2023 3rd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) | 979-8-3503-4643-5/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICREST57604.2023.10070081

Design and Development of E-Waste Monitoring, Segregation and Recycling System

Manas Saha Roy, Md. Nazmul Islam Lusan, Md. Ahadur Rahman Khan, Md. Parvez Khan, Abir Ahmed and Md. Saniat Rahman Zishan
Department of Electrical and Electronics Engineering
American International Univerisity-Bangladesh (AIUB)
Dhaka, Bangladesh
manassaharoy@outlook.com, lusan705@gmail.com, ahadkhanabir1998@gmail.com, parvez242.pk@gmail.com, abir.ahmed@aiub.edu

***Abstract*— Electronic waste is increasing rapidly every year as the use of electronic devices grows. In Bangladesh, people are not that aware of the consequences of e-waste. This paper represents the design and implementation of e-waste detection, sorting, and segregation. The sorted e-waste goes through a segregation process so that it can be recycled. This paper also shows a digital e-waste collection system through a website. A conveyor is designed and implemented to detect electronic waste automatically and collect both e-waste and other waste. Following collection, the sorted waste will go through a shredding process in which the e-waste will be shredded to extract reusable materials from the waste. A website is also being developed to introduce a new way of doing e-waste collection and monitoring. Finally, a new method of e-waste management is designed and implemented that is compared with the typical method of waste management in Bangladesh.**

Keywords*— *E-waste detection, sorting and segregation, website system, shredding process, conveyor, metal detector sensors

I. Introduction

Electronic waste, or e-waste, describes discarded electrical or electronic devices. Toxic substances in this waste include polyvinyl chloride, mercury, lead, chromium, beryllium, cadmium, gallium arsenide, and are extremely harmful to the human body, animals, plants, and, most importantly, our environment [1].

E-waste generation, recycling systems, international trade, and environmental impacts are now major concerns with the advancement of technology. Studies reported on terminology, current environmental concerns, and possible solutions [2–3]. In Bangladesh, e-waste is collected from a dustbin or dump yard because most Bangladeshis are unconcerned about e-waste and do not have a designated place to dump it. Some hawkers collect junk or broken electronics and mainly buy old televisions, broken IPS, old or broken computers, and other broken, old electronic stuff. They collect all this e-waste by roaming around different places [4]. The growth rate of e-waste generation is about 20 percent per year, according to a study by the Bangladesh University of Engineering and Technology. The study carried out last year found that the amount of e-waste rose to 0.4 million tons in 2018 from 0.13 million tons in 2010. The volume is projected to be 4.62 million tons by 2035 [5]. Workers are typically responsible for recycling e-waste. Most of the cases of e-waste are shredded by shredding machines, and the remains are sorted by type and value of materials. Another way of recycling is manual; workers recycle valuable material by hand [6]. Researchers or engineers of different academies and industries have been doing their research, and they have proposed and developed different automated systems for segregating and recycling e-waste [7–9]. A survey in Brazil shows that 91% of the total users are dumping e-waste in the wrong manner [10]. Some researchers show promising results using artificial intelligence to develop management systems [11–12]. An alternative solution for dumping the e-waste is using seagoing ships [13]. A website containing the date of electronics that are imported to Bangladesh, information about the buyer and seller, the lifespan of the product, and when it needs to be dumped can help monitor electronic waste. When the buyer knows the device's lifespan, they can dump the device, or any organization can collect the device as waste. E-waste collection will be systematic and monetized in this manner. The improvement of technology cannot be stopped, so the only way to minimize the effects of e-waste is to manage the waste properly. That is why we are collaborating with the e-waste sorting and recycling system, which will separate electronic waste from garbage and recycle it so that the harm caused by it is minimized and people are aware of where to dispose of e-waste. So, the overall process is divided into three parts: collection, segregation, and recycling.

The main objective is to develop a system that can monitor this e-waste, sort it, and recycle it properly to make Bangladesh clean by maintaining the electronic waste.

II. Methodology and Design

This system will be able to detect electronic waste automatically and recycle it in the most efficient way possible via a website. A lot of trails were required to design a semi-autonomous e-waste management system. The detection system, sorting system, and recycling system were made one after another by following the trial-and-error method in Fig. 1

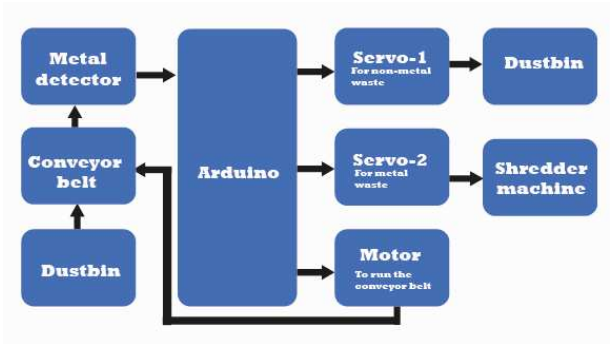

Fig. 1. Block diagram of the system

The conveyor is built in such a way that it can lift different types of waste, like glass, circuit boards, electrical components, plastic, and other objects. It is capable of handling objects weighing up to 500 g.The detection system contains two proximity sensors placed one after another, crosswise. These sensors are calibrated in such a way that they can detect highly dense metal objects and also low-density metal objects too. This sensor works in such a way that it can detect metals.

