Field tests and Machine Learning for adaptive cleaning with an autonomous robot (LABROID)

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Introduction

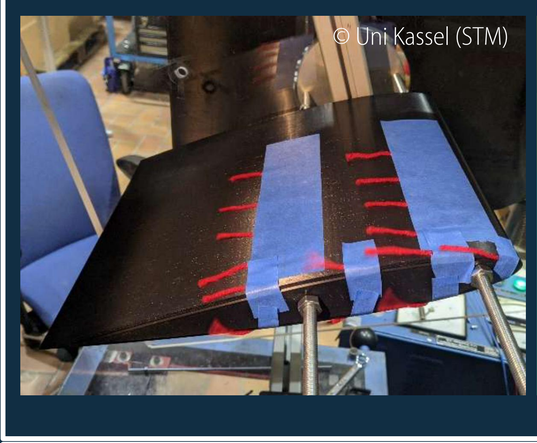
The BMFTR-funded project 'LABROID' addresses robotic underwater cleaning during the voyage of commercial ships and is a collaborative initiative involving the departments of Fluid Dynamics (STM) and Intelligent Embedded Systems (IES) at University Kassel, Dr. Brill + Partner GmbH (DBP) and Briese Schiffahrts GmbH & Co. KG. The robot is designed to clean the underwater hull of a commercial ship - during transit. This shall be achieved through brush roll cleaning and an AI-based computer vision system that will be developed in the project to identify the level of existing fouling on the underwater ship hull, so that the robot can independently detect and determine whether and where it is permitted and possible to clean the biofilm.

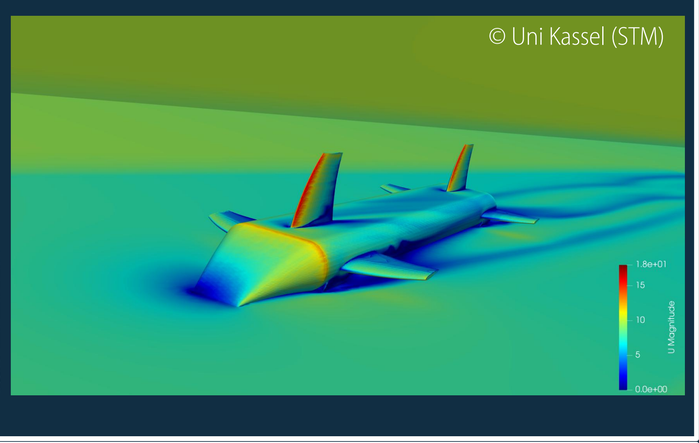
Objectives

- New method of propulsion for hull-mounted in-transit ship cleaning (self-aware control)
- Usage of flow energy through an innovative, nature-inspired fin system
- Fouling detection in real-time through AI-based computer vision to enable compliance with the forthcoming ISO standard through the automatic detection and targeted removal of Fouling Level 1
- Enabling the replacement of antifouling coatings containing biocides through mechanical cleaning and the use of biocide-free hard coatings
- Enabling the prevention of the introduction of invasive species through the regular removal of slime layers.
- Reducing the release of biocides and microplastics into the marine environment

UNI KASSEL (STM)

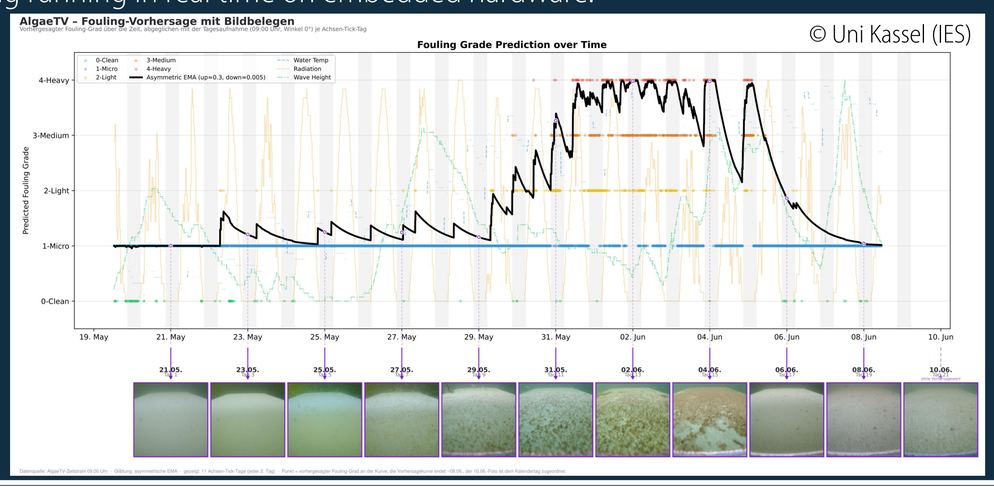
STM develops the robotic system and its energy-efficient, nature-inspired propulsion. A patented fin system turns the hull flow into propulsion and recuperates energy, while a self-aware control adapts the robot to the dynamic flow along a moving ship. A CFD digital twin of the fin system supplies the training data for this control, and STM integrates the fins and sensors into the existing Larabicus platform and validates them on lab and ship-hull test rigs.





