Automated Smart Medical Waste Segregation

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***Abstract*— Improper waste disposal poses significant challenges to human health and the environment worldwide, with the overproduction of toxic waste and outdated waste management practices. Our project introduces an innovative solution – an Automated Smart Medical Waste Segregation system, designed to revolutionize waste treatment processes while aligning with several Sustainable Development Goals (SDGs), including 'Good Health & Well-Being,' 'Industry, Innovation & Infrastructure,' 'Sustainable Cities & Communities,' and 'Climate Action'. Our approach features capacitive, inductive, and ultrasonic sensors to identify three critical categories of waste materials: wet, plastic, and metallic waste. Through a V-gate mechanism, the system facilitated by TowerPro MG996R servo motors, swiftly and accurately segregates incoming waste, directing each material through a pipe to its designated bin. The system's microcontroller, an Arduino Uno, powers the sensors and manages the segregation process. As part of our sustainable vision, we are actively exploring the replacement of the Arduino Uno with rechargeable batteries or renewable energy sources, such as solar power. The choice of plywood for the structure of our prototype shows our commitment to fostering eco-friendly practices in waste management and minimizing environmental impact.**

Keywords*— *capacitive proximity sensor, inductive proximity sensor, ultrasonic sensor, servo motor, V-gate, GSM module, Bluetooth module

I. INTRODUCTION

Not all waste is disposed of in the same way, the process of disposal varies according to the type of waste. Some waste is biodegradable, some is recyclable and reusable, and some is to be handled with ultimate care. So, segregating waste is a must, especially in the medical sector. An automated smart machine can be a solution to this problem.

Our project's goal is to sort at least three different types of waste: plastic, metal, and wet and biodegradable waste. These three types of waste are mostly produced in hospitals. The medical sector generates a diverse range of waste materials, including metal, plastic, and biodegradable waste. Metal waste in healthcare primarily consists of discarded medical instruments and equipment, such as surgical tools and implant materials. Proper disposal and recycling of metal waste are essential to reduce environmental impact and resource depletion. Plastic waste is another significant concern in the medical field, encompassing single-use items like syringes, IV bags, and packaging materials. The persistence of plastics in the environment poses environmental threats, making proper disposal and recycling crucial. Efforts to reduce plastic usage through alternative materials and recycling initiatives are gaining traction. In contrast, biodegradable waste, such as organic matter from surgical procedures or expired medications, has the potential to break down naturally. However, even biodegradable waste management must be carefully controlled to prevent contamination and ensure safe disposal methods.

II. LITERATURE REVIEW

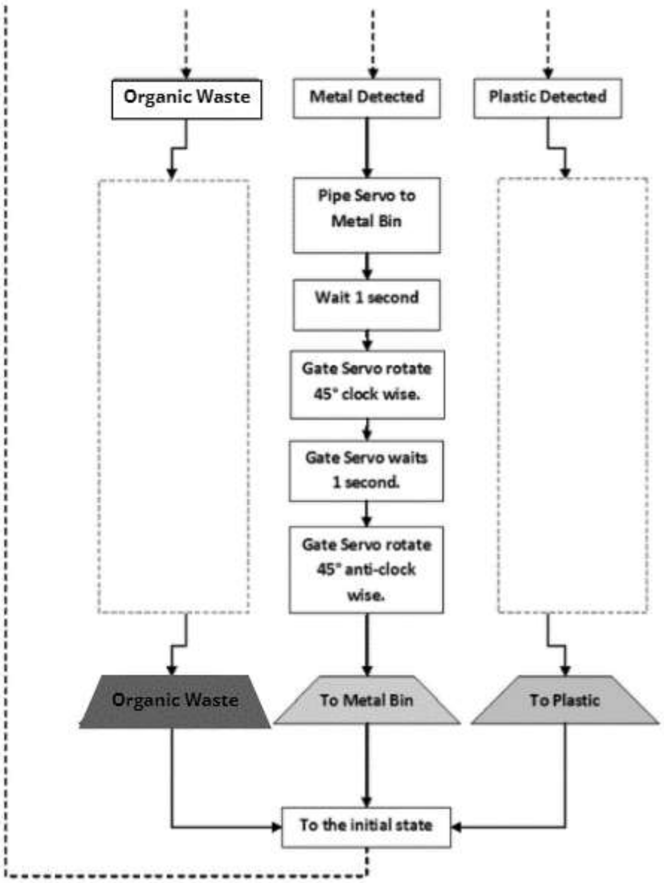
Medical waste management is a critical aspect of healthcare operations. Effective waste segregation is vital to ensure the safety of healthcare workers, patients, and the environment. In recent years, automated waste segregation systems employing inductive and capacitive proximity sensors have gained attention as a means to enhance the accuracy and efficiency of this critical process. For sensing capability systems, proximity sensors are wildly used in industries using food beverages, chemical processing, functionality etc. As fast as 5,000 Hz, proximity sensors can operate with accuracy and repeatability, meeting the demands of a variety of high-speed industrial applications. The proximity sensor will give precision to preserve efficiency and the product's efficacy because the calculation may be made to within 0.001 in. (Irfana et al[1], 2016).

