Fleet monitoring and detection of risk level by utilization of typical operational patterns

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ABSTRACT

Groundings are one of the most frequent types of navigational accidents. By definition, those also often come with the risk of pollution. Prevention of groundings relies on navigational processes and up-to-date information is available. Even though the navigational safety of the vessel is the sole responsibility of the crew, it is also possible to utilize onshore personnel to monitor fleet situations as well as provide advice to the vessels. This task is challenging, especially on large fleets, containing several hundred vessels. In this paper, the utilization of operational patterns as a way for identifying increased risk levels is discussed. The developed method uses typical corridors, combined with sea area categorization as a basis for risk analysis. The risk level of individual vessels was assessed by their location compared to these typical corridors.

Keywords: *Navigational safety, fleet monitoring, grounding risk, operational pattern*

1. INTRODUCTION

Groundings and other types of navigational accidents are very often at least partly caused by human factors as suggested by Eleftheria et al, (2016). It is difficult to find global, up to date statistic on the frequency of accidents, but looking at for example Japan Transport Safety Boards statistics of 2022 until end of March, groundings correspond of 15% of the reported accidents.

There are well-established practices and requirements to ensure that vessels are operated safely. These are detailed amongst others in IMO published Ship's Routing, IMO (2019). Both responsibilities as well as practical aspects should be considered in the creation of safe passage planning. In the context of this paper, we will mostly refer to navigational hazards such as grounding or collision to fixed objects. At present navigational safety relies mostly on the expertise of onboard personnel. It seems possible that the safety of vessels could be increased by adding an additional monitoring of risk level. This could be used to mitigate the risks arising from various types of human errors. such as incorrect configuration of ECDIS (Electronic Chart Display and Information System) safety contours or unnoticed dangerous objects.

Shore-based advisory vessel monitoring is not novel for the industry. However, based on publicly available data, the focus seems to be on highly integrated systems (Neptune) or general situational awareness with the focus being on the weather conditions and avoidance of bad weather (CMA CGM). Implementation of risk detection systems for large fleets, including for example time-chartered vessels poses various restrictions on the available data, due to the limited possibility to install or integrate equipment or to increase the workload of the crew onboard. Because of these reasons, there is a need to develop a methodology that focuses on identifying vessel risk levels for large fleets, with a limited amount of input data. This paper intends to present some practical approaches to risk level monitoring for a fleet-based system, working on limited input data.

2. ADVISORY SYSTEM

Advisory systems in general can be utilized both on board a vessel as well as ashore. The best fit depends on the intended use, the topic being monitored as well as expected event timeline. In the case of collision detection for example, the timeline tends to be short, making communication between shore and onboard personnel impractical.

A risk can be generally understood as being temporal such as encounter of high waves or spatial such as shallow water, wrecks or similar. At the same time, it can be combination of both, such as combination of shallow water and heavy weather as outlined in the accident investigation of MSC ZOE published by the Dutch Safety Board (2020)

Operational patterns

The fundamental assumption made here when using operational data as a baseline is that most of the time spent at sea happens safely, without accidents. This assumption should be correct in terms of distance travelled or time spent at sea. It is also true that due to the environment where vessels operate, some risks are more likely to happen in congested fairways or places where navigational complexity is high, such as the Singapore Strait shown in Figure 1. This topic has been investigated for example by Zhang et al. (2020). On the other hand, some accidents such as grounding, require shallow water to be present.

Figure 1: AIS data for the Singapore Strait showing use of traffic separation as well as common anchorages.

Above assumption leads us to the conclusion that it might be beneficial to divide seas into two categories

- **Restricted areas**, which are close to shore or contain shallow water or traffic limitations
- **Un-restricted areas**, which are safe to navigate in respect to grounding or collision to fixed objects such as oil production platforms.

Transition between the two areas can be tracked. The location of the vessel within one of those allows the system to monitor the most likely risks specific to that area. Based on analyzed past vessel positions for approximately 400 ships for a duration of several months leads to an estimation that 78.6% of distance and 77.6% of time is sailed within un-restricted areas.

Most readily available data sources for operational data are onboard measurements (GPS, Global Positioning System), automatic identification system (AIS, Automatic Identification System) or satellite imagery. The AIS was chosen because it is available for the whole global fleet and does not require separate equipment to be installed.

The use of operational data as a benchmark has an additional implication. The way how vessels are operated can be also subject to influences that are not of direct consideration in a monitoring system that is planned. In an ideal scenario operational data would contain all information that is relevant for safe voyage making, Electronic Navigational Charts (ENC), Navigational Area in the context of Navigational Warnings (NAVAREA), Temporary and Preliminary notices to mariners (T&P), local policies, seasonal effects etc. It could be also described as collective understanding of seafarers on how to navigate safely in a given area. These aspects will be considered in form of a typical corridor as an example of operational pattern.

