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Artificial Intelligence - Based Waste Sorting Machine

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Abstract

This article presents an artificial intelligence waste sorting machine. The artificial intelligence waste sorting machine was designed and constructed using machine learning, sensors, and the mechanical parts. Sorting waste is an important task in managing our impact on the environment. However, manually sorting waste is labour-intensive, slow, and prone to human error. At the end of the construction, we were able to sort out both the metal and non-metal waste. The design can be applied in homes, schools, offices, and other locations where waste sorting is necessary. The traditional methods of separating metals and non-metals use belts or chains to move the conveyors during separation, which introduces energy loss in the form of sound and heat, whereas this proposed system utilises sensor-based servo motors.

Keywords: *Artificial*, *Intelligence Sorting, Waste.*

I. INTRODUCTION

Artificial Intelligence (AI) can be defined as the science of creating or making man-made machines (programs) that can think like humans to do things that can be considered “smart” and can be utilised to assist humans in areas of decision-making and many more. The whole point of artificial intelligence is to help us humans make decisions that we cannot take (better decisions). Artificial intelligence has over the years gotten a great deal of attention all around the world because of its potential to revolutionise entire industries; we can see that in its ability to create apps (Chat GPT or Bard AI, for example), images, audio, video, etc. As a result, there is a need to advance from the conventional ways of decision-making to a more advanced, technology-driven (artificial intelligence) approach to address environmental, economic, and social challenges faced in our world today. As a result, in this work, the term "artificial intelligence-based waste sorting machine" can be considered the efficient and effective use of these man-made machines (AI) to carry out smart waste material sorting. These machines can classify waste into various categories such as metals, papers, plastics, and non-metals. The goal of this research is to automate waste sorting using artificial intelligence, thereby improving accuracy and efficiency compared to the traditional method where humans sort waste, a process that is time-consuming and prone to errors. By using AI, the sorting process can be automated, allowing for a faster and more accurate approach to waste sorting. The artificial intelligence-based waste sorting machine can be used in schools, homes, or industrial waste companies, either for recycling or disposal.

At the end of this research, there would be a machine that could efficiently and accurately sort out waste with the help of artificial intelligence. This work can be beneficial for those in educational institutions, homes, industries, and government agencies; a policy should be implemented by the government regarding the use of this machine. This policy would promote responsible waste management and encourage the adoption of advanced technologies across

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various sectors. By integrating this machine into everyday practices, we can significantly reduce landfill waste and enhance recycling efforts, ultimately contributing to a more sustainable future.

II. LITERATURE REVIEW

In the past few years, many researchers have carried out different studies on the use of artificial intelligence in the sorting of waste; [1] In the work “Automatic Waste Sorting in Industrial Environments via Machine Learning Approaches” concentrated more on industrial waste and how to decrease the complexity of waste management systems. In his experiment he compared two machine language algorithm which are convolution network neuron (CNN) and support vector machine (SVM) by varying various parameters such as the size of the image, amount of input images, properties of the images, variation in layers and different training options, while also studying the performance and accuracy that these algorithms provide in classifying waste image in various industrial environment, the three categories are: paper, plastic and metal. Most recently, waste problems have risen quickly during the industrial and petrochemical revolutions, a rapid rise in world population, and growing mass consumption. The waste generated in such a faster pace mostly end up in a dispose field or incineration plant because they are not properly sorted or managed.

