Deeplearning Based Mobile App for Image Capture and Microplastic Analysis in Water Systems

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DOI: 10.29322/IJSRP.15.02.2025.p15819
https://dx.doi.org/10.29322/IJSRP.15.02.2025.p15819

Paper Received Date: 10th January 2025
Paper Acceptance Date: 12th February 2025
Paper Publication Date: 16th February 2025

Abstract- The widespread presence of micro-plastics in waterbodies lead to great impact on aquatic organisms and our ecosystem. Now a days, water pollution is increasing day by day through human inference. So we need to reduce it by employing some techniques. Traditional methods to detect the micro- plastics are time consuming, labor intensive and limited in accuracy. Recent advancements in deep learning provides promising solutions to automate and enhance the detection and classification of micro- plastics. This study proposes the deep learning models (different types of CNN) such as U-Net or ResNet-50 or Faster R-CNN to recognize the micro-plastic content in different waterbodies. Here the proposed model utilizes a mobile camera to capture the images or upload any images to identify the micro-plastics based on chemical composition. These models are trained with the dataset (micro-plastic dataset for computer vision) ensures robustness in distinguishing micro-plastics from other particles. U-Net provides the best accuracy compare with other models.

Index Terms- Image capture, Micro-plastics, Detection, Deep learning models

I. Introduction

Micro-plastic particles are the plastic particles less than 5mm in size. We all know that, water pollution is quiet natural and it has great concern in today's world. Micro-plastics have a great role in water pollution. These micro-plastic particles from various water sources are accumulated in the body of different aquatic organisms and sometimes it indirectly goes to human body as well. So it is dangerous for both aquatic and land species. Water pollution is evolving through this micro-plastic content for some extent.

The present techniques for micro-plastic detection requires sophisticated laboratory setups for manual sampling, spectroscopy, filtration etc. Some applications like Sea Glass, Marine debris tracker and some other environment sensing applications are prevalent in this field. These traditional methods are labor intensive and rely heavily on specialized equipments. Only researchers, environment analysts and those particular individuals can access those applications as well as the methods. It consumes more time, so affects the latency and scalability of the system. There is a chance for quality issues which often leads to inaccurate predictions or analysis.

To overcome the downsides of current techniques, an innovative solution is obligatory for forthcoming generation. This study emphasizes the micro-plastic identification and analysis from distinct water systems and predict the quality of water, if it is contaminated or not. It steers to create a mobile application which leverages different deep learning techniques to detect the micro- plastic content with the help of a mobile camera as an IoT device. The images captured by the camera be then processed by deep learning models to detect and quantify the presence of micro-plastics in a real time manner. Latest deep learning models provide enhanced accuracy and easy identification. This approach not only enhance the scalability and accuracy but also fosters a great sense of responsibility and awareness about water pollution among the society.

II. Literature Review

The system uses an AI driven camera system to identify the micro-plastic particles in water samples to save aquatic animals. It uses convolutional neural networks to analyze the micro-plastic content in water systems through a real time camera [1]. The captured image undergone preprocessing techniques for effective monitoring. CNN classify and quantify the micro-plastic particles based on visual characteristics. It emphasizes real time data collection, quick identification and detection. It aims to enhance environmental monitoring capabilities help researchers or analysts to introduce a new tool for efficient prediction and reduce micro-plastic content.

Micro-plastic pollution is evolving, so novel identification and analysis is essential to mitigate this issue. The study employs IoT driven image capture system using CNN (Convolutional Neural Networks), which is very popular to detect the micro-plastic content from water samples through real time analysis [2]. The captured high resolution images gone through preprocessing to enhance the clarity and remove background noise. The CNN works based on the features like size, shape etc. The CNN model is trained and validated using large datasets for micro- plastic detection. It reduces latency and improves the systems