Typical corridor

A Typical corridor is a new concept where data describing a vessel's deviation from the imaginary centerline of a fairway is processed in a way that it is possible to establish an assumedly safe corridor for each segment of the underlying fairway data. The fairway data can be also constructed out of operational data or by extracting information from the electronic nautical charts. In this case, data partially derived from ENC was used as the desired fairway centerline and the typical corridors were established using map matching, a typical geospatial practice widely used for example in assigning GPS tracks to specific route segments. Alternatives related to this are described for example by Lou Y. et al (2009).

While the presented concept shares many similarities to the earlier one published by Montewka J. et al (2011) it also has some differences. The most obvious similarity is the fact that distance from fairway centerline is a key parameter in both, combined with a safety contour. The biggest differentiations are. Firstly, in the typical corridor concept presented here, no water depth data is required, even thought it is possible to be included. The typical corridor data can be generated with the AIS data alone. Secondly the typical corridors generated using operational data alone, also implicitly includes information regarding, wrecks, buoys, moving sand banks, turning radius, etc. as those will be considered in the practical ship's navigation. This also enables the tracking of other threats in addition to the grounding. Although exploring those would require further studies.

On the other hand, the writer acknowledge that the grounding probability function approach presented in the Montewka J. et al (2011) has the benefit of being able to describe grounding probability density, which allows more granular estimation of the grounding probability, which can lead to higher accuracy. From the monitoring system perspective, it was seen beneficial to approach with alternative simpler method that works on very limited input data and can be efficiently executed real-time, globally for thousands of vessels.

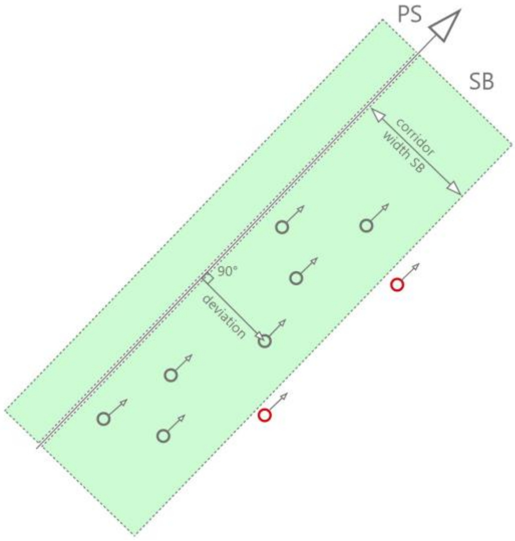

Figure 2: Typical corridor definitions

In this study, the typical corridor data was generated storing a deviation in meters for each data point towards the closest segment. It is good to note that filtering is necessary to identify only the data points travelling alongside the segment. The corridors are based on 3 months of sampled AIS data with an average of 2 million points per day. Depending on the use case, a suitable statistical value can be selected that describes typical with an appropriate safety margin. The selected period balances between describing recent patterns of operation and the coverage of data. The re-creation of typical corridor data should be periodically done. Figure 2. shows the overall concept of typical corridor in simplified form.

The safe corridor is not the same for all vessel types and especially for all vessel sizes. This is considered by using as the maximum draft information of the AIS to describe distinct corridors for different vessel sizes. A similar approach can be used for vessel types and other properties available in the source data.

As described above, exact implementation should depend on desired outcome as well as data that is available for the intended use case. Proposed simple implementation would involve:

1. Selection of underlying fairway centerlines. Utilization of chart data or data derived from AIS is possible.
2. Segmentation of the fairway data into straight line legs.
3. Matching of the raw AIS data into the legs.
4. Calculation of deviation values
    a. Filtering of only moving vessels
    b. Filtering vessels aligned to the leg.
5. Categorization of the deviation values by vessel types. (bulk carriers, container ships, etc.)
6. Calculation of typical corridor for range of drafts. As an example, there would be different typical corridors for max drafts between 15m-16m and 16-17m.
7. Apply selected statistical measure, such as 90% percentile to determine constant allowed deviation.

