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Classificação Automatizada: Mapeamento de objetos de coleta seletiva usando inteligência artificial

Automated Sorting:Mapping of selective collection disposal objects using artificial intelligence

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Resumo

Introdução: A inteligência artificial, especialmente na área de visão computacional, tem se destacado como uma ferramenta poderosa para diversas aplicações, incluindo a classificação de objetos. Neste estudo, desenvolvemos uma pesquisa aplicada que utiliza inteligência artificial para detectar e classificar objetos descartados como lixo em duas categorias principais: papel e metal. **Método:** A pesquisa se baseou em uma base de dados contendo cerca de 897 imagens de objetos descartados, sendo 448 imagens de papel e 449 imagens de metal. Utilizamos o modelo YOLOv5 (you only look once) para treinar e testar a detecção e classificação dos objetos. O YOLOv5 é conhecido por apresentar resultados promissores nesse tipo de tarefa. **Resultados:** Os resultados obtidos demonstraram que o modelo YOLOv5 apresentou um desempenho satisfatório na detecção e classificação dos objetos descartados. A precisão média alcançada foi de 0,88. **Conclusão:** O estudo mostra que o uso da inteligência artificial, por meio do modelo YOLOv5, é eficaz para detectar e classificar objetos descartados em categorias de reciclagem, como papel e metal. Essa abordagem pode contribuir significativamente para aprimorar o processo de coleta seletiva e a gestão de resíduos, promovendo práticas mais sustentáveis e conscientes em relação ao meio ambiente.

Palavras-chave: Inteligência Artificial; Lixo reciclável; YOLOv5; Detecção de objetos

Abstract

Introduction: *Artificial intelligence, especially in the field of computer vision, has emerged as a powerful tool for various applications, including object classification. In this study, we developed an applied research that utilizes artificial intelligence to detect and classify discarded objects as waste into two main categories: paper and metal.* ***Method:*** *The research was based on a database containing approximately 897 images of discarded objects, with 448 images of paper and 449 images of metal. We used the YOLOv5 (you only look once) model to train and test the object detection and classification. YOLOv5 is known for providing promising results in this type of task.* ***Results:*** *The obtained results demonstrated that the YOLOv5 model exhibited satisfactory performance in detecting and classifying the discarded objects. The achieved mean average precision was 0.88.* ***Conclusions:*** *The study shows that the use of artificial intelligence, through the YOLOv5 model, is effective in detecting and classifying discarded objects into recycling categories, such as paper and metal. This approach can significantly contribute to improving the selective collection process and waste management, promoting more sustainable and environmentally-conscious practices.*

Keywords: *Artificial Intelligence; Recyclable garbage; YOLOv5; Object detection.*

INTRODUCTION

Recycling is an obligation for all of society since the production of waste continues to grow. Because of the large amount of waste, detecting recyclable materials is a challenging task. The garbage volume has been a major problem worldwide due to uncontrolled disposal of household waste from citizen's home and industries without an effective and efficient waste management program. This issue can result in health risks and a negative impact on the environment (Islam, Arebey, Hannan, & Basri, 2012). Society needs to keep recycling, so it can control trash accumulation and waste of natural resources. It is seen that in many countries, recycling takes an important role, because it helps to develop the economy and urbanization. In order to keep up with the rising amount of waste, new models should be applied with state-of-the-art technology (Lam et al., 2021; Melinte, Travediu, & Dumitriu, 2020; Ozdemir, Ali, Subeshan, & Asmatulu, 2021; Toğaçar, Ergen, & Cömert, 2020). The existence of techniques that help people to sort trash has become essential in the efficient disposal of those materials.

