PhD Position Available at Dalhousie University

Project Title: **Automatic Sail: AI-Driven Optimization for Sustainable Maritime Navigation and Wind Assisted Propulsion**

Position: **PhD Candidate**

PhD subject: **Autonomous Sailing and Navigation**

Supervisor: Prof. **Ya-Jun Pan**, Dept. of Mechanical Engineering at Dalhousie University, Halifax, Canada

Co-supervisor: Prof. **Christophe Prieur**, Université Grenoble Alpes - CNRS/GIPSA-lab, Grenoble, France

POSITION OVERVIEW

We are seeking a research student to work on the model-based and Artificial Intelligence (AI)-driven optimal navigation and control methods for automatic sail decision-making under variable environmental conditions. Experimental validation of the control method will be conducted based on the small-scale sailboat and 6-meter Birdie Sailboat available in the Advanced Control and Mechatronics Lab (ACM Lab: http://acm.me.dal.ca) at Dalhousie University. The student may have the opportunity to work as a visiting research graduate student in the research group located at the Université Grenoble Alpes – CNRS/GIPSA-lab, Grenoble, France.

The PhD candidate will be fully supported at a comparable annual stipend up to 4 years supported by the Natural Sciences and Engineering Research Council of Canada (NSERC). The overall project is co-funded by the Canada-France CFP on AI by NSERC and French National Research Agency (ANR) in France. The student will be supported to attend international conferences, provided that the student has conference papers accepted.

Both Dalhousie University and Université Grenoble Alpes is strongly committed to fostering diversity and inclusion. We encourage women, Indigenous BIPOC students, as well as researchers with disabilities students, racialized scientists as well as researchers with disabilities and from LGBTQ2+ communities to submit their application.

SCOPE OF THE PHD THESIS

CO_2 emissions of shipping contributed to 2.9% of global emissions induced by human activities in 2018 and may be increased by 44% in 2050 as reported by International Maritime Organization (IMO) in 2024. The greenhouse gas emitted by the maritime transport sector is one of the three steps towards reducing emissions from the shipping sector. While the environmental impacts of shipping are well documented, the "adaptation efforts are only at the planning stage", as mentioned by the latest Intergovernmental Panel on Climate Change (IPCC) report in 2022. The IPCC also reports that sustainable shipping is a key ingredient for the economic system associated with the oceans.

The title of this PhD is "Autonomous sailing and navigation". The first objective is to tackle the problem of **route tracking and adaptation** for wind-assisted propulsion (WAP) in autonomous surface vehicles (ASVs), developing optimal routing strategies that account for the complex, multi-scale dynamics of the ship, wind, and ocean currents. Unlike traditional ship routing, which relies on simplified weather models and static optimization approaches, WAP-enabled ASVs require a fully dynamic approach that integrates real-time environmental data, nonlinear vessel dynamics, and adaptive control strategies. This necessitates the development of multi-layered optimization frameworks capable of adjusting the route continuously based on evolving meteorological conditions and ocean currents.

A critical aspect of route adaptation is the **coupling of ship dynamics with wind and ocean currents**. The ship's nonlinear equations of motion interact with the environmental flows, leading to complex fluid-structure interaction and time-varying control constraints. The modeling part and the approximation of constraints will be done in this project and will be used by the PhD applicant to derive new vessel route planning methods that dynamically adjust to optimize both time efficiency and energy savings. To do that, the PhD will employ Reinforcement Learning (RL) and model predictive control (MPC) to determine optimal sail and rudder configurations at every stage of the journey. RL agents trained on historical weather and ocean current datasets will learn optimal maneuvering strategies under uncertainty, ensuring adaptive, fuel-efficient, and time-optimal navigation.

The second objective of this PhD is to develop a hybrid control approach, where model-based and AI-driven methods are combined to provide robust decision-making **under variable environmental conditions**. Given the limitations of pure data-driven approaches in extrapolating outside training distributions, physics-based constraints must be embedded into AI models to ensure feasible and physically consistent routing decisions. Furthermore, risk-aware optimization strategies, incorporating probabilistic safety margins for extreme weather events and sensor uncertainties, will be explored to enhance the robustness of the routing system.

Finally, **experimental validation** using the WAP-enabled ASVs DragonFlite 95 and MiniJI and high- fidelity numerical simulations will allow us to verify the effectiveness of the routing strategies. Our autonomous sailing platforms equipped with real-time weather sensors, GPS-tracked drift analysis, and onboard AI-driven decision-making systems will provide empirical insights into the performance of different adaptation strategies. By integrating advanced control techniques, PDE-based environmental modeling, and real-time optimization, the next generation of autonomous sailing vessels can achieve unprecedented efficiency in harnessing wind energy while navigating dynamically evolving oceanic conditions.

QUALIFICATIONS

- Bachelor and Master’s degrees in Mechanical Engineering, Electrical Engineering, or a related field.
- Background knowledge in one or multiple fields: dynamic modeling, advanced control, robotics, and mechatronics, robot operating systems (ROS) simulation and implementation.
- Technical writing skills for scientific publications. Communication skills in English.
- A problem-solving-oriented mindset, self-motivation, initiative, resourcefulness, and dependability. Ability to both work independently and as part of a team.
- For international student, a minimum IELTS score of 7.0 or TOEFL iBT score of 92 is required.

HOW TO APPLY

Interested applicants, please send your CV, copies of transcripts, and previous publications (if any) to Prof. Ya-Jun Pan (yajun.pan@dal.ca) and Prof. Christophe Prieur (Christophe.Prieur@gipsa-lab.fr) using the subject line “PhD Position Application – Automatic Sail”.

OTHER DETAILS

All qualified applicants are encouraged to apply. However, only candidates under consideration will be contacted. The starting date is as early as possible.