AI SAIL - Sailing against the wind autonomously

Reinforcement Learning (RL) is a branch of Artificial Intelligence (AI) that can learn to optimise a strategy through interactions with an environment. Reinforcement Learning can have various applications in maritime domain: improving ship operational design, training future pilots or providing advice on board. In order to demonstrate the promise of RL in a relevant but simplified problem, we carried out a project named AI SAIL where a RL agent learned how to sail against the wind. On 24 November 2023, a public demonstration of the AI SAIL project was given in the Offshore Basin at MARIN.

Watch our presentation of the AI SAIL project:

https://vimeo.com/910813826/d585ace6f3

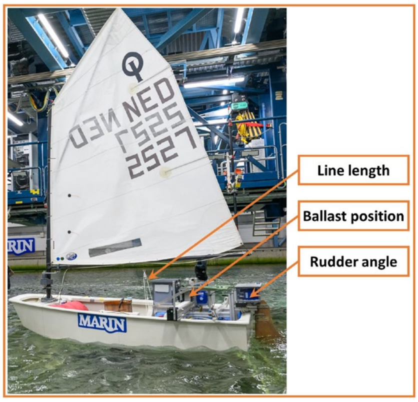

Figure 1: Optimist equipped with remote-control actuators controlling the rudder, ballast position and length of the line connecting the boom and the hull.

The aim of the AI SAIL project was to explore the possibilities and limitation of RL in an intuitive case study: A RL agent learning to sail against the wind using a small sailboat (the Optimist) intended for training children. We thought: If the children can learn to sail with the Optimist, so can the RL agent. Actuators were installed on the boat (as shown in Figure 1) to control the rudder, sail, and the transversely moving ballast (resembling a human being on board). However, training a RL agent in a basin can be costly and dangerous. Therefore, we focused on doing the training in a simulation environment and afterwards transferring the agent to the basin. The main question then becomes: How robust, stable and effective can this agent be when trained in a simulation environment and later applied in real life?

In reinforcement learning, an agent learns a strategy by observing the environment, selecting actions, receiving feedback in the form of rewards, and adjusting its strategy accordingly to maximize the cumulative rewards. This process involves a balance between exploring new actions and exploiting known good actions, ultimately leading to the agent improving its decision-making over time through trial and error. A particular advantage of RL lies in its ability to learn a strategy without requiring explicit knowledge of the environment. Once learned, the strategy can be applied to automate a sequential decision-making process.

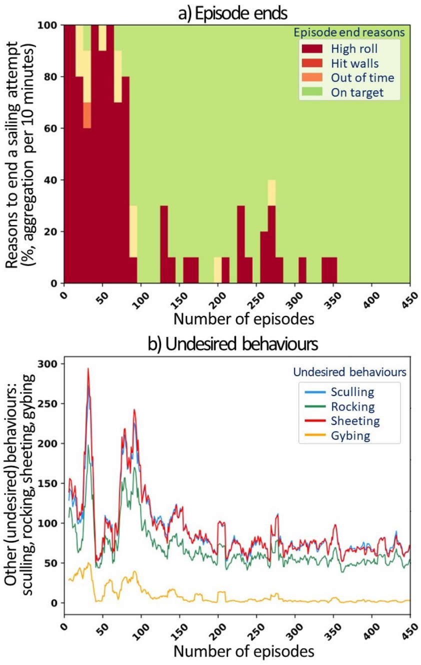

Figure 2: Learning curve of the RL agent trained in the simulation

Training in a simulation has several advantages. It simplifies the development, speeds-up the training and ensures safe exploration while the agent is learning. However, when applied in the real world, the strategy learned in the simulated environment might perform poorly, as the simulation model might not capture the complex physics of the real world phenomena. We addressed this issue by adopting various sim-to-real transfer techniques ensuring that the strategies learned in simulation generalize well to the real world.

For the AI SAIL project, we made a dedicated simulation model for the Optimist. As illustrated in Figure 3, the RL agent was trained in the simulation disconnected from the basin. Within 450 episodes, corresponding to 3 hours of training, the RL agent learned to systematically sail upwind while avoiding cheating or dangerous behaviours such as large roll motions, hitting the basin walls and gybing (see Figure 2). The sailing racing rules and actuators limitation were taken into account by penalizing sculling, rocking, sheeting which are high-frequency use of the rudder, ballast and line sheet.

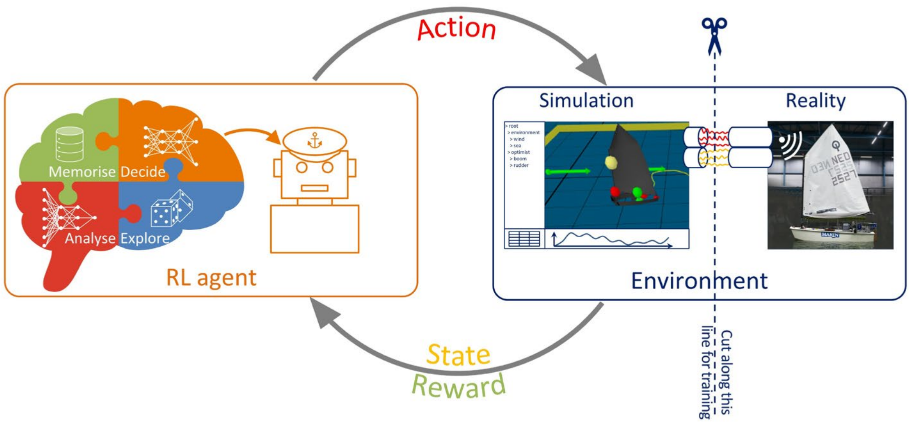

Figure 3: Training setup of the RL agent in the AI SAIL project

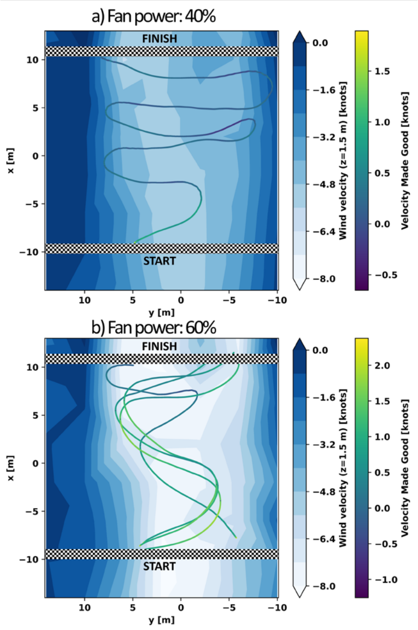

Figure 4: Four basin runs of the RL agent

The RL agent trained (Figure 2) has been evaluated in the basin. Figure 4 shows four runs from this RL agent with different initial locations, initial yaw angles, initial hull speeds and fan power levels. The agent showed the ability to adapt to different starting conditions and wind speed to reach the finish line on the other side of the basin (x>10). With higher wind speed, the agent sails closer to the wind and still keep sufficient speed in the boat which is in-line with real sailing.

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Reference: Kiki Bink, Autonomous sailing with sim-to-real Reinforcement Learning, MSc Thesis, Delft University of Technology, 2024.