Around the world, the incorrect disposal of garbage has caused several problems. For example, in the Republic of Korea, garbage bags have been adopted for garbage disposal in order to avoid littering on street dumps (Huh, Choi, & Seo, 2021). This inappropriate waste disposal damaged the city's landscape and caused several problems, such as the cleanliness of the city and strong odors. In the United States, recycling in addition to being encouraged by the government, also generates a great benefit for the country's economy. In Europe, interest in recycling and the adoption of waste management measures have intensified since 1994 (Huh et al., 2021). According to the portal of Câmara dos Deputados (2021), only 3% of the almost 80 million tons of waste produced annually in Brazil are recycled. Generally, the garbage collected is separated in sorting sheds and sent to recycling or other companies interested in raw material. The more mixed the waste is, the more expensive and time-consuming the process is.

Our motivation is to investigate a method to efficiently automate waste separation, thus helping to reduce inappropriate waste disposal and pollution. In addition, our research has a great community appeal for adding the value of knowledge and social encouragement in the separation and disposal of waste. So, we developed applied research which investigates the YOLOv5, a Convolutional Neural Network (CNN), to create an automated trash sorting system to classify the garbage waste images into two classes: paper and metal.

The novelty of this work lies in the classification of objects in an image as paper and metal. Furthermore, as a result, the system indicates the percentage of correctness (accuracy) of the classification of objects with their categories (ie, paper and metal). Commercially, this algorithm can help companies that work in selective collection to accelerate the garbage separation process, making it more efficient, cheaper and more accurate.

The content of the paper is organized as follows: Section 2 introduces the related work. Section 3 presents the experimental methodology, which includes the image database used and the models and methods. Section 4 introduces the experimental results. Conclusions are detailed in Section 5.

RELATED WORK

The uncontrolled and inadequate disposal of waste is one of the major problems around the world that can result in health risks and a negative impact on the environment (Islam et al., 2012).

Efficient waste sorting plays an important role in sustainable development. It ensures that the garbage is properly disposed of, resulting in a more efficient recycling process and reducing the environmental impact generated by uncontrolled disposal (Arebey, Hannan, Basri, Begum, & Abdullah, 2011; Glouche, Sinha, & Couderc, 2015).

Over the years, many works have been implemented to minimize the impact of uncontrolled waste disposal. For example, the works that used RFID tags to store data from the bins, such as the address where the bins were collected, the weight of the garbage collected, which garbage was collected, among other applications (Abdoli, 2009; Arebey et al., 2011; Chowdhury & Chowdhury, 2007; Glouche et al., 2015; Parlikad & McFarlane, 2007; Swedberg, 2008). Thomas (2008) discussed the use of RFID tags in waste management and a system of discounts and fees to encourage the population in the selective collection process. Unlike previous works, this one aimed to help the population in the proper disposal of garbage.

Thinking about household waste, some authors have proposed systems that use neural networks to improve the detection and identification of different types of waste (for example, paper, plastic, glass, etc.), aiming at the separation of waste into categories of recycling (Arebey et al., 2011; Costa et al., 2018; Glouche et al., 2015; Melinte et al., 2020; Ozdemir et al., 2021; Toğaçar et al., 2020; Ziouzios, Tsiktsiris, Baras, & Dasygenis, 2020).

Detecting specific trash among some garbage is crucial for the correct sort of waste. Costa et al. (2018) proposed an automated system based on a deep learning approach to separate waste into recycling categories. Authors found that the VGG-16 method is an efficient approach for this problem, reaching 93% of accuracy in its best scenario.

Selective collection carried out in a controlled manner reduces pollution environment and the waste of natural resources (the objective of the selective collection is to reduce the volume of garbage, no matter how much), in addition to the economic benefits (such as job creation, mainly through cooperatives.

Released on June 10th 2020, YOLO v5 is a state-of-the-art real-time object detection that uses a Fully Convolutional Neural Network (FCNN). Karthi, Muthulakshmi, Priscilla, Praveen, e Vanisri (2021) explain that YOLO v5 is simpler than its previous versions, for instance, a weights file for YOLOv5 is 27 megabytes while for YOLOv4 is 244 megabytes. That is because in its older versions, YOLO was based on PJ Reddie's Darknet, but the 5th version is based on PyTorch. Darknet is more oriented to research, so its community is smaller and not so production-ready, moreover PyTorch has an easier deployment and it can be compiled in ONNX and CoreML, so deployed in mobile devices.

