DYNAMIC 'STANDING ORDERS' FOR AUTONOMOUS NAVIGATION SYSTEM BY MEANS OF MACHINE LEARNING

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1 **Introduction**

2 Dynamic Standing Orders

3 Conclusion and Outlook

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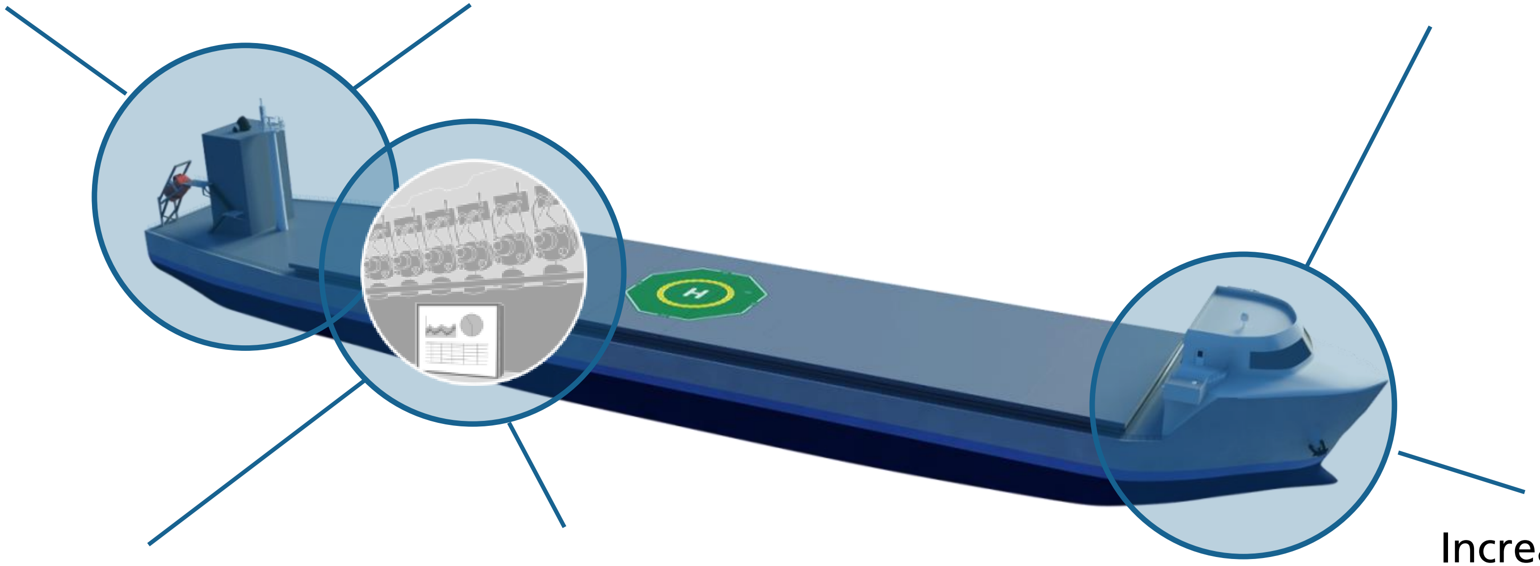
Development of Maritime Autonomous Surface Ships

1. Compliance with emission regulations
2. Reduction of fuel consumption
5. Continued increase in the levels of automation and digitisation



3. Increase in storage and computing capacity
4. Increase of data availability
6. Increase of integrated maritime smart embedded systems

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Development of Maritime Autonomous Surface Ships

