

Enhancing Safety Assurance for ASVs by Model-Based Test Generation

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Motivation

Autonomous surface vehicles (ASVs) are increasingly used in oceanography and cargo transport. In shared waters, safe navigation is a key requirement. To prevent collisions, ASVs must comply with the International Regulations for Preventing Collisions at Sea (COLREGS), a set of rules defined by the International Maritime Organization. COLREGS are written for human operators, making them difficult to formalize for autonomous systems. Ensuring compliance is challenging in complex or rare multi-vessel scenarios, which are often missed in stochastic simulations.

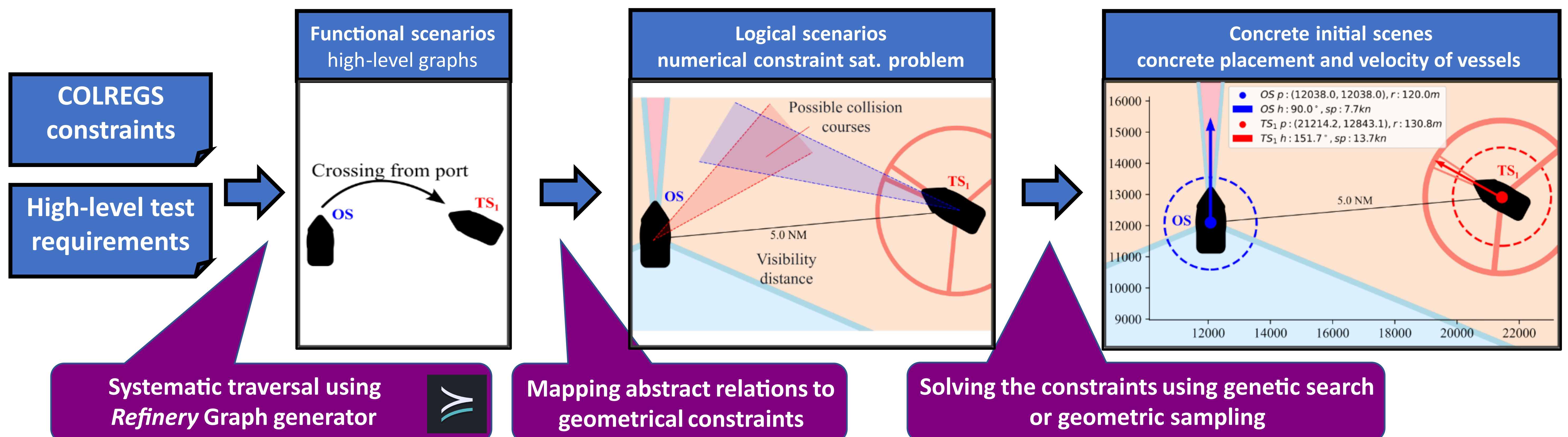
Objectives

1. Define a specification language^[2] for system-level ASV test scenarios.
2. Automatically generate diverse multi-vessel encounter scenarios.
3. Run test scenarios on real control software using naval simulators.
4. Enhance robustness via environment variation, behavior coverage analysis, and feedback-driven test generation.

