



Plasticycle 3D

Muralidharan A.^{1,*} Pramod Chandra P.¹ Steni Dev S. A.¹

¹ UG Student, AI&DS, Panimalar Engineering College, Chennai, India

Emails: anandanmuralidaran@gmail.com · pramodchandrasince2004@gmail.com · stenidev2003@gmail.com

Received: August 09, 2023 Revised: October 29, 2023 Accepted: January 28, 2024 ★ Corresponding author

ABSTRACT

A novel solution has been developed to tackle the largest environmental threat caused by detritus. Our innovative proposal involves a specialized mechanism that employs Convolutional Neural Networks (CNNs) for image processing to automatically segregate garbage. The segregated plastics can be melted based on their type and transformed into 3D filaments, which are subsequently used with 3D printers to create new products. Artificial Intelligence is responsible for running this entire process while ensuring cost efficiency, functionality, and low power consumption as its primary goals. This machine's user-friendly interface ensures access even for those who live on the streets. In addition to promoting a healthier lifestyle through recycled goods production opportunities, our recycling project could help establish new sustainable business models providing employment possibilities. Moreover, utilizing these manufactured items decreases living costs substantially, making them an affordable yet environmentally friendly option at half-price reduction. Our advanced technology brings us one step closer towards overcoming this critical challenge, resulting in creating cleaner ambiance leading toward greener healthy earth benefiting future generations too.

Keywords: Plastic Waste ▪ Recycling ▪ Deep Learning–CNN ▪ Segregation ▪ Sensors ▪ Grinding ▪ 3D Filament

1. INTRODUCTION

The global waste crisis is a pressing challenge that is rapidly escalating in developing nations such as India, Africa, and Albania, as well as developed countries. The accumulation of plastic bags and e-waste is increasingly threatening our planet's delicate balance. In India, waste is a ubiquitous problem that plagues every household, street, city, district, state, and country. Over the past five years, both India's garbage production and plastic usage have increased significantly. Just 30% of the 3.4 million tonnes of plastic garbage produced in India each year is recycled [1]. In 2015, world-wide plastic production was 322 million tons per year and is growing 3.86% per year [2]. About 14 million tons of plastics gets into the ocean majorly from the coastal areas of Asia yearly. An estimate of about 700 species of aquatic life has been affected by the deadly impact of plastic pollution over the years [3].

In response to this crisis, we have leveraged the power of Artificial Intelligence to implement an efficient waste segregation process. Our system captures live images of waste using a webcam and converts them into a digital format. A Convolutional Neural Network then identifies the types of plastics in the waste, based on trained image datasets. We then employ segregating arms that automatically separate non-plastic materials, allowing only plastics to proceed, along with a small quantity of non-plastics.

In the second stage of the process, we sort the plastics by type and store them in dedicated units. Next, we use a shredding machine to break down the plastics into granules, with each storage unit of plastics undergoing a specific shredding process. The granules are then conveyed via a belt system to an Arduino-controlled extrusion line. The temperature is regulated based on the plastic type, ensuring proper melting, and the extruded filament is then rolled by Arduino-controlled

motors. One method of distributed plastic recycling is to up-cycle plastic waste into 3D printing filament with a recyclebot, which is an open-source waste plastic extruder [4]. Once the 3D filament is completed, the machine automatically shuts down. Our 3D printer then takes centre stage, utilizing the recycled plastic filament to create customized products with our desired designs. This process plays a critical role in conserving resources and bolstering the economy, offering a new business sector that benefits society at large. Through this innovative approach, we are taking significant strides in tackling the waste crisis and preserving our planet's health and future.