YOLO is a convolutional neural network (CNN) used to detect objects in real time obtaining results with great precision. It uses a single neural network to process the entire image, then separates it into parts and calculates probabilities for each component. A CNN is a class of neural networks that have been used in different computer vision tasks. It is composed of convolution layers and fully connected layers designed to automatically and adaptively learn spatial hierarchies of features through a backpropagation algorithm (Yamashita, Nishio, Do, & Toashi, 2018).

EXPERIMENTAL METHODOLOGY

In this work, we propose a system that classifies the objects of an image into their classes (Figure 1) using YOLOv5 (2022). As we can see in Figure 1, the waste is detected and classified in its proper category, such as paper or metal.

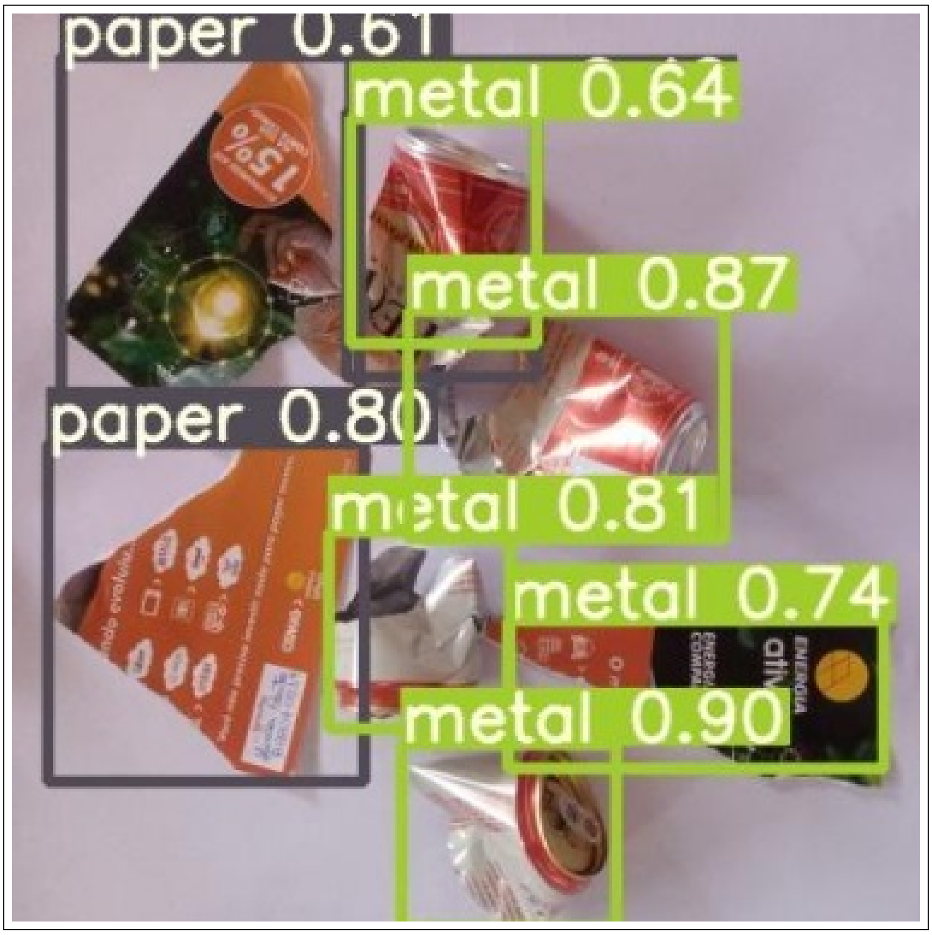


Figura 1. Example of the process of detecting and classifying discarded waste

For the training and testing step, we used 820 images from the database created by Yang e Thung (2016) that consists of images of waste with a white poster-board as a background. They also changed the pose for each photo, so the database would have variation. We took 77 photos using the same methodology and added these images to the dataset. Figure 2 illustrates the photos added in the database with modifications applied to the original images, such as, horizontal flip, vertical flip, and rotation.

