Automation of Waste Sorting with Deep Learning

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***Abstract*—The importance of recycling is well known, either for environmental or economic reasons, it is impossible to escape it and the industry demands efficiency. Manual labour and traditional industrial sorting techniques are not capable of keeping up with the objectives demanded by the international community. Solutions based in computer vision techniques have the potential automate part of the waste handling tasks.**

In this paper, we propose a hierarchical deep learning approach for waste detection and classification in food trays. The proposed two-step approach retains the advantages of recent object detectors (as Faster R-CNN) and allows the classification task to be supported in higher resolution bounding boxes. Additionally, we also collect, annotate and make available to the scientific community a new dataset, named Labeled Waste in the Wild, for research and benchmark purposes. In the experimental comparison with standard deep learning approaches, the proposed hierarchical model shows better detection and classification performance.

I. Introduction

> "Action on climate change is urgent. The more we delay, the more we will pay in lives and in money"
>
> Ban Ki-Moon.[1]

We must bear in mind that global warming does not only affect humankind but also wildlife, on a very serious level. Portugal failed to meet the waste policy proposed by the European Commission[2]. The United Nations wants to ensure environmental sustainability by 2030[3]. Such targets can only be possible to achieve through an appropriate application of today's technology. On our daily lives we may forget to separate correctly the waste of our homes, and industrially speaking the companies responsible for this part have to spend a lot on labor.

Using an intelligent object identification software in waste sorting is an advantageous approach when compared to the traditional recycling methods, due to a large number of objects that are identified in a shorter period of time. The traditional approach is based on human goodwill and labor, both prone to fail on waste separation for recycling.

Deep Learning methods are being successfully applied to diverse areas such as autonomous driving, medical imaging, and multiple industrial environments with remarkable results on object detection problems. Applying these methods to waste separation can increase the quantity of recycled material and consequently, provide an easier day-to-day life for the common person. As well as more efficacy for the industry.

In this work we address some of the identified limitations, making two main contributions: a) the proposal of a hierarchical deep model for waste detection and classification; b) a novel dataset is also presented and will be made freely available to the research community for benchmark purposes. This dataset can be used for different purposes such as a study on the types of waste produced by restaurants and the most common type of waste. To our knowledge it will be the first dataset in this field.

An overview of the existent works for classification of waste is addressed in section II followed by the description of Labeled Waste in the Wild dataset in section III. The proposed methodology is explained in section IV with the experimental study with results discussion presented in section V. Finally, conclusions are drawn and future work is outlined in section VI.

II. Related Work

Over the years, different works have been implemented with the aim of minimizing the impact of the uncontrolled disposal of waste. Maher Arebey et al. [4] propose the gray level co-occurrence matrix (GLCM) method for garbage detection and classification, combining advanced communication mechanisations with GLCM to strengthen the waste assembling operation. The proposed system uses several communication technologies including radio frequency identification (RFID), geographical information system (GIS) and general packet radio system (GPRS) integrated with a camera, streamlining the solid waste monitoring and management. The features are obtained from the GLCM and then used as inputs to a multilayer perceptron (MLP) and a K-nearest neighbor (KNN) methods for garbage separation. The results obtained show that the KNN classifier surpasses the MLP.

Sakr et al. [5] try to automatize the waste sorting by applying machine learning algorithms. The authors use two popular methods, deep learning with convolutional neural networks (CNNs) [6] and support vector machines (SVMs) [7]. The results obtained show that SVMs achieved a high classification accuracy of 94.8% while CNNs only achieved 83%.

At the TechCrunch Disrupt Hackathon, a team created AutoTrash [8], an automatic sorting trashcan that sorts garbage based on compost and recycling features. Their system has a rotating top and uses a raspberry pi camera. The team used Google's Tensorflow AI engine and built their own layer on top of it for object recognition.

Mindy Yang et al. [9] performed a comparison study to classify waste between SVMs with scale invariant feature transform (SIFT) [10] and an eleven-layer CNN architecture

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