Optical Microplastic Sensor based on Artificial *Intelligence Models*

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The microplastic (MP) sensor is a standalone, benchtop device, autonomously operating optical apparatus meticulously designed for the systematic examination of water samples in a continuous flow. Its primary function is the precise identification of microscopically sized polymer particles (MPs), while concurrently discerning them from other naturally occurring particles within the scrutinized water sample.

The imaging component features a commercial microscope objective and high-speed digital camera, ensuring sharp image acquisition across the MP size spectrum (from 0.5 to 5mm). UV and visible light enhance detection capabilities by facilitating differentiation of MPs from organic materials through fluorescence signatures. The sensor employs a pump to draw water from an external source, creating a continuous flow that passes through the various sections of the optical detection system to detect particles. The water inlet can take water from any source (either a container in a laboratory or water from the sea surface in a real-world environment), although it may be necessary to add an auxiliary pumping system if the built-in pump cannot exert the required pressure to draw water from a particular surface. Once processed, the fluid can be returned to the source if the sensor is in a real environment, keeping the water intact during the analysis.

An embedded electronic system oversees the control of the entire sensor, managing the water inlet, capturing images after a particle detection, and controlling the lighting system to take clear images that can be further processed to facilitate the identification of MPs. There is also an integrated computer that stores and processes the captured images by using AI algorithms and distinguishes MPs from the rest of the detected particles. When the computer receives an image with a particle, it runs several previously trained algorithms, and if the detection is successful, the system stores the image, highlighting the identified particle, and the image metadata in the cloud. End users can visualize each detection in real time and use the stored data afterwards.

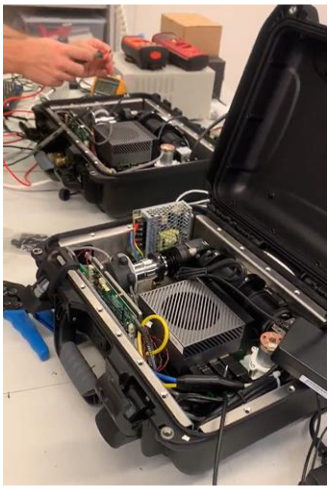

Figure 1. Microplastic sensors during its assembling at Leitat laboratory.

All components are housed and mechanically fixed in an IP67 suitcase to ensure proper particle detection by optimizing the visualization of the water flow with the optical system. The suitcase also protects all the components from hazardous environments and the exposure to extreme meteorological phenomena when the sensor is used in a marine environment, avoiding water inlets that could corrode or wear out the system, and guaranteeing the operation for long periods without the need for continuous revisions or maintenance procedures.

The sensor has been tested at laboratory level, demonstrating that can effectively detect particles passing through the detection area, achieving a detection efficiency of approximately 85-90% for particles larger than the minimum detectable size (250 µm). As part of the Iliad H2020 project (Grant Agreement: 101037643), the sensor has been deployed in two real-world environments: initially, for a month in the Trondheim Fjord (Norway), and secondly, after implementing the required improvements according to the first deployment, at the PLOCAN laboratory in Gran Canaria, Spain, but results are expected for the next months.

The MP sensor, when integrated into a digital twin, is intended not only to measure the quantity of MPs in a specific environment under typical conditions, but also to assess how this quantity might fluctuate over time or in response to factors that could lead to significant increases or decreases of MPs. For example, the sensor could be deployed in a marine environment, such as those at the described testing sites, to monitor whether MP levels vary due to rough weather, shifts in wind, the passage of maritime vessels, or other phenomena that might influence water pollution.

The integration of the sensor in any testing environment is easy to achieve, as it only requires an inlet and an outlet for water, an internet connection, and access to the power grid. Once integrated, linking it to a digital twin is also simple, since there is a web application where all data generated by the sensor is sent, stored, and made available to users. Therefore, using the data generated in any digital twin simply requires some adjustments to adapt the sensor to the specific case and establish a communication system to collect the data stored in the cloud, that is protected to guarantee data privacy and only granted end users can access to get information. All of this makes it easy to compare data from different installations, as they will always have similar structures, ensuring interoperability between any digital twins using the same type of MP sensor simultaneously.

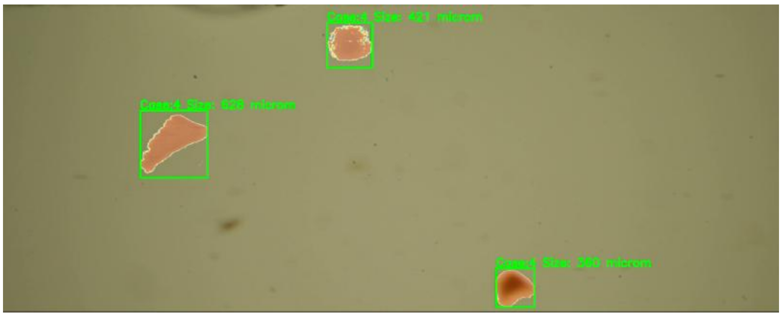

Figure 2. Resulting image of the identification process with AI algorithm. The sensor detects MP and the processing system encloses it in a box and posts the image in the dashboard for visualization along with additional data (timestamp and categorization).

The proposed demonstration consists of operating a complete sensor by simulating its use in a real scenario, although the water will be circulated in a closed loop with a specific concentration of MPs. There will also be a mobile device so that attendants can visualize the web application and all data collected by the sensor, including the detected particles (MPs, water effects, and others) and several graphs to summarize various statistics about the detection during the operation of the sensor.

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