A waste segregator system that was designed where waste inserted with sizes greater than 5 cm into different categories of metal and non-metallic (wet and dry) waste. Only when the inductive proximity sensor is 0-8 mm and the capacitive proximity sensor is 0-12 mm away from the object (trash) can the system of this tool function. With testing utilizing 2 waste objects tested 5 times for each location of waste sorting, the percentage of success attained for sorting non-metallic waste (dry) is 100%, non-metallic waste (wet) is 80%, and metal waste is 100%. (Enina Wika et al[2], 2019)

According to statistical correlations with the human development index (HDI), life expectancy (LE), healthcare expenditure (HE) per capita of gross domestic product (GDP), and environmental performance index (EPI), only 41% of employees had received in-service training in the proper handling of medical waste, and only an average of 38.9% of medical waste was segregated. (YuanYuan et al[3], 2021)

I. METHODOLOGY

The flow chart of the working procedure of the project is given below:



A. Necessary Equipment and Materials

For this project, we needed some mechanical equipment, which we got from 3D print and laser-cut. Shaft cover, pipe support, V-gate Shaft-Bearing support, and V-gate support were 3D printed. On the other hand, the frame, V-gate, Ultrasonic sensor support, Capacitive and Inductive sensor support, and V-gate motor support were laser-cut. The materials we used for the equipment are mostly biodegradable or reusable. We utilized 4mm plywood, 1pc 125mm Upvc elbow, 1pc 125mm UPVC pipe, 1pc 8mm Ss Shaft for motor, 2pcs Servo Motor Coupler, 2pcs radial bearing, and necessary screws and nuts.

Apart from the mechanical equipment, we also needed some electronic components. We used one Arduino Uno, one Prototyping board, Soldering material, and equipment, one inductive sensor, one capacitive sensor, four ultrasonic sensors, two servo motors, one step down converter, one DC power supply and necessary wires and jumpers.

For the software part, we used SolidWorks, Rhinoceros and Arduino.

