Implementation of Machine Learning using Fastai for Image Classification on the Automatic Waste Sorter Prototype

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ABSTRACT
Indonesia is one of the countries that contribute to waste in the world. Waste management is one way to reduce waste generated. Sensing the type of waste with a camera using computer vision is one method to take waste images. Using this method can create an automatic waste sorting system. The scattered waste is mixed of many types, including cardboard, glass, metal, paper, and plastic. This research uses the machine learning Convolutional Neural Network (CNN) Model to classify waste. The prototype uses a notebook to process classification and sends the classification to Arduino with Firmata protocol. The error rate value obtained from the train was 0.096708. while the accuracy value of the prototype is 84%. in this research, to be able to apply waste separation technology automatically to the waste, it can use fastbook when using a server computer and Arduino to control the device prototype.

Keywords
Fastbook, Fastai, Jupyter Notebook, Convolution Neural Network, OpenCV, PyFirmata, Python

1. INTRODUCTION
Waste is the residual waste from a product or item that is no longer used. Oftentimes, the waste is not classified properly, making it difficult to reuse, reduce, recycle. Generally, the waste will continue to grow every day and will be collected together at the final disposal site (TPA). The existing waste has not been classified properly so that it is mixed into one without any sorting. This mixed waste becomes a problem because there is waste that is easily decomposed and not easily decomposed. Good waste management can reduce the volume of existing waste. By reusing waste and recycling waste. This waste classification makes it easier to classify waste according to the material.

Currently with the development of science and technology, especially the development of machine learning. Then machine learning can also be used as a waste classification. In this way, waste can be easily classified according to its type. Computer vision is a technology that can study how computers can see visually and understand visible visuals. The CNN (Convolutional Neural Network) algorithm has the same working system as ANN (Artificial Neural Network) using the working principle of human brain cells. [6]

The existence of waste is a complex problem faced by people in both developing and developed countries in the world, including Indonesia. The problem of waste is no longer just a problem of cleanliness and the environment. The waste management system in Indonesia is generally still fairly traditional, so that waste is often disposed of indiscriminately and not segregated. Based on news sources, Indonesia is the second-largest contributor to plastic waste in the world after China. As much as 80% or 3.21 million tons of plastic waste disposed of by the people of Indonesia is dumped into the sea [14]. Based on data from SWI (Sustainable Waste Indonesia), Indonesia is still not effective in waste management. 24% of Indonesia's waste is not managed, 7% of waste is successfully recycled, and 69% of waste ends up in TPA (Final Disposal Sites). With inorganic waste or waste that is difficult to decompose by 40% [3]. The classification of types of waste has been carried out by various parties. It's just that in the field practice, the waste that has been separated is still put together which is not in the right place.

Waste is divided into various kinds, namely organic and inorganic waste. Organic waste is a type of waste that can be decomposed easily, such as vegetables, fruits, paper, leaves, and others. Meanwhile, organic waste is waste that is not easy to decompose, such as plastic, bottles, and others.

In terms of waste, there are recycle, reuse, and reduce. Recycle waste means recycling waste, Reuse means reusing items that have been wasted, Reduce means reducing the use of materials that are difficult to decompose in nature.

The scattered waste is a mixed waste of many types, including cardboard, glass, metal, paper, plastic, and others. This waste is mixed and not properly separated. To overcome this problem, it is necessary to have a system to classify waste based on its type. On that basis, this paper is about creating a prototype that can classify the types of waste, so that this prototype will make it easier to classify the types of waste.

2. LITERATURE REVIEW
2.1 RELATED WORK
The research [9] is entitled “Fastai: A Layered API for Deep Learning”. Jeremy Howard and Sylvain Gugger conducted this research to make machine learning easier. Python, Fastai, Python, Graphics Processor Unit (GPU), the data libraries used. These research results are an API that makes it easy to

use machine learning. Fastai is made to be easy and more productive. This research corrects the shortcomings of the complex library and Python customizability. Combining the two advantages of hard and PyTorch became the motivation of Jeremy Howard and Silvayn to create layered architectural designs. A high-level API for training models in various applications is easier to use. This way, the user will find it easier to add certain behaviors that suit their needs.

