Automatic Recycling Robot

Team E

Kim Mineun[1], Sim Sangwon[2], Eaum Taekyung[2], Jang Byungwoo[3]

[1]Department of Math Education, SKKU

[2]Department of Mathematics, SKKU

[3]Department of Electronic and Electrical Engineering, SKKU

September, 2022

Abstract

This document is a proposal for a recycling separation robot. An algorithm is learned using YOLOv7, one of the object detection technologies, and combined with robotics technology to implement a finished product. The classification target was focused on plastics, and the plastics were further subdivided into four categories: PE, PET, PP, and PS.

Keywords : Recycling, YOLOv7, Arduino, Robot

1 Introduction

Currently, the recycling of recycling in Korea is done only by pure manpower. However, with the development of AI technology such as object detection, the cost of designing the separation and collection automation system has been lowered and the difficulty has become easier. In the case of overseas separation stations, some are classified using an automated system, and only the parts that cannot be replaced by machines are inputted to reduce costs and increase the efficiency of separation and collection. The result we want to make is to combine the classification algorithm learned through the YOLO object detection algorithm, which is provided as an open source, to the robot. In this way, the goal is to use a robot equipped with the sorting logic created by the separate collection system to first sort the recyclable waste, and then process the unsorted garbage that the machine cannot classify or within the error range using manpower. However, in order to obtain an algorithm with high AP within a limited period, the classification target was specified as a plastic material. The robot equipped with the algorithm we learned recognizes plastic from the indiscriminately mixed pile of garbage and reclassifies it into four categories: PE, PET, PP, and PS.

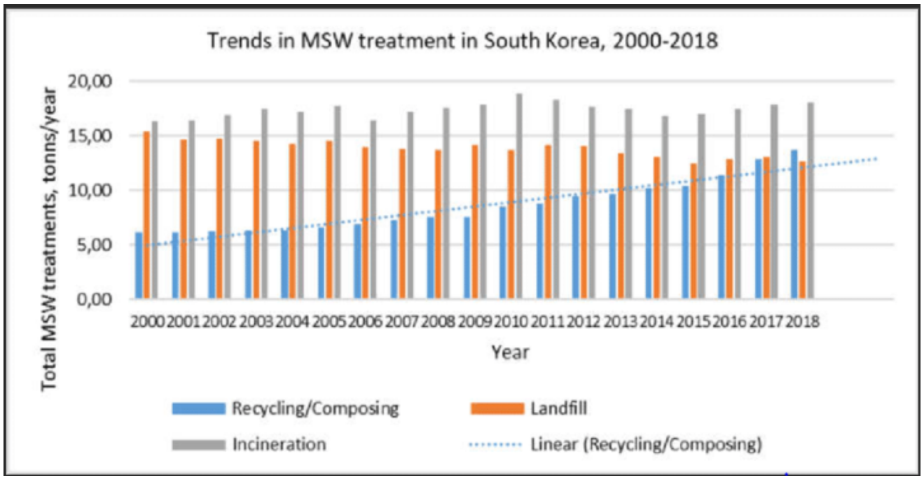

Figure 1: Trends in MSW treatment in South Korea, 2000-2018

2 Motivation

As we can see in figure [1], it has continued to increase from 2000 to 2018, and the amount of waste being sorted for recycling is also increasing. Compared to the increasing amount of waste, the domestic recycling classification and collection system is insufficient. Recycling separation and collection in Korea, which is done only by pure manpower, still does not deviate much from the level of the past. Even this process is being operated under the adverse conditions of high cost, low efficiency, and poor working conditions for workers, so rapid improvement is needed.

In the past, the cost of creating a classification system based on AI learning was too high, and the accuracy was also very low, so it was insufficient to actively use it in an actual classification system. However, with the development of AI-related technologies, the input cost has been lowered and the accuracy has increased. Therefore, compared to the past, the difficulty is lowered and the expected performance is higher. Currently, there are machines used for actual recycling classification in foreign countries, but there are no machines that have been completed until the commercialization stage in Korea. We will create output that can be used in the actual recycling sorting process. To this end, we decided not to end with a simple recycling classification algorithm learning and simulation, but to directly implement a robot equipped with an algorithm in conjunction with robotics technology to perform the actual classification task.

3 Objective

If an object detection-based automated classification machine is created, the existing system, which is made only by pure manpower, can be partially replaced with an automated system. An automated recycling sorting system will lead to cost savings and increased efficiency. To that end, we have two intermediate goals.

