Evaluating Robustness of Deep Reinforcement Learning for Autonomous Surface Vehicle Control in Field Tests

Luis F. W. Batista[1,2], Stéphanie Aravecchia[2], Seth Hutchinson[1], and Cédric Pradalier[2]

1.Georgia Institute of Technology, 2.Georgia Tech Europe - IRL2958 GT-CNRS

Introduction

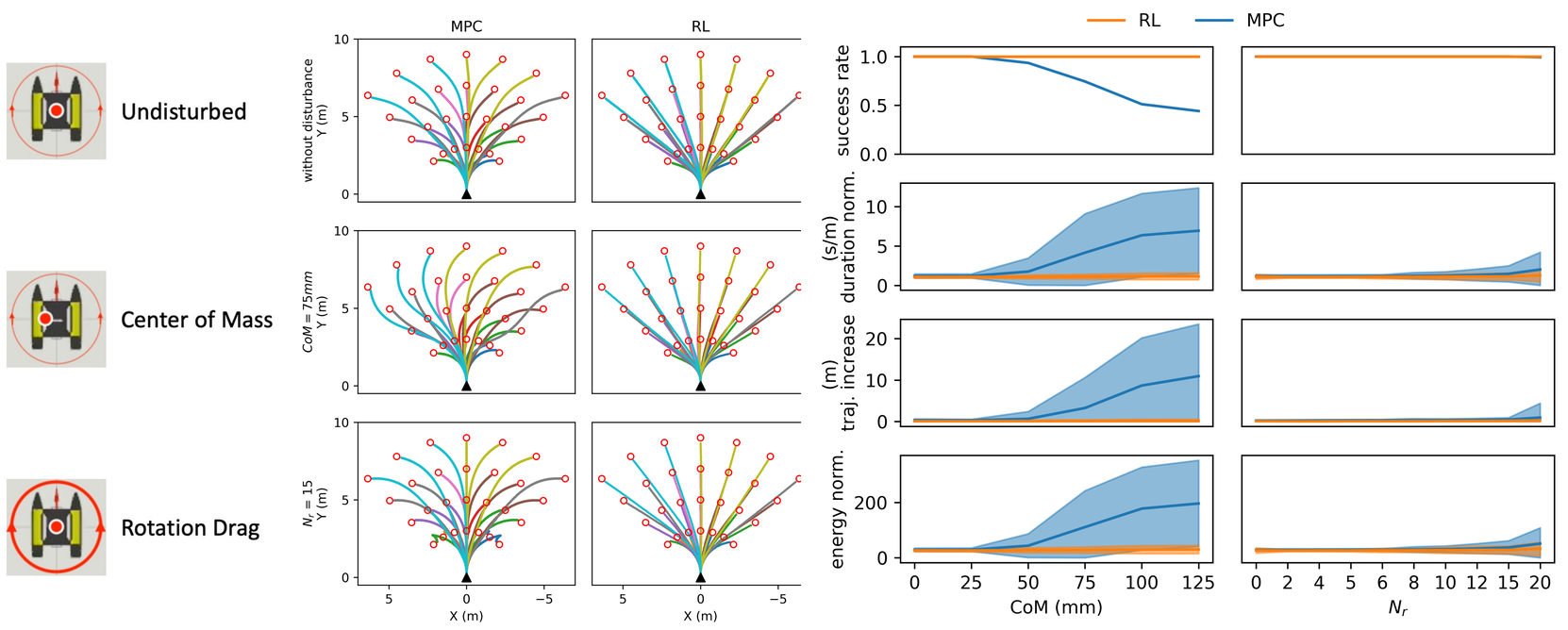
ASV control in real-world floating waste collection is challenging due to shifting payloads and varying drag. To address this, we evaluated the robustness of a DRL-based policy under simulated and controlled real-world disturbances.