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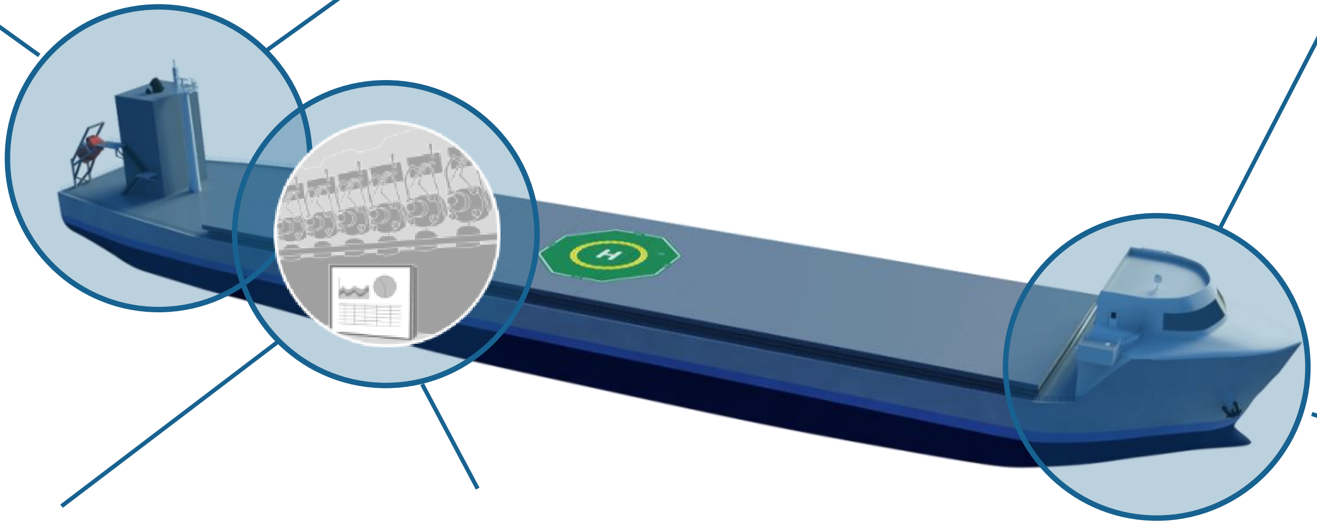

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MASS Business

New Job Profile ‚Data Scientist'

Task: Analysis of data using Big Data Analytics and generation of information that supports the employees responsible for e.g. management of transport and transshipment resources.

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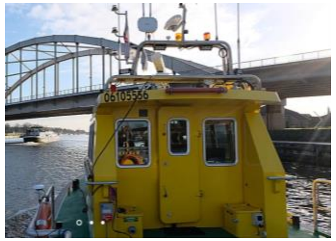
MASS Technology Development

MASS Starting in Protected Waters

Svitzer Hermod

milliAmpere

Vehicle ferry Falco



Autonomous inland waterway vessels

ENOVA

2015 | 2017 | 2018 | 2019

MUNIN Concept
ReVolt Ship design

YARA Birkeland

RT Borkum Demonstration

ABB Demo with passenger ferry

National Demonstrator LoveRiver

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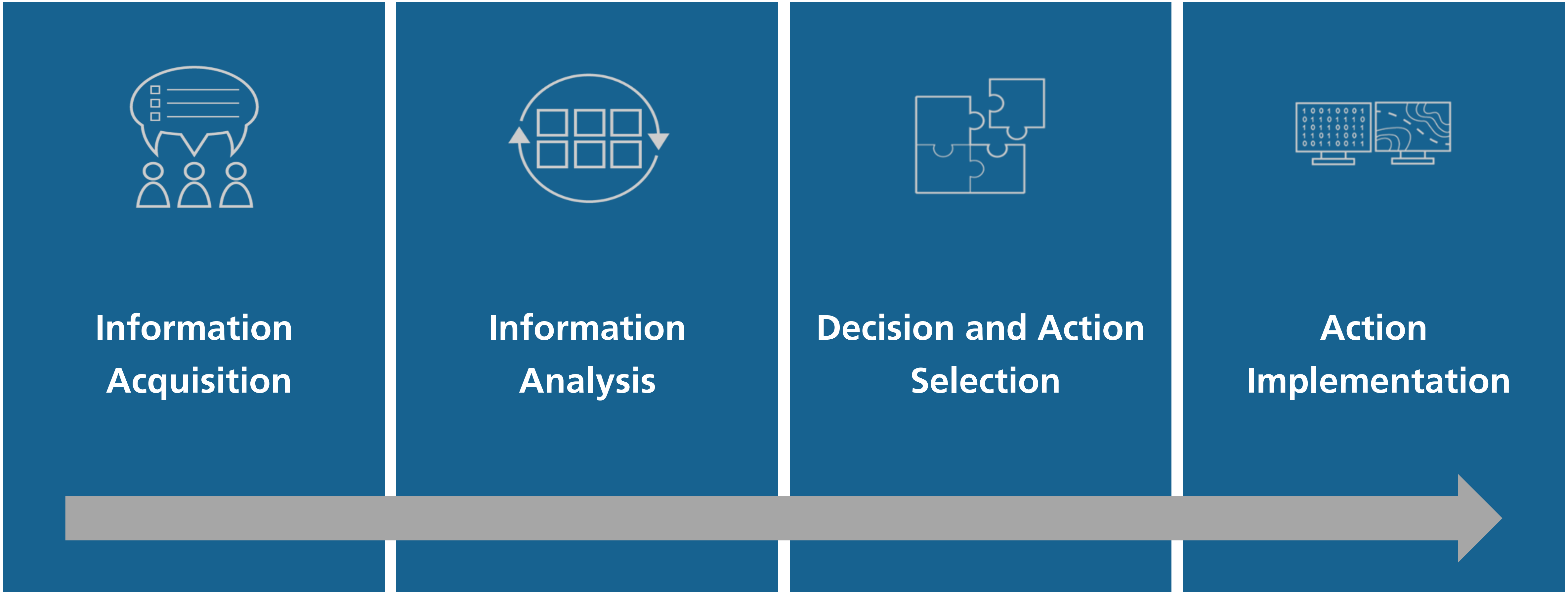
Autonomous Navigation

