Trustworthy Autonomous Collision Avoidance Decision-Making System For Maritime Autonomous Surface Ships

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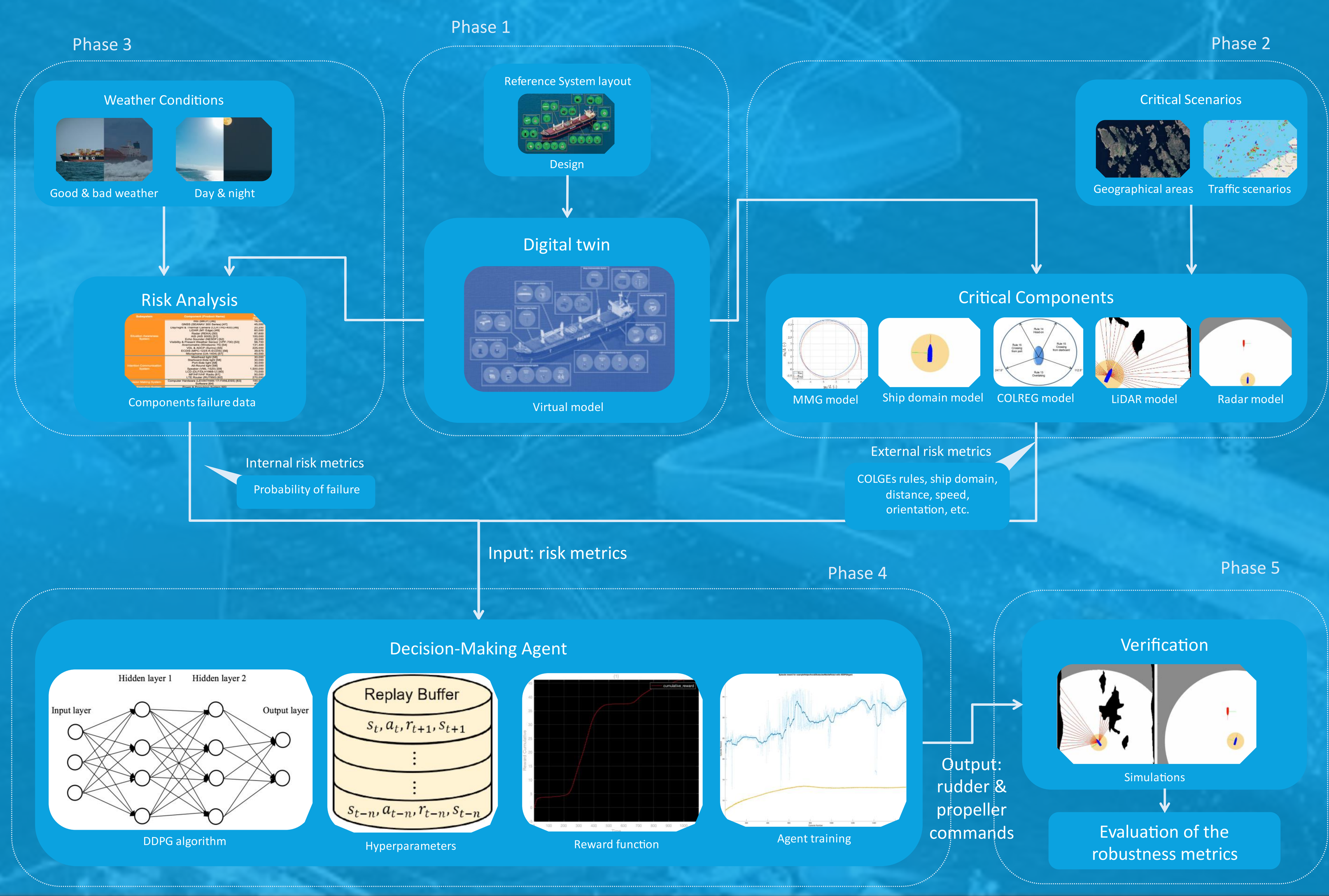
Maritime Autonomous Surface Ship | Collision Avoidance | Decision-Making | Artificial Intelligence | Trustworthiness | Deep Deterministic Policy Gradient | Digital twin | Safety | Risk Metrics

Background & Motivation

- Shipping industry is paving the way towards the new “Shipping 4.0” era, through the implementation of Maritime Autonomous Surrface Ships (MASS).
- New emerging challenges include: autonomous technologies safety assurance, especially when performing safety-critical operations, such as the autonomous collision avoidance.
- Currently, collision is the leading accident category of navigational nature that constitute 13% of all conventional accidents in Europe with human error accounting up to 95%.
- The types and extent of consequences due to the implementation of MASS are currently unknown.