Research [4] entitled "A Deep Learning Approach to Manage and Reduce Plastic Waste in the Oceans". This research is motivated by garbage that is disposed of irregularly. In developing countries, plastic waste is dumped into rivers and oceans. This study uses Deep Learning techniques for image processing and classification to recognize plastic waste. This study aims to identify plastic textures and objects in images to reduce plastic waste in the ocean and facilitate waste management. This study resulted in an accuracy of 99% with the transfer learning method using CNN with pre-processing and 98.46% without pre-processing. Accuracy is 98% with the CNN-SVM combination method. This study explains the importance of pre-processing operations, which previously yielded 95%.

Research [12] entitled Implementation of "Deep Learning Using Convolutional Neural Network (CNN) in Human Expression". This study aims to identify human expressions using the Convolutional Neural Network (CNN) method. Applications made are Python-based, flask-based web, TensorFlow, and OpenCV. The overall stages of the method are pre-processing and classification stages. The dataset used in this study includes expressions of happy, sad, afraid, disgusted, neutral, angry, and surprised. This study shows that the accuracy level is influenced by the number of datasets and the detailed images used in the dataset. This study resulted in an accuracy of 80%.

The study [20] entitled "Classification of Trash for Recyclability Status" examines object recognition using the SVM and CNN algorithms. This study divided waste into six classes based on materials: paper, glass, plastic, iron, cardboard, and trash. In this research, SVM is made using radial basis kernels. With the results of an accuracy reaching 63% and an error of 30%. While the CNN algorithm created is a CNN with five convolution layers, three pooling layers, and three fully-connected layers. The accuracy results obtained using this algorithm are 22%.

The study [16] entitled Convolution Neural Network Application to Detect Types of Waste examined the CNN (Convolution Neural Network) model for sorting waste. Detect garbage using Computer Vision. The accuracy values obtained from the train are 78% and 90%, while the accuracy values from the validation are 74% and 80%. The training in this study aims to implement automatic waste separation using the system. This study aims to reduce time and simplify collecting waste in the waste recycling stage.

2.2 Artificial Intelligence

Artificial Intelligence or commonly called AI is today's technology whose concept "brings human intelligence into machines". AI is artificial intelligence that can understand and analyze a pattern and can learn it. Many AI technologies that have been found are facial recognition, product search recommendations, ad recommendations, and much more. AI helps machine learning to recognize patterns.

2.3 Machine Learning

Machine Learning is an implementation part of AI. Machine learning is an AI learning method that utilizes data to make predictions like humans. The data that enters the machine will be studied and analyzed, which will then produce predictions, suggestions, and decisions.

2.4 Deep Learning

Deep Learning is an artificial neural network algorithm Artificial Neural Networks (ANNs). Deep Learning is a computer technique for extracting and transforming data. Deep learning refers to one of the algorithms used by machine learning in Artificial Intelligence. Deep Learning utilizes complex variables in its analysis, so the machine can understand a pattern or habit that arises from an event. [8][9].

2.5 CNN

CNN (Convolutional Neural Network) is a deep learning technique that is widely used. In the field of Deep Learning, there are several methods in its implementation, one of which is the CNN (Convolutional Neural Network) method. Making Neural Networks is inspired by how neurons in the human brain work [11]. In general, Neural Networks are divided into 3 main parts, namely:

a) Input Layer, is the first layer in the Neural Network and is passive, the Input Layer functions to process Weights data input into the Neural Network in the form of values that will be used for the calculation process at the next Layer, namely the Hidden Layer [10].

b) Hidden Layer, is the second layer in the Neural Network that directly receives the input value from the Input Layer, often there are several Hidden Layers to be able to produce the desired output value, basically, the Hidden Layer is used to calculate and extract the Input data and make decisions on the data to be directly displayed into the next layer, namely the Output Layer [19].

c) Output Layer, this is the last layer in the Neural Network which is responsible for displaying the results of the previous layer, namely the Hidden Layer, at this layer the calculation results will be seen whether the previous one produced a negative or positive value for the input from the first layer, namely the Input Layer [10].

