Plasticycle 3D

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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 via 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 etc., 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%/ 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 Conventional 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 upcycle plastic waste into 3-D 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:

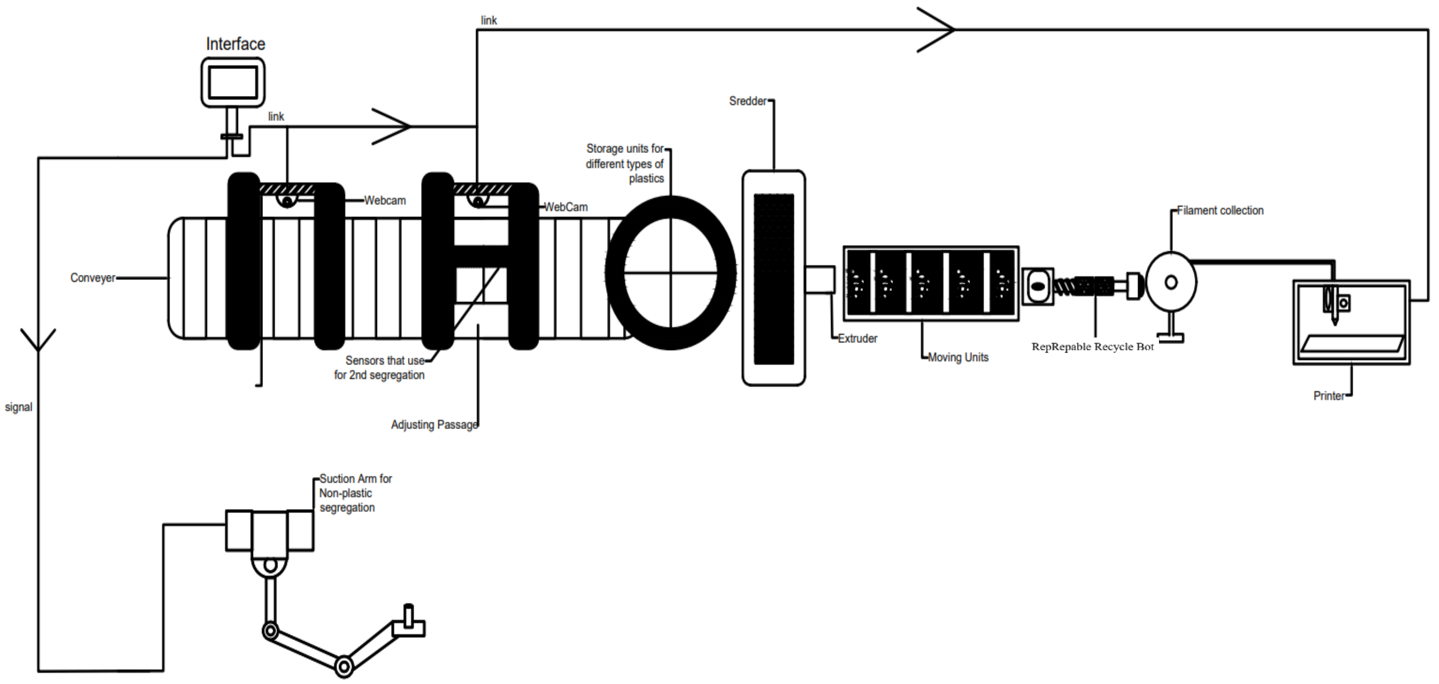

Table 1: Components of Recycling Specialized machine

	Segregation Process 2
1	Atmega 328 x 1
2	Inductive Proximity Sensor x 1
3	Ultrasonic Sensor x 1
4	Soil Moisture Sensor x 1
5	Servo sg 90 x 1
6	16 MHz Crystal Oscillator
7	Buzzer 5V x 1
8	10k Resistor x1
9	1k Resister x 1
10	103 Pre-set x 1
11	10uf capacitor x 2
12	22Pf capacitor x 2
13	Reset Switch x 1
14	LED x 1
15	7805 Voltage Regulator x 1
16	12v 2-amp Power Supply
17	Female Power Jack Connector x 1
	DC MotorController
1	IRF Z44 x 1
2	10k Variable Resistor x 1
3	Heatsink x 1
4	12V 2-amp Power Supply
5	12V DC Motor
	Segregation Process 1
1	Conveyor Belt -based on the machine size
2	Webcam – 1080p Nik Vision
3	Arduino Robotic Arm – with suction unit

4	Personal Computer – with a Moderate Processing Unit
5	RealSense SR300 sensor

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.