responsibility. The paper also implemented a user friendly interface to access real time monitoring results to stake holders.
This paper introduces a sophisticated methodology for detecting and categorizing micro-plastics using deep learning techniques. Uses Convolutional neural networks to analyze images through optical microscopy [3]. Image quality enhanced by preprocessing, followed by segmentation techniques. It isolate micro-plastic particles from the background for accurate analysis. To train the CNN, it uses a large diverse datasets of labelled micro-plastic images. Then tested and validated using separate dataset to improve the robustness and accuracy for counting and classifying the micro-plastic particles based on its characteristics such as its shape and size etc. It also specifies the findings for environmental monitoring and how automated approach improve the efficiency and accuracy of the micro-plastic detection through effective strategies for balancing plastic pollution in aquatic ecosystem.

The paper designed an innovative framework to automate the detection and classification of micro-plastic particles [4]. Utilizes high resolution image technologies like optical microscopy and captures the quality images of micro-plastics with details to enhance the detection process after the preprocessing techniques like filtration and segmentation etc. To enhance the classification accuracy the authors leverages the deep learning model CNN to train the large dataset. The system not only count but also categorize micro-plastic content based on its shape, color and size. The paper also discusses user friendly interface integration which enables researchers and environment mangers to operate the system smoothly and the interpretation of the results. The study aims to facilitate efficient monitoring of micro-plastic pollution with AI-driven methodology leads to environmental sustainability efforts and informed decisions.

The paper 'micro-plastic classification and quantification in water bodies', specifies showcases the innovative methodology for identifying and analyzing micro-plastic content in aquatic environments [5]. The author uses a combination of image processing techniques and machine learning algorithms to create a robust solution for micro-plastic detection. Uses a high resolution microscopy to capture particles from different water samples followed by preprocessing techniques for noise reduction and image enhancement to improve the quality of data. Then in the stage of applying classification algorithm, it uses convolutional neural networks for accurate prediction and classification of micro-plastic content based on its shape, color and size. The study emphasizes the importance of quantification along with classification and detailing how the authors implement statistical methods to recognize the concentration of micro-plastic particles. Also envelops a user friendly software which facilitates real time monitoring and reporting of micro-plastic pollution. Combining with ML algorithms, reliability in the case of micro-plastic assessment will be enhanced. Through that the water quality and environment pollution will be managed for some extent.

The paper explores the application of artificial intelligence methodologies for detecting micro-plastic content in various matrices [6]. The authors highlight the machine learning algorithms such as Support Vector Machine, Random Forest and Decision Tree, which are the algorithms use to classify micro-plastic particles based on its physical and chemical features. Also uses Convolutional Neural Networks, that is excellent in processing complex image data to automate the identification and quantification of micro- plastic samples from water, soil and sediment. Emphasizes the importance of data preprocessing and feature extraction techniques to improve the performance. The author specifies how the importance and quality of dataset affects the performance of the system. It explores the integration of real time monitoring with AI for on spot detection in data collection and analysis.

The authors systematically review existing studies to assess how deep learning algorithms like CNN, RNN. and DNN used [7]. Micro-plastics are detected using some existing methods like FTIR, k-NN, SVM and RDF etc. By analyzing the strengths and limitations of these approaches, the paper highlights the potential of deep learning mechanisms to enhance the efficiency of micro-plastic monitoring in a real time manner. This specifies the effective identification of micro-plastics in open sewer systems. The author implies detection capabilities improve the waste management practices and reduces the water pollution. The systematic review aims for effective monitoring strategies which helps public health initiatives and environmental sustainability efforts.