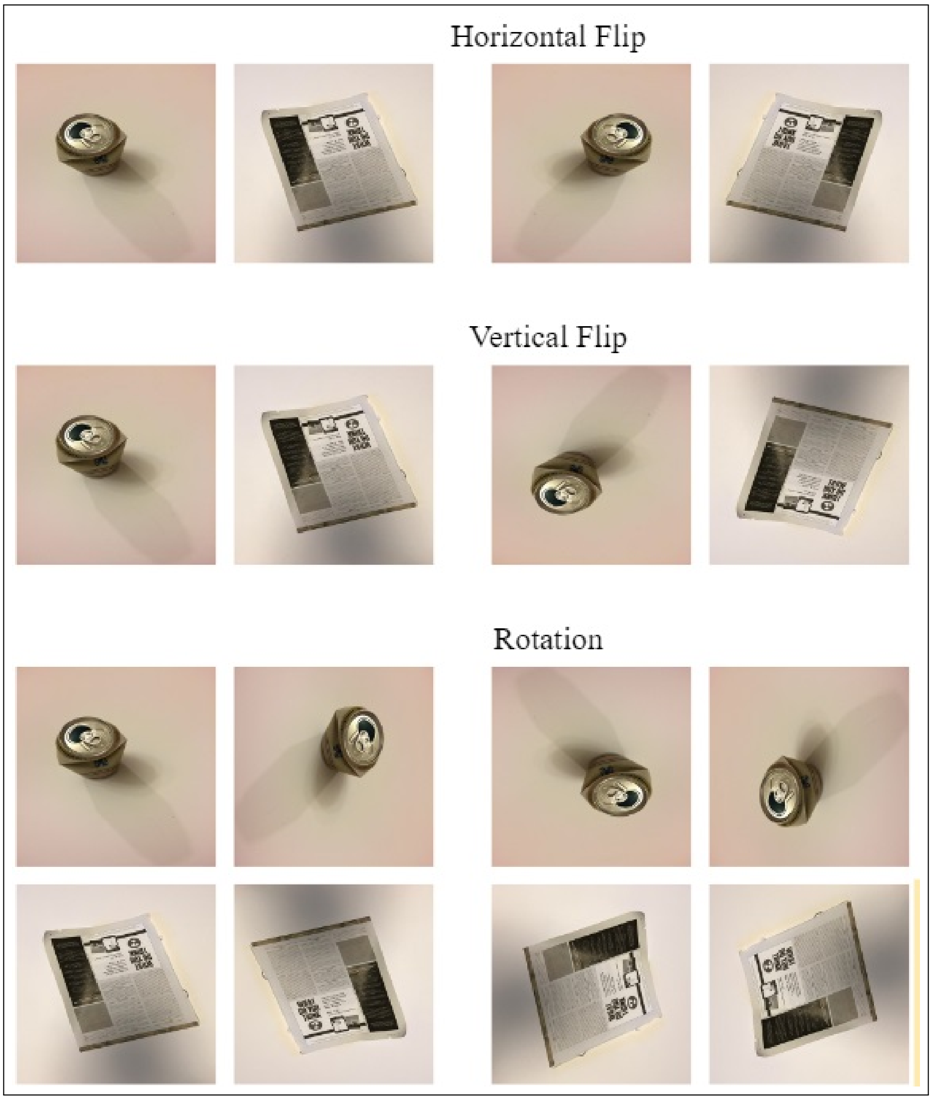


Figura 2. Modifications applied to the original images: horizontal flip, vertical flip, and rotation

Object detectors need large amounts of data with adequate annotations to work. Generally, the annotations are often difficult to collect. Our algorithm pursues the detection of objects in regions with garbage. Then, the algorithm recognizes the identified regions as garbage are cut and forwarded to the classifier, which determines the type of recyclable waste.

EXPERIMENTAL RESULTS

We observed some difficulties while trying to detect all objects in the same image and catch some different types of metals, but we solved this issue by adding more images to the dataset. To train YOLOv5, we used the parameters: 16 batches, 500 epochs and different weights. Results are shown in Figure 3.