2. ARCHITECTURE OF THE RECYCLING SPECIALIZED MACHINE

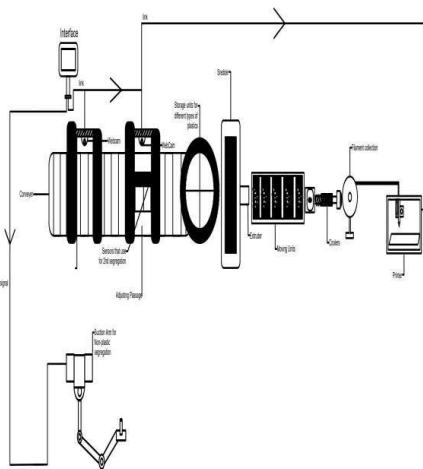


Figure 1. Proposed system.

Table 1. Components of Recycling Specialized Machine

Segregation Process 1	Segregation Process 2
1. Conveyor belt—based on the machine size	1. Atmega 328 × 1
2. Webcam—1080p HikVision	2. Inductive proximity sensor × 1
3. Arduino robotic arm—with suction unit	3. Ultrasonic sensor × 1
4. Personal computer—with a moderate processing unit	4. Soil moisture sensor × 1
5. RealSense SR300 sensor	5. Servo SG90 × 1
	6. 16 MHz crystal oscillator
	7. Buzzer 5V × 1
	8. 10k resistor × 1
	9. 1k resistor × 1
	10. 103 pre-set × 1
	11. 10uf capacitor × 2
	12. 22Pf capacitor × 2
	13. Reset switch × 1
	14. LED × 1
	15. 7805 voltage regulator × 1
	16. 12V 2-amp power supply
	17. Female power jack connector × 1

3. PRIMARY SEGREGATION FOR PLASTICS AND NON-PLASTICS USING CNN AND ROBOTIC ARM

In this part, we segregate the plastic and non-plastic materials using the CNN (Convolutional Neural Network) and robotic arm.

3.1 Image Classification Using CNN

In the CNN part we use a garbage classification dataset created by various people on the Kaggle.com website. Originally, this dataset included 12,578 photos, which were glass, paper, plastic, metal, rubbish, and aluminum can, divided into two classes as plastics and non-plastics that we are considering for our application. Each of these images features various materials in various stances and lighting. Each image is shrunk to 224×224 pixels, and the original dataset is close to 3GB in size. On the Google collaborative platform, the research was implemented utilizing the Keras library as an API and TensorFlow as the backend. Google Collab offers free access to a powerful GPU and a runtime that is fully setup for deep learning. A global average pooling layer is then built on top of this underlying model, serving as our classifier section, and feeding the output directly into the SoftMax activated layer. The data set was divided into 6,289 training images and 6,289 test images, using a test-train split ratio of 50:50 images. The weights on the chosen top models are fine-tuned to take full advantage of the model capabilities executed model.

The network was initially run through 10 epochs, followed by 10 epochs for final adjustment. The given code defines a convolutional neural network model with 8 layers: 4 Conv2D layers with 3×3 filters and ReLU activation, followed by MaxPooling2D layers with 2×2 pool size.

- 1 Flatten layer.
- 2 Dense layers with ReLU and sigmoid activation, respectively.
- 1 Dropout layer with a rate of 0.5.

Adam was employed as an optimizer with a default learning rate of 0.001. The batch size chosen for all training experiments was 32. These are quantified and plotted as performance metrics train and validation accuracy, their corresponding losses, and a confusion matrix for the implemented network model. Using this method, we can obtain up to 92% accuracy on the trained model with a minimal dip in accuracy when converted to use on an edge device.

3.2 Segregation of Non-Plastic Material Using Robotic Arm with MATLAB Software

The segregation of the plastic and non-plastic materials can be done using this robotic arm. Here, we separate the non-plastic materials like glass, paper, plastic, metal, and rubbish from the conveyor belt. The plastic materials remain in the conveyor belt for secondary segregation. We use RealSense SR300 sensor and waste robotics' suction type robotic arm to suck and drop the non-plastic materials from the conveyor belt [6]. MATLAB software provides deep learning toolbox for accessing the various built-in functions. The steps to be followed for picking the non-plastic materials from the conveyor belt are:

1. Connect the robotic arm and RealSense SR300 sensor to the MATLAB software: using `RobotConnection()`

class we can connect the robotic arm with the MATLAB software. The SR300 sensor is connected to the computer using USB cable and it is linked with the MATLAB software by device().

