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Rapid Classification of Microplastics by Using the Application of a Convolutional Neural Network

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Abstract **-** The Convolutional Neural Network (CNN), a Deep Learning method, was used for the categorization of microplastics with the goal of automatically classifying the particles into four categories: fragments, pellets, film, and fiber. This has been done by using image dataset taken with a mobile phone after microplastic analyses by density separation, wet digestion and extracting. After the microplastic particles have been isolated, the three models included efficientnet_b7, inception_v3, and mobilenet_v3_large_100_224 are used to classify microplastics. The dataset consists of 1600 images that 70% of the image input are used for training, 20% for validation and 10% for testing. The findings demonstrated that the mobilenet_v3_large_100_224 is capable of classifying microplastic particles with an accuracy of 92.5%, and the network performs well when classifying fiber class. The automatic classification of microplastic particles based on the models provides a powerful tool in for environmental protection to control microplastic particles pollution.

***Keywords*:** Classification; Convolutional Neural Network; efficientnet_b7; inception_v3; mobilenet_v3_large_100_224; microplastics

1. Introduction

The rapidly increasing production of plastics have become one of the most important environmental issues due to their accumulation that can cause the plastic waste pollution and the problems in the environment on natural ecosystems and living organisms [1]. Microplastics (MPs) are plastic particles with a diameter of less than 5 millimeters [2] that have the ability to absorb a variety of pollutants, such as dioxins, polychlorinated biphenyls (PCBs), and other persistent organic pollutants (POPs), and act as carriers of these pollutants to contaminate the environment [3]. The detrimental impacts of microplastics on aquatic species and the bioaccumulation of microplastics through trophic transmission have lately been studied [4]. During the identification process of microplastics, several stages have been involved including density separation, organic digestion, and polymer type characterization by using Raman Spectroscopy [5] and/or Fourier transform infrared spectroscopy (FTIR) [6]. Despite their advantages in determining chemical compositions, these techniques are usually time consuming to detect and count microplastic particles with expensive optical instrumentation and are costly due to the large equipment required [7].

The deep learning technique is a multi-layer neural network designed to recognize visual patterns directly from pixel images with minimal pre-processing. The Convolutional Neural Networks (CNNs) is a deep learning model for image classification with many applications, for example, image classification of floating marine macro-litter [8]. This technique is simple, less time consuming, more efficient, cost-effective and makes classification easier, with less human intervention [7]. The recognition of microplastics in environmental samples is challenging to differentiate microplastic from other particles [9]. However, to the best of our knowledge, none of them were trained or tested to recognize microplastic contamination in the environment for a baseline level and monitoring purpose in Thailand. To tackle this challenge, this study explores the feasibility of deep learning for microplastic morphology to be analysed based on the CNNs to provide a potential solution for evaluating the ecological risks of MPs based on big data. Therefore, the aim of the present study is to use the convolutional neural networks to facilitate microplastic classification based on the four types of morphology of fragments, pellets, film, and fiber of microplastics by using the three models, namely, 1) efficientnet_b7, 2) inception_v3, and 3) mobilenet_v3_large_100_224. These networks were selected based on these networks having been applied successfully for image classification tasks in the previous studies and their classification accuracies [10]. This research can stimulate the research in this area and serve as a baseline for future research work. The results of this study can be used for the planning policy and mitigation measures in terms of environmental quality management and monitoring.

