A Deep Convolutional Neural Network for classifying waste containers as full or not full

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***Abstract*— There is a common understanding that cleanliness is somehow proportional to the economic development of a country. Thus, in order to become clean, a country needs to have an efficient garbage monitoring system. One important component of such a system is garbage collection time because if we delay emptying the bins, the trash ends up to putting public health at risk. This paper is about creating a Deep Convolutional Neural Networks (DCNNs) based model for classifying a waste container as full or not, so that can be later on used by real-time garbage monitoring systems to process images acquired by cameras installed nearby the trash bins or smartphones. To achieve this, we trained and tested different well-known DCNNs architectures, namely, ResNet34, ResNet50, Inception_v4 and DarkNet53. The models were trained and tested using Repeated K-Fold Cross-Validation, running 5-Fold Cross-Validation 6 times. The results have showed that Inception_v4 outperformed the other models, with near-perfect results: PR-AUC = 0.994, F1 = 0.988, Precision = 0.989, Recall = 0.987 and ACC = 0.987. With these results can be said: a high Precision DCNNs based model was built.**

Keywords— Deep Learning, Image Classification, Pattern Recognition, Artificial Neural Networks.

I. INTRODUCTION

Waste has become a major problem around the world due to industrialization, excessive consumption, and lack of effective and efficient waste management. This problem is so serious that poses a threat not only to public health but also impacts negatively to the environment [1]. In underdeveloped countries like Mozambique, where the waste management is poor it is common to see waste containers full for quite a number of days making the place filthy with an unpleasant view and smell, therefore putting surrounding people at risk. So, on-time waste collection response is important and one way to achieve that is to have a real-time alert system that triggers as soon as the container became full. Instrumentation can be one option to choose when implementing such systems. Instrumentation is the delivery of real-world data from sensors (smartphones, ultrasonic sensors, surveillance cameras, RFID detectors, etc.) in real time [2]. Many approaches have been proposed to instrument waste container, for instance, some approaches have used embedded systems combined with ultrasonic and infrared sensors [3] and [4]. The drawback of this approaches is that they require do install sensor on the waste repository, therefore, introducing flexibility risk, cost problems and a high environmental impact [5]. This study presents a different approach which make use of Deep Convolutional Neural Networks (DCNNs) to classify the state of waste container: "Whether they contain enough waste to collect or not," from images taken by citizen's own smartphones or cameras installed near waste container. Effective waste container instrumentation can significantly influence the waste collection process, and a cost-effective solution would be a participatory collaboration with citizens [6] who would use their smartphones to capture images of waste container that would be automatically sent to a server running a prediction model built using DCNNs to classify the state of waste container. However, a question arises: "Can we achieve high Precision in classifying the state of waste container in the outdoor through the use of DCNNs?

This paper is structured as follow: section II Related works, section III methodology, IV Results and Discussion, Conclusion, Acknowledgement and References.

II. RELATED WORKS

Deep Convolutional Neural Networks (DCNNs) are the predominant types of neural networks used to multidimensional signal processing. The term deep refers generally to networks with multiple convolution layers, and deep learning refers to training methodologies of these networks [7].

DCNNs are currently the approach of choice to deal with complex image recognition tasks and other areas including speech recognition, semantic image segmentation and natural language processing [7]. DCNNs architecture consists of: convolutions, activation and pooling. A DCNNs is composed of several stages interconnected in series. The Fig. 1 shows the basic components of a DCNN stage.