There were several advantages to this experiment. The experiment conducted showed that machine learning can be efficiently and effectively used to sort waste in industrial environments. It could also be of use to increase the trash sorting rate and efficiency so that the industry could reuse the resource in-house or could be a useful tool for a recycling plant to recycle the product without dilution. As expected, between the two selected algorithms for machine learning classification, CNN performed better than SVM. The development of CNN focused on the classification of images and objects. With the use of sliding convolution windows, it manages to reduce the number of learnable parameters without losing the quality of the model. In the challenges experienced from the experiment conducted, it was discovered that these sorting algorithms are not powerful enough to complete the job by themselves and still require human input time and again. Waste management systems that conduct intelligent sorting have to provide low error rates and provide timely warnings. For the time being, the technology we have at our disposal is powerful enough to do our task but not powerful enough to replace it. In the past few years, many researchers have carried out different studies on the use of artificial intelligence in the sorting of waste [1]. The work “Automatic Waste Sorting in Industrial Environments via Machine Learning Approaches” concentrated more on industrial waste and how to decrease the complexity of waste management systems. In his experiment he compared two machine language algorithms, which are the convolution network neurone (CNN) and support vector machine (SVM), by varying various parameters such as the size of the image, amount of input images, properties of the images, variation in layers, and different training options, while also studying the performance and accuracy that these algorithms provide in classifying waste images in various industrial environments. The three categories are paper, plastic, and metal. Most recently, waste problems have risen quickly during the industrial and petrochemical revolutions, a rapid rise in world population, and growing mass consumption. The waste generated at such a faster pace mostly ends up in a disposal field or incineration plant because it is not properly sorted or managed. There were several advantages to this experiment. The experiment conducted showed that machine learning can be efficiently and effectively used to sort waste in industrial environments. Additionally, it could help increase the trash sorting rate and efficiency, allowing the industry to reuse resources in-house

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or providing a useful tool for recycling plants to recycle products without dilution. Between the two selected algorithms for machine learning classification, CNN performed better than SVM. The development of CNN focused on the classification of images and objects. With the use of sliding convolution windows, it manages to reduce the number of learnable parameters without losing the quality of the model. In the challenges experienced from the experiment conducted, it was discovered that these sorting algorithms are not powerful enough to complete the job by themselves and still require human input time and time again. Waste management systems that conduct intelligent sorting have to provide low error rates and provide timely warnings. For now, the technology we have at our disposal is powerful enough to do our task but not powerful enough to replace it.

Wojciech Czekała *et al.* [2], in their research work "Modern Technologies for Waste Management: A Review", discussed the various waste management technologies and how it has evolved over the years, motivated by the desire to minimise the environmental impact of waste and enhance the effectiveness of waste management procedures. There is a wide range of approaches, ranging from conventional techniques like composting or landfilling to modern, more advanced solutions using IoT technologies. One of the modern technologies in waste management is smart bins. Designing a smart waste bin has a purpose: to provide an effortless solution to handle all of the waste bins in a city. The smart waste bin incorporates a variety of sensors and technologies to enhance waste management efficiency [3]. These sensors can detect a wide range of data, such as the fill level of the bin, gas emissions produced by the waste, humidity, weight, and many more [4]. An effective method of controlling the fill level of waste is using an ultrasonic sensor which compares the current fill level by measuring the distance between the top and bottom of the bin [5]. Then, the microcontroller compares this value with waste bin fill capacity so that it can send a notification to the authorities. Another waste management technology discussed in the paper is artificial intelligence and robots; computer vision allows the robots to interact with waste physically. Robots can efficiently detect different types of waste based on their visual characteristics, such as shape and colour. It may serve a purpose in sorting waste on a conveyor belt, where individual pieces are automatically transported to the right container for further recycling. It also has the potential to spot illegal waste dumping [6], a problem that can have a serious impact on our health and environment. AI-powered software could analyse satellite images to pinpoint potential locations for illegal dumping [7]. Such an approach can prevent further pollution and damage to the environment [8].

This study aimed to show the potential that modern technologies have for waste management. The studies presented demonstrate significant potential for improving and automating waste management processes. The smart waste bin is an innovative technology that uses sensors and Internet of Things connectivity to optimise waste management processes. Sensors attached to a bin can detect the amount of waste inside and other parameters, such as temperature and humidity. Waste management companies can use this data to access real-time waste status information and enhance their service efficiency. Artificial intelligence and robots are being increasingly used in waste management. AI algorithms not only speed up processes, but they also improve their accuracy and safety. Various situations can utilise AI, from powering machines to predicting illegal dumping locations using photos from space. Computer vision has shown significant promise in tackling the global waste management crisis, using its ability to distinguish types of waste based on visual characteristics. AI capabilities are able to enhance recycling rates and optimise waste collection. Robots can do their job faster, more efficiently, and more precisely than humans constantly learning about a given task. Using these