The aim is to develop a robust and innovative method for detecting and identifying micro- plastics in water systems using deep learning models. The author uses Adversial Networks and Generative Adversial Networks to improve the accuracy regarding identification, sometimes it is difficult because of transparency, size and diversity of shapes [8].The model uses a combination of generative and discriminative components. The generator creates synthetic images from various water forms and the discriminator evaluates the images, whether it is real or not. The adversial training process improves the model ability to differentiate between micro- plastics and other substances from water. It leads to better identification and classification accuracy. GAN especially used for image processing are computational intensive. So it requires significant processing power and memory. This limits the practical deployment in some cases. The model's heavily rely on the quality of dataset always, which leads to performance. Chances for overfitting of data. Realtime implementation is challenging often. Domain expertisation is very important while working with these models otherwise leads to collapse of this model. It provides improved accuracy through adversial networks. Automated and scalable detection, adaptability to various environments, data augmentation and potential for real time monitoring are the advantages of this system.

Here, It evaluates the presence of micro- plastics and quality of available data in fresh water bodies and water sources[9]. Highlights the methodologies to detect micro-plastics and the potential risks to pose human health and environment. The paper discusses the sources, distribution and fate of micro- plastics in aquatic systems, focusing on freshwater bodies, rivers, lakes and other drinking water sources. The authors assess data quality and consistency in micro-plastic research. Also points out the challenges for doing the same. It provides a detailed view of sampling methods, analytical techniques and data interpretation. It emphasize how inconsistent methods leads to incomplete data. Deep learning model such as Convolutional Neural Network and Generative Adversial Networks used here. CNN used for image recognition particularly for high resolution images.

Then Recurrent Neural Networks (RNN)/ Long Short Term Memory Networks suits for sequential data rather than spatial features. During continuous monitoring of micro- plastic detection these models provide time series analysis. GAN benefits here for data augmentation, that highlights the paper. Limited labelled datasets make training harder in case of deep learning models. In this case GAN helps for data generation and training robust models.

Also uses auto-encoders, which is a unsupervised model used for anomaly detection. These auto-encoders identify patterns, that is typical for micro-plastic contamination. It helps to distinguish micro- plastic particles from other substances. Data quality, detection accuracy, standardization and reproducibility are the challenges of this paper.

This paper focuses a deep learning approach for automatic detection and classification of micro-plastic particles from environment samples [10]. The proposed system leverages Convolutional Neural Networks to analyze images of micro-plastic samples automatically based on the size ,shape and material properties. The author compares the deep learning approach with the traditional image processing methods for detection and categorization of micro-plastic particles of complex systems. Existing system rely on traditional methods like sampling, manual and automated processes. So its prone to human errors and interference and time consuming as well. But the deep learning model like CNN provides greater efficiency ,scalability and objectivity, but the limitation with the large labelled dataset training is difficult in some cases. The performance of automated system with deep learning technique is more efficient than the traditional in the case of precision and speed.

The paper reviews a comprehensive review of current state of micro-plastic pollution and different strategies for analysis and prevention [11]. It also specifies various analytical techniques like spectroscopy, chromatography and microscopy, which are used to detect and quantify micro-plastics in water samples. This paper mainly focuses on chemical and environmental aspects of micro-plastics, also touches the emerging technologies for efficient detection and quantification with deep learning and machine learning models. Convolutional Neural Network, a promising tool for automating the identification and classification from complex water samples. The deep learning systems compared to traditional methods and the chemical analysis yields high throughput, accuracy, the ability to handle large datasets and the potential to avoid overfitting. The review showcases a multidisciplinary approach integrating with deep learning and analytical techniques with public awareness and regulatory efforts for long term success in managing micro-plastic pollution.

It provides a detailed review of the current state of machine learning techniques used in detection and classification of micro-plastic particles [12]. The authors utilizes both deep learning and machine learning algorithms to check the efficiency of the model. Convolutional Neural Networks(CNN), Support Vector Machine(SVM) and Random Forest have been applied to identify and categorize various plastic particles from environment settings. The model analyze both image and sensor data to classify distinct plastic particles based on its shape, texture and color. Manual sorting, rule based systems like traditional labor intensive methods used and it is less scalable as well. Here the labelled dataset provide better accuracy and classify the plastic particles as PET, HDPE or PVC. The major advantage with deep learning is the ability to automatically extract features. The potential for real time monitoring enables waste management and recycling facilities.