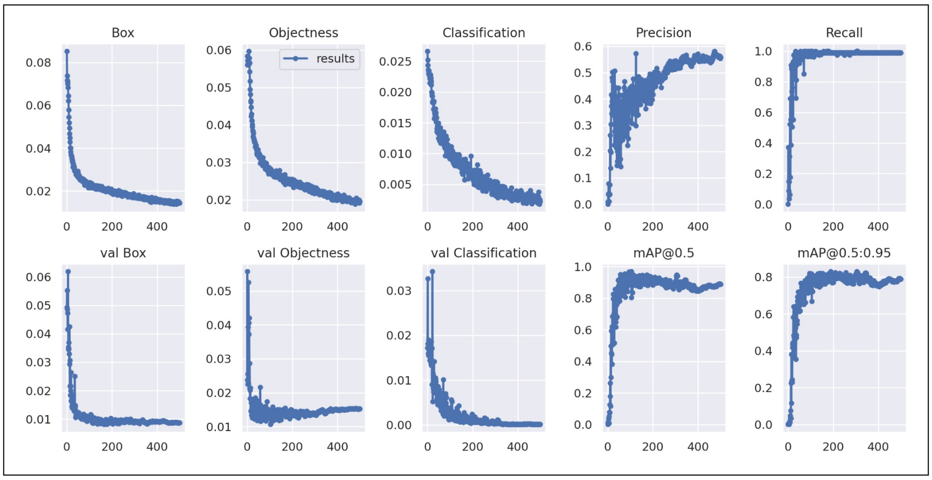
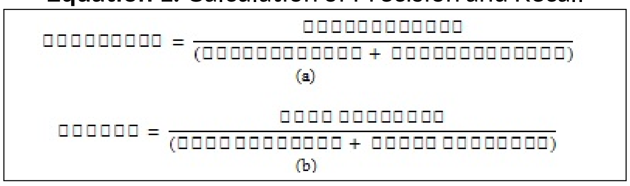


Figura 3. Plotting of the box loss, object loss, classification, precision, recall and mean average precision (mAP) over the training epochs for the training and validation set

The charts in Figure 3 show the metrics: box loss, objectness loss, classification loss, precision and recall. The X axis shows the evolution of the algorithm in epochs, while the Y axis shows the percentage of correctness. Box loss is a metric that represents the precision of the algorithm in locating the center of an object and how much the predicted bounding box covers an object. Objectness loss measures how much an image window contains an object. Classification loss measures how well the algorithm predicts the correct class of an object. Precision is the metric used to measure correct predictions of the model, shown in Equation 1 (a). Recall is the true positive rate. It measures the probability that exact reference objects will be detected correctly, shown in Equation 1 (b).

As a metric to evaluate how well the algorithm detects the garbage in the image, we use the Average Precision (mAP). As mentioned, the mAP shows how well the algorithm was able to detect garbage, and whether the class label is correct (classification). The algorithm calculates whether the detected area matches the exact area of garbage in the image, considering a bounding box to check. By definition, "AP is the average accuracy rate, which is the integral of the P index to the R index, that is, the area under the Precision–Recall curve; mAP is the average accuracy of the mean, which means that the AP value of each category is summed, and then divided by all categories, i.e., the average value." (Yao et al., 2021, p.9). mAP is also related to IoU (Intersection over Union). It is denoted as mAP @ p, where p (0.1) is the IoU. Mean average precision(mAP 0.5: 0.95) means average mAP over different IoU thresholds, from 0.5 to 0.95, step 0.05 (0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95).