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technologies can significantly increase waste management effectiveness. However, there are also disadvantages of these technologies. For instance, the cost of smart waste bins is significantly higher than that of regular waste bins. We have to keep in mind that waste bins should be almost everywhere in the city. Smart waste bins are larger, and the costs of repairing them can be burdensome for the authorities. These devices need to be maintained regularly, which is also a cost. It is crucial to acknowledge the "technological literacy" of society in such systems. We should minimise any solution that necessitates user interaction, such as opening the bin via a touch screen. It will also be a challenge to implement AI in waste management successfully. The cost and scalability of AI systems are uncertain. Furthermore, we must acknowledge and manage the risk of job displacement for waste management workers, as is the case with any automation. Bingbing Fang *et al.* [9], in their review article, "Artificial intelligence for waste management in smart cities: a review," provide an overview of waste types, their generation, and associated issues, as well as explore various applications of artificial intelligence in waste management. These applications include intelligent bin systems, waste-sorting robots, sensor-based waste monitoring, and predictive models of waste generation. Additionally, the paper discusses how artificial intelligence can help monitor and track waste materials throughout the recycling process, optimise the logistics and transportation of recycled waste, identify and reduce illegal dumping and waste treatment practices, and analyse the chemical composition of waste. One of the unique contributions of this paper is the combination of artificial intelligence and waste chemical analysis to improve the process of converting waste into energy.

Studies have suggested that integrating waste management into future smart cities with entire product lifecycles could be a potential step toward achieving "zero waste" [10]. In order to achieve this goal, we must undertake three steps: Waste prevention, precise refuse collection, and functional value recovery from collected waste are all priorities [11]. Furthermore, we should encourage the Internet of Things waste management networks to enhance the life cycle of products and their recycling value [12]. However, the cost of implementing smart garbage bins is relatively high, making it challenging to promote them widely. Furthermore, environmental factors such as temperature and humidity can affect the regular operation of these bins. Another challenge is that the waste-sorting robots are impractical due to their high installation and maintenance costs compared to traditional waste-sorting methods, while for the sensor-based waste monitoring, the setback with regard to this system is its inability to display real-time filling levels of the garbage bin.

According to the authors Shirazush Salekin Chowdhury *et al.* [14], in their paper "Design and Implementation of an Autonomous Waste Sorting Machine Using Machine Learning Technique", an autonomous waste sorting machine was made which could detect multiple classes of waste materials and then separate them accordingly. The waste products were taken as input in a funnel-shaped structure and dropped one by one to a conveyor belt where they would be detected by machine learning technique using Faster-RCNN (Regions with Convolutional Neural Network) a machine learning algorithm used for object detection, and then a servo motor would separate them according to the detection result. The main benefit of their work is that instead of using human intervention, computer vision is implemented to sort out the waste materials. The problems encountered by their studies are that there is a short time delay during image processing and the conveyor size- limiting the size of the materials. Also in the research carried about by Alberto Bacchin *et al* [15] in their project "AI and Robotics for waste sorting and recycling" developed an AI-powered robot manipulator for waste sorting. Their goal was to increase efficiency and lower the cost of waste separation in order to reduce

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the amount of waste directed to the thermal destruction plant. For the recognition of waste, Deep Learning, Self-Supervised Learning and Data Augmentation techniques was widely used in this project in order to deal with the complexity of collecting large amount of labeled data in real-world industrial settings. However there are limitations to this work, it is specifically anticipated that the items to be separated are put on the conveyor belt so they do not overlap. Because it is not always possible to guarantee that condition and because additional machinery must be placed before it in order to better distribute the waste, this necessity restricts the separation yield. This necessity restricts the separation yield, ultimately leading to inefficiencies in the overall process. To enhance the effectiveness of the system, it is crucial to explore alternative methods for item distribution and separation that can accommodate varying conditions on the conveyor belt.

III. MATERIAL AND METHOOLOGY

Materials required for this work are stated as follows; Amega328P (Arduino microcontroller), ultrasonic sensor, inductive metal sensor, SG90 and MG996R servo motors, voltage regulators, 9v batteries, switch and also the mechanical construction.

The design and simulation method were used to implement this research using Proteus and Arduino software. Figure 1 represents the block diagram of the proposed system. It represents the flow of information from the power supply to the sorting mechanism and conditions. A flowchart of the developed system is shown in Figure4.