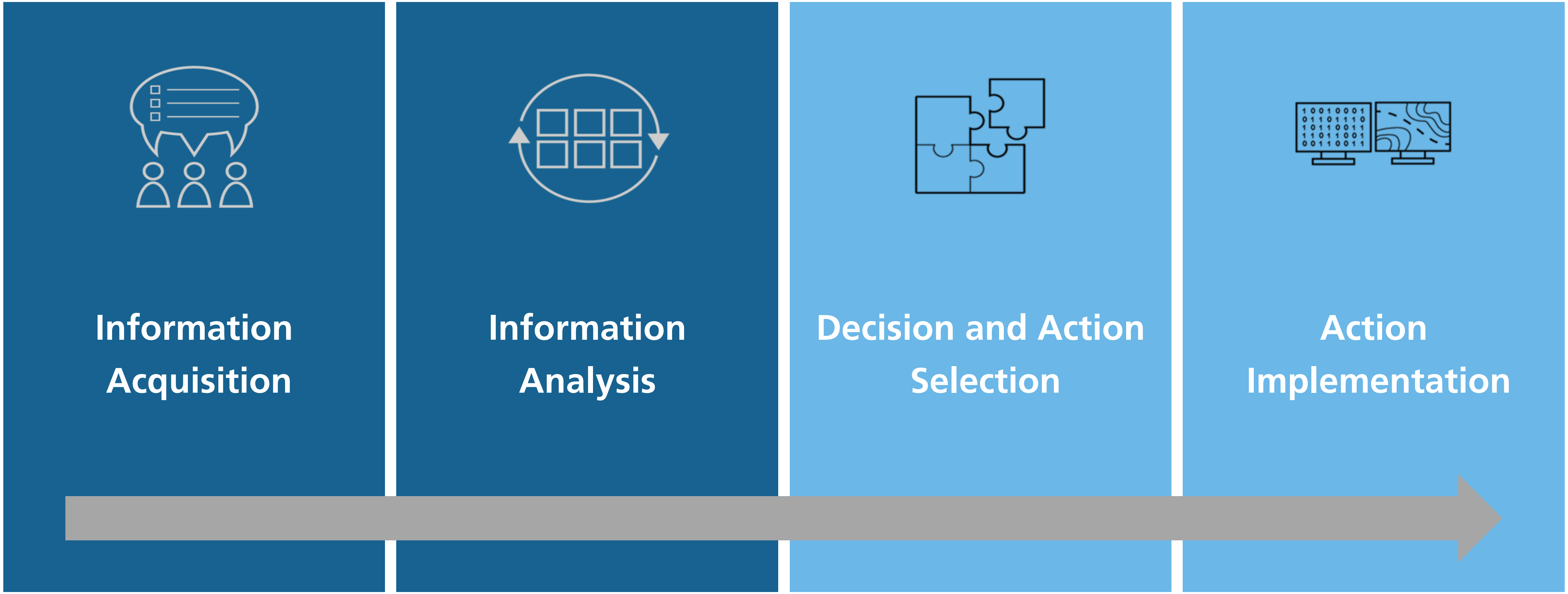
Four Process Stages of Control



Parasuraman R, Sheridan, T B and Wickens C D 2000 A model for types and levels of human interaction with automation IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans 30 286