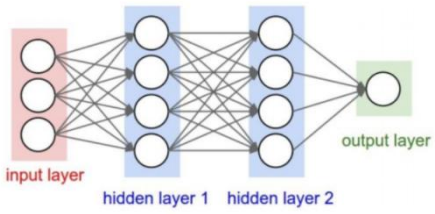


Fig 1: Illustration of input, hidden, output layer

An MLP (Multi-Layer Perception), As shown in Figure 1 has i layers (Red and Blue squares) with each layer containing ji neutrons (white circles). MLP accepts one-dimensional input data and propagates that data on the network to produce output. Each connection between neurons in two adjacent layers has a one-dimensional weight parameter that determines the quality of the mode. A linear operation is performed in each input data layer with the existing weight values. Then the computational results will be transformed using a non-linear operation called the activation function. The data propagated on CNN is two-dimensional data, so CNN's linear operations and weight parameters are different. Linear operations on CNN use convolution operations, with

weights that are no longer just one dimension but are in the form of four dimensions, a collection of convolution kernels as shown in Fig. 2. The weight dimensions on CNN are:
CNN weight dimension = input neuron x output neuron x height x width

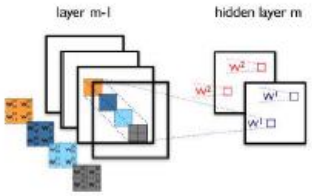


Fig 2: Convolution process on CNN [17]

CNN is a further development of MLP because it uses a similar method with more dimensions. In this CNN algorithm, the input from the previous layer is not a 1-dimensional array but a 2-dimensional array. If it is analogous to the features of the human face, the first layer is a reflection of strokes in different directions, in the second layer features such as the shape of the eyes, nose, and mouth begin to appear, this is because pooling is done from the first layer which is still in the form of scratches. In the third layer, a combination of the features of the eyes, nose, and mouth will be formed which will later be concluded with the face of a certain person [17].

2.6 Anaconda

Anaconda is the most popular Python distribution platform in the world with more than 25 million users worldwide. Anaconda supports an open-source ecosystem where all users are given the freedom to be creative. Anaconda comes with thousands of program packages and open-source libraries. Anaconda consists of various applications already integrated with it such as jupyter notebook, JupyterLab, and Visual Studio. Anaconda works using the python language.

2.7 OpenCV

OpenCV (Open-Source Computer Vision Library) is a library devoted to real-time dynamic image processing, created by Intel and now supported by Willow Garage and Itseez. This program is free and is under the open-source BSD license. This library is a cross-platform library. OpenCV already has many features, including face recognition, face tracking, face detection, Kalman filtering, and various AI (Artificial Intelligence) methods.

2.8 Python

Python is a computer programming language often used to build websites and software, automate tasks, and conduct data analysis. Python is a general-purpose language, meaning it can be used to create a variety of different programs and is not specialized for any specific problems. This versatility, along with its beginner-friendliness, has made it one of the most-used programming languages today. A survey conducted by industry analyst firm RedMonk found that it was the most popular programming language among developers in 2020.

2.9 PyFirmata

PyFirmata is a communication protocol between computer software and a microcontroller. The protocol can be implemented in a microcontroller's firmware or a software package. In theory, the Firmata protocol can be implemented on all types of microcontrollers. However, the complete implementation is on the Arduino microcontroller, including a microcontroller that is compatible with Arduino [13].

2.10 PyTorch

PyTorch is a development of the Torch Framework which was originally written in the Lua programming language. PyTorch, which Facebook developed, supports as a framework for the Machine Learning computing process so that it can be paired with similar frameworks such as Tensorflow (developed by Google), Keras, Theano (no longer developed), Caffe2, and. The syntax that PyTorch uses is not too different from the functions in Numpy, even compared to other frameworks, PyTorch has a neater and simpler syntax [15].

2.11 Fastbook

Fastbook is a library written in Python programs including open-source software. This library is devoted to various machine learning purposes. Fastbook library uses FastAI and Pytorch in its development. After Pytorch was launched in 2017, Jeremy and his colleagues developed this Fastbook Library. This Fastbook library is an advanced development of FastAI [9]

2.12 FastAI v2

FastAI V2 is a library written in Python programs to facilitate the development of Deep Learning. The slogan used by fastai is "Being Cool is About being exclusive". Fastai Aims so that various educational backgrounds can easily learn and create machine learning. Make deep learning easier to use. [9]. FastaiV2 is a new form of library development from FastAI. Where FastaiV2 is not a development of the fastaiV1 library. The commands of fastaiV1 will not work with the FastaiV2 library. FastaiV2 Is a library developed based on the Pytorch and KERAS.

3. RESEARCH METHODS

This chapter will explain the research method based on the theories described in the previous chapter. This research aims to implement machine learning technology to make a prototype of a waste sorting tool. This prototype will sort the garbage automatically. This research consists of several stages of creating a learning system to detect the type of waste using the Convolutional Neural Network (CNN) method and implementing the learning system into a prototype.