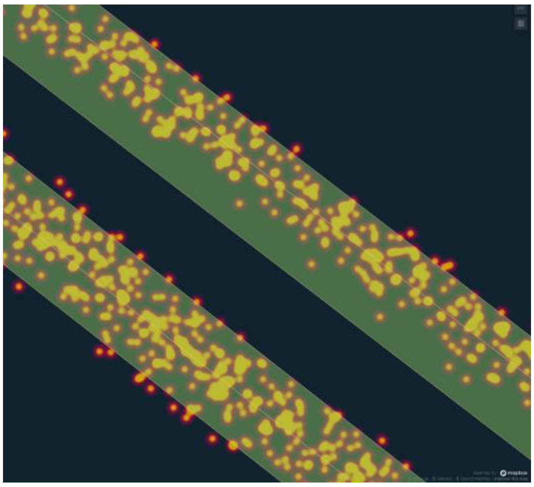

Figure 3: Typical corridors at Malacca Strait with AIS heatmap overlayed for ships with 12m-13m max draft.

Usage of the defined typical corridor data is then relatively straight forward. In the Figure 3. there is an example of overlaying heatmap of vessel traffic on top of a typical corridor. It is good to note that in addition to the typical corridor it is easy to enhance application by adding further data at this point such as depth data or areas to be avoided. Key steps of implementation would include:

1. Detect closest leg and corresponding typical corridor from the AIS position. Considering:
    a. Vessel type
    b. Draft
2. Calculate status relative to the corridor. Ship is within the corridor or outside of it.
3. Track events that change the corridor status. For example, when previous position was within corridor and the next one is outside, ship is leaving typical corridor.
4. Optionally include further consideration of the navigation context, such as proximity of shallow water or areas to be avoided.

Success criteria

For the fleet monitoring system to be effective two aspects need to be met. First, it needs to reliably identify increased risk. Secondly, it must not create too many false alarms. The latter becomes very relevant when the monitored fleet becomes very large, for example over 500 vessels.

Reliability can be estimated using past accident data. In the scope of the above-mentioned area categorization and typical corridors, it is important to understand whether accidents occurred within restricted areas and whether those happen outside of typical corridors.

The rate of risk events should be considered in the context of the implemented monitoring and severity of alarms. Dedicated vessel monitoring or safety team can handle a bigger number of events compared to for example individual persons getting notifications via email or similar. On the other hand, it is equally important that categorization works reasonably well, and the platform can communicate as much of the event context as possible. For that reason, it is good to consider providing information using electronic charts or temporary notices for mariners and other similar supporting data.

3. CASE STUDIES

Case studies are discussed through two examples that are somewhat well-known and details are in the public domain. The case studies were chosen to highlight the big variety of possible scenarios, which should be accounted for in the development of the methodology and consequently tools.

Ever Forward – Chesapeake Bay

A recent case where a large over 300m LOA container ship grounded. While the full accident report is still not available at the time of writing, we can see from Figure 4. a few properties that have been discussed previously. Firstly, typical corridors are very narrow in this section of the passage for the ship of that draft. Supporting this, the overall water depth in the area is shallow (Gebco). Secondly, point of grounding is well outside of the typical corridor.

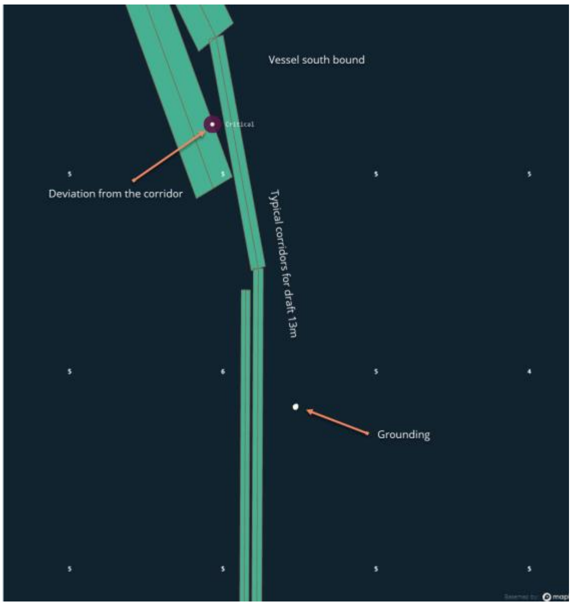

Figure 4: Trajectory of Ever Forward together with typical corridors

Tina I, Singapore Strait

Another case is from 2020 where a smaller size container ship grounded just south of Singapore and at the same time collided with another vessel that had been grounded in the same location previously. This case gives us an example that does not seem to fit that well with the typical corridor concept. As seen in Figure 5. the vessel crosses three traffic separation schemes diagonally, which makes it difficult to reason about what should be the action taken by the system. The topmost has travel direction to South-West the lower two would have North-East.

Starting from the basics we see that in the near past timeline there were three AIS points outside of the typical corridors and one inside. This can be seen as an indication of increased risk level. The timeline between the first deviation and the grounding is approximately 20 minutes.