A. Image classification using CNN

In the CNN part we use a Garbage classification dataset created by various people on Kaggle.com website. Originally, this dataset included 12,578 photos, which were Glass, paper, plastic, metal, rubbish, and Aluminum can are divided into 2 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 by 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 6289 training images and 6289 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 10epochs, followed by 10 epochs for final adjustment. The given code defines a convolutional neural network model with 8 layers:4 Conv2D layers with 3x3 filters and ReLU activation, followed by MaxPooling2D layers with 2x2 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 network. implemented 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.

B.Segregation the non-plastic material using robotic arm with MATLAB software (robotic arm part)

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. 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,

1.Connect the robotic arm and RealSense SR300 sensor to the MATLAB software: Using RobotConnection () class we can connect the Robotic arm with the MATLABsoftware. The SR300 sensor is connected to the computer using USB cable and it is linked with the MATLAB software by. device ().

2.Stream the SR300 sensor and get the co-ordinates: We start the streaming the SR300 by. EnableStream () method. The co-ordinates of thenon-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].

3.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.

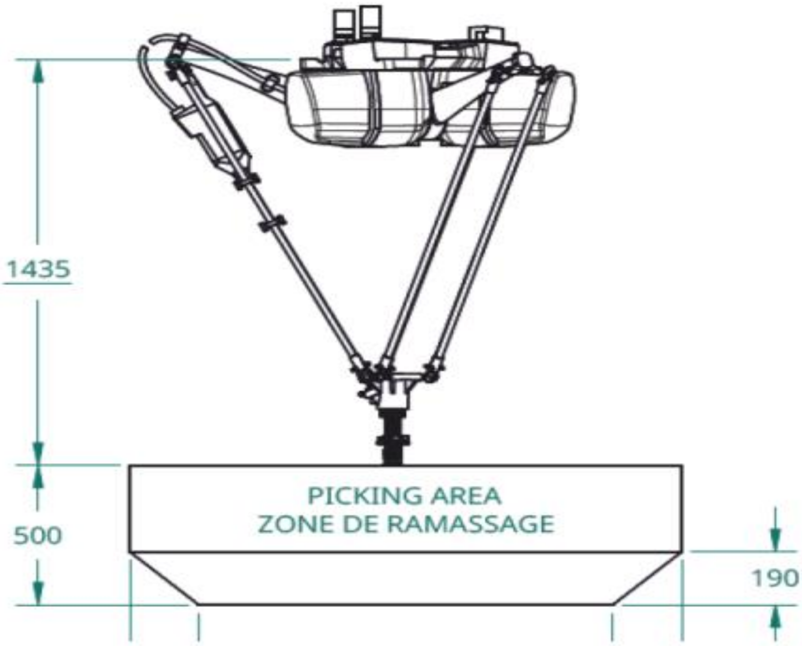

Figure 1 [6]: Suction typerobotic arm

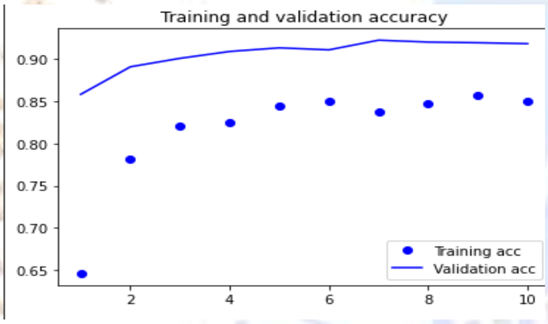

Figure 2: Training and validation accuracy rate

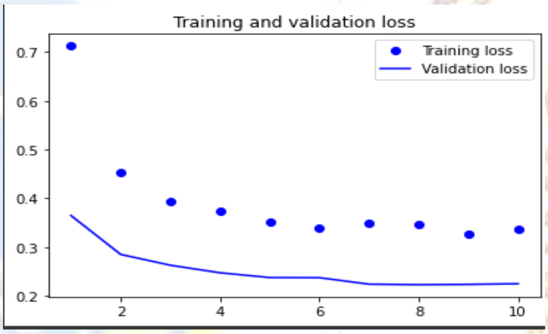

Figure 3: Training and validation loss rate

4. Secondary segregation for plastic types and non-plastic using CNN and Sensors

In this part, we segregate four main different types of plasticwhich is dominated plastic waste in our houses namely PET, PP, PS, PT-HD [7] and also, we segregate the metal and wet waste which are failed to segregate in the primary segregation using the proximity sensor and soil moisture sensor.

A.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.