Autonomous Navigation

Four Process Stages of Control



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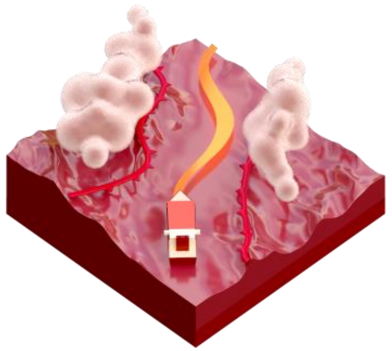
Autonomous Navigation



PARAMETRISATION OF SYSTEMS

- Human intervention
- Perception of environmental influences

REQUIREMENTS

- Intelligent algorithms for determining relevant parameters have not been developed
- A system which provides the optimal operating parameters taking into account
  - ship-specific characteristics and
  - influencing factors for existing autopilots

is not available on the market

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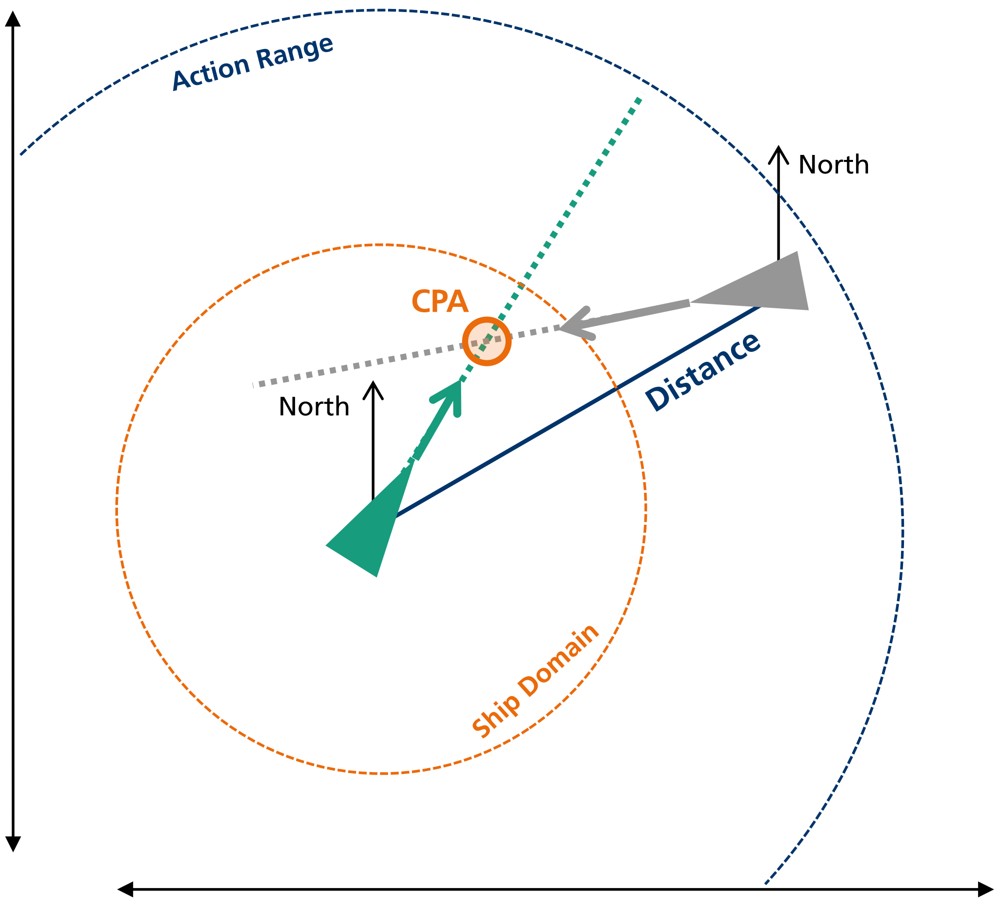
Machine Learning in Collision Avoidance

