the vessel Victoria, is shown in figure 12. Three different timestamps are marked. At time stamp 14:35:02 UTC the system register the first alarm. Then, between first timestamp and 14:52:41, some OK values were registered. After the timestamp 14:52:41 UTC the abnormal behaviour of Victoria is repeatedly indicated. The grounding occur at 16:31:41 UTC, which is about 118 min after the first alarm and approx. 90 min before the second time stamp, at 14:52:41 UTC.

Figure 9: Victoria behavior analysis.
2.6 Discussion

Warning systems has a number of difficult and sometimes contradictory aspects to take into consideration, such as how warnings should be presented to the user and when to warn. Too many warnings and there is a risk that users lose confidence in the system, too few and there might not be enough time to react before the warning turns into a critical error.

Confidence in the reliability of an alarm appears to be a function of both people’s experience with it and the presence of other concurrent alarms, which people apparently take as confirming or opposing evidence of its validity.

The problem of irrelevant alarms is a difficult aspect when designing a system. The degree to which a system produces false warnings must be weighed against the likelihood that it will have missed warnings, i.e. situations in which a real problem exists, but for which the system does not produce an alarm. Alarms will not be effective if they can be easily misinterpreted.

2.7 Future work

More testing with actual groundings is vital to test filter and dampening levels of the system, in order to minimize the amount of false positives.

Future work also includes integrating the system into route optimization, to get a grounding risk estimation for optimized routes.

2.8 References


3 Evaluation of the Dynamic Predictor

3.1 Introduction

Scope and purpose

The Dynamic Predictor is developed by SSPA AB as a decision support tool in ship handling. The purpose of this analysis is to identify user needs and user aspects for the concept of a dynamic predictor.

3.1.1 Objective

The objectives of report are:

- to identify possible user benefits introduced by the Dynamic Predictor;
- to identify possible user improvements in the Dynamic Predictor; and
- to analyze training needs which would be required to use the Dynamic Predictor.

3.1.2 Method

As stated above the purpose of this analysis is to identify user needs and user aspects for the concept of a dynamic predictor. Examples are:

- Presentation of information;
- Operational functions; and
- Training aspects.
- Four areas of operations as been investigated:
  - Port;
  - Restricted waters;
  - Open waters; and
  - Contingency operations.

This analysis is based on data collection performed by:

- Interview of users;
- Onboard observation; and
- Simulator demonstration.
3.1.3 List of abbreviations

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<tr>
<td>COG</td>
<td>Course over Ground</td>
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<td>SOG</td>
<td>Speed over Ground</td>
</tr>
<tr>
<td>ROT</td>
<td>Rate Of Turn</td>
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3.1.4 List of reference documents

- ACCSEAS Final Report, 13/05/2015
- EfficienSea, Efficient, Safe and Sustainable Traffic at Sea, 2011. Test bed for evaluation of methods for decision support in collision avoidance. Deliverable No. W_WP4_4_8

3.2 Results

3.2.1 Background

The Dynamic Predictor is a visual aid for as precise as possible predicting and monitoring ship movements during demanding maneuvers. The system is mainly used for berthing/unberthing operations. Although being developed for increasing safety it also has potential to enhance efficiency in docking operations thus saving both fuel and reducing time. Dynamic Predictor is in use on a number of ships today.

Conventional predictors use the vessel’s SOG, COG and ROT to predict the vessel movement. In addition to these values the Dynamic predictor uses the actual depth, vessel draught, trim, wind speed and angle, rudder angle, propeller pitch and/or RPM and finally but not least important a hydro dynamic model of the vessel. The prediction is presented to the operator as a chain of ship contours stretching out from the ship symbol on the ECDIS screen. With all the information mentioned above fed into the system, the Dynamic Predictor will immediately indicate the effect of all measures taken by the operator, such as but not limited to change of thrust or rudder angle.

3.2.2 Port manoeuvring

This paragraph describes user needs and aspect for the use of a dynamic predictor in a docking mode for ships maneuvering on its own or by support of tugs.

As described above the Dynamic Predictor is developed for use in docking operations and has as such proved to be of high value to operators. However, the system is today only designed for vessels maneuvering by themselves and not when assisted by tugs. Generally speaking the more demanding the operation is,
the higher the need for tug assistance. Hence, one can say that there is a need to develop the system to being able to handle tug assisted operations.

In the EU project ACCSEAS (ACCSEAS 2015), some research on the subject has been done by SSPA and the result so far is that more testing needs to be done to find significant results and also tests with more complicated operations with larger vessels and multiple tugs.

With ever larger vessels being developed and a constant strive for more efficient yet safer operations, this is definitely a field that should be looked at more in detail.

3.2.3 Open sea and anti-collision

During the EU project EfficienSea (Efficient, Safe and Sustainable Traffic at Sea, 2011) project the function of exchanging predictor data between vessels nearby each other was tested. The result of that research was that it did not add any value concerning anti-collision navigation. Mainly since the information presented was not the intended route that was presented and it was too much information to handle.

3.2.4 Controlled navigation in restricted waters

This paragraph investigates the use of a dynamic predictor as a tool in controlled navigation for a passage in restricted waters.

In order to increase safety during controlled navigation in restricted waters, it can be of value to develop the Dynamic Predictor’s function for higher speeds than those used at docking operations. The Dynamic Predictor could then serve as a complement to the methods that are already in use for controlled turns and navigation in restricted waters, e.g. concentric indexing, fixed radius, tangential bearings etc.