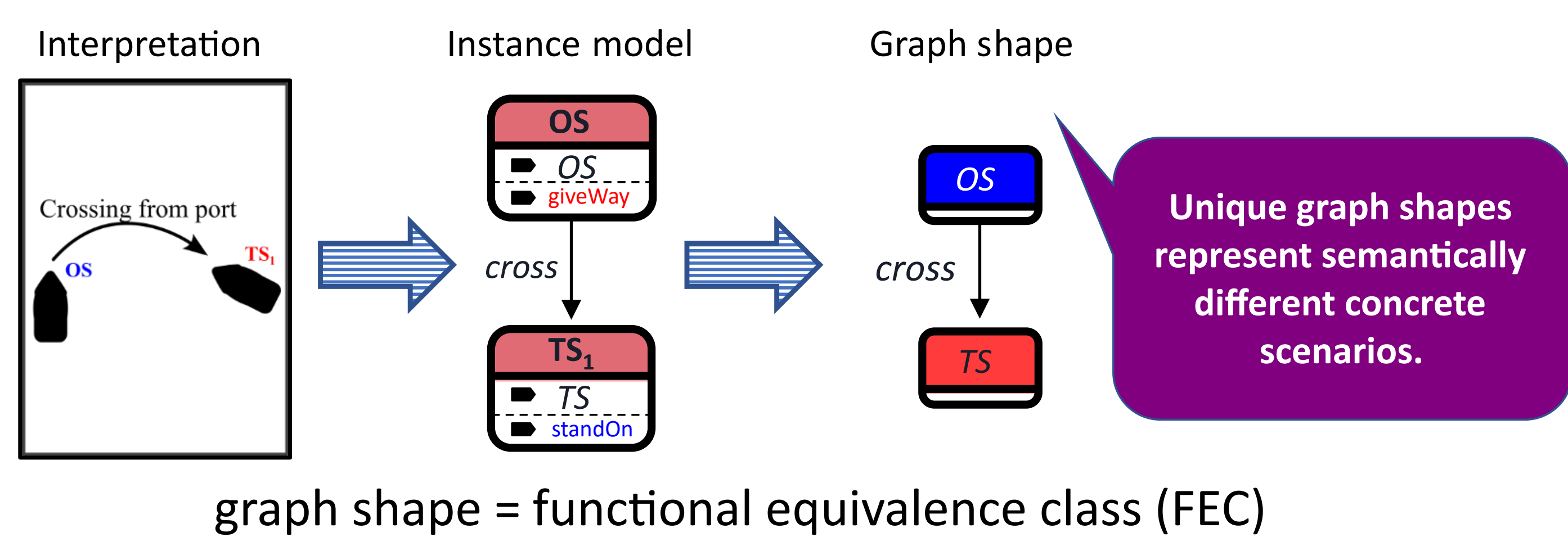
Added value

- Enhance ASV system-level safety assurance using a multi-level, model-based test generation approach^[3].
- Use qualitative abstractions to (1) improve scalability by minimizing redundant tests across equivalent scenarios; (2) Strengthen assurance via formal coverage and diversity guarantees.

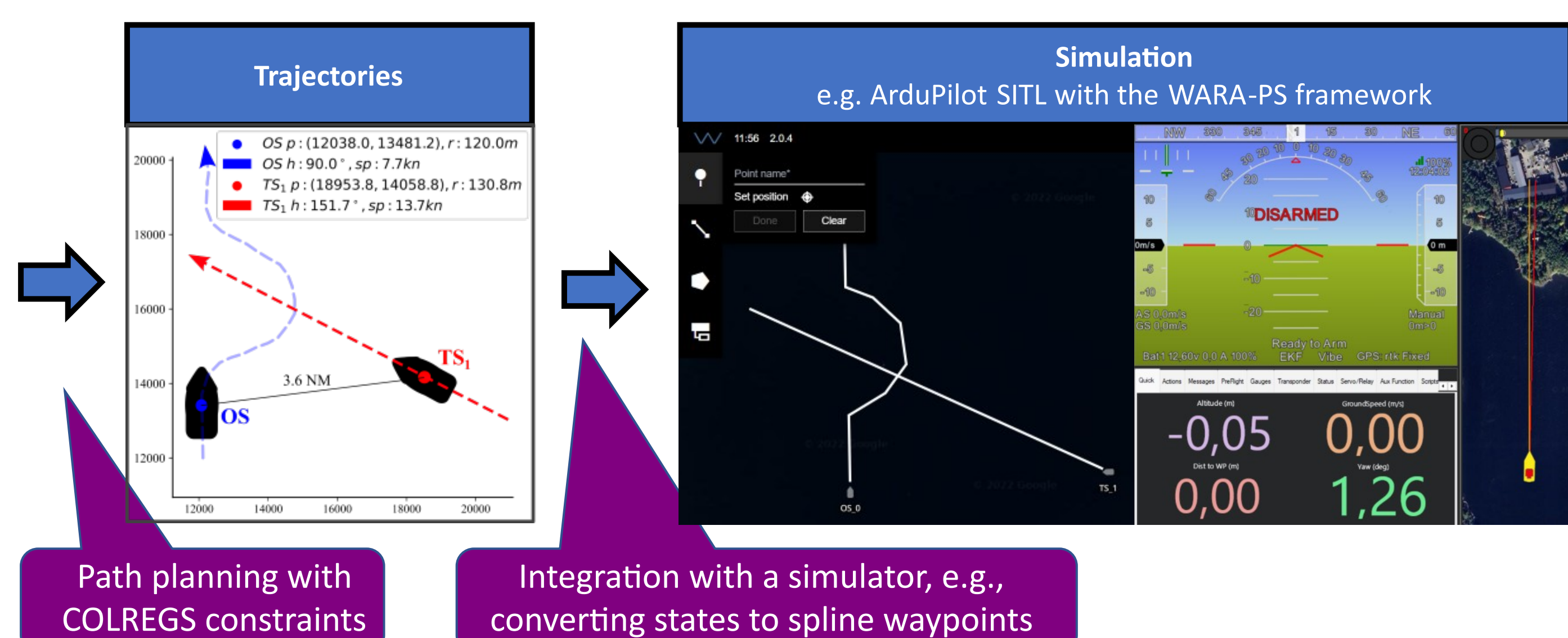
Generating test scenarios with multi-step refinement