Dynamic Standing Orders for ANS



STANDING ORDERS

- Action Range: 6 NM
- Ship Domain: 1 NM

CRITICAL ENCOUNTER

- Distance < Action Range
- DCPA < Ship Domain

DATA SOURCE

- AIS

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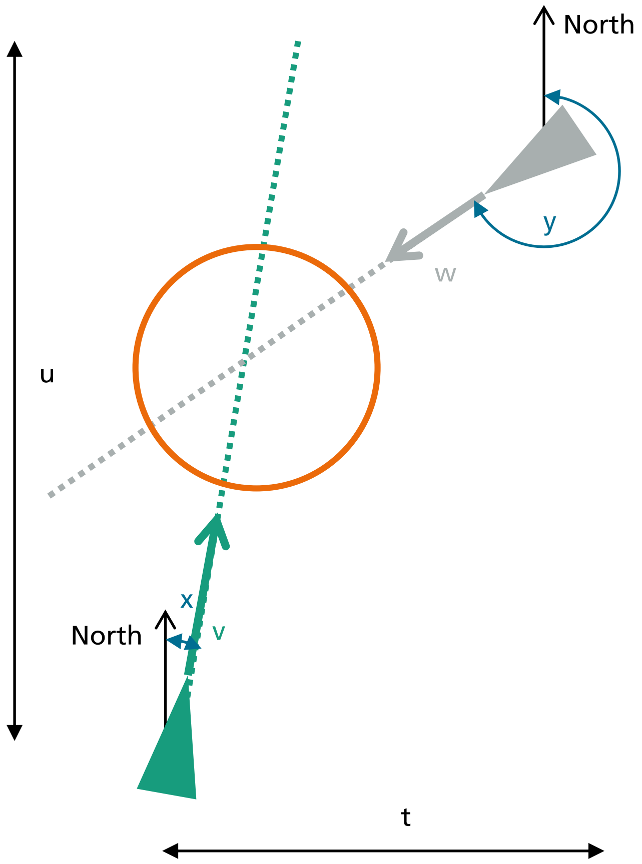
Dynamic Standing Orders

Standard Traffic Situation



PARAMETER

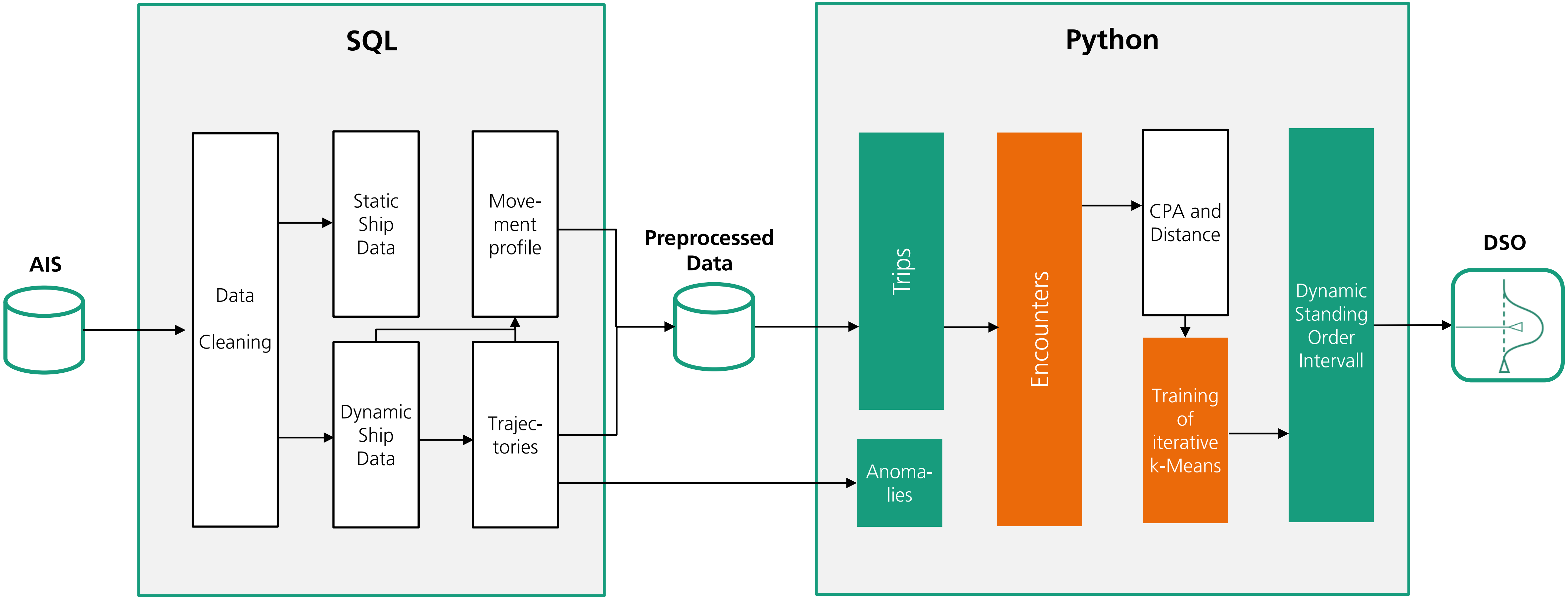
- x := COG of Ownship
- y := COG of Trafficship
- v := SOG of Ownship
- w := SOG of Trafficship
- t := Longitudinal distance
- u := Lateral distance