It proposes an innovative and cost effective system for monitoring micro-plastic pollution in fresh water environments. This system integrates Internet Of Things with deep learning techniques specifically for instance segmentation to automate the detection, classification and quantification [13]. Instance segmentation, a computer vision technique that combines object detection with pixel level segmentation which is used to identify micro-plastic particles with images captured by low cost cameras integrated with IoT sensors. IoT devices such as low cost sensors and cameras are using to monitor the particles in real-time. This system is advantageous because of its affordability, scalability and real time monitoring capabilities. Data processing is highly challenging due to high variability in water conditions. Extensive training for deep learning models and limitations in sensor sensitivity are the other downs of this system.

In this study, it captures high resolution images of water samples followed by data preprocessing to enhance the quality of the image[14].The deep learning model, Convolutional Neural Network(CNN) employed to detect and distinguish the image based on texture, shape and color of the particles. The hybrid approach enhance the accuracy compared to conventional methods. The main advantage of the system is the ability to handle large volumes of water samples quickly and automatically.

It proposes a deep learning approach for automatic detection of micro plastic in water systems. This study employs Convolutional Neural Networks for image classification and segmentation tasks [15], mainly designed to analyze images of water samples for the identification of particles. The proposed system leverages both supervised and transfer learning techniques to improve the accuracy and generalizability. It uses pre-trained networks like ResNet and VGG network for feature extraction, followed by fine-tuning of dataset with labelled images. Automation is the main advantage of the system, which removes the need for manual inspection. Real time identification and robustness are the other highlights. Also the system integrated with IoT based water monitoring devices for continuous and scalable environmental monitoring. The system relies on high quality labelled dataset, which is the main dis advantage of the system. Poor light conditions, unclear images sometimes leads to misclassification, thus degrade the performance .

PROPOSED SYSTEM.

Water is essential for all living organisms. So water quality has a great role in today’s world.

Here Identify the micro-plastic content from various water samples. It captures the picture of water sample through an mobile camera as an IoT device. Those uploaded or captured images then processed using different deep learning models like Faster R-CNN, YOLO v8, ResNet-50 and U-Net. The well performed model uses for image classification and identification. It provides the real time visual feedback. Thus helps to improve the latency and scalability of the model.

METHODOLOGIES.

Water pollution creates a great impact to our eco system, reducing it for some extent is necessary. Here uses some deep learning models for effective identification of micro- plastic content from water samples. Here uses the micro-plastic dataset for computer vision tasks for better results. It works well with other datasets as well.

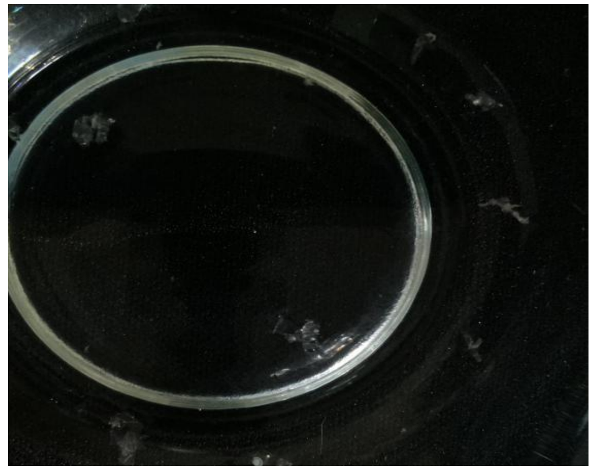
A. PROBLEM STATEMENT AND OBJECTIVE

Micro-plastic pollution is a significant threat to aquatic life, food chains and human health. Traditional methods to detect micro-plastic content are time consuming, labor intensive, relied on specialized equipments and laboratory industries. Real time monitoring is impractical and large scale assessment is not viable in the existing system. Current monitoring techniques user manual sampling and analysis, which results delayed response. An efficient, accessible and scalable solution for real time analysis and cost effective approach is needed to reduce water contamination.