Semantic coverage

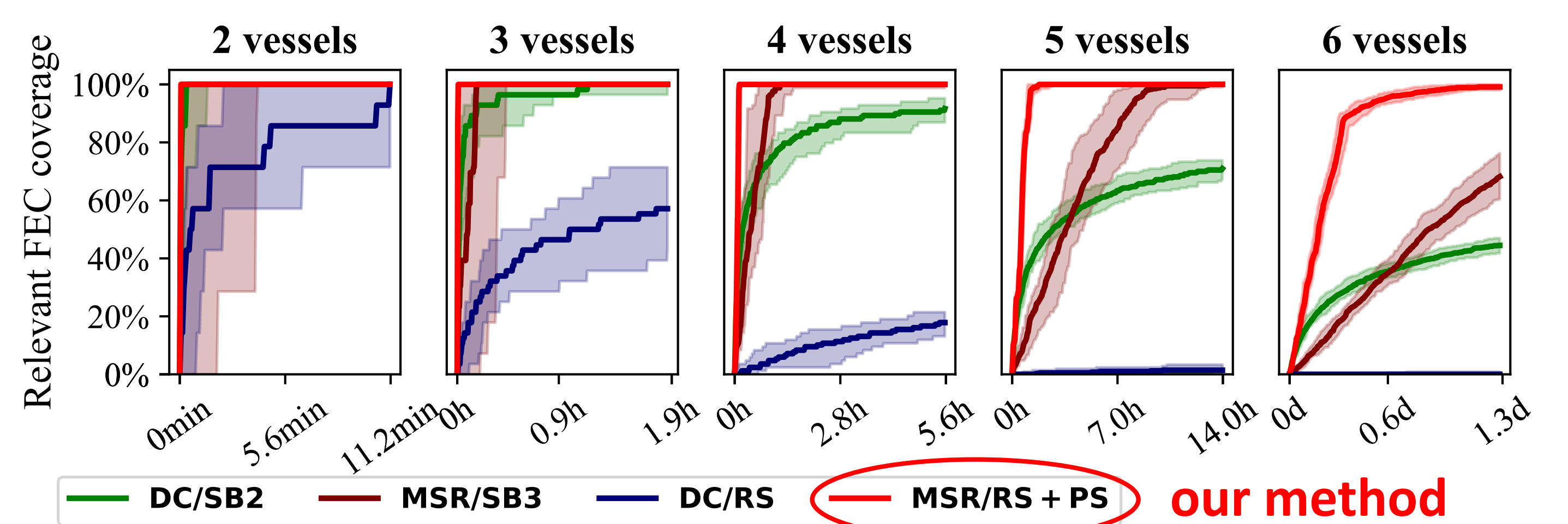


Ongoing work: path planning and simulation



Results: evolution of coverage over time

For semantic-diversity^[1], we measure the percentage of covered unique graph shapes among all possible graph shapes: $\frac{\text{covered shapes}}{\text{total shapes}} \times 100$.



References

- [1] Assessing Scene Generation Techniques for Testing COLREGS-Compliance of Autonomous Surface Vehicles
D. Frey, U. Kargén, D. Varró. *ISSTA, PACMSE, 2025, Trondheim, Norway*
- [2] Towards Automated Test Scenario Generation for Assuring COLREGS Compliance of Autonomous Surface Vehicles
U. Kargén, D. Varró. *MODELS, 2024, Linz, Austria*
- [3] Concretization of Abstract Traffic Scene Specifications Using Meta-heuristic Search
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