The first step is to obtain a learned object detection algorithm to be mounted on the robot. As mentioned above, we will learn based on four kinds of plastic image datasets. It aims to achieve performance close to 56percent, known as YOLO's average accuracy. As the accuracy of the classification algorithm increases, the performance and efficiency of the classification system increase significantly. In order to increase the accuracy within the limited project period, we focused on the material called plastic among the vast amount of garbage, and we will train about 800,000 image sets within a limited period. Through this, it learns the four detailed image data of plastics we have decided to focus on, and obtains an algorithm to be mounted on the recycling separation robot. When a garbage pile is captured by a camera, it is recognized as four types of plastic PP, PS, PE, and PET, and aims to ignore the rest and pass it on to the next sorting process.

The second goal is the development of robots. We will design an Arduino-based robot and aim for the target coverage to be within 40cm of the robot. After calculating the real world coordinates of the plastic object on the conveyor belt detected by the object detection algorithm, it aims to pick up and classify the plastic object using a gripper. Making plastic sorting out of stationary garbage a priority. If the first task shows sufficient accuracy, the second task is to classify plastic objects on a moving conveyor belt. Considering the operating speed of the low-cost gripper, the speed of the conveyor belt will be assumed to be low speed. Therefore, the ultimate goal is to create a gripper that automatically separates and collects waste in an environment similar to that of a recycling collection point.

4 Background and Related work

4.1 Background

The minimum required fps for real time recognition is 30 fps. The ultimate goal is to sort the plastic out of the trash on a conveyor belt at an actual recycling bin. Therefore, the object detection technology we will use must be able to detect at least 30 fps to recognize a moving garbage pile in real time. Therefore, among the real-time object detection algorithms, the algorithm to be used was selected considering both aspects of fps and AP.

In the robot design, it is judged that it is difficult to mount the algorithm inside the robot, so the pre-processing of image information and the derivation of coordinates are performed using a connected PC. Since the robot only performs a simple operation of picking up and moving an object of coordinates transmitted from a PC, the burden of developing complex robotics can be reduced.

4.2 Related work

4.2.1 YOLOv7

[2] YOLO is one of the object detection algorithms. YOLO's background started from the approach to increase FPS (frame per second) even with a rather low accuracy. YOLO decided that the reason why the existing R-CNN was slow, such as the large number of proposals, and the large overhead in the process. Therefore adopted the grid method. Object detection was performed by dividing the image into a specified grid and predicting the BBOX and class for each grid cell. Adopting the grid method was accompanied by problems such as that only one class can be predicted per grid cell and that small objects are not easily found.

Such problems were quickly resolved through v2 and v3. The problem of not being detected when several objects are contained in one per grid cell has been solved by having 5 Anchor Boxes predicted for each cell, and High Resolution feature map / Low resolution feature map predicts large and small objects well, respectively By introducing a pass through layer using, it is possible to combine the feature map of the upper layer with the feature map of the lower layer, preventing information about small objects from disappearing.Nevertheless, when the problem that small objects could not be continuously detected was raised, 3 scales were used as prediction feature maps, and 3 anchor boxes were used for a total of 9 for each scale to improve performance by increasing the number of predicted boxes. did it In YOLOv4, there was a change in the model architecture. The model was constructed by dividing the structure into backbone, neck, and head, and designing a network suitable for each structure. In the backbone, image features are searched, in the neck, the found features are aggregated, and in the head, object detection is finally performed. This structure will be the basis for future YOLOv7.

YOLOv7 developed in this way outperforms all existing real-time objection detection models that operate at 30fps or higher. We use the latest technology in computer vision and use optimized modules and optimization methods that do not increase inference cost. Backbone used the E-ELAN model that extended ELAN, and designed a planned re-parameterized convolution in the neck, which consists of 75percent fewer parameters than v4, 36percent less computation time, and 1.5 times higher AP. We adopted it based on the high FPS and AP of the YOLO algorithm, and we will perform object detection through YOLO.

4.2.2 Robotics

forward and inverse kinematics Robotics is the study of the relationship between location, speed and acceleration of links considered in robots. Two pieces of information are needed to represent the coordinates of the end point of the robot arm. The first is a position indicating how far it is from the origin, and a posture indicating how much it is rotated. Robotics is the study of the relationship between location, speed and acceleration of links considered in robots. Two pieces of information are needed to represent the coordinates of the end point of the robot arm. The first is a position indicating how far it is from the origin, and a posture indicating how much it is rotated. There are two types of mechanics: forward kinematics and inverse kinematics. Forward kinematics is a problem of obtaining the position and orientation on the orthogonal coordinates of the end-effector given a series of joint angles. Forward kinematics is relatively simple compared to inverse kinematics, and solutions are obtained using homogeneous transforms. Inverse kinematics is the problem of obtaining joint angles given the position and direction of the orthogonal coordinates of the end-effects, as opposed to forward kinematics, because the mechanical equation is a nonlinear equation consisting of transcendent functions, it may be relatively difficult or impossible to find a solution compared to forward kinematics. There may also be no solution, or there may be several solutions.