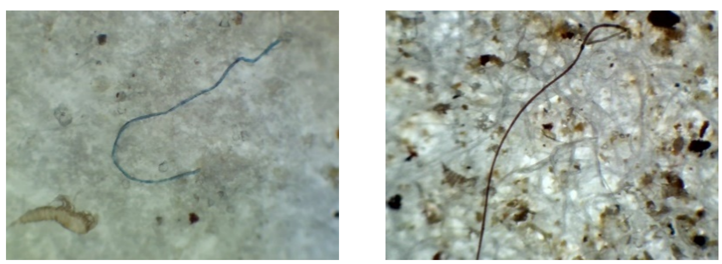
2. Methodology

2.1. Microplastic digestion and analysis

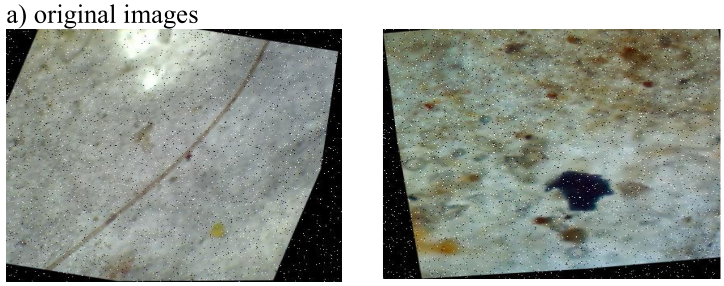
In this study, microplastics collected from the wastewater treatment plant, Phuket Province, Southern Thailand was extracted after several processes such as density separation (NaCl), wet oxidation of organic materials (hydrogen peroxide, H_2O_2), density separation (NaCl), and filtration [2]. Then, microplastics on the filter were examined under a stereomicroscope (7 to 45 times magnification using HumaScope Stereo Trinocular 110-250V/50-60Hz) and images are taken using a digital smartphone camera to take pictures of MPs from the microscope and subjected to convolutional neural networks for MPs classification purpose. In this study, data augmentation for image classification was done as a technique to enhance the quality of the dataset [10] by adding slightly modified copies of the original data to reduce overfitting when training machine learning or deep neural network models [11].

2.2 Data set and Convolutional Neural Network models

The dataset consists of 1600 images of fiber (n = 400), fragment (n = 400), film (n = 400) and pellet (n = 400); and the objects are labelled and performed on these four classes. This category corresponds to the common shapes of microplastic which are abundant in the ecosystem. Examples of microplastics images taken from digital smartphone camera and the augmented images are given in Fig.1.



a) original images



b) transformed images

Fig. 1: Examples of the microplastic images used in this study.

The images were split into training (70%), validation (20%) and testing (10%) images datasets. Once the models have been trained, the accuracy of the trained models then be determined from the testing image data. Three models of CNNs have been presented, namely 1) efficientnet_b7, 2) inception_v3, and 3) mobilenet_v3_large_100_224. The input image size was directly resized from 224 x 224 pixels into the output pixels during the training. The comparison for microplastic classification by using different models were then assessed by using the confusion matrix for each model's testing phase.

3. Results and Discussion

The performance using different models on the full dataset is shown in Table 1. Accuracy of the trained models were then tested using the testing image dataset (10%) which consist of 160 images (40 images of each class). According to the results, the mobilenet_v3_large_100_224 architecture showed the highest testing accuracy with 92.5 percent followed by inception_v3 with an accuracy of 91.25 percent and efficientnet_b7 (90.00%). The models used in this study as an image classification models have been shown to attain greater than 90% accuracy on the dataset.

Table 1: The performance of each model.

Model	**Accuracy**	**Loss**
efficientnet_b7	90.00%	0.27
inception_v3	91.25%	0.24
mobilenet_v3_large_100_224	92.50%	0.21

In order to further analyse the performance of the model, the normalized confusion matrix of the mobilenet_v3_large_100_224 network, the highest accuracy, was done as shown in Table 2. According to the results, the network has good classification performance, especially on fiber class. Alternatively, the fragment class showed a 10% error rate in this class. Due to the effectiveness and speed of the procedure, the automatic classification of microplastic particles based on models offers a powerful tool to address microplastic particle pollution.

Table 2: Confusion Matrix of Mobilenet_v3_large_100_224.

Classes		**Actual**				
		Fiber	Fragment	Pellets	Foam	Total
Predicted	Fiber	**40**	0	0	0	40
	Fragment	0	**36**	2	2	40
	Pellets	0	2	**37**	1	40
	Foam	0	1	1	**38**	40
	Total	40	39	40	41	160

4. Conclusion

This research proposes an automatic methodology for the first time microplastic classification from the digital images through the deep learning techniques based the Convolutional Neural Network in Thailand. The efficientnet_b7, inception_v3, and mobilenet_v3_large_100_224 models have been proposed for microplastic classification into four categories: fragments, pellets, film, and fibers. Comparative analysis has been presented with these models, and from the results, mobilenet_v3_large_100_224 model achieved the highest accuracy with 92.50%. Additional study is required to increase the identification of microplastics and increase the number of training images to improve the model's precision.

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