Identifying Microbiome's Health in Marine Environments from Data Collected via a Real-time Opto-fluidics Monitoring system

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IDEAS TO IMPACT

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Motivation

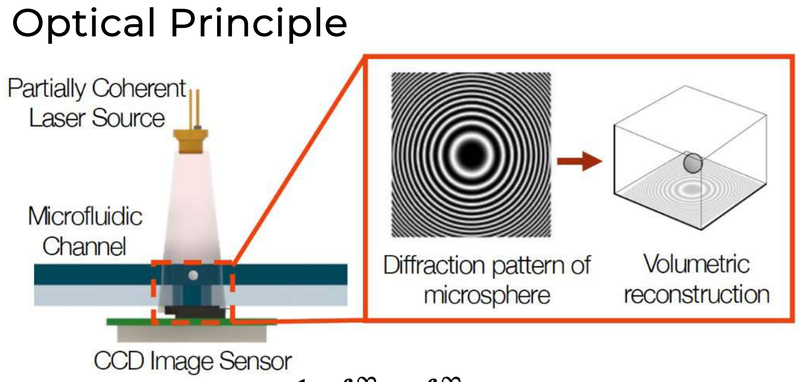
The marine microbial community plays a vital role in global nutrient cycles, the marine food chain, and aquaculture production [1]. Monitoring and studying the dynamic patterns and interactions of these microbial communities can provide insights into their impact, safeguard natural resources and the environment, and promote sustainable aquaculture production [2, 3]. The objective of our MIT-Portugal collaborative project is to develop a real-time marine microbiome monitoring system for continuous deployment in aquaculture farms. This system will **monitor the demographics and dynamics of microbiome populations, which are critical indicators of the health and resilience of marine ecosystems.**

Fig. 1 Scripps institute A. taxiformis cultivation farm. Common biological contaminations in A. taxiformis cultivation: (a) clean A. taxiformis; (b) green algae; (c) diatom.

Methodology

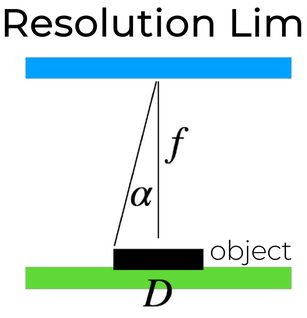
- in-situ digital in-line holographic microscopes (DIHM) for monitoring microbiome
- environmental sensors (temperature, salinity, pressure, optical)
- collaboration with marine microbiologist for detection of developing diseases

Optical Principle



$$C(K_x, K_y) = \frac{1}{4\pi^2}\int_{\infty}^{\infty} dx \int_{\infty}^{\infty} dy\ f(x,y)\ e^{-iK*r(x,y)}$$

