Emerging Ideas on Data-Driven Ship Operation and Green Transition

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Key Takeaways

1. The most urgent applications of digital technologies into vessel operations are those that accelerate the green transition by reducing energy consumption and GHG emissions.

2. A focused research agenda is needed to ensure such applications are not only demonstrated in individual cases but scaled and quantified in the global fleet.

Scope

- Commercial transport vessels.
  - Vessel’s main mission is transport itself.
  - Biggest OPEX is fuel / bunkering.
  - Out of scope: energy rigs (oil, gas, wind), offshore support vessels, military equipment.

- Operation phase.
  - Longest life cycle phase.
  - Incurs the biggest quantity of emissions during the life-cycle.
  - Out of scope: design, production, scraping.

Outline

Part 1

- Background
- Applications
  - Autonomy
  - Digital Twins
  - Remote Supervision
- Takeaway 1

Part 2

- Status of Technology Adoption
- Takeaway 2
- Near-Term Research Agenda
- Mid-Term Research Agenda
- Conclusions

Background

- General interest in “data” motivated by success of online advertising companies.

- Development in technologies for the Internet of Things:
  - Ongoing trend on miniaturisation and performance increase of computer components. (Leiserson et al. 2020, link)
  - Cloud computing and networking.
  - Sensing infrastructure and connectivity.

Applications

- Autonomy

- Digital twins

- Data-driven monitoring and decision-making

Autonomy: Concept and Promises

- Ability to maintain transport capacity with reduced human workload.

- Replacement of road transport for sea transport with higher capacity and lower emissions (European Commission 2011, link).

Yara Birkeland.

Autonomy: Technologies and Challenges

- Examples of enabling technologies (Xu et al. 2023, link):
  - Path planning and collision avoidance.
  - Automatic manoeuvring and control.

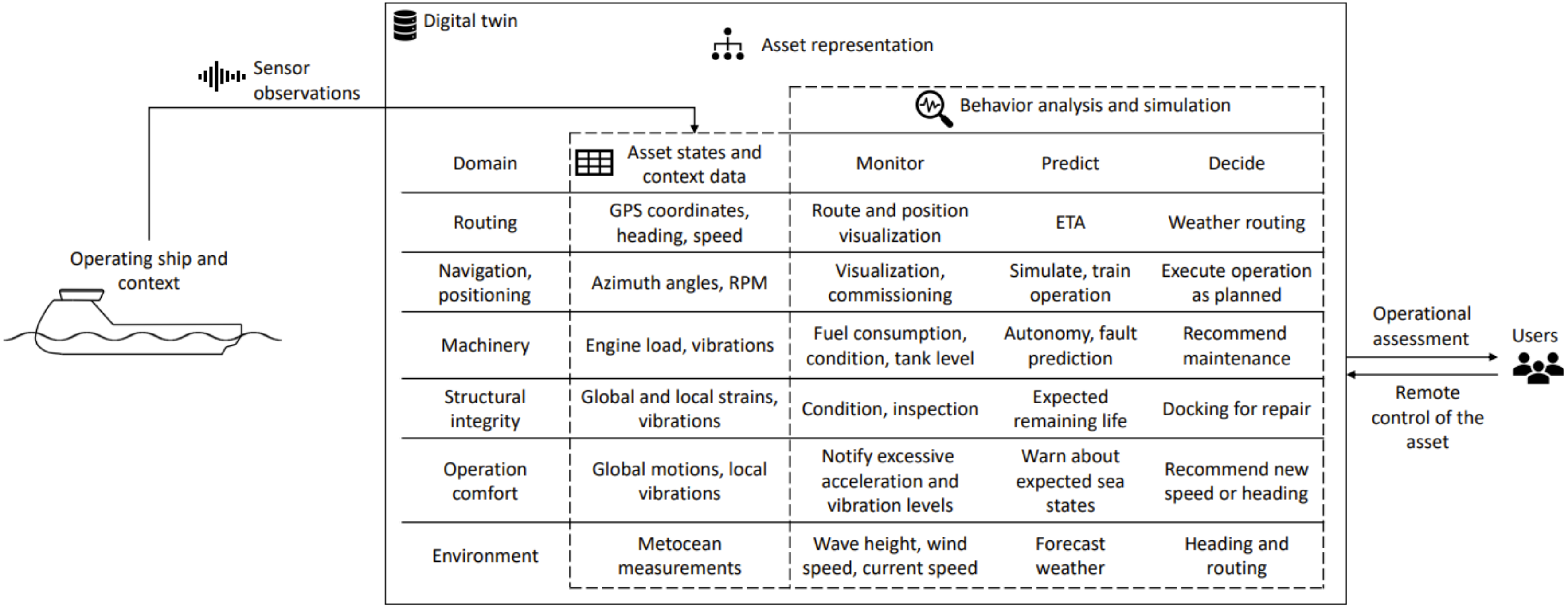
- Limitations and challenges:
  - Affordability.
  - Lag in regulation and infrastructure.
  - Limited scope and range of automation.

Digital Twins: Concept

“A digital twin is an integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin.”

