Maritime shipping is one of most efficient modes of transport today. With the growth in world trade, ship traffic in the world’s oceans has greatly increased over the past few decades, making maritime safety increasingly challenging. Safety in maritime transport includes various aspects such as human safety at sea and at port, and also environmental safety and sustainability. In order to enhance navigational safety and prevent collisions at sea, several navigational rules have been developed over the past 40 years. In 1972, the International Maritime Organization (IMO) published the International Regulations for Preventing Collisions at Sea (COLREGS), which set the international rules of the road for maritime navigation.

Despite the considerable effort by the maritime authorities, safety is still a concern especially in heavy traffic areas. The European Maritime Safety Agency (EMSA) has reported 20,616 marine casualties and incidents worldwide from 2011 to 2017. Globally, the combination of collision (23.2%), contact (16.3%), and grounding/stranding (16.6%) shows that navigational casualties represent 53.1% of all casualties with ships. Furthermore, human error is found to be behind 75% of 15,000 marine liability insurance industry claims analyzed by Allianz Global Corporate & Specialty (AGCS). It is worth noting that an incident involving a fully loaded ultra-large container ship can easily result in a US$1bn–$2bn insurance claim, including damage to cargo, hull, salvage and wreck removal costs.

Currently, the average number of conflicts occurring at the Singapore Strait is about 2,000 per month. Among these conflicts, some have resulted in severe accidents that had a significant impact on the environment and resulted, tragically, in the loss of life. Three collisions within three months in 2014 spilled a total of 760 tons of oil into the sea, and more recently, further fatalities have been recorded after collisions. Therefore, in heavy-traffic regions such as the Singapore Strait, ensuring the safe passage of vessels can be challenging. Hence, it is crucial for the ship captains conducting maneuvers to understand its own future position with respect to target ships in a specific time span to more effectively solve close encounter situations in these regions.

THE VESSEL COLLISION AVOIDANCE SYSTEM (VCAS)
A PORTABLE COLLISION PREDICTION & PREVENTION SYSTEM

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VTS, NAVIGATION, MOORING AND BERTHING

PATTERN RECOGNITION AND MACHINE LEARNING
Leveraging on the rich information transmitted through the Automatic Identification System (AIS), movement patterns of vessels are analysed to construct predictive models. This is done in four levels:

1. Destination prediction: Based on the historical movement records of each vessel, pathways of the vessel in the sea is decomposed to identify the arrival, departure, stopping and turning points, and then vessel movement sequence is generated. This historical movement sequences are then used to train the machine learning algorithm to predict the next destinations of the vessel.
2. Speed/course prediction: Predicted destination is used subsequently with other temporal and spatial movement analysis results of the vessel to predict the course and speed of the vessel.
3. Pilot behavior modeling: Speed/course prediction is done assuming there is no interaction among the vessels. Further predictive models are required to model the ship captain behavior under close encounter situations. This includes predicting the possible reaction and maneuvers of the captain.
4. Vessel motion modeling: AIS data is used to train machine learning algorithms to simulate the vessel motion dynamics. The main objective of vessel motion modeling is to identify vessel movement characteristics such as instantaneous acceleration rate, tactical diameter, etc. and predict the position of the vessel in the near future given the target speed and course.

AGENT-BASED SIMULATION
Predictive models generate probabilistic measures for possible movement directions of the vessel. The agent based model is developed to simulate the resulting stochastic environment and calculate measures such as conflict or collision risk, movement distance and time. For this purpose, domains of each vessel are calculated and using the vessel motion simulator, movement of vessel for possible destinations is simulated and considering the probability of own vessel and target vessel domains violation, the collision risk is calculated. Using agent-based simulation makes it possible to incorporate external factors such as wind and ocean current disturbances into the model.

COLLISION AVOIDANCE
If the collision risk level returned by the agent-based simulation is beyond a predefined threshold, e.g. if there is 60% or more chance of collision, the collision avoidance module is activated. Vessel pilot is informed of the possibility of collision, with alternate route suggestions to prevent collision. This is done by finding a trajectory which optimizes safety out of the conflict situation, and minimize the deviation from the main course of the vessel. Fast simulation-optimization techniques are used for this purpose, to make the system useful for real-time applications.

The Centre of Excellence in Modeling and Simulation for Next Generation Ports (C4NGP) has been working closely with PSA Marine to use expert knowledge on vessel pilotage in developing the VCAS for pilot usage. Although several projects are currently looking into the issue of safe passage in heavy traffic regions, to the best of authors’ knowledge, VCAS is the only portable, easy-to-use product developed specifically for pilots, without requiring any hardware installations on-board the vessel. We believe that it can enhance the situational awareness of the pilots, by providing them accurate predictions of close future situations and alerts.

By using the popular smartphone operating systems (i.e. Android and iOS) as the development platform, C4NGP aims to make the VCAS available for small vessels (e.g. passenger ferries, fishing boats and pleasure crafts) as well as large cargo ships and tankers. Additionally, the proposed framework is location-independent and can be applied in other regions of the world with heavy maritime traffic.

Figure 1: Vessel Collision Avoidance System (VCAS) Framework

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ABOUT THE ORGANIZATION
Established in 2018, Centre of Excellence in Modeling and Simulation for Next Generation Ports (C4NGP) is an S$18 million Research Centre, funded by Singapore Maritime Institute and NUS, to help Singapore’s maritime and port industries develop innovative capabilities and enhance their global competitiveness. C4NGP aims to be a global leading Research Centre in modelling, simulation, and optimization of maritime systems, collaborating closely with companies in Singapore’s maritime and port sectors to improve their technical know-how, efficiency and productivity, contributing to Singapore’s economic development and society.

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