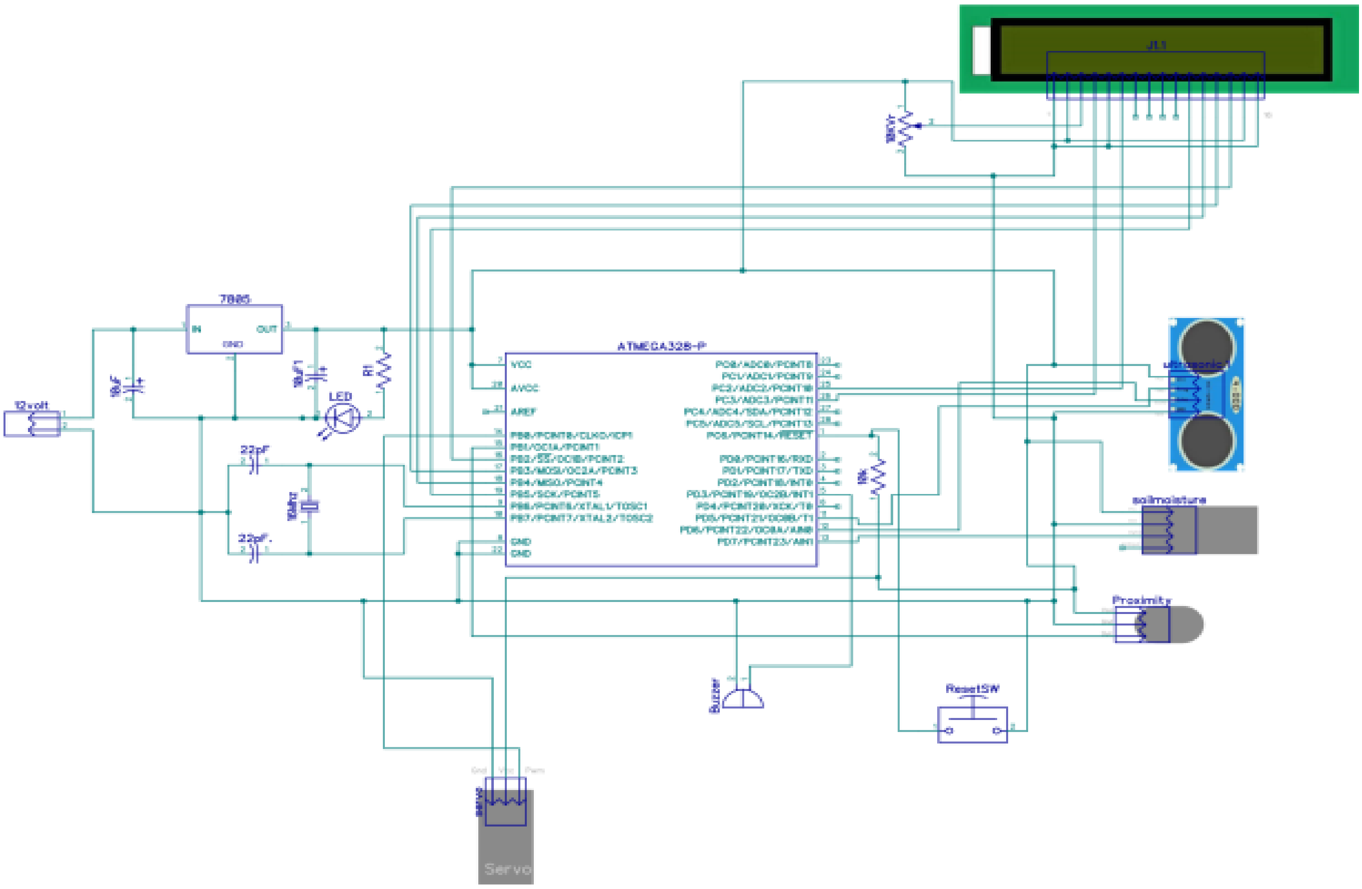

Figure 4[8]: Arduino with sensors circuit

B. 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.

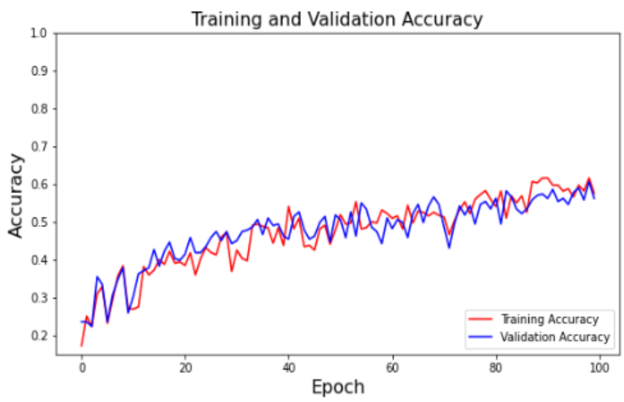

Figure 5[9]: Training and validation accuracy rateFigure 6[9]: Training and validation loss rate

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 x 600 x 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 10kg of plastic per hour. The overall model is given in Figure.

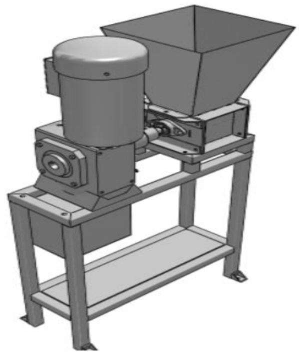

Figure 7 [11]: Plastic Shredder

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 3-D filament:

For converting the plastic sherd to usable 3-D filament we can refer and use RepRepable Recycle Bot an open source 3-D printable extruder for converting plastic to 3-D 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 ±4.6%. The average cost of 3-D filament in the market is about $150-200 per kilogram [13] meanwhile, the 3-d filament we created is only 2.5 cents/kg which is <1000x lesser than 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, spooler.

A. 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].

B. 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 transfer 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.

C. 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 2mm, producing filament with a 1.75mm diameter[12]. The materials required are barrel mount, barrel, Nichrome wire, nozzle, Thermistor. Power supply is given to this system.

D. 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].

E. 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].