The objective is to develop a mobile application which leverages different deeplearning techniques for real time detection of micro-plastic particles from different aquatic environments. It provides real time analysis and visual feedback. Comparing with the traditional methods, it will be cost effective and efficient monitoring approach. Deployment of deep learning models on mobile device ensures fast, accurate and power efficient performance.

B. IMAGE CAPTURE SYSTEM

Image capture system is the key module of deep learning based mobile application for microplastic analysis in water systems. It allow users to capture high quality images through a user friendly interface, which includes both captured and uploaded images. The system automatically stores all images taken with camera or uploaded. Once an image is captured, it undergoes basic preprocessing to enhance the quality of the image. It makes the image stores and suits for deeplearning analysis . This model emphasize user experience and reliability.



C. IMAGE PRE PROCESSING

The image preprocessing module is essential to enhance the quality and suitability of the captured images before analysis. It performs a series of automated tasks to improve image clarity, consistency such as resizing to a standard format, adjusting brightness and contrast and applying filters to reduce noise. It also includes the techniques like normalization and histogram equalization to boost features relevant for micro-plastic identification. By qualifying images in this way makes deeplearning model analysis more accurate and efficient leads to reliable results.

D. MODULE ANALYSIS OR DEEPLEARNING MODEL ANALYSIS

The analysis module integrates different deeplearning models such as Faster R-CNN, U-Net, ResNet 50 or YOLO v8 to deliver accurate analysis of water samples. Actually, Faster R-CNN and YOLO v8 mainly used for object detection, helps to detect multiple objects efficiently. U-Net architecture commonly used for segmentation tasks, can easily delineate micro-plastic boundaries. The deeplearning model which provides the best accuracy which chooses for micro-plastic detection.

ResNet 50:

ResNet 50(Residual Network with 50 layers) is a deep convolutional neural architecture. It is designed to solve the problem for training very deep neural network. It is also known as Residual connections. It allows for better training and deeper architectures to mitigate the gradient problem. ResNet uses a bottleneck for residual connections. Residual blocks,50 layers, Identify mapping, improved gradient flow, ease of training are the features of ResNet.

U-Net:

This is a deeplearning model mainly used for image segmentation tasks, especially it is used in medical image analysis. U-Net lies in U- shaped architecture. It consists of two parts. Contracting path and expansive path. Contracting path or encoder captures the context and reduce the spatial dimensions of the input image through convolutional and pooling layers. Expansive path or decoder restores the spatial resolution to the original input size by using transposed convolutions and combines the low level features from the encoder.

YOLO v8:

It is the latest version of YOLO (You Look Only Once) family and primarily used for real time object detection. It is deeplearning based object detection model for real time inference and high speed detection. It uses latest advances and optimization techniques. It uses CSPDarknet as the backbone for feature extraction. YOLO adopts FPN (Feature Pyramid Network) and PAN(Path Aggregation Network) as part of neck architecture. Enhanced training strategies and performance improvements are the features of YOLO. Real time inference, high accuracy, flexibility, pre-trained models and cross platform support are the advantages of YOLO.

Faster R-CNN:

Faster R-CNN (Region Based Convolutional Neural Network) is a popular and powerful object detection framework created for identifying and localizing objects in images. It helps to improve the speed and accuracy of the system. It helps to ease feature extraction process, these features then used for object detection. It integrates region proposal generation and object detection into a single network. It supports multi scale object detection.

E. DATA STORAGE MODULE

Data storage module is a vital component for micro-plastic detection. It securely managing and organizing all captured images, analysis results and user data. This module facilitates both local and cloud storage options. Users can access their data while maintaining data integrity and privacy. It stores preprocessed images along with analysis results, which facilitates easy data retrieval and comparison. It improves the functionality of the app by implementing efficient data management practices. It helps to monitor the water samples and changes in water quality

F. ISUALIZATION MODULE

This module is an essential part of deeplearning based mobile app for micro- plastic identification, which is designed to present analysis results in a user friendly and informative way. It converts complex data into more attractive visual representations such as graphs, charts and annotated images etc. It allows users to easily interpret the presence of micro-plastics in water samples. It enables users to track changes in micro- plastic concentration. The visualization module empowers users to make informed decisions and great awareness of water quality issues.