Key Contributions

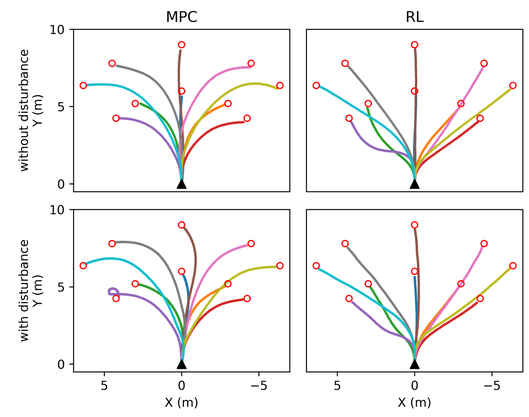
- **First demonstration of DRL-based ASV control in real-world waste collection**
- **Robustness evaluation of a DRL-based ASV controller via simulations and field tests, highlighting resilience to center of mass shifts, rotational drag, and external disturbances.**
- **Practical insights into DRL control strategies, detailing strengths and limitations, with open-source code provided for reproducibility.**

Evaluation

Simulation



Field

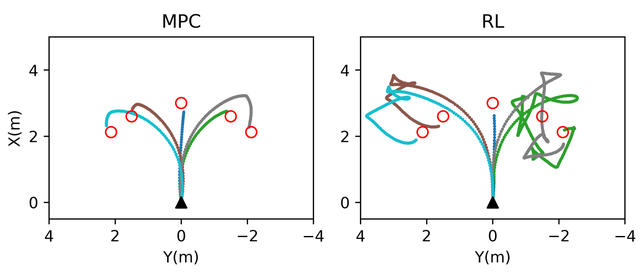


Agent	Metric	Normal	Disturbed	Degradation %
RL	T_{norm}	1.094	1.247	13.96
	E_{acc}	28.619	36.248	26.66
	Δ_d	0.246	0.160	-34.88
MPC	T_{norm}	1.175	1.350	14.89
	E_{acc}	33.457	36.457	8.96
	Δ_d	0.697	0.775	11.23

Challenges

- **Field tests were essential for exposing challenges and limitations, offering insights to improve sim-to-real transfer of DRL policies.**

Overshooting sharp turns

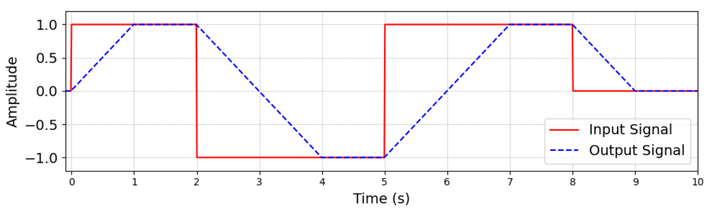


Simplified dynamics

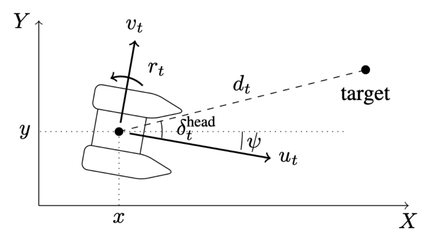
$$\mathbf{D}_l = \begin{bmatrix} X_u & 0 & 0 \\ 0 & Y_v & 0 \\ 0 & 0 & N_r \end{bmatrix}$$

Thruster modeling

Unknown software-introduced delays



Methodology



Metrics:

$$T_{norm} = T/d$$

$$\Delta_d = d_{real} - (d - d_{threshold})$$

$$E_{\text{acc}}^{\text{norm}} = (\sum_{i=1}^{N}(|\mathbf{u}_t^{\text{left}}| + |\mathbf{u}_t^{\text{right}}|))/d$$

MPC Formulation

$$\mathbf{M}\dot{\nu} + \mathbf{D}_l\nu = \tau_{\text{thruster}}, \quad \text{where} \quad \nu = [u \quad v \quad r]^T$$

DRL Formulation

Observation: $\mathbf{o}_t = [u_t \quad v_t \quad r_t \quad \cos(\delta_t^{\text{head}}) \quad \sin(\delta_t^{\text{head}}) \quad d_t]^T$

Action: $u_t = [u_t^{\text{left}} \quad u_t^{\text{right}}]^T$

Reward: $r_t = r_t^{\text{dist}} + r_t^{\text{head}} + r_t^{\text{energy}} + r_t^{\text{time}} + r_t^{\text{goal}}$

Conclusion

- **Field testing is vital for validating DRL policies and refining simulations to capture real-world dynamics.**
- **DRL shows strong potential for ASV control, as a flexible and robust alternative to traditional methods.**

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