PhD: Kite pilot design for autonomous vessel propulsion based on physics-guided neural network models

Location: IMS-lab, UMR 5218, 33405 Talence Cedex (Bordeaux agglomeration), France.
Duration and period: 3 years, starting September 2026.
Supervisors: Christophe Farges, Tudor-Bogdan Airimitoaie.
Keywords: tethered kite, physics-guided neural networks, path/trajectory planning, kite control.

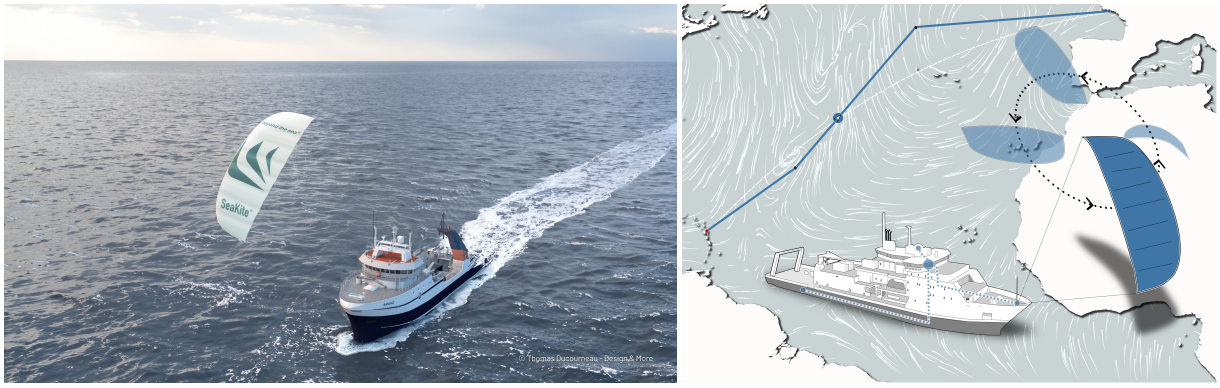

Figure 1: The SeaKite autonomous tethered kite from Beyond the Sea: in action for vessel propulsion using lemniscate trajectory (left), and using kiteloop trajectories for AWAKE project (right).

The IMS-laboratory (University of Bordeaux, Bordeaux INP, CNRS) has been working on control and supervision algorithms design of autonomous tethered kites for vessel propulsion fig. 1 (left) in partnership with Beyond the Sea (BTS) since 2015 [1]. The objective is to reduce fuel consumption by using the traction provided by a kite wing attached to the boat. The main advantage compared to a fixed wing is to benefit from higher relative wind velocity because of the motion of the kite and of the higher wind in altitude.

Multiple versions of these kites have been developed during the KiWin project[1], starting from a beach kite of 5m^2 and going up to 800m^2 for large vessel propulsion. An estimated 20% reduction in fuel consumption of the vessel is expected, providing great benefits for maritime transportation and environment preservation.

A new project, named AWAKE (Automated Wind Assistance by Kite for Optimal Efficiency), has recently been awarded by ADEME France to a consortium lead by BTS, for which the IMS laboratory is again in charge of the autonomous pilot design for the kite. To further improve efficiency, the kite and propulsion system design have been modified to allow circular trajectory, see fig. 1 (right). Accompanied by personalized ship routing algorithms, the AWAKE project should allow for a 40% reduction in green house has emissions. The role of this PhD thesis is to work on the modeling and control of the kite.

Previous work during the KiWin project focused on point mass modeling [1], cinematic model [2], rigid body modeling [3] of the kite, and actuator dynamics [4]. Robust LTI [5], periodic controllers (under review) and path planing [6, 7] have been developed based on these physics-based models.

These physics-based models have the advantage of being generalizable and explainable but some of their parameters are difficult to find in practice. During the AWAKE project we plan to develop physics-guided neural networks (PNN) models of the new kite configuration. These models will be trained based on real flight data of the tethered kite. Based on these models, kite trajectory planing and novel control algorithms should be designed.

[1] https://beyond-the-sea.com/en/the-kiwin-project-revolutionizing-maritime-transport-with-kite-traction/

During the KiWin project, a mini-car experimental setup was developed at IMS-lab. The different modeling and control strategies may be first tested on this local facility.

The main tasks of this PhD are organized as follows:

1. First year of PhD:
   (a) Bibliographic study of kite modeling principles (first 3-6 months).
   (b) Bibliographic study of physics guided neural networks adapted to the aerodynamic modeling (first 3-6 months).
   (c) Definition and development of a PNN model of the kite based on real data from BTS.
   (d) Design of a first robust control algorithm based on existing literature.
   (e) Optimization of desired trajectories for kite-loop based on existing literature.
   (f) Simulation and experimental validation of the proposed algorithms.
   → Report to be sent to BTS and ADEME before the end of the first PhD year.
2. Second year of PhD:
   (a) Proposal of dedicated control and optimization algorithms based on PNN models.
   (b) Simulation and experimental validation of the proposed algorithms.
   → Delivery of a report to BTS and ADEME before the end of the second PhD year.
3. Third year of PhD:
   (a) Fine tuning of control and optimization algorithm.
   (b) Simulation and experimental validation of the proposed algorithms.
   → Delivery of a report to BTS and ADEME before the end of the third PhD year.

PhD supervision and organization will include:

- weekly meetings with the supervisors;
- regular online meetings and some in-person meetings at BTS in La Teste-de-Buch;
- technical reports for BTS according to the work-packages of the project.

Required skills: dynamic systems modeling, robust control, coding skills in Matlab/Simulink.
Additional skills: python programming, deep-learning notions.
Grant: approx. 1770 € net per month (French net salary).
How to apply: send CV, motivation letter, and available grade transcripts to: christophe.farges@u-bordeaux.fr, and tudor-bogdan.airimitoaie@u-bordeaux.fr

References

[1] Baptiste Cadalen. "Modélisation et commande robuste d'une aile de kite en vol dynamique. Application à la traction d'un navire". fr. PhD thesis. Université de Bordeaux, 2018.

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