F. 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.

G. 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 RepRepable 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, they have different properties and different print and bed temperature.

Table 2: Properties of different types of plastic (includes Print and Bed temperature)

Filament	Special Properties	Uses	Strength	Density (kg/m^3)	Flexibility	Durability	Difficulty to Print	Print Temperature(°C)	Bed Temperature(°C)	Printing Notes
Linear Low-Density Polyethylene	Excellent Toughness, Resistance, Permeability	Packaging, Coating and Automotive Parts	Medium	910-940	High	High	High	190-220	50-70	Annealing, sanding or chemical smoothing
polypropylene	Flexible, Chemical Resistant	Flexible Components	Medium	1040^ [16]	High	Medium	High	210-230	120-150	
polyvinyl Chloride	Resistant, High temperature Electrical Insulator	Pipes Flooring Window Frames	High	1330	High	High	High	200-220	50-70	proper ventilation
Polyethylene Terephthalate	Strong, Flexible Durable, Recyclable	Water bottle, Food container, Beverage container	High	-	High	High	Medium	220-250	No heated bed Needed.	
High Density Polyethylene	Resistant, High tensile, Recyclable	Packaging, Pipes, and fitting, Medical	High	940	Low	High	High	220-260	80-100	Enclosed Region
Low Density Polyethylene	High flexible, Electrical Insulation, Resistance	Medical, Pipe, Packaging	Low	910	High	High	High	170-240	50-80	Enclosed Region
Polystyrene	Light weight, electrical Insulation, Recyclable	Packaging, Insulation, Medical	Low	1040	Low	Low	Low	200-240	60-90	Enclosed Region