Resolution Limit

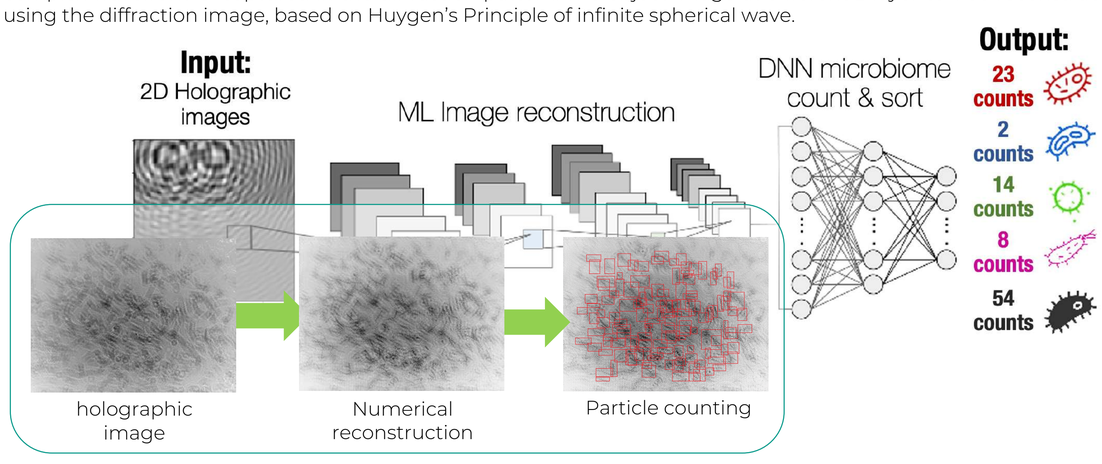


$$d_{min} = 0.61\lambda/NA \quad \lambda = 635nm$$

$$d_{min} = 0.61 * (635nm)/0.244$$

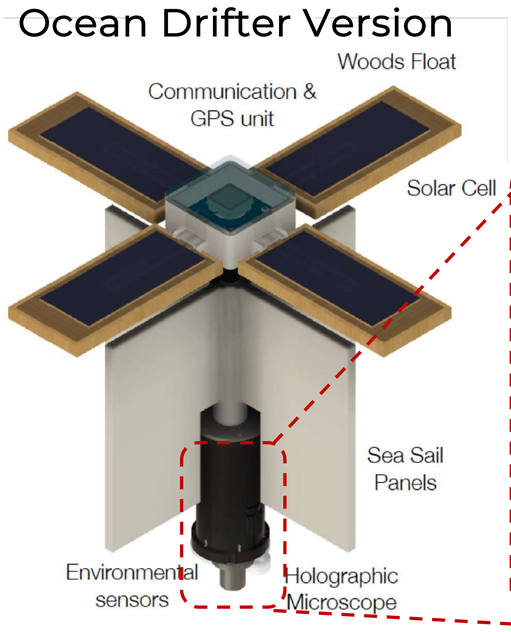
$$d_{min} = 1.935um$$

Fig 2. Schematic of DIHM. Coherent light illuminates an object and forms a highly magnified diffraction pattern captured by the image sensor. The 2D intensity image records the whole information of the 3D scene. The object's complex wavefront is captured in the diffraction pattern. The object image at different z-layer can be reconstruction using the diffraction image, based on Huygen's Principle of infinite spherical wave.



Design & Result

Ocean Drifter Version



Single Board Computer
Uninterruptable Power Supply
Rechargeable Batteries
Cellular & GPS Modem

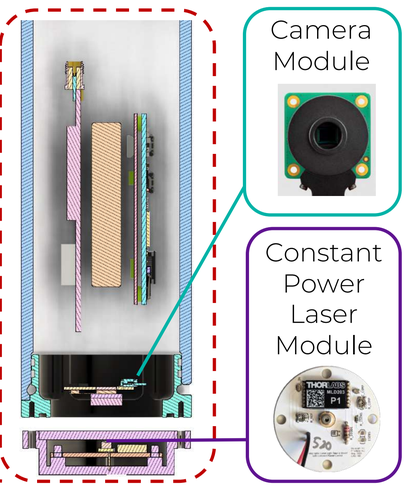
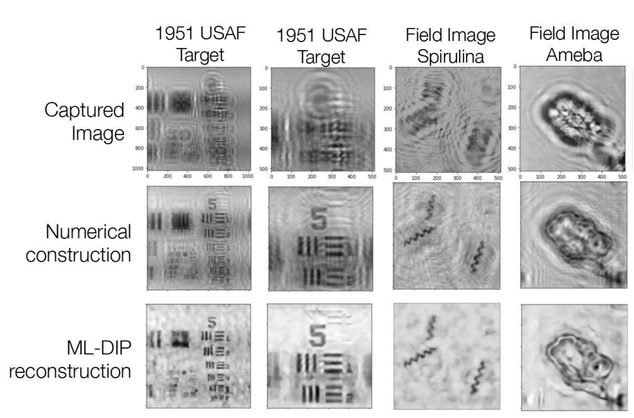


Fig 3 - Schematic of monitoring device, cylindrical pressure housing contains batteries and sensor module. Solar cells are attached to the wooden floats for recharging. Cellular communication and GPS units are positioned above the water line.

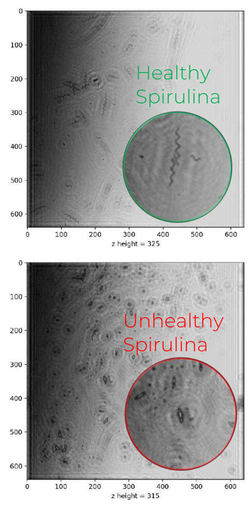
Fig 4. Prototype of underwater digital holographic microscope

Microbiomes can quickly adapt to the earliest signs of harmful pathogens and climate changes, and thus monitoring them allows farmers to quickly react before harmful pathogens spread further. For instance, **real-time microbiome monitoring can detect the onset of harmful algal blooms, which can contaminate coastal waters and kill fish, mammals, and birds.** Thus, our novel monitoring system has the potential to contribute to the modeling and understanding of the marine microbiome and the overall health of our planet.

Testing & Deployment



ML-DIP reiterative reconstruction method recovers the amplitude and phase information and suppresses the twin image and noise artifact. Resolution of 7.8um is achieved with the imaging system, reducing reconstruction computation resources and improving speed.



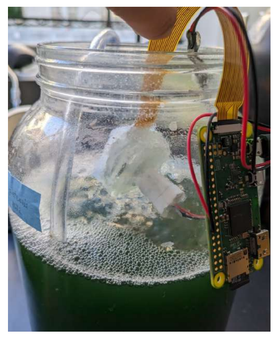


Fig 5. Lab testing of holographic microscope inside a spirulina cultivation jar. Temperature were varied during the experiment to see the change of spirulina morphology

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References:

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