Various types of e-waste contain copper, aluminum, lead, metal, and other materials. So when an electronic object moves near the sensor, it detects This detection depends on the type and density of material inside. The system detects e-waste, sorts it, and then passes it to the shredder machine. This system is based on a microcontroller (Arduino), which is used here as a suitable component for this purpose. For the detection of e-waste, metal proximity sensors are used here. The sensor gives data to the Arduino. Arduino sends the signal to servo motors based on the received data from sensors. The servo will then turn and collect the waste based on its type. An LCD will show the type of waste that passed through the conveyor. The LCD will be linked to the Arduino via I2C serial communication. This makes fewer wire connections possible.

A. Design of the Conveyor

The conveyor is designed in such a way that it can be carried by one person. The circuitries related to the conveyor are designed to be placed in the sideways direction of the conveyor body in Fig. 2.

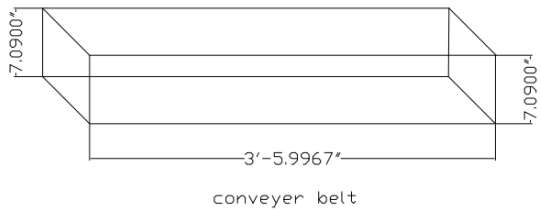

Fig. 2. 3D design of conveyor

A DC motor is used to run the conveyor. In Fig. 3, it is shown how the DC motor will be connected to the battery and switch. The system will be based on an on/off push switch. When the switch is pushed on, the conveyor will start, and when the switch is pushed off, the conveyor will stop.

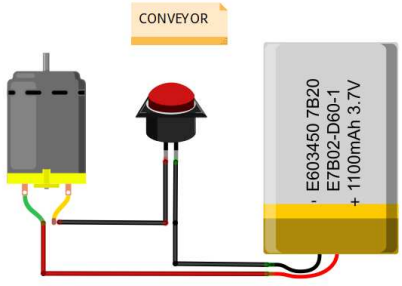

Fig. 3. Simulation setup of the conveyor

B. E-Waste Detection System

The detection system for e-waste is designed with an Arduino and an LCD display, along with two metal proximity sensors shown in Fig. 4. These sensors will be installed on the conveyor's upper section so that when waste passes over it, the sensors can detect the type of waste and the LCD can display the type of waste.

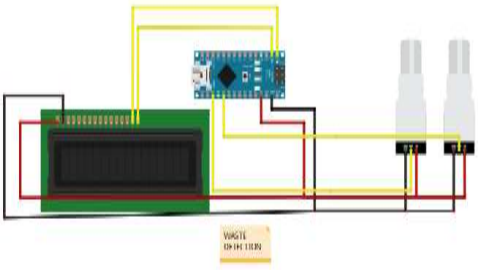

Fig. 4. Design of e-waste detection system

C. Design of the Waste collector

The waste collector is designed in Fig. 5 to be placed at the end of the conveyor. It is based on a servo motor. The sensors will send data to Arduino, and then Arduino will send data to a servo to turn based on the waste type. Although the servo has a 180-degree rotation, 90-degree and 45-degree rotations were used in this system.

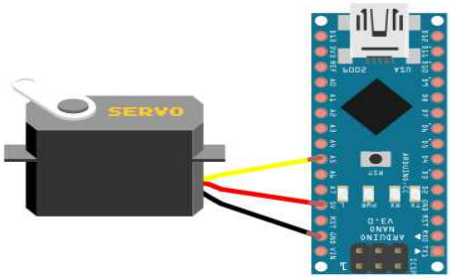

Fig. 5. Design and simulation of sorting part

D. Design of Shredder Machine

A shredder machine requires a very high-torque motor and a strong mechanism. But for this project, a brushless motor is used. A brushless motor has high speed and torque. A propeller is made of metal. The shape of the shredder machine is square shown in Fig. 6. The motor is located in the lower portion of the box. The top will be covered with a plate.

