Physics-Aware Planning for Autonomous Unmanned Surface Vehicles

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THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

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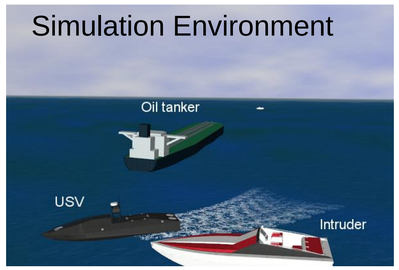
Motivation

- Autonomous operations of USV in complex and dynamic environments presents many planning challenges
  - Need to consider vehicle's non-linear dynamics and control in planning
  - Needs to consider intentions of civilian vessels while performing avoidance maneuvers
  - Need to find a balanced trade-off among the trajectory length, collision risk, and violation of COLREGs
  - Need to employ a short sense-plan-control cycle especially when operating at high speeds



Future Research

Long-term Planning

- Long-term autonomous operations of USV needs to exploit the ocean currents
  - Need to incorporate the weather forecast directly into planning
  - Need to develop lattice-based planner to exploit the ocean currents by introducing free flow actions
  - Need to incorporate dynamic programming based approach to tackle the uncertainties in the weather forecast
  - Perform start time optimization to improve the overall efficiency of the mission

Technology Transfer

- We have teamed with Hyperion Technologies under a MIPS project
  - Developing heuristics to efficiently compute trajectories for large maps
  - Integrating nautical charts and weather forecast model into trajectory planners
  - Integrating Radars and GIS data for real-time reactive obstacle avoidance
  - Developing interfaces and planners to actively interact with the user and modify the mission goals online

