Real-Time Microplastics Detection via AUV Sampling Under Variable Flow Rates in the Ocean

Design a Promising Microplastic Detector for Mounting on Autonomous Underwater Vehicles (AUV)

Design a microplastic sensor that can potentially be used to explore AUV

The Explorer AUV, with a 5.3 m length and 0.69 m diameter, can dive deepest to 3000 m under the ocean. The speed range of Explorer is from 0.5 m/s to 2.5 m/s

Figure 1. Explorer AUV Adapted from [1]

[1] Memorial University of Newfoundland. (n.d.). Large AUV Explorer. Retrieved October 11, 2024, from https://www.mun.ca/creait/autonomous-ocean-systems-centre/large-auv-explorer/

Current Exist Technology

Li et al. [1] developed a method using a polarization camera to intelligently detect microplastics in flow rates ranging from 2 ml/min to 15 ml/min with good performance. However, the flow rate is too slow compared with the cruising speed of AUV, which is 1.5 m/s (4,050 ml/min with an inside cross-section of 5mm x 9mm). The team plans to build the same laboratory environment by applying extra machine-learning algorithms and improving the detection speed to match the AUV cruising speed.

[2] Li, Y., Zhu, Y., Huang, J. et al. High-throughput microplastic assessment using polarization holographic imaging. Sci Rep 14, 2355 (2024). https://doi.org/10.1038/s41598-024-52762-5

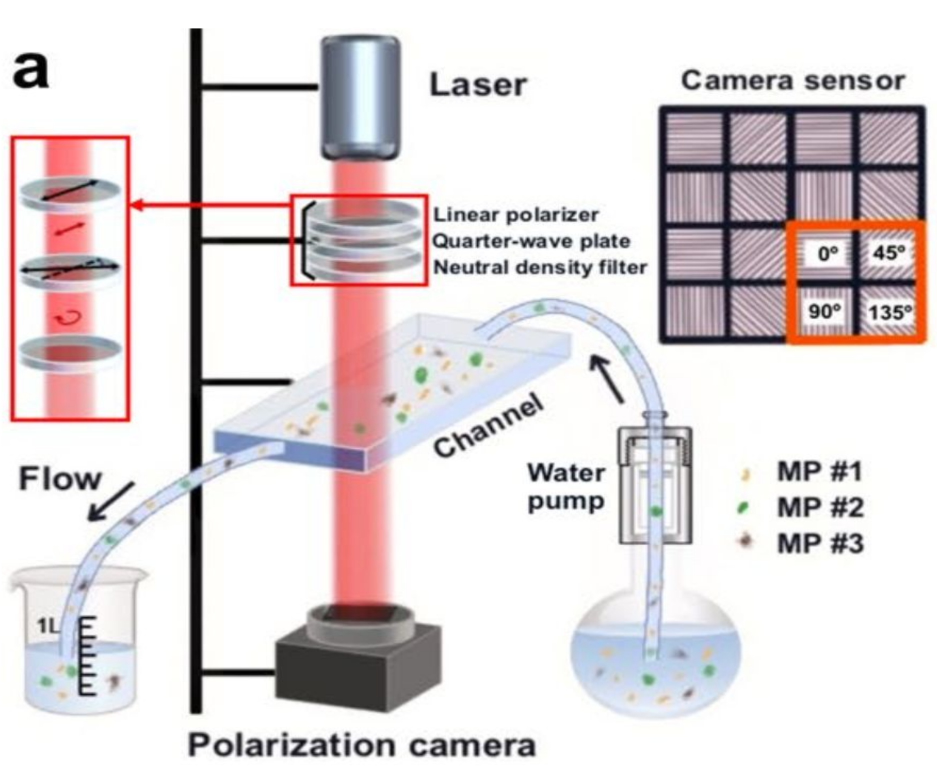

Figure 2. The layout of the polarization holographic imaging system [2]

Abstract

An abundance of plastic waste enters the ocean, where it undergoes fragmentation into particles smaller than 5 mm, known as microplastics. They are tiny and ubiquitous in ecosystems, even in the bodies of creatures. Due to their porous structure and difficulty degrading, they might contain harmful bacteria and hurt the ecosystem and the lives on the earth in the long run (Context). Löder et al. (2015) proposed a rapid and robust method for detecting enriched microplastic from environmental samples through Function Point Analysis based on a Fourier-Transform infrared (FTIR) spectroscopy system for the first time. But it is labour and time-consuming. Li et al. (2024) developed a method using a polarization camera to intelligently detect microplastics in flow rates ranging from 2 ml/min to 15 ml/min with good performance. However, the flow rate is too slow (Problem). No existing microplastic detector sensor can be used on Autonomous Underwater Vehicles (AUV) to help researchers monitor microplastic in the ocean (Knowledge Gap). The AUV cruising speed is 1.5 m/s, and the program will try to match this speed as closely as possible to detect 0.5 mm - 3 mm microplastic in a lab environment.