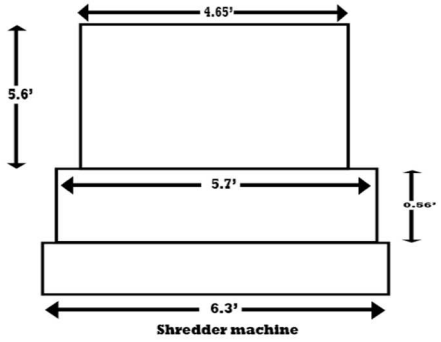

Fig. 6. 3D Design of Shredder machine

The object that will be shredded will be placed inside the box, and the top will be covered. As shown in Fig. 7, the brushless motor will be connected to the battery through a switch. When the switch is turned on, the motor begins to rotate.

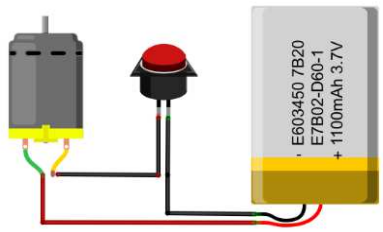

Fig. 7. Simulation setup of the Shredder machine

E. Website Design

website is designed to keep data on electronic devices that are sold to buyers by the seller. The website shown in Fig. 8 contains three panels. One is for the admin of the website, one is for the buyers, and another is for the sellers. The admin panel will contain details and control of the website for the admin. The buyer's panel will include information about the product purchased by the buyer, the date of purchase, the expiry date of that product if it is available, and personal information about the buyer. The seller panel will have details of the seller's information. The seller will have a section where he or she can see if the product has been returned or not. This website will notify both buyers and sellers when their products will be discarded.

Fig. 8. Website design (homepage)

F. Simulation of Overall System

In Fig. 9, overall system has three parts. One is the conveyor part, where the waste is passed through sensors. Then comes the detection phase.

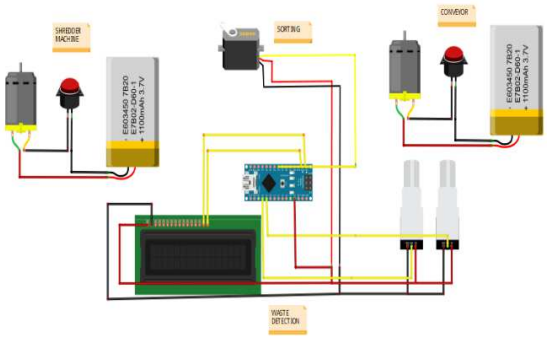

Fig. 9. Overall System simulation

The detection system separates e-waste from waste that has passed through the conveyor. It has been designed with two metal-detecting proximity sensors. The waste sorting system is driven by a servo motor. There is an LCD connected to display the process and results. The last part is the shredding machine, which is based on a DC motor, switch, and battery, the same as the conveyor design. This whole system is run by an Arduino Uno.

III. Hardware Implementation

A. Implementation of the conveyor

In Fig. 10, The conveyor is made of steel. To rotate the conveyor belt, a dc motor is attached on the side. The conveyor belt is made of plastic-type paper. The conveyor is about 2 meters in length. The conveyor belt is around 1.8 meters long. Because the circuit is installed upside down, there is a gap on the bottom. There is space sideways too. There is no border on the conveyor's upper part, considering sensor placement.

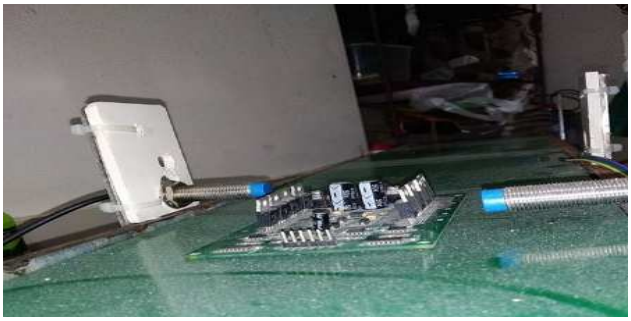

Fig. 10. Implementation of the conveyor for metal detection.

B. Implementation of the E-waste Detecting System

The e-waste detection system is made with two metal proximity sensors placed one after another shown in Fig. 11. This sensor placement is done in such a way that if objects going through the conveyor miss one sensor, they will be detected by the other one. The sensors are attached to both sides of the conveyor. One is on the right side, and the other is on the left. Sensors are attached with a built-in screw system, and cable ties were used to make them attach accurately.

Fig. 11. Sensor attached in the left side of conveyor

Fig. 11 depicts two sensors placed one after the other in such a way that the system does not miss any object and detects any object passing through the conveyor.

C. *Implementation of the sorting system*

The sorting system works when an object passes through the conveyor. The sensors detect the type of that object and send the data to Arduino. Then, depending on that data, Arduino gives a signal to a servo to rotate the collector box. In Fig. 12, the collector box has two chambers. One is for e-waste, and the other is for other waste. The collector box is placed over a servo motor shaft. So, the box rotates when the servo rotates. The box is made of plywood. As the servo that is used has low torque, the box is made with low-weight materials. This collection system is also sorting the waste.