This prototype referred to a study entitled "Application of Convolution Neural Network to Detect Types of Waste" [16]. Waste sorting is divided into five types of waste, namely plastic, glass, iron, paper, and cardboard waste, using the CNN method. The CNN model used in this study is resnet18. This research uses the Fastbook API with Fastai Deep Learning Library. Fastai has advantages in terms of speed because Fastai can integrate the learning process using the Graphic Processor Unit (GPU) [9]. The training process in this study uses CUDA technology.

3.1 Design Prototype

Planning for making this prototype is to make a prototype classification of types of waste with several predetermined criteria. Data for classification is obtained by classifying types of waste with photos. Collect various photos to create a dataset for classifying waste. After the photos of the types of waste were collected, and then grouped each type of waste classification. In making this prototype, use five types of waste classification, namely cardboard, plastic, glass, metal, and paper waste. The prototype is made like a selection conveyor using five servos. The prototype was made using the python programming language Arduino as a servo controller and sensor input. Communication between python and Arduino uses a data cable with the pyfirmata library. The user interface of this prototype uses a jupyter notebook based on

anaconda python. This prototyping method uses the Convolutional Neural Network method.
Analysis of prototype needs is done by analyzing what is needed to manufacture and develop this prototype. Beginning with creating a dataset for classification into a prototype that can classify itself based on the dataset. The extracted dataset will then be processed with the help of the fastbook, fastaiv2, and pytorch libraries.

In this prototype, use a notebook HP Pavillion Gaming 15 with RTX2060 MAXQ design as a machine learning training medium, camera Xiaomi Xiaovv Webcam 1080P for taking an image. Prototype specification is used ArduinoMega, Driver Motor L293D, Motor DC N20, 5V DC power, infrared Sensor, and 5 pieces of the servo.