CPA

$$CPA^2 = \frac{(u \cdot w \cdot \sin y - t \cdot w \cdot \cos y - u \cdot v \cdot \sin x + t \cdot v \cdot \cos x)^2}{v^2 + w^2 - 2 \cdot v \cdot w \cdot (\sin x \cdot \sin y + \cos x \cdot \cos y)}$$

$$CPA = \sqrt{\frac{(u \cdot w \cdot \sin y - t \cdot w \cdot \cos y - u \cdot v \cdot \sin x + t \cdot v \cdot \cos x)^2}{v^2 + w^2 - 2 \cdot v \cdot w \cdot (\sin x \cdot \sin y + \cos x \cdot \cos y)}}$$

Dynamic Standing Orders
Framework



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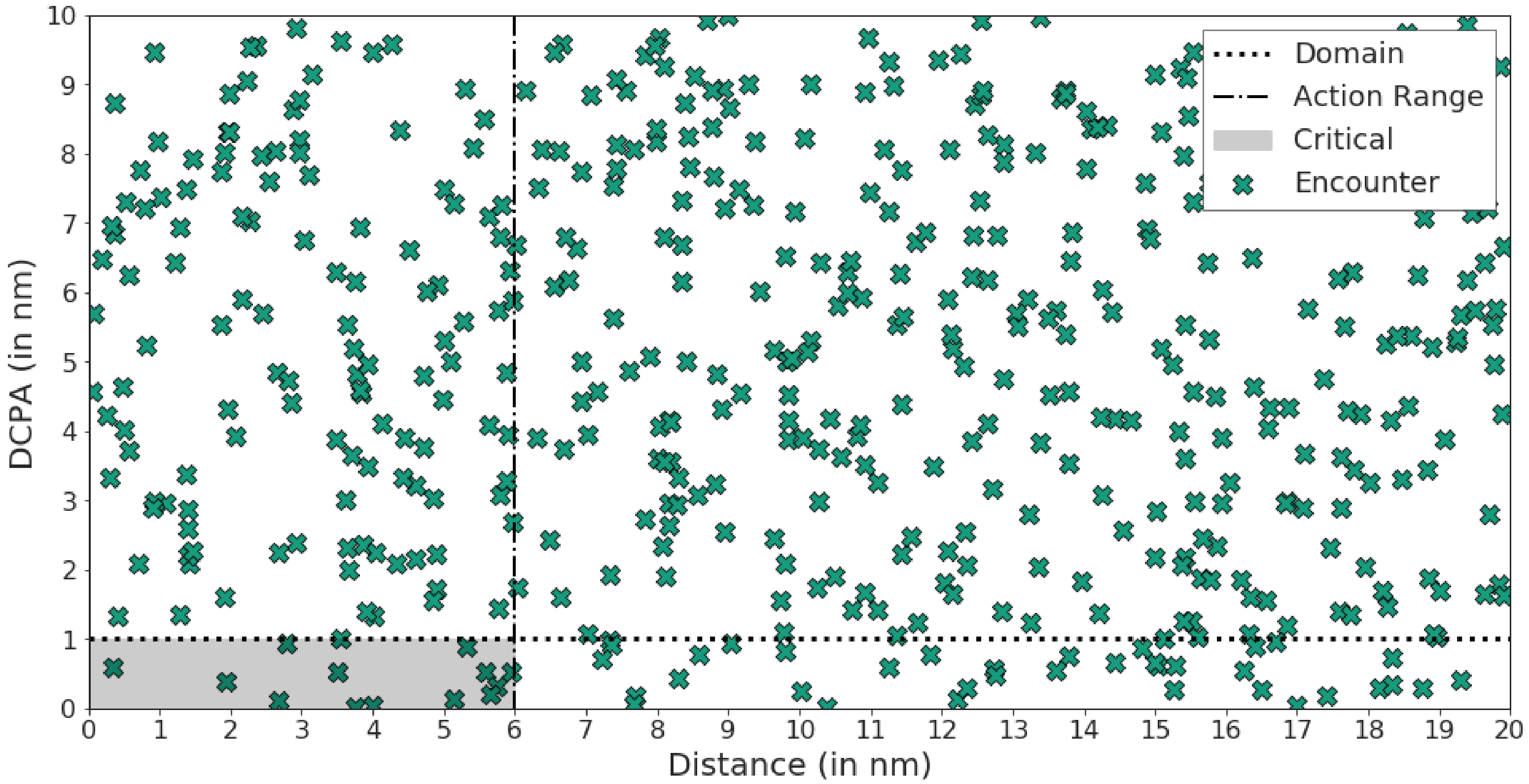
Dynamic Standing Orders

