On-Shore Plastic Waste Detection with YOLOv5 and RGB-Near-Infrared Fusion: A State-of-the-Art Solution for Accurate and Efficient Environmental Monitoring

ABSTRACT

: Plastic waste is a growing environmental concern that poses a significant threat to onshore ecosystems, human health, and wildlife. The accumulation of plastic waste in oceans has reached a staggering estimate of over eight million tons annually, leading to hazardous outcomes in marine life and the food chain. Plastic waste is prevalent in urban areas, posing risks to animals that may ingest it or become entangled in it, and negatively impacting the economy and tourism industry. Effective plastic waste management requires a comprehensive approach that includes reducing consumption, promoting recycling, and developing innovative technologies such as automated plastic detection systems. The development of accurate and efficient plastic detection methods is therefore essential for effective waste management. To address this challenge, machine learning techniques such as the YOLOv5 model have emerged as promising tools for developing automated plastic detection systems. Furthermore, there is a need to study both visible light (RGB) and near-infrared (RGNIR) as part of plastic waste detection due to the unique properties of plastic waste in different environmental settings. To this end, two plastic waste datasets, comprising RGB and RGNIR images, were utilized to train the proposed model, YOLOv5m. The performance of the model was then evaluated using a 10-fold cross-validation method on both datasets. The experiment was extended by adding background images into the training dataset to reduce false positives. An additional experiment was carried out to fuse both the RGB and RGNIR datasets. A performance-metric score called the Weighted Metric Score (WMS) was proposed, where the WMS equaled the sum of the mean average precision at the intersection over union (IoU) threshold of 0.5 (mAP@0.5) × 0.1 and the mean average precision averaged over different IoU thresholds ranging from 0.5 to 0.95 (mAP@0.5:0.95) × 0.9. In addition, a 10-fold cross-validation procedure was implemented. Based on the results, the proposed model achieved the best performance using the fusion of the RGB and RGNIR datasets when evaluated on the testing dataset with a mean of mAP@0.5, mAP@0.5:0.95, and a WMS of 92.96% ± 2.63%, 69.47% ± 3.11%, and 71.82% ± 3.04%, respectively. These findings indicate that utilizing both normal visible light and the near-infrared spectrum as feature representations in machine learning could lead to improved performance in plastic waste detection. This opens new opportunities in the development of automated plastic detection systems for use in fields such as automation, environmental management, and resource management.