Autonomous Underwater Vehicle (AUV) for Real-Time 3D Microplastic Concentration and Toxicity Mapping via Deep Learning and Integrated Microscopy

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Microplastics have a devastating effect on global ecosystems, however, conventional monitoring methods are expensive, inefficient, and cumbersome requiring week-long laboratory analyses, which may lack the ability to capture three-dimensional spatial data. This study presents a novel, low-cost autonomous underwater vehicle(AUV) for real time 3D visualization of microplastic concentration and toxicity.Designed using Fusion 360, the proposed AUV is highly hydrodynamic, and comprises a Raspberry Pi-control system, an autonomous imaging system, and a specialized multi-layer filtration unit. The AUV is equipped with a microscopic camera capable of two-dimensional movement, while capturing high-resolution images of the filtered samples at varying depths of 1-30m to enable real time visualization. The machine learning architecture integrates a YOLO v8 model for real-time particle detection and a residual CNN for polymer identification. A Random Forest model filters environmental noise, while a custom toxicity algorithm interpolates the data into 3D heatmaps.Seawater expeditions covering areas of approximately 1km demonstrated that the AUV successfully mapped high toxicity voxels near the surface due to buoyancy effects. The proposed system achieved a 98% reduction in analysis time compared to traditional methods and cut deployment costs by 96%, from approximately $7,500 to $300 per deployment, while maintaining an accuracy of 85-90%. By eliminating the need for specialized laboratory facilities, this technology enables autonomous water quality monitoring in resource-limited regions and aquaculture environments. The proposed AUV provides a scalable, and inexpensive solution for achieving global SDG targets through advanced robotics and machine learning.

Awards Won:
Second Award of $2,400
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King Abdulaziz &amp
his Companions Foundation for Giftedness and Creativity: Mawhiba Universal Enrichment Program awards (and a $200 cash prize)