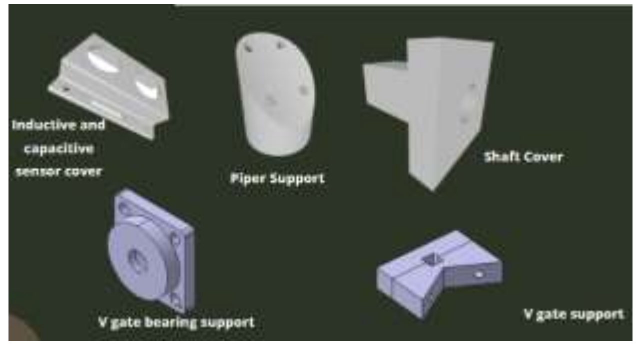


Figure: 3D printed Parts

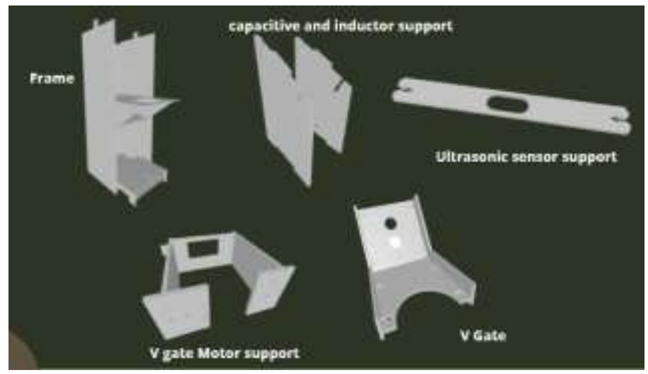


Figure: Laser Cut Parts

B. Gate Shaft Calculation:

Here, the wood density, d= 0.600gm/cc, volume (According to the CAD design), V= 206.4cc.

So, the total weight= d*V/1000 = 0.12348kg

The two parts of the V-gate have the same weight = $\frac{0.12348*9.8}{2}$= 0.61N

Let us take a maximum waste mass, MWM = 0.72 kg.

Torque = $F * L$= MWM*9.8*150 + 0.61*75 – 0.61*cos(60)*75 = 104.95 N-mm = 1.72875 kg-cm

Yield Strength, T = 250 MPa = 250 N/mm^2

$T= \frac{\frac{F}{A}}{\frac{d}{L}} = \frac{F*I}{A*I} = \frac{F*I}{V} = 104.95/V$

$V= \left(\frac{1}{16}\right) * d^3 * \pi$

d= 4mm

C. Motor Calculation:

Here, MG 996R has these specifications:

Weight= 55g, Torque(kg)(4.8v)= 9.4, speed= $\frac{0.17sec}{60deg}$, A= 42.7mm, B= 40.9mm, C= 37mm, D= 20mm, E= 54mm, F= 26.8mm.

MWM = 0.72 kg.

Using simple approximations, torque, T= 0.72*7.5* sin(120)

T= 4.8 kg-cm

D. Detection and Logic Development:

We have used three types of sensors for detecting different kinds of waste: one ultrasonic sensor, one capacitive sensor and one inductive sensor. The ultrasonic sensor detects whether any waste is put or not.

For metal waste, both capacitive and inductive sensors detect the waste, and show the result later by moving the servo motor. For the wet and organic waste, the capacitive sensor works, but the inductive sensor does not. When none of these two sensors can detect the waste, then it is detected as a plastic waste.

E. Feedback From Waste Bins

When the Waste box is filled, an alert system is activated, and the cleaner assigned to discharge the box receives an SMS. For this, a Bluetooth HCO5 module is needed, along with one Arduino UNO, three ultrasonic sensors, one breadboard, some jumper wires, and a battery.
The Bluetooth Module is powered by Arduino Uno. In the Arduino code, we set the level (80%) that the box is filled with waste. Here, basically, we set the distance between the ultrasonic sensor and the waste level. Moreover, the cleaner also requires having an app installed and opened in his mobile to receive the SMS.

II. DESIGN

Figure: Primary Structure

Figure: Output from Bluetooth Module (Notification system)

III. RESULTS

We used around 20 individual wastes to test our system. Out of which 18 were successfully detected but 16 were successfully dumped into designated waste basket. We faced some problems with disposal of waste after the v-gate due to friction which lowered our accuracy for segregation,

Detection accuracy: 90 percent
Segregation accuracy: 80 percent

IV. NOVELTY

A. Very Low installation Cost

Instead of importing, sourcing local materials and using available components, we were able to reduce the cost. The overall cost is around 15,000 BDT.