The AIS point in the first TSS (Traffic Separation Scheme) is within the typical corridor if one does not consider the course of the vessel. Based on that there is no immediate risk of grounding. Next information is received between typical corridors, this indicates unsafe status. Especially if consideration of shallow water in forward proximity is taken into account. Following points southward from the lowest TSS indicate still increased risk due to the closer distance and time to shallow water.

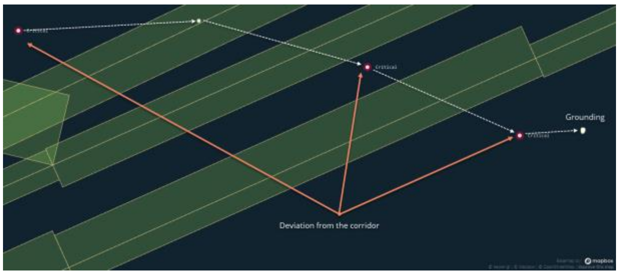

Figure 5: Trajectory of Tina I together with typical corridors

Again, turning back to basic questions on the typical corridor concept we can see that grounding happens outside of the typical corridor and within restricted sea areas. Further to that, there seemed to be some indication of increased risk levels prior to the actual accident.

4. DISCUSSION

The area categorization into restricted areas and non-restricted areas together with the typical corridor concept is not sufficient alone to achieve the goal of reducing the number of alarms to a suitable level. Additional measures describing the context of deviation should be implemented to efficiently categorize the severity and more specifically other factors possibly increasing the risk. These could be for example proximity of shallow water, wrecks, or other navigational hazards.

Other factors that could be of use would be the use of a ship's route plan, made with ECDIS as a reference to the deviation. This would enable monitoring of the plan in cases where the typical corridor does not make sense, such as at open sea. However, with this it is mandatory to set up a mechanism and agree on practices that allow such a plan to be utilized by shore-based monitoring infrastructure.

In addition to the prediction of near-future accidents, more research could be made on the possible statistical use of such a metric to predict a vessel's probability to have an accident. In addition to the obvious use with the insurance context, this could be used as a support for enhancing company-specific safety culture and training schemes. Further to this, it would be also beneficial to establish baseline metrics globally for sea areas and vessel types. As the operational profile of a vessel heavily affects the amount of time and distance spent on the restricted waters.

5. CONCLUSIONS

Fleet Monitoring which is systematic and largely automatic, has the potential to prevent part of the accidents. The usage of operational data as a baseline for risk detection can help to identify anomalies and highlight cases, where risk levels are increased. This can be very beneficial in case of large fleet sizes and can be effectively combined into a human-based monitoring setup in the onshore monitoring centres. The typical corridor concept described here can be seen as a building block for more holistic risk detection. It can be combined with for example water depth, weather forecast or anchorage area information to cover a wide range of risk situations.

REFERENCES

Carnival Neptune, “Carnival Corporation opens Fleet Operations Center in Seattle”, 2017, Cruise & Ferry online article, https://www.cruiseandferry.net/articles/carnival-corporation-opens-fleet-operations-center-in-seattle

CMA GGM, “Navigation and Port operations center”, SHIP TECHNOLOGY, 2017, https://www.ship-technology.com/news/newscma-cgm-opens-new-navigation-and-port-operations-centre-in-singapore-5718065/

Dutch Safety Board, 2020, “Safe container transport north of the Wadden Islands”

Eleftheria E., Apostolos P., Markos V., 2016, ” Statistical analysis of ship accidents and review of safety level”, Safety Science

Gebco, General Bathymetric Chart of the Oceans, https://www.gebco.net

IMO, “SHIP’S ROUTEING, 2019 Edition.

Japan Transport Safety Board, 2022, “Statistics of Marine Accident”, https://www.mlit.go.jp/jtsb/statistics_mar.html

Lou Y., Zhang C., Zheng Y., Xie X., Wang W., Huang Y., 2009, “Map-Matching for Low-Sampling-Rate GPS Trajectories”, Proceedings of 18th ACM SIGSPATIAL Conference on Advances in Geographical Information Systems

Montewka J., Krata P., Goerlandt F., Mazaheri A., Kujala P., 2011, ”Marine traffic risk modelling – an innovative approach and a case study”, Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability.

Zhang, M., Montewka, J., Manderbacka, T., Kujala, P., Spyros H., 2020, "Analysis of the Grounding Avoidance Behavior of a Ro-Pax Ship in the Gulf of Finland using Big Data." Paper presented at the The 30th International Ocean and Polar Engineering Conference, Virtual