Iterative k-Means



Form $n \in \mathbb{N}$ Cluster

Extract most dangerous quarter

Determine Standing Orders

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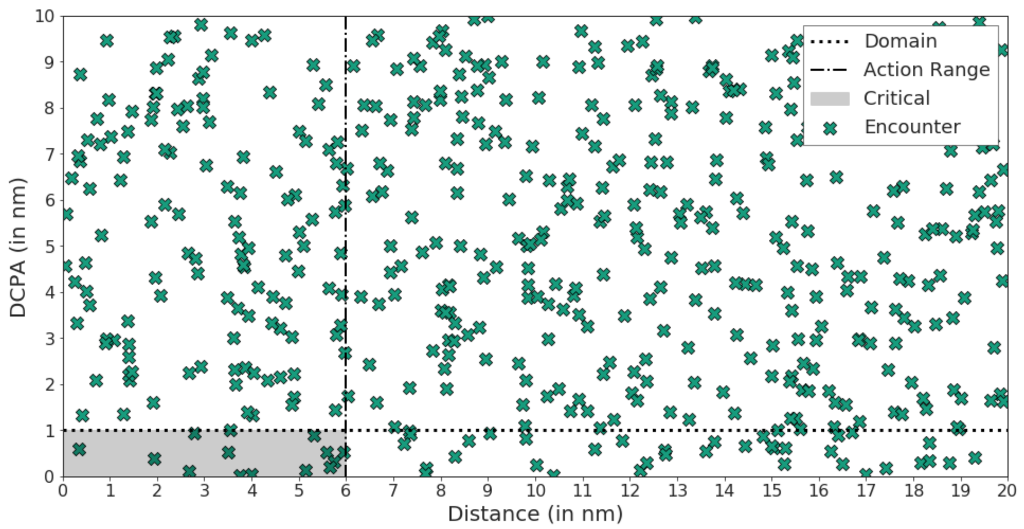
Dynamic Standing Orders

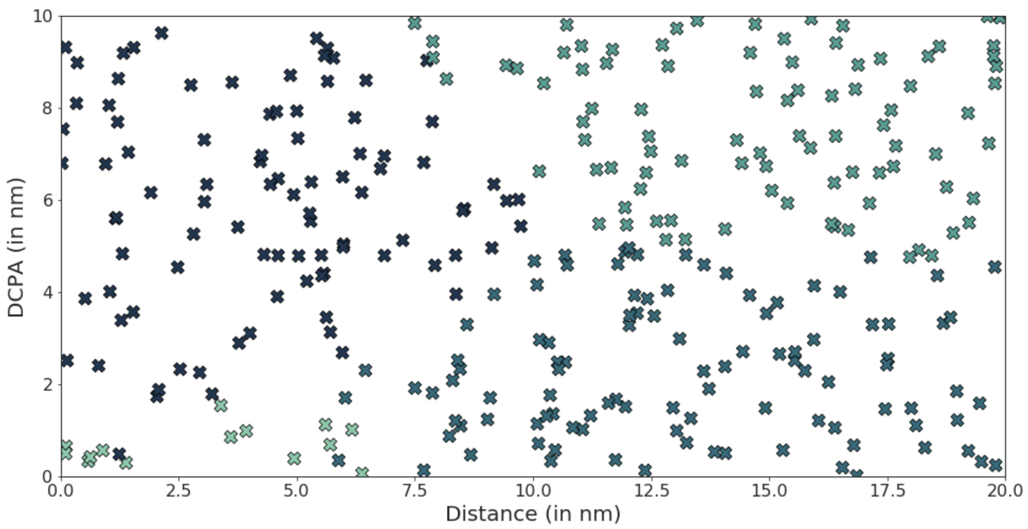
Results

Iteration 0



Scatterplot of DCPA and distances and visualisation of ship domains and action ranges for defining critical areas.

Iteration 1



Scatterplot of DCPA and distance for a subsample after the first clustering.