Fig. 12. Waste collector

D. *Implementation of the shredding machine*

Shredder machines need high power and a strong mechanism. Fig. 13 shows that a brushless motor with high torque is used in this system. The propeller of the motor is made of metal. The motor is placed beneath a box made of plywood. The mechanism used here is the speed of the brushless motor and the metal blade of the propeller. When an object hits the blade rapidly, it will break into pieces.

Fig. 13. The Shredder machines

E. *Development of the website*

The website is for a better e-waste collection system. There are three pages on the website. One each for the administrator, the seller, and the buyer. HTML and CSS are used to create the website. The design is kept simple, with a background image. Fig. 14 shows the admin panel.

Fig. 14. Admin panel of the website

Fig. 15. User or buyer panel of the website

For the user panel in Fig. 15 and the seller panel in Fig. 16, a table is kept where information about the user and seller will be shown. This will be kept secure so that other users' information cannot be viewed. Only the buyer and seller can see each other's information. They will see the expiration date of the product on the website. If the product is broken or unusable, they can update it through the website, which will help collect it as e-waste.

Fig. 16. Seller panel of the website.

IV. Results Analysis

A. *Detection System for Different Objects*

Different types of electronic components and circuit boards can be detected through this system. A printed circuit board integrated with some electronic components has been detected, as shown in Fig. 17.

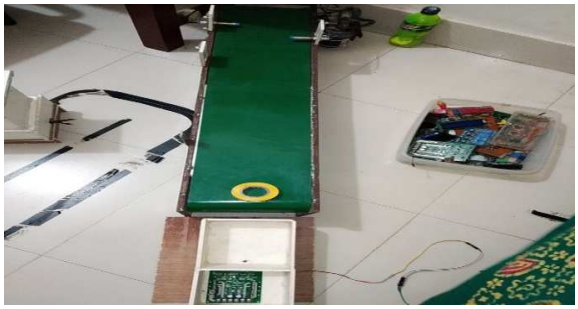

Fig. 17. Electronic components through system

Fig. 18. Items sorted after detection

The sorting process takes place right after the detection process. The rotation of the servo is determined by the type of object detected. Here, different types of objects have been detected, as shown in Fig. 18 after sorting. This collection process takes 8 seconds. For six different items, it took 56 seconds to be sorted.

B. Time analysis of Conveyor Performance

To properly detect electronic waste, different types of objects were used. The sensors are positioned and calibrated in such a way that they can detect even a minimum amount of metal. Different types of objects were passed through the sensors by conveyor, sorted, and their processing times were analyzed for different objects. The time varies based on the types of objects, whether they are metal or non-metal. Based on the detection time, conveyor performance varies. The summary of the conveyor's performance is shown in Table I. After collecting the sorted e-waste, it will go through a shredding process in which the e-waste will be shredded to extract reusable materials from it. The performance of shredder machines has been summarized in Table II.

TABLE I. TIME ANALYSIS OF CONVEYOR PERFORMANCE

Task	*Quantity (pieces)*	*Types of Object*	*Duration (seconds)*
Object pass through conveyor	1	Various	7
Object detection by 1	1	Metal	2
Object detection by 1	1	Non-metal	1

TABLE II. TIME ANALYSIS OF SHREDDER MACHINE PERFORMANCE

Task	*Quantity (pieces)*	*Types of Object*	*Duration (seconds)*
Shredding	1	Metal	36
Shredding	1	Non-Metal	14

Sensors have been sorting wet, dry, glass, and metallic wastes. It has been discovered that the change in capacitive value of metallic and non-metallic wastes differs. Other types of dry waste, such as glass and wood, are also sorted by sensors. So, this system shows that the e-waste has been successfully monitored, segregated, and recycled by using this automatic e-waste sorting and recycling process. The system is faster and more reliable than the typical system of waste collection and sorting. It is also more accurate and requires less labor than the system followed throughout the country.

V. CONCLUSION

This web-based E-waste monitoring, segregation, and recycling process is more effective than any other previously reported work for e-waste management. It has greater accuracy in detecting e-waste, and it will reduce the pollution in our country. It is extremely safe for the environment because it emits no harmful waste products. It only needs an initial investment. It has a long-life span. Overall, it is a good, reliable, and affordable solution for e-waste monitoring, segregation, and recycling. This research is primarily aimed at reducing e-waste in the country and ensuring a toxic-free environment. This recycling system will also contribute to economic development in our country. In addition, website development for e-waste collection and segregation plays a vital role in this research. Finally, it's an invention for an e-waste collection system.

In Future, the system can be designed for heavy materials. An autonomous e-cycling system also can be integrated to make it more useful.

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