Modeling, Simulation & Constrained MPC for a Sail-Assisted Ship (3-DOF)

MSc/Engineering (6-months internship)

Motivations

Greenhouse gas emission regulations for maritime transport are becoming increasingly stringent, forcing industry stakeholders to find ways to reduce fuel consumption on ships. Among the emerging solutions are WASPs (Wind Assisted Ship Propulsion systems), which consist of adding a wind- propulsion system to existing or newly built vessels.

In this context, Michelin, through its WISAMO initiative (WIng SAil MObility, based in Nantes and Vannes), is developing an **automated wing sail** designed for maritime transport. This wing sail is hoisted, reefed, and operated automatically, notably based on wind measurements.

The variability of the occurring sailing conditions requires **advanced control strategies** to operate **optimally and safely** under variable wind, disturbances, and operational constraints.

At **Michelin**, advanced tools are available to simulate various ship physics. Together with the **LIAS** laboratory (University of Poitiers), control strategies are developed for the WISAMO sail propulsive system.

Scientific Objectives

The objective of this project is to build a reproducible, control-ready simulation environment under MATLAB/Simulink (with optional Python tooling) for a sail-assisted ship, and to design a constrained Model Predictive Controller (MPC) ensuring both guidance performance and sail protection.

The main scientific tasks are:

- **Control-oriented sail modeling**, producing forces, yaw moment, and a load proxy (engineering-grade, tunable, non-CFD), linking actuator inputs to physical effects and safety constraints.
- **Identification of a predictive dynamic model** of the ship from the simulator, suitable for MPC design. The model must capture the vessel's response to control inputs and disturbances while remaining simple enough for real-time use.
- **Analysis of physical and technical constraints**, including actuator limits, maximum rates, admissible sail loads, and safe operating envelopes under various wind and navigation conditions. These constraints will be directly embedded in the control law.
- **Design and implementation of a constrained MPC** for waypoint guidance while respecting physical and safety limits of the sail. The MPC will handle trajectory prediction, ship attitude regulation, and sail load protection against excessive stresses.
- **Automated validation and performance assessment**, through a campaign of simulations over a grid of wind conditions and standard maneuvering scenarios, producing KPI dashboards and documenting a safe and reproducible operating envelope.

Expected Outcomes

- A reproducible MATLAB/Simulink simulation environment for a 3-DOF sail-assisted ship with environmental disturbance injection.
- A control-oriented sail model block providing forces, yaw moment, load proxy, and safety envelope.
- A constrained MPC for guidance and sail protection.
- Automated validation scripts, KPI dashboards, and final technical documentation.

Work Organization

The 6 months internship will be **primarily based at LIAS (Poitiers, France)**

The intern will be supervised by **Dr. Mohamed Elsherbiny** (Michelin) and **Prof. Guillaume MERCÈRE** (LIAS) followed by **Dr. Florent KRAVTSOFF** (WISAMO).

A week of immersion at WISAMO (Vannes, France) at the beginning of the internship to apprehend the wingsail and the problematic is desirable.

Requirements

Final-year engineering student (MSc level) with strong skills in automatic control, system identification, and state estimation; solid background in modeling and simulation of dynamical systems; interest in fluid dynamics and real-world system behavior.

Technical skills: MATLAB/Simulink (including toolboxes for control, estimation, and simulation), Python (optional), Git.

Preferred experience: Model Predictive Control (MPC) or other control strategies, numerical optimization, and simulation of complex systems.

Contact

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References

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