# Safe and Robust Navigation Algorithms for Autonomous Surface Vessels in Challenging Environments

## Summary

*This PhD position focuses on the research and development of novel algorithms for autonomous marine navigation. The candidate will investigate approaches to enable safe and efficient navigation for autonomous ships, particularly in complex and high-traffic environments such as harbors, while ensuring compliance with COLREG (International Regulations for Preventing Collisions at Sea). The research will explore real-time path-planning techniques that involve navigation algorithms, for example, artificial potential fields, RRT*, and hybrid A*-like methods, etc., combined with formal modeling approaches or neural networks for collision prediction and threat assessment. A key challenge lies in designing algorithms that adhere to COLREG rules while also guaranteeing safe navigation in scenarios where other vessels fail to follow these regulations. The outcomes of this research will contribute to the development of robust navigation algorithms, empowering autonomous ships to operate safely and reliably in dynamic and unpredictable marine environments.*

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| Research field: | Environmental, marine and coastal technology |
| Supervisors: | Kristjan Tabri<br>Dr. Karl Janson |
| Availability: | This position is available. |
| Offered by: | School of Engineering<br>Kuressaare College |
| Application deadline: | Applications are accepted between January 01, 2025 00:00 and January 24, 2025 23:59 (Europe/Zurich) |

## Description

Advancements in artificial intelligence (AI) have brought significant attention to autonomous surface vessels (ASVs) from researchers and companies worldwide, driven by their potential in applications where having a human captain onboard may be either risky or expensive. For instance, ASVs are frequently employed for tasks such as scanning and monitoring the seafloor, including mapping for offshore wind parks or harbors and inspecting underwater infrastructure. These vessels can operate autonomously and perform tasks on a regular schedule. This allows a single operator to remotely oversee multiple ships, significantly reducing operating costs.

Ensuring safe autonomous navigation is particularly challenging in complex environments like busy harbors. Marine navigation is governed by COLREG (Convention on the International Regulations for Preventing Collisions at Sea), a set of rules intended for human captains. These rules depend heavily on subjective judgment and interpretation, making them difficult to formalize into algorithms. Consequently, an ASV must:

- Accurately assess its surroundings in dynamic environments and navigate safely among human-piloted vessels, each applying their own interpretation of the situation.
- Handle scenarios where other vessels fail to adhere to COLREG rules, maintaining safe navigation despite such unpredictability.

**Research Focus**

The research will investigate real-time path-planning techniques utilizing various navigation algorithms, such as artificial potential fields, RRT*, and hybrid A*-like methods. These approaches will be integrated with formal modeling techniques or neural networks to enhance collision prediction and threat assessment. By combining algorithmic path-planning with data-driven and formally verified methods, the goal is to enable autonomous vessels to navigate adaptively, responding reliably to environmental changes and the behavior of nearby vessels.

A key challenge lies in designing marine navigation algorithms that adhere to COLREG rules while ensuring safe navigation, even in situations where other vessels fail to comply with these regulations. This involves developing robust algorithms capable of interpreting incomplete or uncertain data, responding to unpredictable vessel behavior, and maintaining safe trajectories in dynamic, high-traffic maritime environments.

Ultimately, this research aims to create safe and robust navigation algorithms that guarantee the operational safety of the ASV itself and the safety of surrounding vessels.

**Responsibilities and Foreseen Tasks**

1. Conducting a comprehensive literature review: The student will conduct a comprehensive literature review on existing approaches for autonomous navigation in marine environments.
2. Researching and developing algorithms for real-time path-planning, collision prediction, and threat assessment, taking into account marine navigation rules.
3. Proposing and helping to conduct real-world data collection experiments.
4. Testing and validating proposed methods in simulated environments and real-world scenarios.
5. Collaborating with other researchers and companies to align research goals with practical applications in marine technology.
6. Documenting and publishing research findings in peer-reviewed journals and present at conferences.

**Applicant Requirements**

Applicants should fulfill the following requirements:

- A master's degree in computer engineering or computer science
- A clear interest in the topic of the position • Excellent command of English
- Strong and demonstrable writing and analytical skills
- Excellent programming skills (especially in Python and C++)
- Capacity to work both as an independent researcher and as part of an international team
- Capacity and willingness to aid in organizational tasks relevant to the project

**Beneficial Experience**

- Previous work experience in the field of artificial intelligence, signal processing, or algorithm design
- Experience working with the Robot Operating System (ROS)
- Previous work experience in the field of autonomous driving or robotics

**What We Offer**

- Collaboration on the development of autonomous technologies, utilizing field data from real autonomous vessels and opportunities to test developed algorithms on actual autonomous platforms
- Access to research infrastructure (test basin), sensors, and autonomous platforms
- Opportunities for attending conferences, research stays, and networking with globally leading universities and research centers

**Employment**

The position is offered by the Marine Technology Competence Centre of Kuressaare College, which belongs to the School of Engineering of the Tallinn University of Technology. The expected duration of doctoral studies is four years. Following the standard practice in the School of Engineering, the contract will be made initially for one year, then it will be extended further after a successful progress review. The salary is according to the salary system of the Tallinn University of Technology.

The position will be fulfilled as soon as a suitable candidate is found. TalTech reserves the right for justified reasons to leave the position open or to extend the application period.

**How to apply for a doctoral candidate position**

Please read the admission guidelines at https://taltech.ee/en/phd-admission.

**Further information**

• Job location: Kuressaare & Tallinn, Estonia.

• For additional information, please contact

Kristjan Tabri (email: kristjan.tabri@taltech.ee) or

Karl Janson (email: karl.janson@taltech.ee)

To get more information or to apply online, visit https://taltech.glowbase.com/positions/913 or scan the the code on the left with your smartphone.