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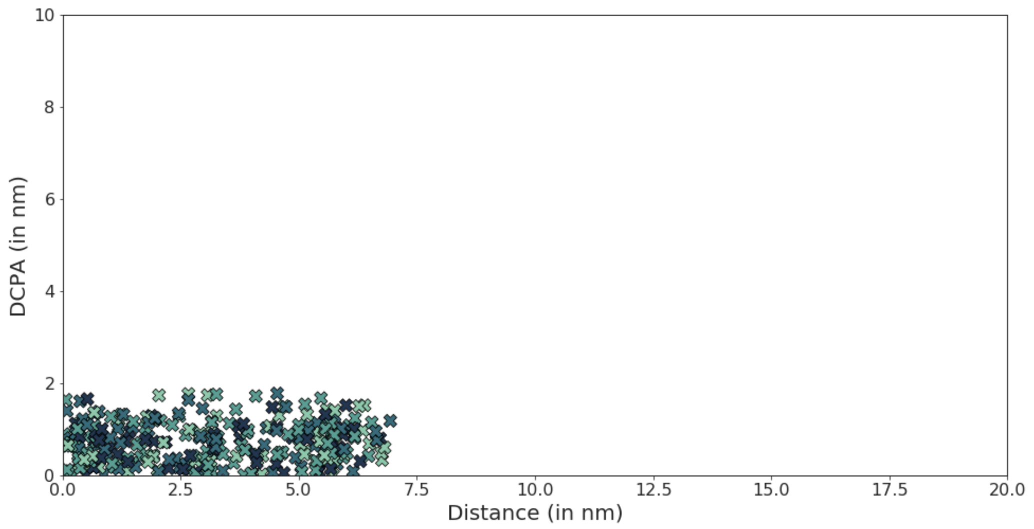
Dynamic Standing Orders

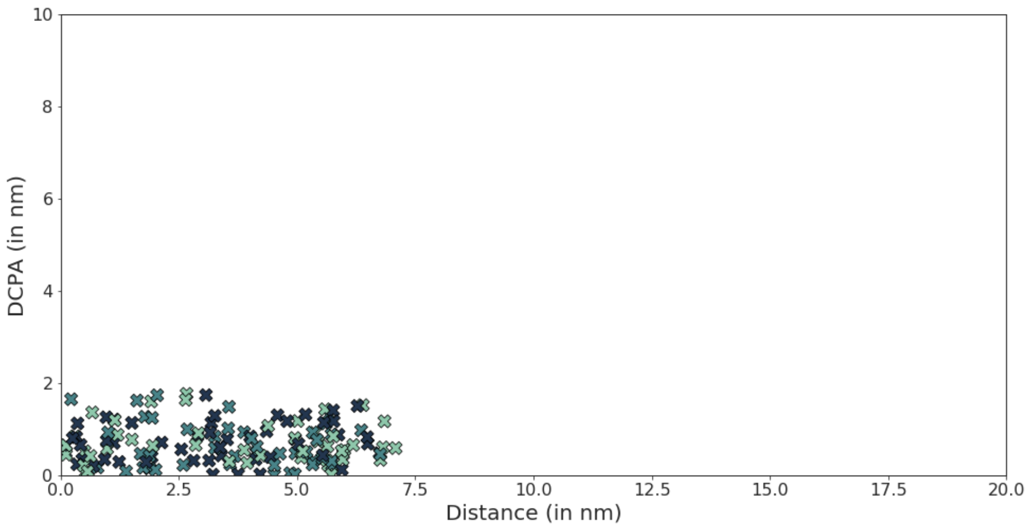
Results

Iteration 2



Scatterplot of DCPA and distance for a subsample after the second clustering.

Iteration 3



Scatterplot of DCPA and distance for a subsample after the third clustering.

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Dynamic Standing Orders

Results

- After the third iteration, the amount of data is limited to critical situations whose action ranges and ship domains are specified by the following intervals

- Action Range:

$$A = [1.32\ NM, 5.25\ NM]$$

- Ship Domain:

$$S = [0.31\ NM, 1.15\ NM]$$

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Conclusion and Outlook

From the first internal tests it can be concluded that standing orders can be dynamically adapted before the start of a working shift for a predefined sea area

- The inclusion of weather or sea chart data could further increase the accuracy of the algorithm and increase the safety of maritime traffic on the way to more automated navigation
- Certification of machine learning algorithms to be discussed
- Real-time capability of the algorithms must be further investigated

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