Shafto et al. 2010, link

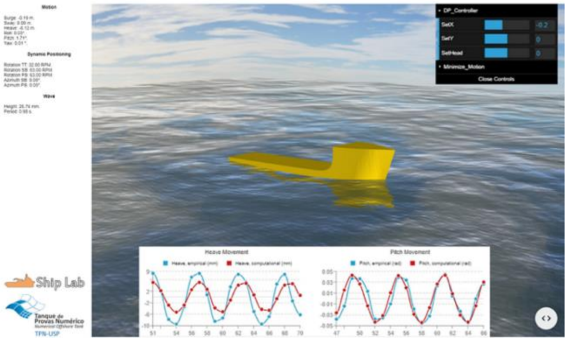
Digital Twin: Promises

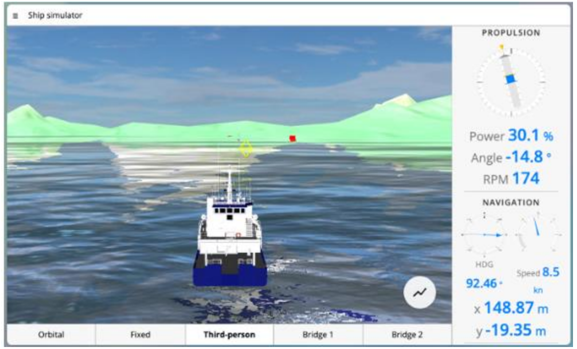


Fonseca et al. 2020, link

Monitoring and Decision-Making: Examples

- Wave basin controller (Fonseca et al. 2020, link).
- Traffic-aware navigation simulator (Fonseca et al. 2023, link).
- Fluid structure interaction (Bekker et al. 2021, link).





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Takeaway 1: Urgency of Green Transition

- Urgency of vessel decarbonisation:
  - Climate concerns. Maritime transport accounts for around 3-4% of GHG emissions in Europe (European Commission, link).
  - Prices of renewable fuels.
  - Increasing regulatory penalties against GHG emissions.

- Case for prioritising autonomy:
  - Could enable new markets by replacing trucks and railways in inland transport, if technology becomes sufficiently affordable.
  - Unlikely to create significantly change maritime transport soon.
  - Not enforced or incentivised by regulation.

Takeaway 1: Urgency of Green Transition

	Outcomes for Successful Stakeholders	Consequences for Laggard Stakeholders	Environmental Impacts Mitigated
Autonomy	Ability to tap into new inland and short sea supply chains (if competitive price is reached long-term).	Expansion to short and inland routes remain unexplored.	Might accelerate substitution of road transport with a greener mode.
Energy Transition / Emissions Performance	Mitigate expected increase in costs of fuel and regulatory compliance.	Regulatory compliance costs, e.g., penalties and carbon allowances, would intensify.	Abates share of emissions incurred by maritime transport.

Green Transition: Topics and Examples

(Poulsen et al., 2015, link)

- Voyage execution:
  - Weather routing or optimisation.
  - Speed adjustment and just in time arrival.
  - Trim optimisation.
- Onboard power demand:
  - Load balancing.
  - Engine and machinery health.
- Performance monitoring:
  - Hull and propeller condition.
- Retrofits and energy saving devices:
  - Quantification of expected savings.
  - Validation of attained results.

- Examples:
  - Coraddu et al. 2019: Data-driven ship digital twin for estimating the speed loss caused by the marine fouling – ScienceDirect.
  - Wei et al. 2023: A digital twin framework for real-time ship routing considering decarbonization regulatory compliance – ScienceDirect.

Adoption Status and Obstacles to Scaling

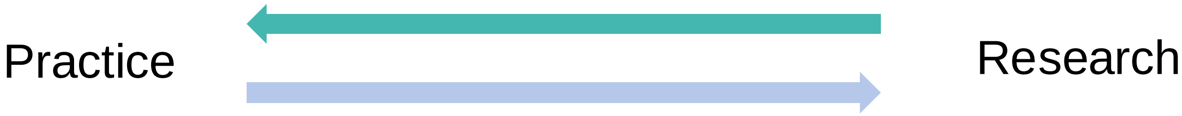
If application of digitalisation to vessel energy performance can enable savings today, why is it not widespread already?

- Software providers:
  - Lack of pre-existing sensor / IoT infrastructure.
  - When infrastructure is available, it is usually inconsistent.
- Adopters:
  - Unclarity on commercial potential, e.g., return over investment.
  - Split commercial incentives between, e.g., owners, charterers, and third-party operators (Poulsen et al., 2015, link).

Takeaway 2: Research Should Consider Scaling

- Increasing regulatory pressure is likely to gradually make energy performance management inescapable.
- Research that addresses or bypasses existing infrastructure limitations would accelerate that uptake.
- Research should reduce the gap between state of the art and practice (models, case studies, etc) in both directions.

Near-Term: How can the environmental impact of the existing fleet be mitigated leveraging existing tech setups?



Mid-Term: How to ensure the most effective methods to mitigate impact of operations is adopted across the global fleet?

Near-Term Research for Adoption and Scaling

- Demonstrate digital applications for emissions reduction in low tech setups.

- Quantify emissions reduction possible in different scopes, e.g., regional, global (e.g., Mason et al. 2023, link).

Mid-Term Research for Adoption and Scaling

- Make research truly reproducible.
  - Share datasets registering case study setup (environmental condition and operational input) and supporting results.
  - Specify or document sensor setups.

- Measure commercial performance in case studies (e.g., Talluri et al. 2016, link).
  - Quantify or translate savings to energy, fuel, or expenditure.
  - Document such concerns empirically through open data.
  - Ideally consider robustness in varying operational contexts.

Conclusions

- Prioritisation of research topics should consider expected results under different time frames.

- There is room to incorporate digitalization aspects that have been neglected into the research: scaling and adoption.

- Incorporation of such aspects will maximize effect of these solutions in challenges faced by society.

Discussion

Questions?

Additional examples.