- Stream the SR300 sensor and get the co-ordinates: we start the streaming the SR300 by `EnableStream()` method. The co-ordinates of the non-plastic object can be obtained by “far and near” method in the deepvision [5]. The best vision detection range of RealSense SR300 is 500–700 mm [5].
- Pass the co-ordinates to the robotic arm and control the movements: open a serial port connection to the robotic arm by `serialport()` function and the co-ordinates (x, y, z) can be sent to the robotic arm. Now, the robotic arm can be controlled by `write` function.

The above-mentioned steps are followed if and only if the object in the conveyor belt is a non-plastic.

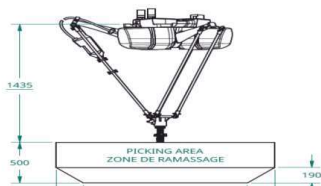


Figure 2. Suction type robotic arm.

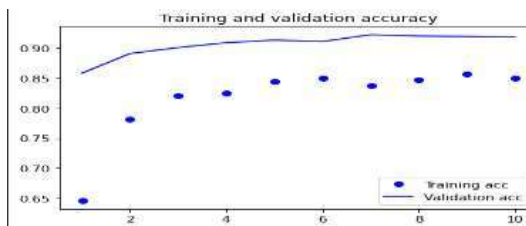


Figure 3. Training and validation accuracy rate.

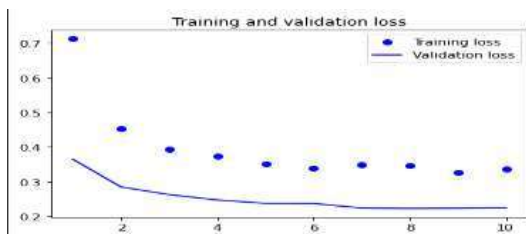


Figure 4. Training and validation loss rate.

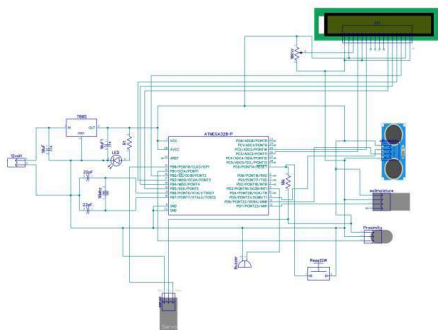


Figure 5. Arduino with sensors circuit.

4. SECONDARY SEGREGATION FOR PLASTIC TYPES AND NON-PLASTIC USING CNN AND SENSORS

In this part, we segregate four main different types of plastic which dominate plastic waste in our houses, namely PET, PP,

PS, and PT-HD [7]. We also segregate the metal and wet waste which failed to segregate in the primary segregation using the proximity sensor and soil moisture sensor.

4.1 Segregating the Metal and Wet Waste Using Sensors

Using inductive proximity sensors and soil moisture sensors, we can locate and separate out the metal and wet trash. With the Arduino IDE platform, we employ the Arduino/ATmega328 microcontroller, which is programmed in C++. An inductive proximity sensor is positioned at the side of the conveyor belt to identify any metal trash that the initial segregation process was unable to separate. The wet garbage from the conveyor belt is found using the soil moisture sensor. The gadget for collecting waste is made with a servo SG90 motor. This motor and Arduino microcontroller are connected. The Arduino's `analogwrite()` function uses a PWM (Pulse Width Modulation) signal to communicate with the motor.

4.2 Segregation of Different Types of Plastic Using CNN

The segregation of the different types of plastic is done using Convolutional Neural Network (CNN). Convolutional Neural Network is a mathematical model of an artificial neural network. The structure of neurons is like mammalian visual cortex. It consists of three layers: convolutional, pooling and fully connected [7]. The programming is done in Google Collab platform.