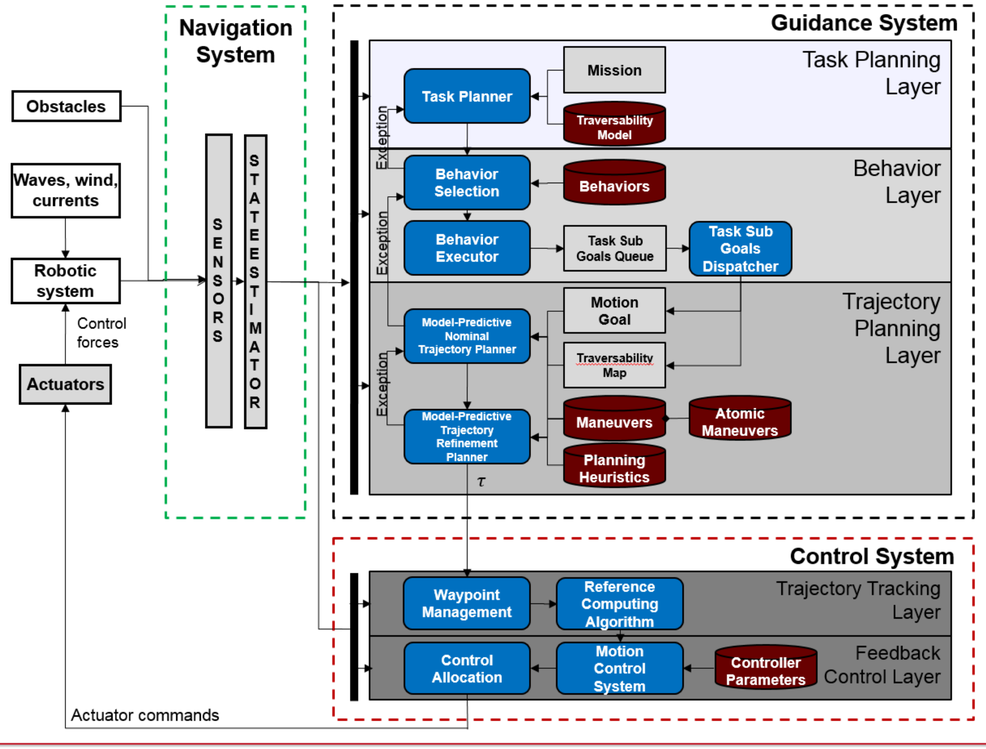
Trajectory Planning

Reactive Planner

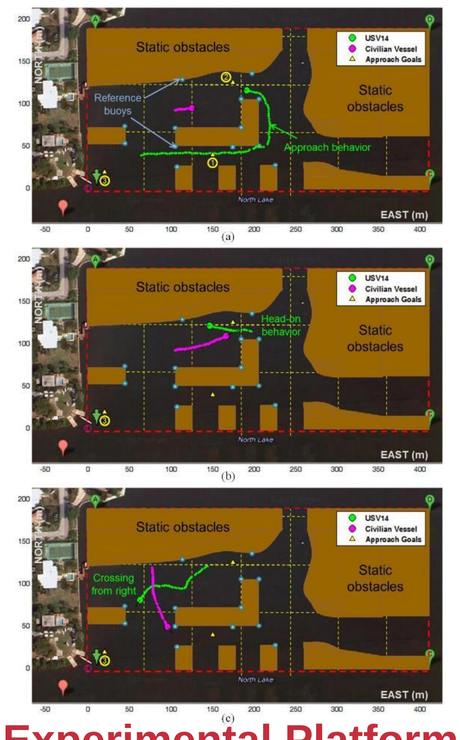
- Developed a generalized velocity obstacle based planner that computes dynamically feasible COLREGs compliant collision-free trajectories through resolution adaptive sampling

Deliberative Planner

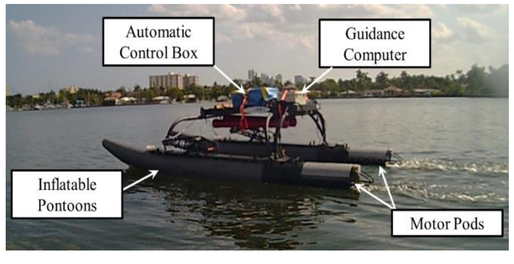
- Developed 5D $[x, y, \psi, u, t]^T$ lattice-based planner to compute dynamically feasible trajectories by incorporating intension model of civilian vessels and contingency control actions



Experimental Results

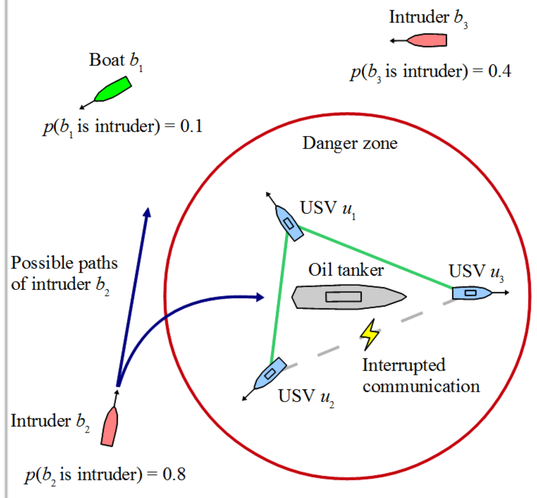


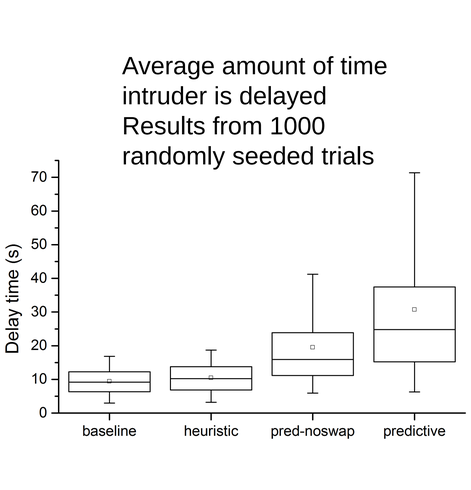
Experimental Platform



Multi-USV Team Guarding Behavior

- Synthesized strategies and behaviors for multi-USV team to protect asset from the threat of possible adversaries
  - USVs must deal with uncertainty about which boats are adversaries
  - Difficult due to very large problem space, uncertainty about state of world, real-time performance requirements
- Online, decentralized task allocation
  - Uses model-predictive simulation to evaluate task assignments
  - Monte-Carlo sampling to find expected outcome over set of possible worlds





- Predictive strategy performed best
- 169% better than the baseline
- 89% better than the purely heuristic
- 34% better than predictive w/o swap

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