In summary, forward kinematics is the process of determining the location/posture of the end of the robot for a given joint variable, and inverse kinematics is the process of determining the joint variable corresponding to the location/posture of the desired end. Among these, we need interpretation of the inverse kinematics because we have to perform the task of picking up plastic waste at the location transmitted from the computer.

distal end of the robot Numerical methods are needed for interpretation of the inverse kinematics. If the speed path of the end portion is given, the speed of each driving joint is numerically obtained by calculating the inverse matrix of the Jacobian matrix. Due to repeated algorithms to reach the convergence range, the time to find solutions is somewhat longer, and there is no guarantee that all solutions can be saved if multiple solutions exist. Therefore, we will derive the joint angle through the calculation of the inverse kinematics matrix, and the joint angle through direct calculation using the minimum joint.

5 Problem Statement

As previously described, the recycling rate of waste is still low. One of the causes of the low recycling rate is the fact that the classification process in the separation collection company is operated by manpower. This is an inefficient classification at high cost, so the loss is inevitably large in many ways. What do we need to build an automated system that can distinguish products and even physically classify them?

First, we decided to focus on plastic among recycled items. Plastic is largely divided into four items: PE, PET, PP, and PS. Most plastic waste is mixed and thrown away without going through these four categories, and is 100% hand-divided by the recycling company. Errors always occur because it is not easy to classify quickly in a pile of garbage that is pushed over the conveyor belt. We are trying to develop a robotics system that minimizes this error and does not have to pay high costs.

6 Proposed Solution

First, in the process of distinguishing products, it is necessary to accurately determine which of the four categories plastic waste is. Machine learning is used in this process of judgment. An Arduino camera is installed on the conveyor belt, which recognizes objects on the conveyor belt and transmits them to the computer. The computer determines which type of plastic the object on the conveyor belt belongs to based on the received information. YOLO is used in this process. We believe that YOLOv7 is the best model to outperform the performance of all object detectors up to date in terms of speed and accuracy of up to 160 FPS. After the computer determines which classification the object belongs to, it transmits information about the location to the robot arm next to the conveyor belt. then The robot arm moves the distal end to the position to pick up the object and physically separate it.

7 Limitation

There are some limitations to this study. It takes too many datasets to expand and proceed with the entire range of garbage. Therefore, we conduct research only on the classification of plastic, not the whole trash. Also, the robot arm to be used in the study has a small cover range of less than 40 cm. Therefore, the conveyor belt, which is flooded with garbage, should also be used with a narrow width, and the size of the garbage should also be reduced. Limit the size of the garbage to 1.5L bottles of bottled water.

8 Planning Detail

From October after the Proposal is submitted, a learning algorithm of the image set using YOLO is implemented. This learning algorithm goes through a three-step process. First, an incomplete learning algorithm learned 25% of the dataset is used. Using this algorithm, we test the classification of garbage made of only immovable plastic. At this time, if the accuracy is too low, we obtain another dataset through dataset re-selection work and relearn the algorithm with a new dataset. If the first test shows an accuracy of more than 75%, the second test proceeds. The second test tests the classification of test sets mixed with other types of garbage in addition to immovable plastic. And in the last 3rd test, we test the moving plastic and other waste using an algorithm that learns all the datasets.

Once the classification algorithm is completed, the development of Arduino for recycling robots begins. The most important part here is the process of adjusting the position of the end of the robot arm with the actual coordinates of the detected plastic. To this end, joint angle is derived based on matrix calculation of inverse kinematics or coordinates are derived using open source API. We implement a method of sending commands to move the derived coordinates from the computer to the Arduino robot.

After completing the implementation of the robot, the first test is conducted on how much plastic the robot arm can actually extract. It is tested based on two criteria: the accuracy of the robot arm end position and the accuracy of the classification algorithm, and if the utility is low, it is supplemented by determining which part of the gripper or algorithm is the problem. When the accuracy reaches the target point, a second test is conducted to classify waste consisting of only plastic moving on the conveyor belt. The focus is to test whether the gripper can detect and pick up moving plastic. Finally, an environment similar to the actual recycling center is created and tested. The test is conducted in an environment where plastic and other waste are mixed on a moving conveyor belt. Measure the accuracy of the classification and if it is below the target point, adjust the target point downward in consideration of the gripper's limit or re-learn Arduino's system or algorithm to increase the accuracy.

Reference

[1] Shvetsova, Olga Lee, Jang. (2020). Minimizing the Environmental Impact of Industrial Production: Evidence from South Korean Waste Treatment Investment Projects. Applied Sciences. 10. 3489. 10.3390/app10103489.
[2] Chien-Yao Wang, Alexey Bochkovskiy, Hong-Yuan Mark Liao et al,"YOLOv7: Trainable bag-of-freebies sets new state-of-the-art for real-time object detectors", axXiv preprint arXiv:2207.02696 (2022)