Experiment: For our input we take the input image by using the Hikvision webcam. Python provides OpenCV library to achieve this. We can run and separate the different types of plastic using servo SG90 motor. This prediction of the CNN can be given to the servo SG90 motor by using Arduino.



Figure 6. Training and validation accuracy rate.

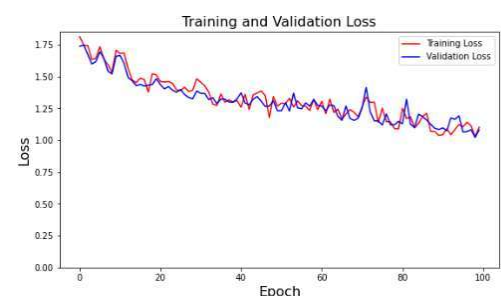


Figure 7. Training and validation loss rate.

5. SHREDDING THE PLASTIC

The device that makes it possible to shred plastic into tiny flakes is a shredder [10]. The plastic will begin to be shredded when the sorting process is complete. Around 25,173 rupees is the standard market price of a plastic shredder [11]. For this method, we can build a single plastic shaft. The necessary components are a power source, a sieve, a hopper, and laser files. This shredder measures $280 \times 600 \times 1142$ mm and weighs around 90 kilos [10]. The blades are 5 or 6 millimetres wide, and they can produce plastic flakes of 0 to 30 millimetres in length. This shredder can shred plastic of the types of PP, PS, PET, and PE-HD as inputs. We utilise a motor with about 2.2 kW that is geared down to 70 rpm for the power supply [10]. We have to attach the sieve which will determine the size of the shredded plastic. This shredder can shred up to 10 kg of plastic per hour. The overall model is given in Figure 8.



Figure 8. Plastic shredder.

Laser files: Laser files are laser cut steel which act as a mini component for our shredder. Using the laser files we produce blades, shaft, and components for shredding part of the shredder.

6. CONVERTING PLASTIC FILAMENT TO 3D FILAMENT

For converting the plastic shred to usable 3D filament we can refer and use RepRapable Recyclebot, an open source 3D printable extruder for converting plastic to 3D printing filament. We refer this hardware article because it is cost effective and highly efficient. The total cost required to build this machine is less than \$700 and it can produce 0.4 kilogram of filament per hour using 0.24 kWh/kg [12]. The filament produced will be in a diameter $\pm 4.6\%$. The average cost of 3D filament in the market is about \$150–200 per kilogram [13]; meanwhile, the 3D filament we created is only 2.5 cents/kg, which is less than 1000 times the market price [12]. This process can be divided into 7 parts, namely collection part, heating part, cooling part, puller and diameter sensing part, puller and traverse part, and spooler.

6.1 Power Supply and Control System

The power supply transforms the mains electricity coming from the wall into 12 V, which powers the control panel. It has a left side entry and a wire exit on the right side. The cover needs to be installed before the Recycle Bot can be used. The control panel houses all of the Recycle Bot's electronic controls. After everything is finished, it is heavy with cables but fits everything well [12].

6.2 Collection of Plastic

The plastic collection includes a hopper, an auger, motor brackets, and feet. The system receives the polymer from the hopper [12]. A geared Nema 23 stepper motor, an extrusion auger coupler, and an auger are needed for the auger to trans-

fer the feedstock to the hot zone for extrusion. The motor assembly is held in place by the motor brackets. The motor is supplied power supply.

6.3 Heating the Plastic

With the use of a barrel, the plastic is heated. Steel was selected as the barrel material because it has a high melting point and is robust. For optimum heating and for forecasting the internal environment in the barrel as material passes through, nichrome wire use and regular spacing are essential. To prevent the wires from fusing together, Kapton tape is employed. The nozzle size is set at 2 mm, producing filament with a 1.75 mm diameter [12]. The materials required are barrel mount, barrel, nichrome wire, nozzle, and thermistor. Power supply is given to this system.