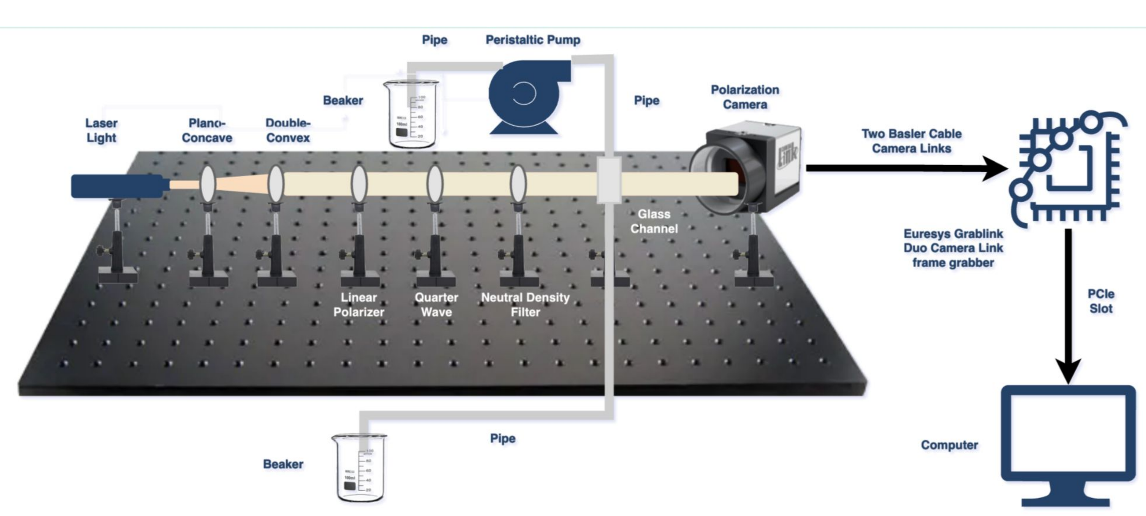

Figure 3. Layout of the Microplastic Detector

The potential microplastic detector (shown in Figure 3) preparation and mounting on AUV uses a machine learning algorithm to detect high-speed MP. The research team will compact the design and make it promising to be used on AUV (Conceptual Framework). This research aims to design a microplastic sensor that can detect MPs in the real time at lab environment using AUV sampling (Purpose Statement).

Research Objectives

The primary aim of this study is to explore the capabilities of autonomous underwater vehicles (AUVs), assess existing methodologies for microplastics (MPs) detection, identify an effective detection strategy for microplastics, and test it at varying flow rates. Several specific objectives support this overarching goal:

1. Select a microplastic sensing system in a laboratory environment capable of analyzing and delivering immediate results.
2. To set up a microplastic sensing system in a laboratory environment capable of analyzing and delivering immediate results.
3. Data will be collected using the existing laboratory setup.

Below shows the images captured by polarization camera:

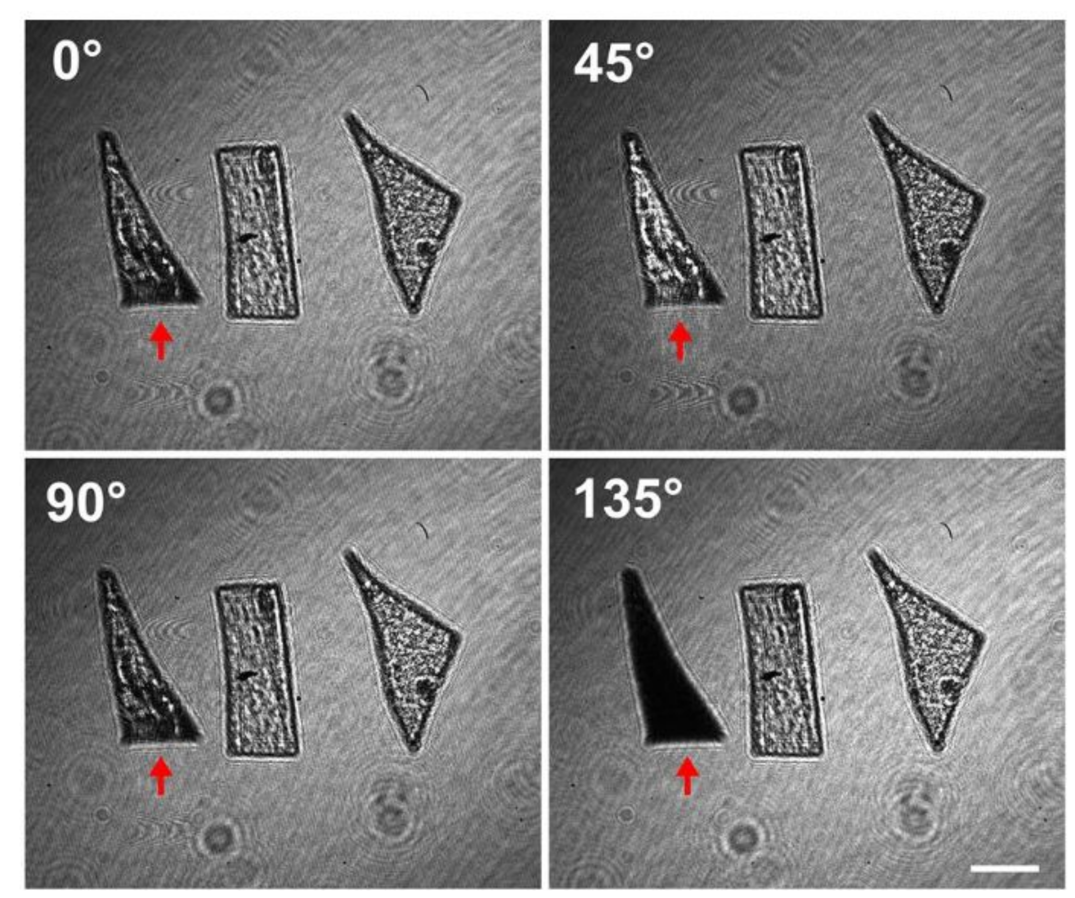

Figure 4. Representative polarized digital holograms of MPs at four angles [2]

4. To develop machine learning (ML) algorithms specifically designed to detect microplastics efficiently and to test them in varying flow rates of mixed fluids, such as seawater combined with microplastics. And find the high-speed flow rate that allows for effective MP detection with high performance.
5. To test the laboratory setup and algorithms using purchased microplastics and analyze the resulting data.
6. Analyze data samples from an autonomous underwater vehicle (AUV) with baby legs.

Background

Plastic garbage enters the ocean and slowly breaks into plastic particles, which are not all easily visible. The particles with a diameter of less than 5mm and greater than 0.1 μm are called microplastics. Microplastic pollution has become a particularly significant threat to marine life and ecosystems due to resistance to natural degradation processes. It contains toxic chemicals, including phthalates and bisphenol. The diminutive size allows them to enter the bodies of ocean life, wreaking havoc on the delicate balance of marine ecosystems. In aquatic environments, various sources, including tiny plastic beads (less than one millimetre-sized particles found in makeup and cleaning products) and degraded plastic debris, are major microplastic contaminants. Identifying and quantifying the microplastic for protecting the ocean environment is imperative.

Research Question

1. Which methods and strategies currently exist for spotting microplastics underwater?

2. Which microplastic sensors are most suitable for detecting underwater microplastics, and what are their main advantages and drawbacks?

3. What are the deployment methods for a Machine Learning algorithm designed for microplastic detection in a laboratory environment, and which algorithm is best suited to achieve high accuracy in identifying microplastics at high flow rates? what measures should be taken to ensure the comprehensive testing and validation of the newly developed system?

Team

Supervisors:
Dr. Neil Bose | Dr. Jimin Hwang | Dr. Ting Zou
Faculty of Engineering and Applied Science
Memorial University of Newfoundland
St John's, NL, A1c 5S7

PhD Candidate:
Qian Zhong
Faculty of Engineering and Applied Science
Ocean and Naval Architectural Engineering
Email: qzhong@mun.ca

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