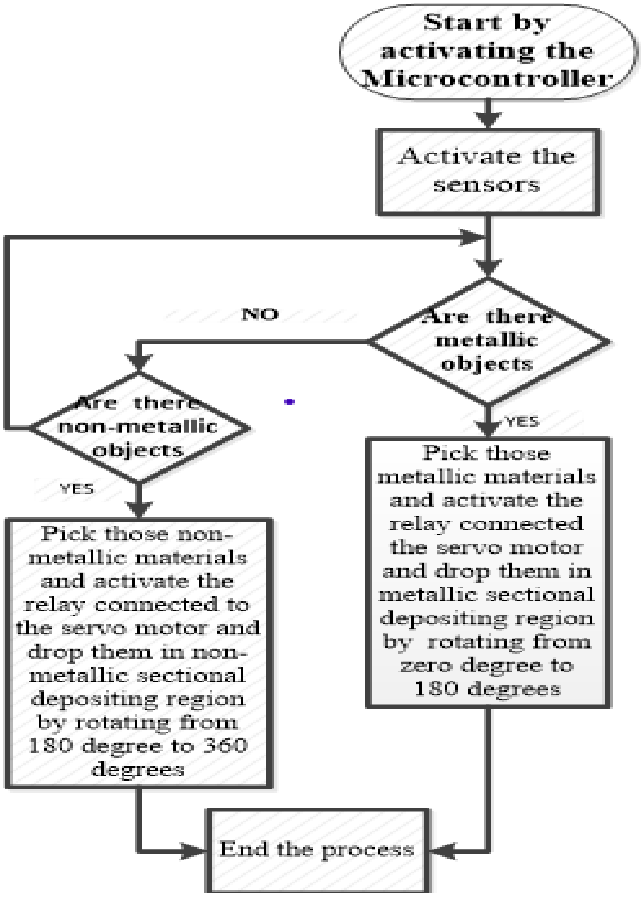

Figure 4: Flowchart showing the process of sorting

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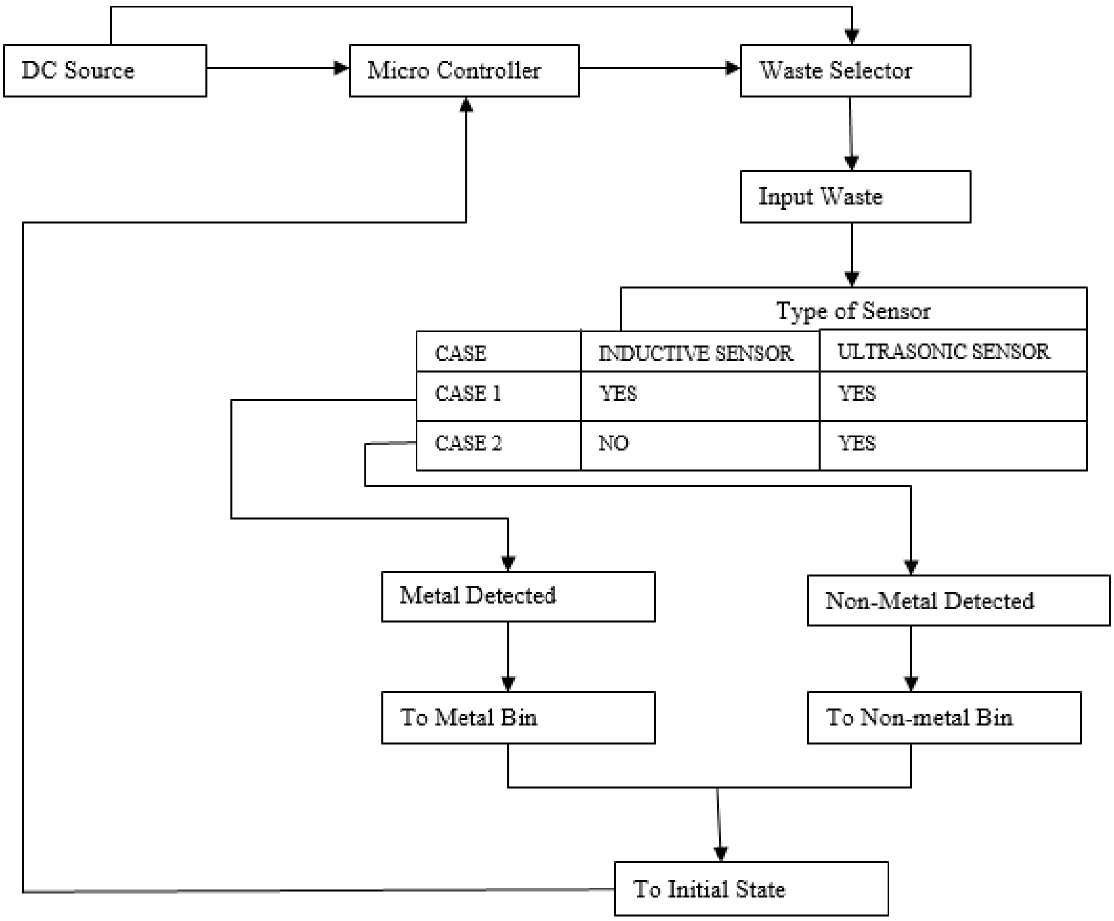

