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Cost effective operation and maintenance of floating photovoltaic power plants based on unmanned surface vehicles

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The context

Floating photovoltaic (PV) power plants (FPV) can be alternative installation sites to agricultural land, whose use is increasingly restricted. However, these installations can significantly impact the aquatic ecosystem, making effective monitoring crucial [1]. In this work, the use of an unmanned surface vehicle (USV), which can also be used as an Autonomously Surface Vehicle (ASV), is proposed to overcome the difficulties of maintenance and monitoring in aquatic environments. The ASV could be equipped with sensors for measuring parameters such as water temperature, turbidity, pH, dissolved oxygen and chlorophyll, which are essential for assessing environmental impact. The autonomy of the ASV would allow continuous and detailed mapping of the aquatic environment, providing real-time data for optimized management of FPV installations. The literature review highlights the lack of a cohesive monitoring framework, emphasizing the need for standardized guidelines for water quality monitoring and management in relation to FPV facilities [2]. The implementation of ASVs would be a key step towards efficient and sustainable monitoring of FPV plants, ensuring protection of the aquatic ecosystem and optimization of energy production. A collaboration with autonomous underwater vehicles, in the near future, is proposed for a more complete characterization of the renewable energy producing site [3].

Xfloat floating PV system.

The robot

PREMISE
The aim was to build a floating vehicle with autonomous locomotion (Autonomous Surface Vehicles, ASV) and capable, in the near future, of transporting instrumentation and sensors for measurements from the water surface in an environmentally friendly and non-invasive manner.

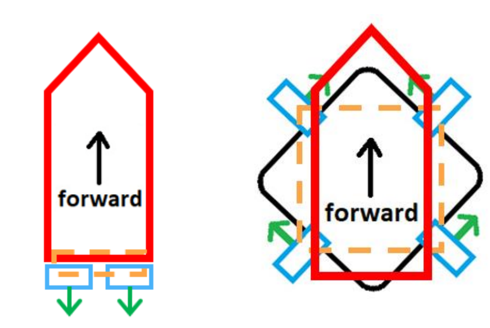
THE HULL
This vessel consists of a double-layer GRP hull, weighing about 40 kg and about 2.5 m long, equipped with high sides to effectively protect the instrumentation from the water.

THE MOTORS
The motors used are common thrusters, very popular in the scientific community oriented to prototype-type robotic realizations. They are each capable of 5kgf of thrust.

THE HARDWARE CONFIGURATION
The boat was built in two configurations: one with two motors, the other with four motors.

- TWO-PROPELLERS SYSTEM (version 1)
In the two-propellers configuration, motors are placed on the thruster-frame and oriented at right angles to the thruster itself (see figure). Hull rotation is achieved by using only one engine or both but in differentiated or opposed thrust

Launching the robotic boat in ver.1 (left) and ver.2 (right)



Two possible operating configurations: 2-motor (ver.1) and 4-motor (ver.2)

Preparatory work on the robotic boat (ver.2) before a launching test in a relevant environment

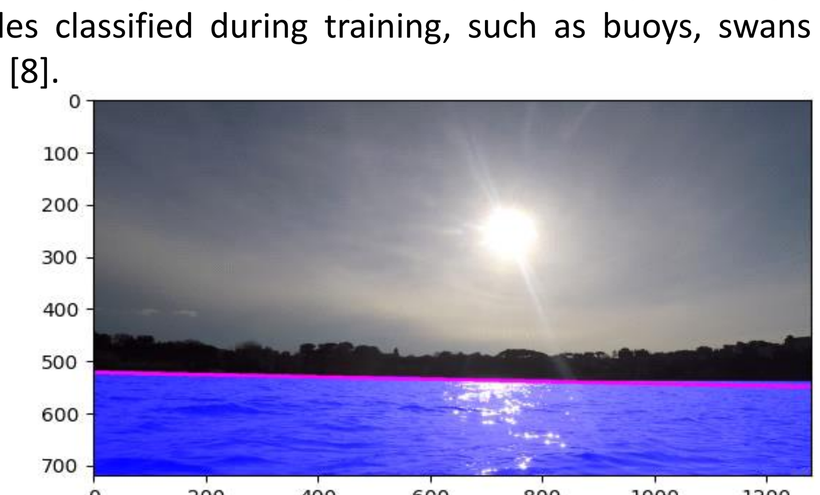
Robotic boat in autonomous navigation: view from shore and drone