3.2 Prototype Work Diagram

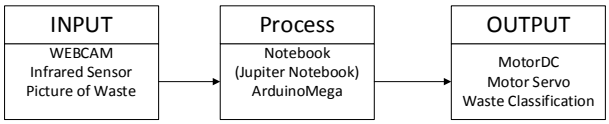


Fig 3: Prototype Work diagram

3.3 Flowchart

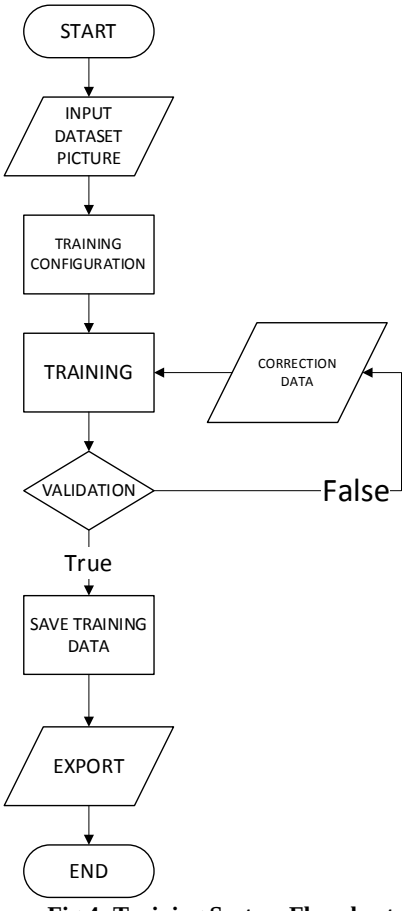


Fig 4: Training System Flowchart

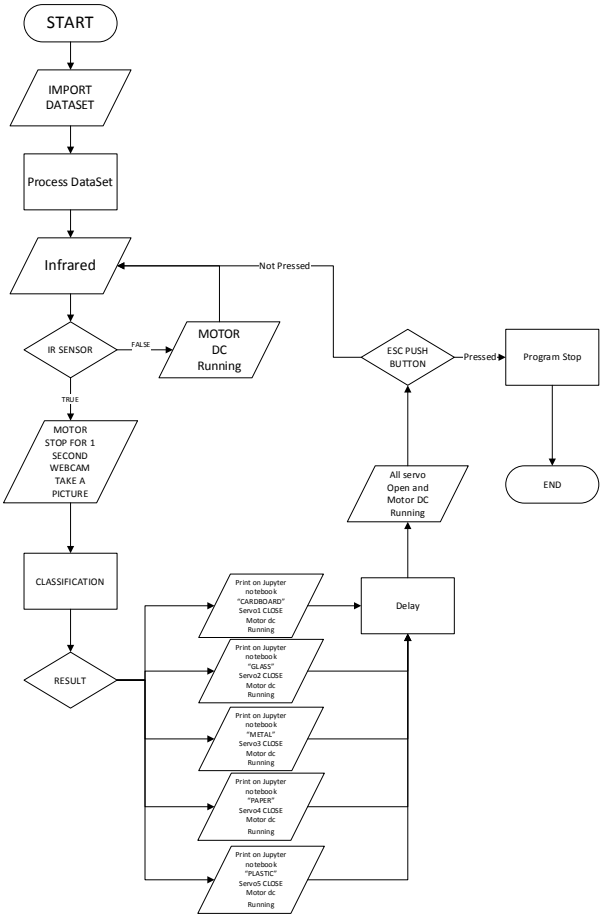


Fig 5: Prototype Work System Flowchart

3.4 Prototype Hardware Schema

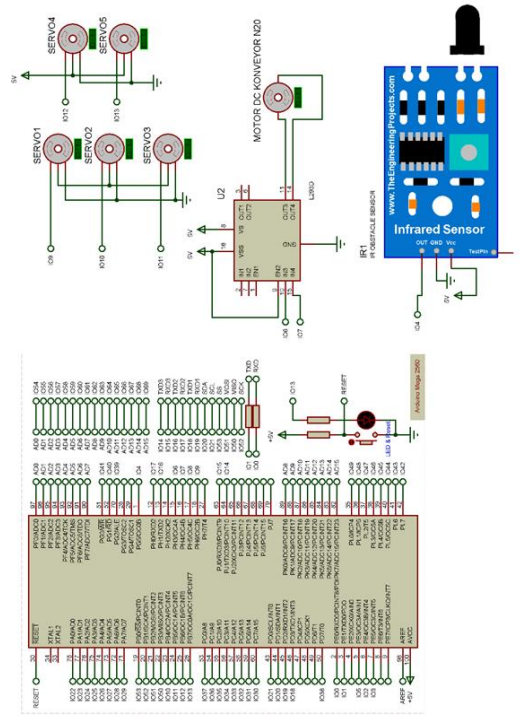


Fig 6: Prototype Hardware Design Schema on Proteus 8

Table 1: Pin Input Output Signal on Prototype

Power Suply1	Power Suply2	ARDUINO MEGA	Infrared Sensor	DRIVER MOTOR	Control 1	Control 2	Control 3	Control 4	Control 5	FUNCTION
VCC	-	-	-	-	VCC	VCC	VCC	VCC	VCC	Supply Power
GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	
-	VCC		VCC	VCC	-	-	-	-	-	
-	-	4	Signal	-	-	-	-	-	-	As input infrared signal to Arduino
-	-	6	-	IN3	-	-	-	-	-	As Logic to control the motor
-	-	7	-	IN4	-	-	-	-	-	
-	-	9 PWM	-	-	Signal	-	-	-	-	As output data from the results of the classification process As Signal from Arduino to Servo
-	-	10 PWM	-	-	-	Signal	-	-	-	
-	-	11 PWM	-	-	-	-	Signal	-	-	
-	-	12 PWM	-	-	-	-	-	Signal	-	
-	-	13 PWM	-	-	-	-	-	-	Signal	

4. RESULTS FROM PROGRAM MACHINE LEARNING

Results using learning fastbook with CNN method. In this study, 2430 datasets were used, consisting of 409 cardboard images, 504 glass images, 417 metal images, 605 paper images, and 495 plastic images.