Table 3: Cost estimation and power consumptionfor Protype of Recycling Specialized Machine

Components	Cost (Dollars/Rupees)	Power Consumption (Watts)
Conveyor Belt (F=49N and Speed=100 cm/s)	**$1000 / Rs.80,000**	**0.54 W**
Robotic Arm (With Suction unit capacity to carry 1kg)	**$250 / Rs.20,000**	**50-500 W**
RealSense SR300 Webcam	**$180 / Rs.14,400**	**4.5 W/s**
HikVision Webcam	**$50 / Rs.4000**	**2-5 W**
High End Processing Unit	**-**	**100 W**
4 x Arduino Mega 2560	**$200 / Rs.16,000**	**2 W**
Inductive Proximity Sensor	**$50 / Rs.4,000**	**0.1 W**
Soil Moisture Sensor	**$30 / Rs.2,400**	**0.0045 W**
Ultrasonic Sensor	**$7 / Rs.420**	**0.5 W**
Shredder	**$400 / Rs.32,000 [11]**	**1000- 3000 W /kg**
RepRepable 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 (CNNs). 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 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", "Praxis Global Alliance".

[2]PlasticsEurope (PEMRG); Consultic. Global plastic production from 1950 to 2015 (in million metric tons) (accessed 12.19.2017).

[3]Schmaltz, E., Melvin, E.C., Diana, Z., Gunady, E.F., Rittschof, D., Somarelli, J.A., DunphyDaly, M.M., 2020. Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. Environ. Int. 144, 106067.

[4]C. Baechler, M. DeVuono, J.M. Pearce, Distributed recycling of waste polymer into RepRap feedstock, Rapid Prototyping J. 19 (2) (2013) 118–125.

[5] "Deep Vision Servo Hand-Eye Coordination Planning Study for Sorting Robots" by Tao Ning, Changcheng Wang and Yumeng Han.

[6] Automated pneumatic vacuum suction robotic arm with computer vision J Lim[1], P Yang[1], P Yuanda[1], R V Bakkara[1], M Sinaga[1], H Siagian[1], E D Suryanto[1] and D Perangin-angin[1] Published under licence by IOP Publishing Ltd

[7] "Deep Learning for Plastic Waste Classification System" by Janusz Bobulski and Mariusz Kubanek

[8]Garbage Sorting machine using Atmega 328/Arduino

[9]Garbage Classification using CNN by **TOHID YOUSEFI.**

[10]Precious plastic "community.preciousplastic.com".

[11]"Design and Construction of a Low-Cost Plastic Shredding Machine" byBriggs M. Ogunedo, Beneth C. Chukwudi.

[12] "RepRapable Recyclebot: Open source 3-D printable extruder for converting plastic to 3-D printing filament" by Aubrey L. Woern, Joseph R. McCaslin, Adam M. Pringle, Joshua M. Pearce. Article released:3 May 2018.

[13] "All3dp" online magazine founded by mathias plica.

[14] "Speed Control of Permanent Magnet (PM)DC Motor Using Arduino and LabVIEW" by Angalaeswari. S, Amit Kumar, Divyanshu Kumar, Shubham Bhadoriya.

[15]"Sustainable plastic waste management in a circular economy" by K.O. Babaremu, S.A. Okoya, E. Hughes, B. Tijani, D. Teidi, A. Akpan, J. Igwe, S. Karera,M. Oyinlola, E.T. Akinlabi.