B. *Use of Biodegradable or Recyclable Materials*

We have used plywood, metal shaft, PVC pipe etc. in this project. Among them, PVC pipes can be replaced with PLA, which is a biodegradable plastic. Thus, our project will be more environmental-friendly.

C. *Push Notification System*

As we have implemented a push notification system in our project, the cleaner does not have to check the waste boxes every now and then. When the box is filled with waste, he/ she automatically receives a message on the phone app. So better time management is ensured.

Multiple waste boxes can be handled simultaneously. Whenever any box is filled, the cleaner receives the message of that box.

V. FUTURE SCOPES AND SCALABILITY

A. Improvement in waste sortation with object detection algorithm. We would want to use a limited number of sensors to improve detection.
B. Using Choetsu for waterproof coating which is completely biodegradable. It is a special water proof coating that is biodegradable and environment friendly.
C. We’ve used 9V non-rechargeable batteries. We can easily replace it with LiPo batteries and use different rechargeable batteries to increase energy efficiency.
D. Increasing the categories of waste to segregate hence improve waste handling by using more precise and a wide range of sensors.
E. Bulk produced from molds instead of 3D printed and PVC parts would reduce a lot of material cost as well as making the design more environment friendly.
F. The ultimate goal is it to have this system be used as central waste collection and segregation system so

that we can segregate and dispose of the wastes of an entire facility and increasing the scope of application.

G. The notification feature needs to implemented centrally and using GSM800L sim module instead of Bluetooth and wi-fi connection to allow everyone to have access to information about the type and amount of waste collected so that costs and other measures can be taken accordingly backed up by statistical data.

VI. QUOTES FROM EXPERTS

"Biomedical Waste Disposal is an essential commitment to providing our patients with a safe and hygienic experience. And that will only be effective by filtering out hazardous elements and taking proper safety measure to handle so."

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- Dr. Manifa Afrin
  Associate Professor, ChildCare
  Universal Medical College and Hospital

"Incinerating different materials may produce different toxic, especially metal. Again, reusable plastics also need to be segregated for sterilization in hot air oven, sterilizing it along with metals may cause shrinkage or tempering of the equipment."

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- Dr. Ching Key Prue
  Medical Intern, Armed Forces Medical College and Hospital

"Such a system can be useful for implementing in places with high crowd where there is no effective segregation system, yet the amount of waste disposal is huge."

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- Dr. Radwana Noor
  Medical Officer, Shahed Suhrawardy Medical College and Hospital

VII. COST ANALYSIS

Equipment	Cost (BDT)
Inductive sensor	630
Capacitive Sensor	700
Ultrasonic Sensor	380
Arduino Uno	740
Battery	300
3D Printed Parts	800
TowerPro MG996R Servo Motors	950
Plywood Chassis	7,000
PVC Pipe	200
Pipe Elbow	570
Pipe Extension	200
Metal Shaft	1,000
Coupler	640
Screws & Bearings	230
HC05 Bluetooth Module	350
Miscellaneous	850
Total	**15,540**

VIII. CONCLUSION

The main goal of the project was to segregate waste in an environmentally friendly way in order to save time and reduce health hazards. We used ultrasonic sensors to identify the existence of the waste, then detected it with capacitive and inductive sensors. Next, we used servo motors to throw the waste in their respective bins.

We conducted several tests to calculate and improve the success rate of our project. Our system was successful in identifying the object in 90 percent cases, and in 80 percent cases, it could segregate rightly. This accuracy can be increased by taking the necessary steps as mentioned before. Thus, the project can be implemented in larger scale, which will be a revolution in the sector of waste segregation in our country, especially in medical sector.

IX. ACKNOWLEDGEMENTS

It will not have been possible for us to develop this project without the guidance of Professor Dr. Celia Shahnaz. Her motivation and rigorous input helped us improve our ideas significantly. We are grateful to her. We would like to thank Md. Jawad Ul Islam Sir for constantly providing us with resources, inputs and answering our queries throughout the process. They helped us a lot, provided us with advice, and continuously monitored the progress of our project.

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