- FOUR-PROPELLERS SYSTEM (version 2)
In the 4-thruster configuration, motors are arranged equally spaced two towards the bow and two at the stern, by means of a specially constructed bridge, visible in the figure (orange dotted line). The orientation of the propellers is 45° and the handling of the movement is slightly more complicated than in the two-engine configuration. The advantage lies in the improved maneuvering precision and greater versatility compared to the two-motor configuration. For example, in version 2 it is possible to make pure translatory movements on the sides of the barge

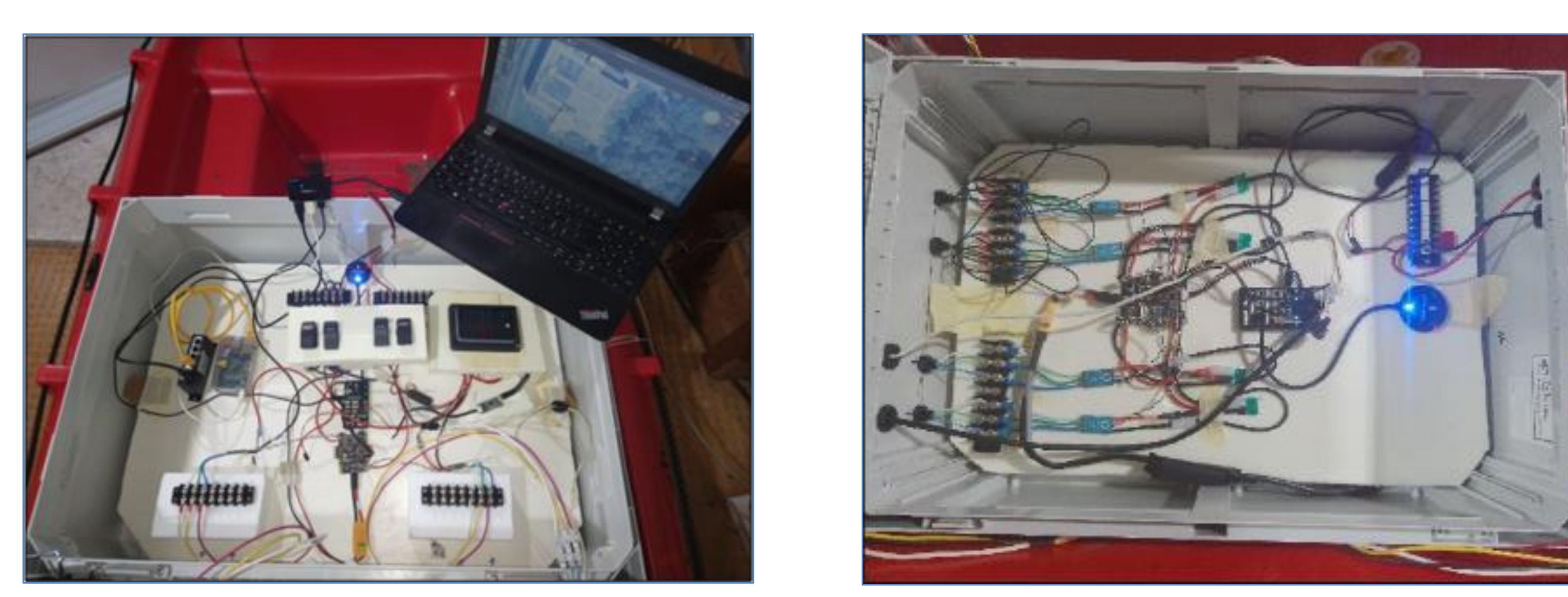
THE AUTOPILOT
The ASV's autopilot is based on PixHawk 4 [4] an open-source standard. An SBC (Single Board Computer) connected to the PixHawk is dedicated to higher-order tasks (real-time video link, obstacle detection under development, etc.)

THE MISSION CONTROL SYSTEM
The ASV's mission control and planning software is based on Qgroundcontrol [5] and managemant of the entire mission through SBC (by wire) is possible via the MAVLINK protocol [6]; it also makes both telemetry available on the ground stations and radio remote operation of the ASV possible. Since the code is open-source, it is possible to modify it in order to optimize and customize the control system.