Table 2: Result Training Waste Classification

Epoch	Train Loss	Valid Loss	Error rate	time
0	1.719215	0.517452	0.174897	00:19
1	0.824326	0.363804	0.125514	00:22
2	0.650297	0.345492	0.117284	00:23
3	0.488330	0.264235	0.092593	00:24
4	0.387829	0.266367	0.096708	00:24

Table 2 shows that this training uses four epochs with VGA support by NVIDIA RTX 2060 MAXQ DESIGN. The learning process can be carried out with a fast process. From the table above, the result of the learning four epoch error rate is 0.096708. The learning results are then exported to aplied in prototype

4.1 Testing Program Machine Learning Fastbook

Observations on the results of the learning program by manually inputting the image and classifying it whether it is appropriate or not. The type of classification test can be seen in table 3

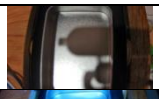
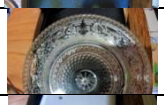
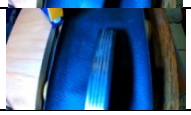
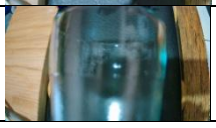
Table 3: Result Testing Waste Classification Program Manual Upload

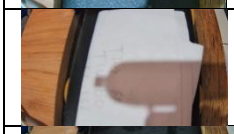
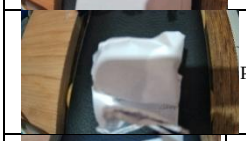
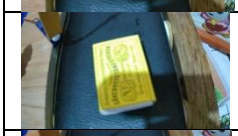
Picture Upload	Waste type	Classifica-tion Machine Learning	Result
	Glass	Glass	Match
	Glass	Glass	Match
	Cardboard	Cardboard	Match
	Cardboard	Cardboard	Match
	Metal	Metal	Match
	Metal	Metal	Match
	Plastic	Plastic	Match
	Plastic	Plastic	Match
	Paper	Paper	Match
	Paper	Paper	Match

4.2 Testing Prototype Automatic Waste Sortir

Test the prototype to run automatically. Prototype takes an image automatically with the infrared sensor as a trigger to take an image.

Table 3: Result Testing Prototype Automatic Waste Sortir

Picture Upload	Waste type	Classifica-tion Prototype	Result
	Metal	Metal	Match
	Metal	Metal	Match
	Metal	Metal	Match
	Plastic	Plastic	Match
	Glass	Metal	Not Match
	Plastic	Plastic	Match
	Plastic	Plastic	Match
	Plastic	Plastic	Match
	Metal	Metal	Match
	Plastic	Plastic	Match
	Paper	Paper	Match
	Paper	Paper	Match
	Plastic	Cardboard	Not Match
	Cardboard	Cardboard	Match
	Plastic	Plastic	Match
	Metal	Cardboard	Not Match
	Metal	Cardboard	Not Match
	Plastic	Plastic	Match
	Cardboard	Cardboard	Match
	Glass	Glass	Match
	Plastic	Paper	Not Match
	Plastic	Plastic	Match
	Glass	Glass	Match
	Cardboard	Cardboard	Match
	Paper	Paper	Match
	Paper	Paper	Match
	Metal	Metal	Match
	Metal	Metal	Match
	Paper	Paper	Match
	Paper	Paper	Match
	Metal	Metal	Match
	Metal	Metal	Match
	Glass	Glass	Match

	Plastic	Cardboard	Cardboard
	Plastic	Paper	Not Match
	Plastic	Metal	Not Match
	Metal	Metal	Match
	Paper	Paper	Match
	Paper	Paper	Match
	Paper	Paper	Match
	Paper	Paper	Match
	Metal	Plastic	Not Match
	Paper	Paper	Match
	Plastic	Plastic	Match
	Cardboard	Cardboard	Match
	Cardboard	Cardboard	Match
	Cardboard	Cardboard	Match
	Plastic	Plastic	Match
	Metal	Metal	Match
	Plastic	Plastic	Match

From table 3, it is obtained that information from 50 test data obtained the relevant test results as many as 42 pieces and 8 pieces contained information errors. From these results can be calculated accuracy of 84%.

5. CONCLUSIONS

Results Based on the results obtained in this study, the results of this Machine Learning Program can be applied to the prototype of an automatic waste sorter machine. the Automatic waste sorter into various recycling is possible through machine learning, computer vision, and controller Arduino. The plan of implementation of machine learning for an assembly to prototype automatic waste sorter based on notebook and ArduinoMega has succeeded. This Prototype can classify cardboard, glass, metal, paper, and plastic. Quality of camera, dataset training, lighting when taking a picture of waste take effect to result in classification.

The development of this research can be done by changing the data into more classes, such as organic, rubber, and electronics waste. This can increase accuracy because the image train process is more detailed and has almost the same shape between classes. In addition, more data can be added, such as one class of 1000 data. In the future, there will be robots that can sort waste automatically.

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