6.4 Cooling the Plastic

In order to cool both the aluminium and the filament, the cooling assembly comprises of an angled aluminium component with fans blowing downward. The programme allows for the speed and placement of the fans in various areas. If the temperature control is accurate, the hot filament material that is extruded out of the nozzle has a slightly viscous rheology. The outside of the filament freezes entirely as that substance hits the thermally conductive aluminium and becomes hardened. In contrast, the core of the filament retains a considerably lower viscosity and a greater temperature since polymers in general are poor thermal conductors. If it is adequately cooled, this combination makes aluminium a non-stick surface for close to molten filament material. The filament can be stretched without splitting, compressed by the rollers, and spooled with a sharp curve and tensioning force without losing its continuity [12].

6.5 Puller Part

This RepRapable Recyclebot's puller, which establishes the filament's diameter, is a crucial component. The diameter of the filament generated is inversely related to the puller speed. With the help of the Arduino and LAB VIEW interface, the motor's speed may be adjusted appropriately [14]. The primary components needed are the 12V DC motor, motor mount, and pulley rollers. While the filament is extruded, a diameter sensor may be fixed to measure each location's diameter [12].

6.6 Roller Guide and Traverse

The tension of the filament for spooling may be changed or maintained using the roller guide. The filament will pass beneath the roller guide and through the diameter sensor [12]. Traverse uses a motor, cart, and switch to shift the direction of the motor when tightly winding the filaments onto the spool. Traverse keeps the filaments from overlapping and spools it uniformly and firmly [12]. Spooler is the system which winds the filament into spool; it uses 12VDC motor and smooth belt to spool the filament.

6.7 Plastic 3D Printer

A 3D printer for plastics is a device that creates desired plastic items from plastic filament [15]. The 3D filament is given to 3D printer from the RepRapable Recycle Bot. This 3D printer is connected with the computer, and we can print our desirable product using the 3D printing software. As we recycled the plastic from the waste, each filament may have

different type of plastic, and they have different properties and different print and bed temperature.

Table 2. Properties of Different Types of Plastic, Including Print and Bed Temperature

Print Temperature(°C)	Bed Temperature(°C)	Printing Notes
190-220	50-70	Annealing, sanding or chemical smoothing
210-230	120-150	
200-220	50-70	proper ventilation
220-250	No heated bed Needed.	
220-260	80-100	Enclosed Region
170-240	50-80	Enclosed Region
200-240	60-90	Enclosed Region

Table 3. Cost Estimation and Power Consumption for Prototype of Recycling Specialized Machine

Components	Cost (Dollars/Rupees)	Power Consumption (Watts)
Conveyor Belt ($F = 49N$ and speed=100 cm/s)	\$1000 / Rs.80,000 [16]	0.54 W
Robotic Arm (with suction unit capacity to carry 1 kg)	\$250 / Rs.20,000 [17]	50–500 W
RealSense SR300 Webcam	\$180 / Rs.14,400 [18]	4.5 W/s
HikVision Webcam	\$50 / Rs.4000 [19]	2–5 W
High End Processing Unit	–	100 W
4 × Arduino Mega 2560	\$200 / Rs.16,000 [20]	2 W
Inductive Proximity Sensor	\$50 / Rs.4,000 [21]	0.1 W
Soil Moisture Sensor	\$30 / Rs.2,400 [22]	0.0045 W
Ultrasonic Sensor	\$7 / Rs.420 [23]	0.5 W
Shredder	\$400 / Rs.32,000 [11]	1000–3000 W/kg
RepRapable Recycle Bot	\$700 / Rs.56,000 [12]	240 W/kg
Total cost required	Around Rs.2,30,000–Rs.2,50,000	Around 4–4.5 units

7. CONCLUSION

The management of plastic trash is currently the main environmental issue, especially in developing nations. By utilising convolutional neural networks, this system will be useful in lowering the amount of plastic waste, such as PET, PP, PS, and PT-HD, in the environment. With the help of this method, we can turn plastic trash into 3D filaments that can be utilised in 3D printers to produce new goods. This will benefit several areas, including the environment by lowering the amount of trash in the seas, rivers, and other natural areas. Reducing plastic waste can also have a positive impact on the economy. Advantages for public health can be achieved because we can assist in lowering these health hazards and enhancing public health by managing plastic garbage. In resource conservation, petroleum and other non-renewable resources are frequently used to make plastic garbage. We can assist future generations protect these resources by limiting plastic waste.