Methodology



Aim

To enhance the trustworthiness of the autonomous collision avoidance decision-making (ACA-DM) for MASS considering both critical external and internal risk metrics in the decision-making process.

Objectives

(a) Develop a digital twin of a MASS system;
(b) Identify possible collision scenarios of high-risk;
(c) Investigate critical external and internal risk metrics;
(d) Develop an artificial intelligence-based decision-making agent;
(e) Develop and assess trustworthiness metrics.

Results & Key Findings

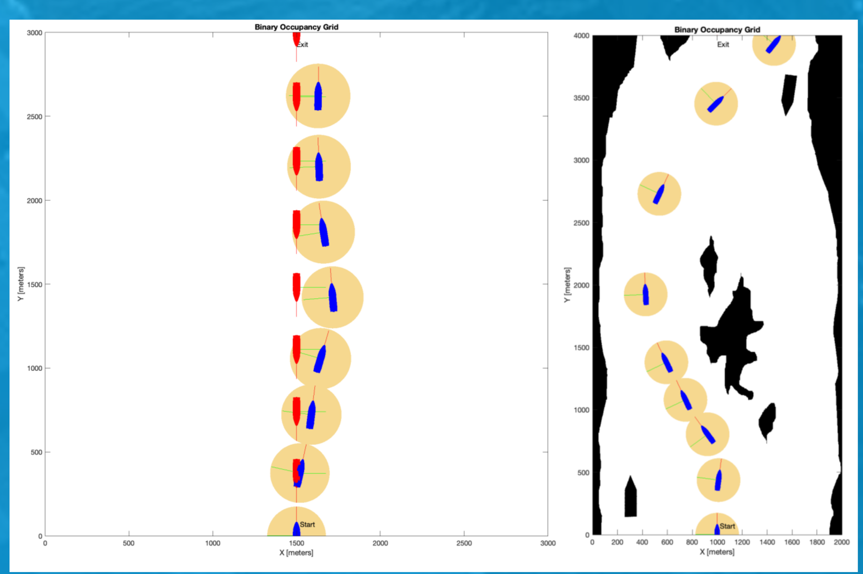


Figure 1

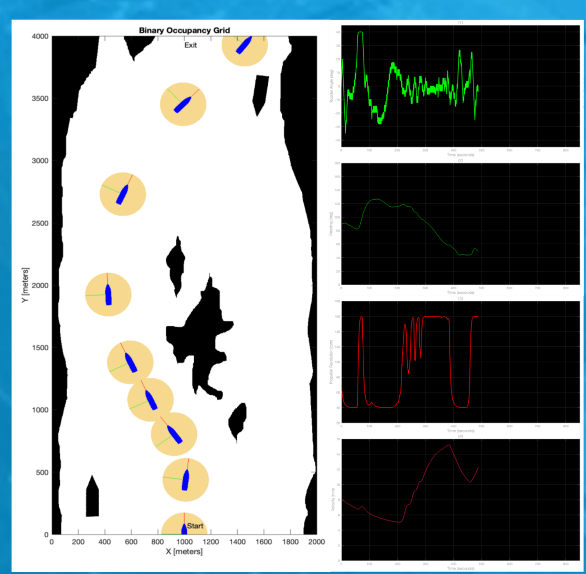


Figure 3

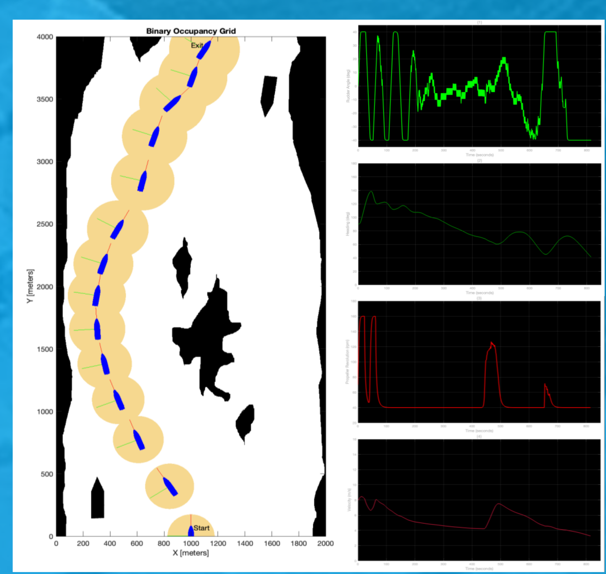


Figure 4

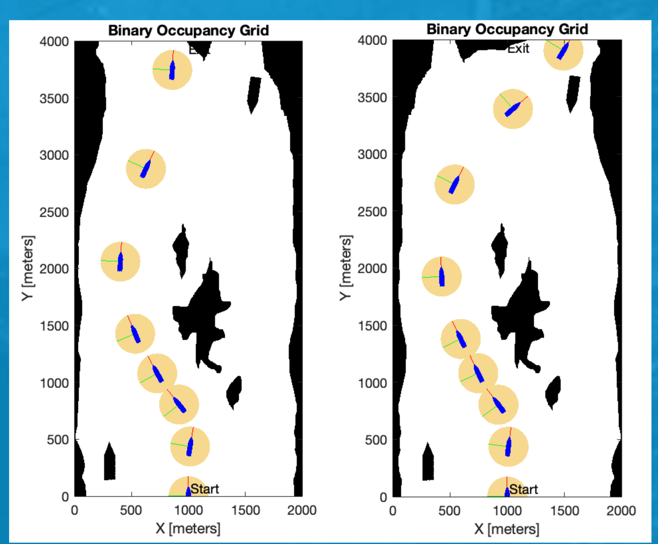


Figure 2

Main attributes of trustworthiness	Internal risk metrics not considered	Internal risk metrics considered
Reliability	● (red)	● (green)
Availability	● (red)	● (red)
Safety	● (orange)	● (green)
Confidentiality	● (red)	● (red)
Integrity	● (green)	● (green)
Robustness	● (red)	● (orange)
Maintainability	● (red)	● (red)
Adaptability	● (green)	● (green)
Usability	● (green)	● (green)
Timeliness	● (green)	● (green)
Leanness	● (orange)	● (green)