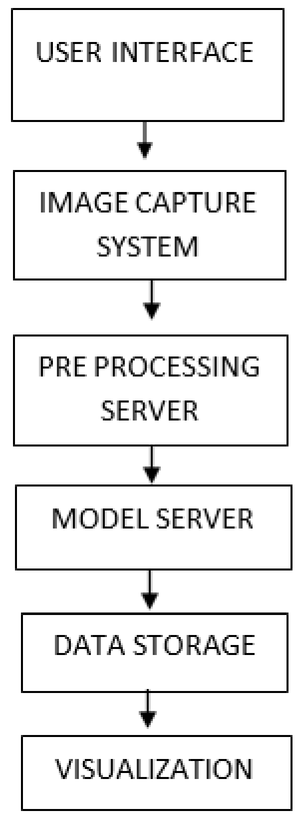


Fig 1:Proposed System Architecture

Here, a user can capture or upload images/pictures through a mobile camera and provides raw data for micro-plastic analysis. Preprocessing server resizes or de-noise and normalizes the images, which enhances the quality for better analysis. Also seperates the micro-plastics from other non micro-plastic particles. The trained deeplearning models detect and classifies micro-plastics based on the size, shape and type. Preprocessed images saved into the model in the data storage module. For high computational tasks like training and model updates, cloud storage will be helpful. Then it will convert to visually attractive form like graph. Visualization module showcases the visual representation of micro-plastic content in various water samples.

RESULT:

The performance of four models –Faster R-CNN,U-Net,ResNet-50 and YOLOv8 were evaluated for object detection, semantic segmentation and classification tasks.

Result Comparison Table

Model	Task	AP (IoU=0.50: 0.95)	AP50	AP75	Validation Loss	Validation Accuracy
Faster R-CNN	Object Detection	30.47%	68.37%	23.37%	-	-
U-Net	Semantic Segmentatio n	-	-	-	0.1161	96.03%
ResNet-50	Classification	-	-	-	0.2091	94.02%
YOLOv8	Object Detection	37.6%	78.4%	32.1%	-	-

The models were evaluated using accuracy, loss and COCO style average precision for bounding boxes and segmentation masks. Faster R-CNN achieved an AP of 30.47% at IoU=0.50:0.95 with better performance for medium(42.47%) and large objects(65.12%) but lower for small ones(13.86%).U-Net excelled in semantic segmentation with 96.03% accuracy and a loss of 0.1161.While ResNet-50 yielded 94.02% accuracy and a loss of 0.2091 for classification. YOLO v8 demonstrated strong performance with an mAP50 of 78.4% and mAP50-95 of 37.6% making it ideal for real time micro-plastic detection due to its speed and precision.

CONCLUSION:

This study demonstrates the potential of integrating advanced technology with environmental monitoring efforts.By using deeplearning algorithms and mobile functionality ,we have developed a user friendly platform that enables real time image capture and identification of microplastic content in aquatic environments. The deeplearning algorithms like Faster R-CNN, U-Net, YOLO v8 and ResNet-50 were implemented and compare the performance of these models in terms of average precision and validation accuracy. U-Net achieves higher accuracy (96.03%) and lower validation loss(0.1161), indicating strong performance in recognizing and segmenting microplastics. U-Net is the more appropriate model for microplastic detection if your focus is on precisely identifying and segmenting microplastics at a pixel level. This project not only addresses the need for effective monitoring but also empowers users ranging from researchers to environment specialists contribute for data collection and awareness. This mobile app provides an adoptable solution in various settings and encouraging environmental conservation.

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