Figure 1: Block Diagram of an Artificial Based Waste Sorting Machine

Equations on the AI waste sorting machine

(a) Distance Calculation

The ultrasonic sensors measure distance by emitting sound waves and calculating the time it takes for the waves to bounce back. The distance measured by the sensor, D is expressed as

$$D = \frac{t \times v}{2} \tag{1}$$

t is the time taken for wave to return, v is the speed of sound in air (approximately 343 meters per second)

(b) Inductive Sensor

The inductance can be calculated with formula;

$$L = \frac{N^2 \times \mu \times A}{l} \tag{2}$$

where N is the number of turns in the coil, μ is the permeability of the core material, A is the cross-sectional area of the coil, and l is the length of the coil.

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Voltage Regulator

The output voltage V_{out} can be calculated using the formular:

$$V_{out} = V_{ref} \times (1 + \frac{R2}{R1}) \tag{3}$$

V_{ref} is the reference voltage of the regulator

R1 and R2 are resistors connected in a voltage divider.

(c) Power Dissipation

$$P_{diss} = (V_{in} - V_{out}) \times I_{load} \tag{4}$$

Where V_{in} is the input voltage, V_{out} is the output voltage, and I_{load} is the load current.

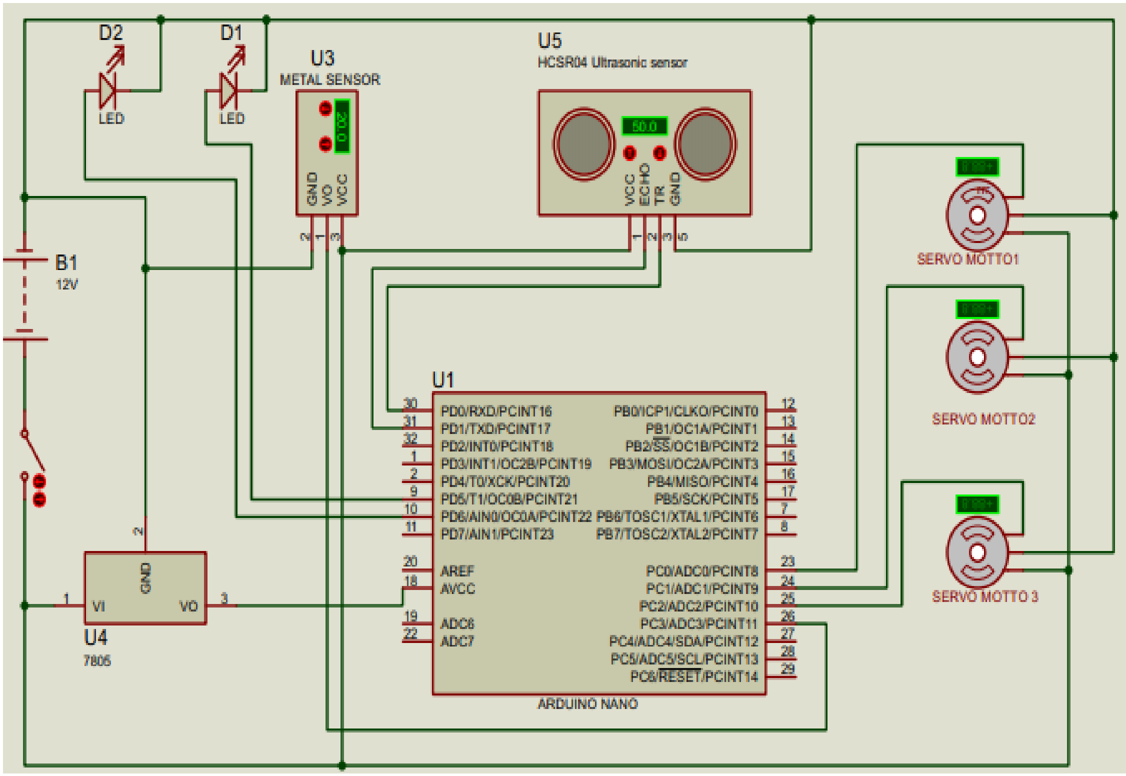

Figure 2: Circuit Diagram of Artificial Intelligence Waste Sorting Machine

In this project, the ATMEGA328 microcontroller was programmed using the C++ language due to its familiarity and ease of adjustment in case of errors. The microcontroller, which operates with a maximum input voltage of 5V, acts as the central processing unit of the system. It receives coded instructions through Arduino programming and executes them accordingly.

As shown in Figure 3.2, a voltage regulator configuration is implemented at the voltage source (Battery) with voltages exceeding 5V. As a result, the input from the battery to the microcontroller is stepped down from its initial value to remain within the microcontroller's voltage limit which is 5v.

This adjustment is subsequently accommodated in the code. The battery also supplies voltage to the servo motors. The microcontroller also gives coded information to the servo motors, sensors and also the LED.

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IV. RESULTS AND DISCUSSION

The artificial intelligence waste sorting machine aimed to improve waste management by leveraging artificial intelligence for automated waste sorting processes. By developing a design that is able to classify two different kinds of waste. The A.I waste sorting machine comprised of a microcontroller, sensors, servo-motors, which was able to segregate two different kinds of waste from the utilization of a machine language code which was understandable to the machine design. The construction carried out in this project is summarized below in addition to the circuit design discussed in chapter three.