Another application for Dynamic Predictor connected to restricted waters and controlled turns is that of traffic management in these areas. For example, handling meeting traffic after a turn in a fairway. In both these cases the Dynamic Predictor has the advantage of taking the dynamic factors into account. This is not done at all in the methods of controlled turns or a curved heading line for example.

In order to achieve this type of Dynamic Predictor the system needs to be adjusted. Since it, as has been mentioned before, is designed to docking operations it is very sensitive. It must be as it is one of the prerequisites to make the system work for berthing or unberthing. However, this means that at higher speeds the predicted information becomes very volatile. The trend symbols or contours move quickly over large areas of the screen. This is simply due to the greater distances travelled by the ship at higher speeds and that even the
slightest alteration of rudder angle thus has a great impact on the predicted position. This makes the information maybe not useless but very hard to interpret for the operator. In order to overcome this problem some sort of damping or filtering of the data is needed to achieve a more stable and realistic presentation of the vessel’s predicted position.

If one manages to adapt the Dynamic Predictor as has been described above, i.e. that the information presented is more reliable and is of a higher quality than today’s available methods of determining how close two vessels will pass each other after a turn, an exchange of predictor information between the two vessels can become more attractive than it is today. The use of Dynamic Predictor information exchange may therefore be considered useful in in-shore navigation and in ship to ship operations. The latter being a common method of transferring oil/oil products. In itself an activity with high health, safety and environmental demands.

In my view this is something that could be worth looking at forward going.

3.2.5 Emergency and mode awareness

In addition to Port Maneuvers and Controlled navigation in restricted waters the Dynamic Prediction proves to be of high value when it comes to contingency planning in emergency situations or abnormal situations. With the system constantly calculating and producing a real time simulation, the operator immediately gets the effect of a failure or a breakdown presented as a predicted position. Thus the Dynamic Predictor helps the operator in making the right decision in the task at hand.

3.2.6 Training

An important aspect of the user perspective, mentioned in the introduction is training. It is important that note that training and training needs should be considered in parallel when developing new concept, processes and technical solutions.

Results from the training need analysis are presented focusing on the ship bridge crew.

Ship handling is an activity which requires partly theoretical knowledge about how the vessel works and the forces acting upon it and partly a great deal of practical, hands-on experience. The Dynamic Predictor can have a significant role to play in this regard, in two ways:

- Onboard training
- Training course

**Primarily regarding the training situation on board for an officer new to a ship**
The officer can be considered to be a person with more or less previous experience of ship handling and is supposed to learn the maneuvering characteristics of the vessel. Assisted by the Dynamic Predictor, the learning curve can be much steeper since the system, provided it is well tuned off course, constantly gives the operator feedback on every intended maneuver. Thus facilitating for a reduction in training time, or if you like, improved training within the same time as was used before. This is also something that should be taken into consideration when building the business case of purchasing a Dynamic Predictor system for a vessel.

**Training course**

The second role for the Dynamic Predictor when it comes to training is the one of training and educating ship handling at universities and training centers where both students on a basic education are trained as well as experienced officers are going through continuing education. For the student going through a continuing education, one can say that the system plays the same role as for training on board. A system which confirms whether the intended maneuver has the desired effect or not.

For the other group, students at their basic education, another approach to Dynamic Prediction can be used in their training. As stated before, a lot of practical experience is needed in order to become skilled at ship handling. What we strive for is the ability to handle our ship in a safe and efficient manner but also to be able to judge when a maneuver is possible to perform or not. The risk of introducing Dynamic Predictor to a student during basic education is that the ship handling operation becomes too similar to a video game as opposed to one system of many all playing their part in the total information flow on the vessel bridge. Ultimately, this risk can possibly lead to the student not learning ship handling the proper way. The consequences of this are obvious and need no further clarification here. However, in this context it is worth noting that there is a risk involved in Dynamic Prediction systems that the operator relies too much on the system and what happens on the computer screen that he/she forgets to look out the window to take in what is going on in the real world. That said, this risk cannot disqualify the technological progress and the obvious advantages and possibilities they bring. Still the responsibility rests upon us who are training the students and using the system so it is done in a correct and proper manner.

Given the above, it is my view that when using the Dynamic Predictor in training students at the basic education, the Dynamic Predictor system should be used more as a teaching instrument than as a system they are being trained to use or become operator of. As such it can have major advantages. For instance during ship handling training in a simulator where the Dynamic Predictor is not on or at least no visible for the student and the instructor can pause the exercise and make the predictor visible to the student in order to make a point or prove an effect of a given rudder order or thruster setting etc.
3.2.7 Improvement of model

As stated in the Background the Dynamic Predictor needs a hydro dynamic model of the vessel in order to predict the vessel’s future movements. Obviously the quality of the prediction is depending on how well tuned this model is. In order to further improve the performance of the system, one could look at making the model adaptive. It can be compared to steering a vessel by hand. No matter how experienced the helmsman is, he/she will always need a few minutes to get used to or get the feel of the vessel after taking the wheel. An adaptive Dynamic Predictor system would do the same to adapt fully to the vessel actual configuration and present environmental conditions and thereby increasing the performance of the system.

The technology of adaptive models has been used within the Dynamic Positioning systems for a long time and is well proven.
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