In Situ Microplastic Detection Using Holographic Imaging and AI on an Autonomous Bionic Sea Turtle

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Marine ecosystems are paramount to the planet's health, but they are threatened by human-introduced pollutants. In particular, microplastics have proven to be detrimental to aquatic wildlife, with scientists detecting their presence in 90% of species. Accurately quantifying microplastic contamination is essential to successful recovery initiatives. However, conventional methods are limited in analyzing large geographical regions; they require bulky, costly, and complex equipment, considerably limiting the frequency of assessments. This project details the development of a compact, submersible holographic imaging device to conduct in situ detection of microplastics on an autonomous bionic robot. Digital holography facilitates high-detail, large depth-of-field particle imagery through an extensive sampling volume without complicated refocusing optics. Using optical simulations and component optimization, an ultracompact device with an imaging resolution of <10 um was constructed. Numerical algorithms were implemented, enabling accurate image reconstruction and the extraction of key particle features. To identify microplastics, custom-trained AI models were developed using PS, PE, and PET microplastic reference samples, resulting in 94% detection accuracy. The device was integrated onto a novel biomimetic sea turtle robot to demonstrate feasibility of true in situ monitoring. CFD simulations and pool testing confirmed optimal swimming kinematics. Performance was evaluated across 15 field trials at 10 bodies of water, yielding statistics on particle size and concentration. Microplastics and various microorganisms were identified, demonstrating the system's efficacy as an innovative, low-cost platform for robust in situ microcontaminant tracking in fragile marine ecosystems.

Awards Won:

First Award of $6,000

Gordon Moore

International Council on Systems Engineering - INCOSE: Certificate of Honorable Mention, a 1-year free student membership to the INCOSE, and free virtual admission to the 2022 International Symposium of the INCOSE

Midjourney: Eight awards of $2,500