Reactiveness	● (red)	● (red)
Proactiveness	● (red)	● (orange)

Figure 5

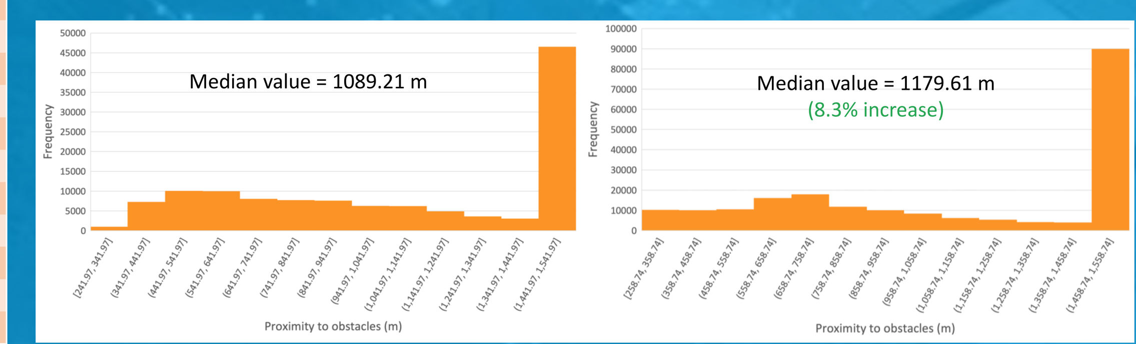


Figure 6

The developed ACA-DMS:

1. Capable of making collision avoidance decisions in both static and dynamic environments (Figure 1).
2. Exhibits generalisation capabilities by conducting collision avoidance manoeuvres even in new environments prior unknown (Figure 2).
3. Exhibits different decision-making when only internal risk metrics are considered (Figure 3) compared to when both external and internal risk metrics are considered (Figure 4), leading to the enhancement of trustworthiness both qualitatively (Figure 5) and quantitatively (Figure 6).

Research Outlook

Future research include: (a) identification of more critical and unpredictable scenarios, such as unknown unknowns; (b) consideration of more critical internal risk metrics, such as uncertainty of input data; (c) investigation of higher failure rates of critical components considering mean time between failure distribution; (d) development of a wholistic and quantitative trustworthiness metric; and (e) development of high-fidelity digital twin.

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