a) The circuit diagram of the design was first implemented using the Proteus 8 professional by placing all the required components, the components used in the design of the circuit diagram was also used in the main construction which serves as a major guideline in the designing of the project. The reason for this was to understand how the circuit works before the physical construction.

b) The physical implementation of the work was carried out using hardware components which consisted of the adapter box; where all the connection wires from all the components are been connected to the breadboard and also from the power source. Fig 4.1 shows the physical design below.

Figure 3: Artificial Intelligence Waste Sorting Machine

The Arduino IDE was used to program the microcontroller (ATmega328P), giving it set of instructions that will be interpreted by the sensors and servo motor. Despite the success, the work encountered so many challenges, including different compilation errors from the code, sensor limitation and mechanical challenges. But those challenges underscored the importance of ongoing research and development to address issues faced and improve the reliability of the artificial intelligence waste sorting machine.

V. CONCLUSION

Comprehensive research has been carried out into the utilization of artificial intelligence in the sorting of waste materials. The AI waste sorting machine presents a promising solution to the challenges of waste by using advanced technology. Through the integration of artificial intelligence, the system demonstrates the efficiency and accuracy in sorting wastes. This not

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only reduces the burden on traditional wastes sorting facilities but also promotes recycling and environmental sustainability.

The implementation of this technology has the potential to advance the way we approach waste management on a big scale, offering a scalable and adaptable solution that can be designed to meet specific needs and challenges.

VI. RECOMMENDATION

Moving forward it is recommended to further optimize the AI algorithms to enhance the machine sorting capabilities, particularly in distinguishing between other types of waste materials. Additionally, investment in research and development can lead to the creation of more affordable and scalable versions of this technology, making it accessible to a wider range of waste management facilities and communities.

Additionally efforts should be made to raise awareness and educate the public about the benefits of AI waste sorting machine and the importance and the importance of responsible waste management practices**.**

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