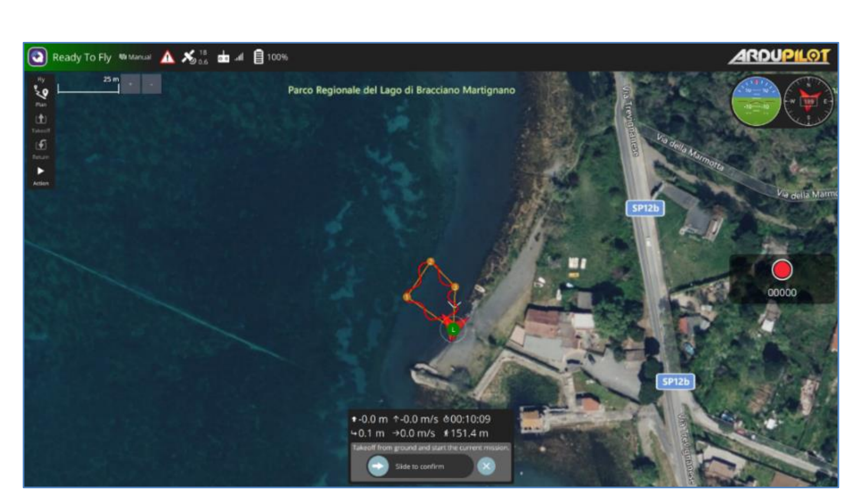
OBSTACLE AVOIDANCE
The system is based on image segmentation, to generate binary masks capable of distinguishing regions of water from those without it. The training of the neural network was performed using public datasets provided by the European project INTCATCH [7]. Once the segmentation of the images has been completed, the next step is the identification of the waterline using the RANSAC algorithm, which allows the waterline to be drawn on the segmented images. After precisely defining the waterline, the system proceeds to identify obstacles classified during training, such as buoys, swans and boats, monitoring their position frame by frame [8].



Obstacle avoidance:Water and not water identification



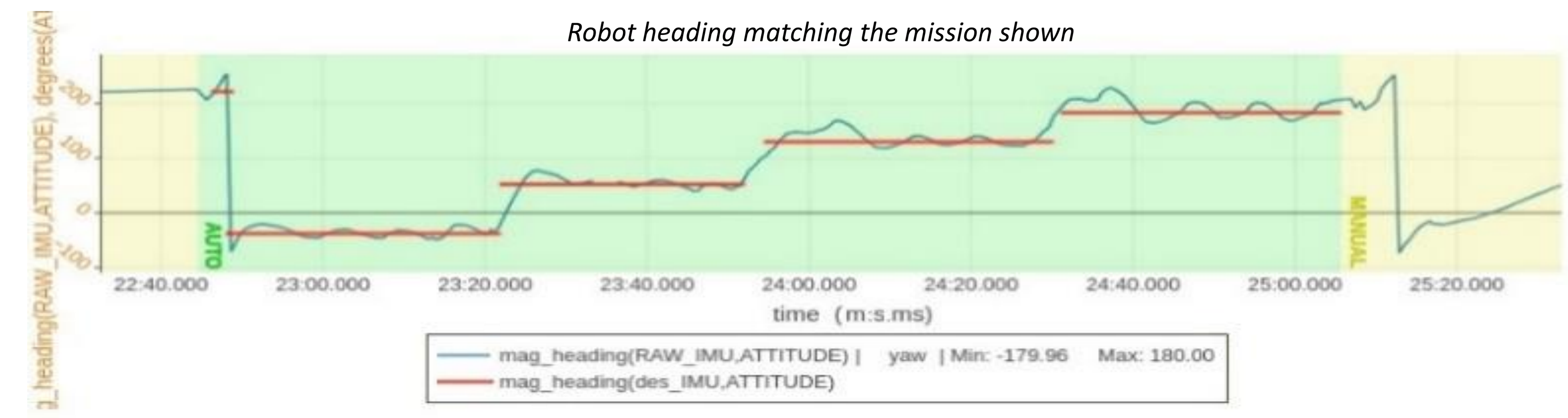
On-board electronics in the first version (left) and second version (right)



Screenshot captured on the control station during the execution of a mission

An early example of a trajectory before (left) and after (right) PID parameter tuning

Robot heading matching the mission shown



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Considerations and future developments

The aim was to develop an ASV with a very low price (<5K euro), comparable with much more expensive commercial similar items.
The system is easily expandable and customizable. The obstacle-avoidance system using cameras and neural networks is under development.

Financial

The robot project started thanks to the LAHKE (LAke Heritage Knowledge and Exploration) project, 'DTC second phase' call with funds from the POR FESR (European Regional Development Funds) Lazio 2014 - 2020. It is currently being developed through a three-year ENEA research project

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