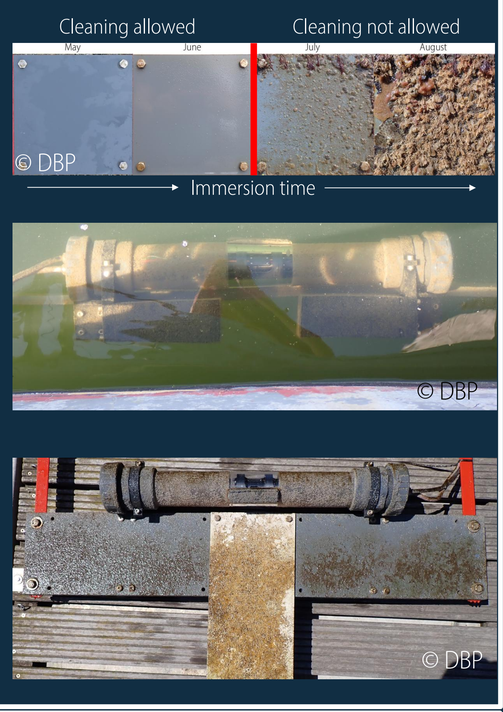
UNI KASSEL (IES)

IES develops a computer vision module for real-time fouling detection based on the AMPP pictorial standard[1)], aligned with the IMO Biofouling Guidelines (MEPC.378(80))[2)], and PINN-based control models trained on CFD data. The onboard software further integrates sensor fusion, autonomous mode switching between cleaning and mapping, and RL-based path planning running in real time on embedded hardware.



DBP - Field tests on Norderney

- Development of standardized test and training data for fouling classification and for the biological validation of the cleaning technology
- Exposure of test panels in the harbour of Norderney, in the North Sea
  - Closely monitoring the fouling level
    - Camera with **red-green-blue (RGB)** light source receives real-time data
    - Transmits live video feed to determine biofilm succession and to decide the optimal time for cleaning with roller-brushes
- Development of new methods of **gravimetric** and **tensile strength measurement** of biofilm
  - Determine **optimal settings for roller brushes** for cleaning biofilm from various ship coatings



Briese Schiffahrt – Real-world testing

Lastly, Briese provides real-world test environments using commercial ships and evaluates the operational performance of the technology under practical conditions. It supports validation and ensures that the system is feasible and scalable for industrial deployment in maritime operations. With a fleet of around 130 vessels operated since 1984, Briese covers the ship types needed for the staged sea trials: a stationary harbour test, moving-ship trials, and piloting in liner service, validating the CO2 savings under real operating conditions.

Outlook

- Developed technology has the potential to save 0.5% of the worldwide CO2 emissions
- Expanding a cleaning robot platform (**LARABICUS**) to include **two technical components:**
  1. a **nature-inspired and patented fin system**, which enables a new mode of locomotion through intelligent **self-aware control**,
  2. And **real-time biofouling detection** using **AI-based computer vision**

Take-home message

Overall, the project aims to significantly reduce the environmental impact caused by fouling on ship hulls:
- **Increased fuel consumption,**
- **Introduction of Non-Indigenous Species,**
- **Release of Biocides and Microplastics,**

→ thereby making a significant contribution to Climate Protection.

References

1) AMPP Pictorial Standard for Underwater Evaluation of Fouling Degree on Ship Hulls NACE SP21421-2025.
2) RESOLUTION MEPC.378(80) (adopted on 7 July 2023) 2023 GUIDELINES FOR THE CONTROL AND MANAGEMENT OF SHIPS' BIOFOULING TO MINIMIZE THE TRANSFER OF INVASIVE AQUATIC SPECIES

Acknowledgements

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