Current and Emergent Trends in Maritime AI

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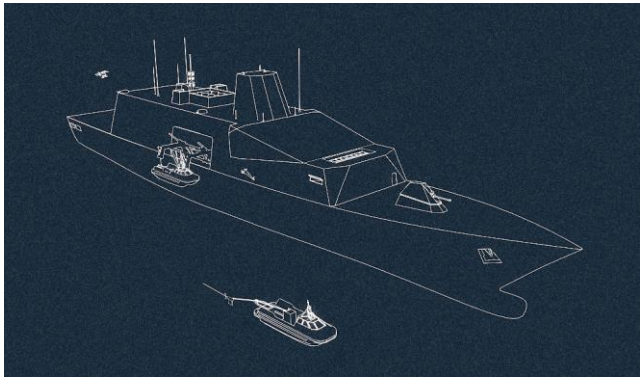
Introduction

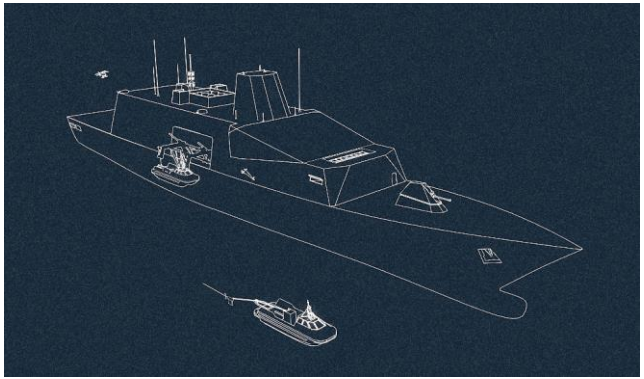
- Maritime industry transports 80–90% of global goods, yet lags in technological adoption compared to land and air domains.
- AI has potential to widely benefit navigation, autonomy, safety, and operational efficiency.
- AI is being investigated across surface, subsurface, and aerial platforms, with growing interest in multi-domain integration.



(Durlik et al., 2024. & Nakashima et al., 2023.)

Current and Emerging Trends

- We will look at different areas within maritime that have been explored within AI and Autonomy literature.
  - Situational Awareness
  - Navigation & Control
  - Naval Warfare
  - Miscellaneous



A) Situational Awareness

- Human error accounts for the majority of maritime incidents.
- AI leverages multiple sensors: cameras, radar, LiDAR, Automated identification systems, and audio that have already been utilised on vessels.
- Machine learning enables object detection, vessel classification, anomaly detection, and predictive analytics.
- Data fusion from multiple sensors increases robustness and reliability in complex environments.
- Internal sensors also support predictive maintenance and onboard hazard detection (e.g., fire risk).

(Allianz, 2020)

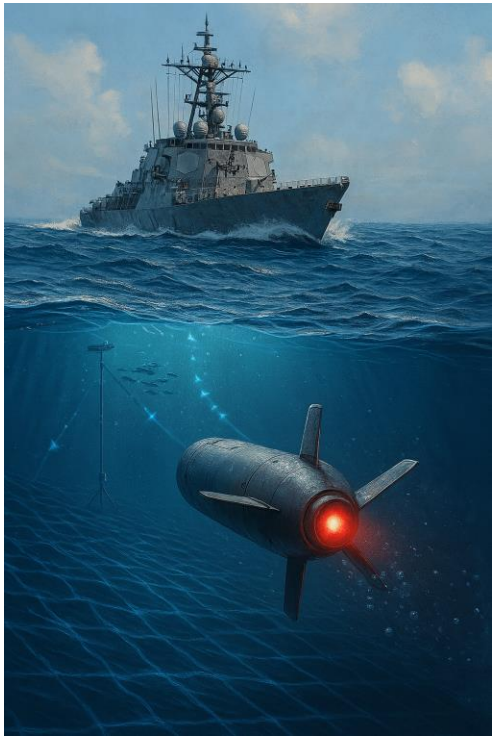
B) Navigation & Control

- Autonomous and semi-autonomous vessels rely on AI for safe and efficient route planning.
- Traditional algorithms (A*, Dijkstra) are used for pathfinding; behaviour trees and finite state machines for control logic.
- Reinforcement learning enables adaptive behaviour, learning from environmental interactions.
- AI-driven navigation improves fuel efficiency and reduces environmental impact.
- Deep learning models are being trained in simulators to handle real-world ocean dynamics.
- However, AI within navigation doesn’t always mean autonomy, it can also aid in conventional vessel decision support.

(Saga et al., 2024)

C) Naval Warfare

- The UK MoD’s Intelligent Ship initiative showcases diverse AI applications in defence.
- AI supports mission planning, threat evaluation, damage control, and tactical decision-making.
- Systems like GALILEO, TACNAV, and RED/BLUE MIRROR demonstrate AI’s role in combat readiness.
- Reinforcement learning is used for evasive manoeuvres and weapon-target assignment.
- Cybersecurity is enhanced through AI-driven threat detection and adaptive response agents.