Equation 1. Calculation of Precision and Recall



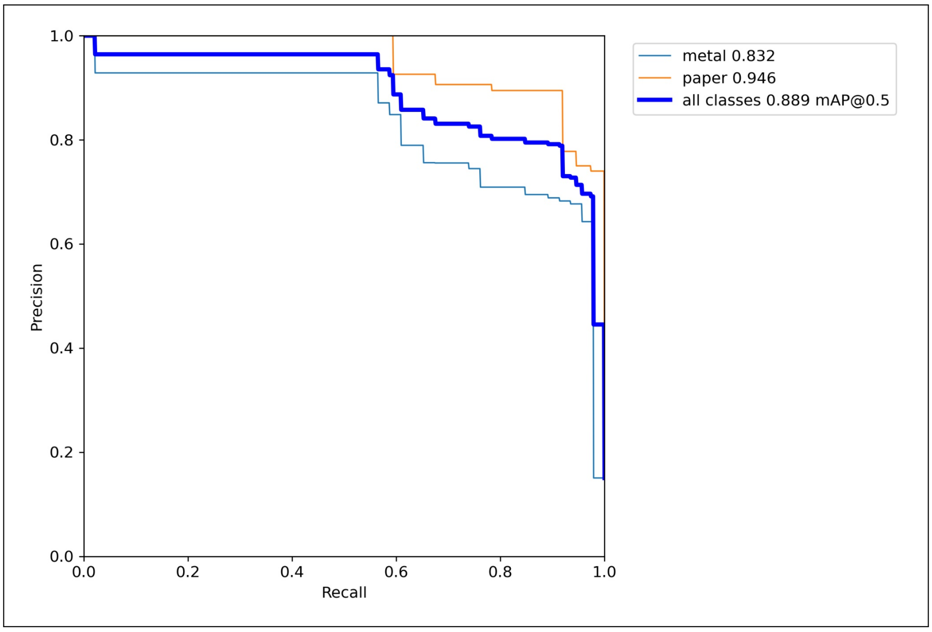


Figura 4. Precision–Recall curve chart

Considering the mentioned metrics and comparing their values with the works of Karthi et al. (2021) and Kasper-Eulaers et al. (2021), both dealing with object classification tasks, we can affirm that our YOLOv5 setup achieves satisfactory results and therefore is suitable for the task of garbage detection and classification. As we can see in Figure 4, we obtained the mAP value of 0.889 for the image dataset used. In comparison, Karthi et al. (2021) used 5 different datasets to obtain mAP values of 0.84, 0.86, 0.87, 0.90, and 0.91. Our result outperforms the result of 3 out of 5 datasets from Karthi et al. (2021). This significantly shows that the algorithm works with high accuracy for the classification and detection of waste objects. Figure 5 illustrates the classification's result performed by the YOLOv5 algorithm.

Figura 5. Objects classified in the paper and metal categories, and the level of accuracy resulting from running YOLOv5

We observed that the YOLOv5 algorithm had a good performance for the two analysed classes, which indicates that it is a method to help classify different types of garbage. We can also observe that the algorithm performed relatively better for the role class. Based on these results, we propose to expand the research on the application of YOLOv5 with new classes of disposable waste in future works.

CONCLUSIONS

With the aim of making recycling more efficient, an automated system that separates trash into categories was proposed. Our work with YOLOv5 can recognize as well as detect the multi-object in targeted images with a good level of precision. We obtain a mAP result of 0.889 which reveals a good accuracy for detection of the object class and area. In this way, we can conclude that Yolov5 is a suitable tool for the development of an automatic solution for waste separation. Results were satisfactory, but to achieve even better performance, a larger image dataset is needed. In future work, we will implement the glass and plastic classification in our solution. We intend to use more images and search for better performance using YOLOv5.

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NOTAS DA OBRA E CONFORMIDADE COM A CIÊNCIA ABERTA

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Concepção do manuscrito	X		X			
Escrita do manuscrito	X	X	X	X	X	X
Metodologia				X	X	X
Curadoria dos dados	X	X	X	X	X	X
Discussão dos resultados	X	X	X	X	X	X
Análise dos dados	X	X	X	X	X	X

Disponibilidade de Dados Científicos da Pesquisa

Os conteúdos subjacentes ao texto da pesquisa estão contidos no manuscrito.

EQUIPE EDITORIAL