REFERENCES

- [1] Indian Institute of Science and Praxis Global Alliance.
- [2] PlasticsEurope (PEMRG) and Consultic, “Global plastic production from 1950 to 2015,” Statista, accessed Dec. 19, 2017.
- [3] E. Schmaltz et al., “Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution,” *Environmental International*, vol. 144, p. 106067, 2020.
- [4] C. Baechler, M. DeVuono, and J. M. Pearce, “Distributed recycling of waste polymer into RepRap feedstock,” *Rapid Prototyping Journal*, vol. 19, no. 2, pp. 118–125, 2013.
- [5] M. Prakash, M. Sumithra, and B. Buvaneshwari, “General ChatBot for Medical Applications,” *Journal of Cognitive Human-Computer Interaction*, vol. 4, no. 1, pp. 08–14, 2022.
- [6] Waste Robotics, “Robots recycling.”
- [7] A. K. R, A. Kumar, and V. K., “An Automated Optimize Utilization of Water and Crop Monitoring in Agriculture Using IoT,” *Journal of Cognitive Human-Computer Interaction*, vol. 1, no. 1, pp. 37–45, 2021.
- [8] “Garbage Sorting machine using Atmega 328/Arduino.”
- [9] “Garbage Classification using CNN,” Kaggle.
- [10] Precious Plastic, “Build a shredder.”
- [11] M. Ashok Kumar, A. Abirami, P. Sindhu, V. D. Ashok Kumar, and V. Rani, “Modern Medical Innovation on the Preferred Information about the Medicine using AI Technique,” *Journal of Cognitive Human-Computer Interaction*, vol. 1, no. 1, pp. 8–17, 2021.
- [12] A. L. Woern, J. R. McCaslin, A. M. Pringle, and J. M. Pearce, “RepRapable Recyclebot: Open source 3-D printable extruder for converting plastic to 3-D printing filament,” released May 3, 2018.
- [13] All3DP, online magazine founded by Mathias Plica.
- [14] S. Angalaeswari, A. Kumar, D. Kumar, and S. Bhadoriya, “Speed Control of Permanent Magnet (PM) DC Motor Using Arduino and LabVIEW.”
- [15] K. O. Babaremu et al., “Sustainable plastic waste management in a circular economy.”
- [16] “Flat Belt Conveyor, Load Capacity: 501–1000 kg,” IndiaMART.
- [17] P. Kavitha, R. S. Shini, and R. Priya, “An Implementation of Statistical Feature Algorithms for the Detection of Brain Tumor,” *Journal of Cognitive Human-Computer Interaction*, vol. 1, no. 2, pp. 57–62, 2021.
- [18] “Intel RealSense Depth Camera,” Fab.to.Lab.
- [19] “HikVision Webcam.”
- [20] “Arduino Mega 2560 Rev3,” Arduino Corporation.

- [21] K. Parvesh, C. Tharun, and M. Prakash, “Apparel Recommendation Engine Using Inverse Document Frequency and Weighted Average Word2vec,” *Journal of Cognitive Human-Computer Interaction*, vol. 1, no. 2, pp. 46–56, 2021.
- [22] “Soil Moisture Sensor,” iBhejo.
- [23] G. PonKumar et al., “Power Backup for Failsafe Power System,” *Journal of Cognitive Human-Computer Interaction*, vol. 3, no. 2, pp. 26–35, 2022.