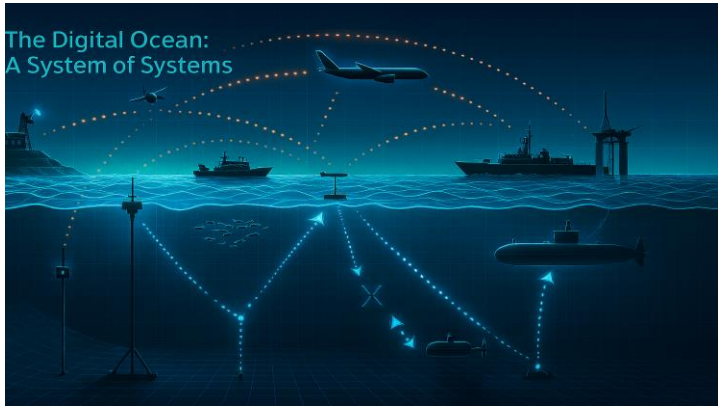
(Cooke & Tate, 2023. & Wilson, A., Holmes, W., Menzies, R., & Whitehead, K. S. 2024)

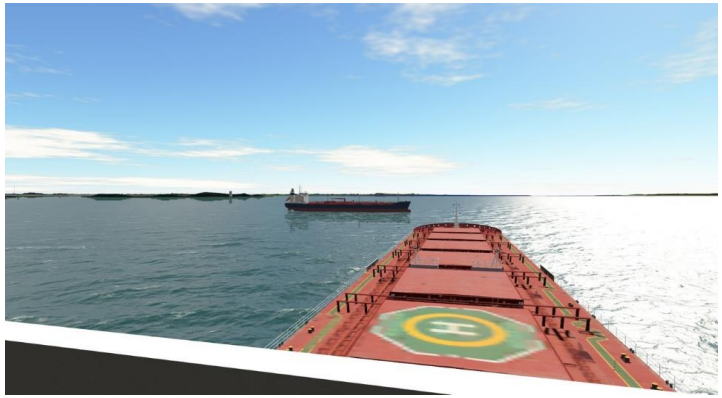
D) Other Areas

- AI is being applied to:
  - Mission planning
  - Multi vehicle coordination
  - Localization and mapping
  - Operational or mission data analysis
  - Predictive maintenance
  - Route, power and propulsion optimisation
  - Optimised design & manufacture
  - Launch and recovery operation
  - Report generation (back-office tasks)

Pivotal Enablers to AI

- Simulators provide safe environments for training, testing, and data generation.
- High-fidelity simulators like BMT’s REMBRANDT enable realistic modelling of vessel behaviour.
- Simulations are essential for reinforcement learning, which requires the freedom of repeat interactions.
- Digital oceans (real-time digital twins) enhance situational awareness and support decision-making.
- These systems help detect anomalies, predict weather/ocean patterns, and counter electronic warfare.



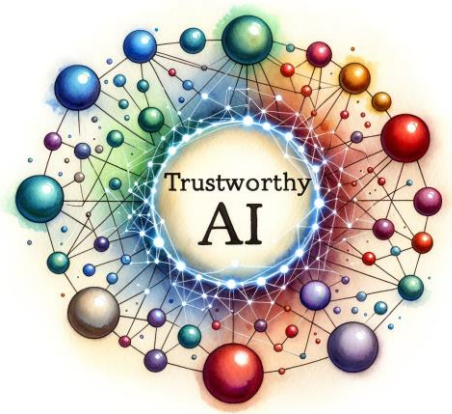


Applying AI within the maritime space

- Despite its potential, AI adoption in maritime is hindered by trust and governance issues.
- Trustworthy AI is essential for safety-critical and mission-critical applications.
- Legal, ethical, and operational concerns must be addressed to enable widespread deployment.
- Each AI system must be evaluated individually, considering its unique risks and context.
- AI certification is in its infancy, especially within the maritime space.

B) Assurance

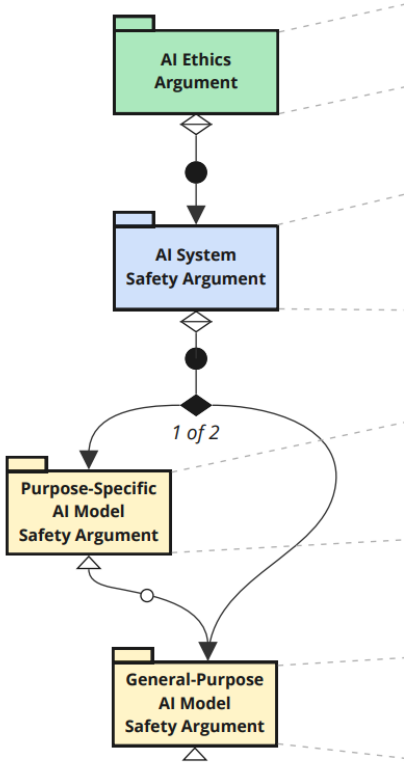
- Trustworthy AI encompasses:
  - Safe AI: Minimising risk of harm.
  - Assured AI: Verified through formal methods.
  - Explainable AI: Transparent and understandable decisions.
  - Ethical AI: Fair, accountable, and aligned with societal values



(European Commission 2019)

B) Assurance

- Frameworks:
  - BIG Safety Argument (University of York): Practical, design-integrated assurance.
  - Safe AI Process (Alan Turing Institute): Theoretical, checklist-driven guidance.
  - The EU AI Act
  - UK GOV. AI Management Essentials
- Over 900 tools catalogued by OECD and 400+ standards by UK AI Standards Hub.
- ISO standards provide foundational guidance for AI risk management and safety.
- MoD JSP 936 Dependable AI Lifecycle – JSP 936 Part 2



(Habli et al., 2025)

Conclusions

- AI has transformative potential in maritime, but adoption is slow due to trust and assurance gaps.
- Addressing trustworthy AI holistically across ethics, safety, governance, and explainability is key.
- Future progress depends on case-by-case evaluation and integration of trustworthy AI principles.
- These principles and the laws around them are currently being crafted, but the Turing and York approaches to safe AI development appear to be playing a fundamental role.

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