

MASTER THESIS PROPOSAL:
Optimal Sensor Placement and Pressure Observation for an Inflatable Sail

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Keywords: Distributed systems, PDE opbservation, Lyapunov-based control, adaptive sailing.

The use of wind-assisted propulsion (WAP) and sail-assisted cargo ships presents a potential solution for sustainable and efficient shipping, garnering increasing interest from the industrial sector. Among the various available technologies, Norsepower develops rotor sails, Yara Marine Technologies constructs hard sails, and Michelin is developing inflatable sails for cargo ships. While the aerodynamics of sails has been extensively studied and optimized for steady-state operation, surprisingly few scientific studies focus on the design of feedback control strategies and the use of distributed sensing capabilities to adapt to changing environmental conditions. Moreover, there is a growing interest in autonomous shipping, as evidenced by the ongoing development of a new regulatory framework for Maritime Autonomous Surface Ships. Autonomous ship operations are being explored at different levels, ranging from limited autonomous processes and decision-making to fully autonomous vessels.

In this context, **automated wing sails** are designed for maritime transport. Such wing sail is hoisted, reefed, and operated automatically, notably based on wind measurements. Depending on the vessel, wind sensors may be located at the top of the mast, at the bow, the stern, or a combination of these positions. This variability in measurement points, combined with the sensitivity of wind data to the ship's superstructure, makes it difficult to characterize the **incident wind on the sail**. To address this, we are exploring alternatives to sail control strategies that depend solely on direct wind measurements. More precisely, a concept for **dynamic onboard control** based on the **pressure field across the sail** is currently under development at GIPSA-lab. This internship is specifically focus on adapting this control strategy to **wing sails**.

Scientific Objectives

This project aims to develop a **sail control method based on dynamic adaptation to sail performance**. Performance will be inferred using a **limited but optimally placed set of pressure sensors** on the sail surface, combined with **onboard resolution of simplified flow dynamics models**.

Methodological Steps

1. **Adapt the method** for calculating optimal pressure sensor placement—developed for conventional wings (constant airfoil along the span)—using existing CFD simulations.
2. **Develop observation/estimation algorithms** to reconstruct the complete pressure field (and therefore sail performance) from a limited number of sensors and a simplified real-time physical model.
3. **Evaluate numerically** the impact of the inflatable structure (profile variation along the span) on the method's accuracy (observation error analysis).



4. **Validate and generalize** the approach for representative wind load cases using CFD simulations.
5. **Design and test wireless pressure sensors** to acquire realistic pressure field data for algorithm validation.

Requirements

- Enrolled in a **Master 2 program in Automatic Control**,
- Excellent **academic record**,
- Strong background in **partial differential equations (PDEs)** and related systems.

How to Apply

Send **transcripts**, a **motivation letter**, and a **reference letter** to:

Prof. Emmanuel Witrant — emmanuel.witrant@univ-grenoble-alpes.fr

References

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- [3] D. Le Pelley, D. Morris, P. Richards, and D. Motta, “*Aerodynamic force deduction on yacht sails using pressure and shape measurements in real time,*” *The International Journal of Small Craft Technology*, 157:65, 2015.
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