Automatic Biomedical Waste Segregation System

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***Abstract*—Biomedical wastes from hospitals, clinics, diagnostic centers and laboratories must be sorted carefully. Sorting biomedical wastes prevents mistakes in disposal avoids cross-contamination and keeps hospital staff safe, from materials. Doing this sorting by hand can put people at risk of coming into contact, with substances. This project introduces an Automatic Biomedical Waste Segregation System Using Image Processing. It uses a learning algorithm to recognize different types of biomedical waste. Then an automated mechanical system sorts the waste according to the identified categories. This system helps reduce exposure and improves safety.**

In the proposed system, a camera is used to capture an image of the biomedical waste at the input port; the image is processed in laptop using a convolution neural network EfficientNetB0 algorithm to identify the category of biomedical waste. The ESP-32 microcontroller is used to control the automated mechanical system. The ESP-32 receives the classification result from the laptop via serial communication; it then controls the TB6600 stepper-driver and NEMA-23 stepper motor to rotate the four-compartment bin platform to the appropriate bin according to the classification result.

The MG996R Servo motors open the waste input door of the appropriate bin allowing the biomedical waste to fall into the bin. An appropriate bearing and central shaft are used to ensure smooth and even rotation of the bin platform. It is expected that this project will help improve waste management. It aims to reduce contact and offer an automated way to sort biomedical waste. This will be done using image processing and deep learning algorithms. The system will recognize types of waste and separate them accurately. This approach can make waste handling safer and more efficient.

***Index Terms*—Biomedical Waste Management, Image Processing, Deep Learning, Convolution Neural Network (CNN), EfficientNetB0, Waste Classification, Computer Vision, ESP32, NEMA-23 stepper motor, Servo Motor, Automatic Segregation.**

I. INTRODUCTION

There are several categories of waste from healthcare institutions, including infective wastes, sharps, plastics and glass, anatomical waste, pharmaceutical wastes and many others. The segregation of these wastes at the source is critically important since the inappropriate mixture will result in the increased risk of exposure to potentially dangerous substances and their challenging treatment and disposal. Manual segregation is dangerous and may lead to inaccurate classifications of waste types by employees. In the last few years, AI-based methods have been widely used for waste classification using image processing and deep learning methods. A EfficientNetB0 experiment showed 82.92% accuracy for domestic waste classification into four categories and proved that a light weight model was better suited for deployment on mobile devices in comparison with conventional CNN baseline models. Even though this experiment deals with municipal waste and not biomedical, it proves the relevance of transfer-learning architecture for automatic classification of objects based on images. The issue of classification of biomedical waste is more complicated since some categories might look similar and because of possible negative consequences of wrong classification. Thus, the combination of accurate image classification with proper segregation method should be used. In this paper, we discuss the progress in developing this kind of system and define possible gaps in research.

II. LITERATURE REVIEW

More and more waste from hospitals, clinics and laboratories makes biomedical waste management a serious issue. When people separate waste, by hand healthcare workers risk catching infections. The

likelihood of improper disposal rises. To solve this researcher, use sensors, image processing, machine learning, the Internet of Things and automation to make segregation more accurate and to ease the work. I think that using these technologies protects workers and keeps waste from harming the environment.

[1] Automated Medical Waste Segregation Using Image Processing.

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The people who wrote this created an Automated Waste Segregator (AWS) by using embedded technology to separate waste, metal waste and plastic waste. The system uses moisture sensors, metal sensors and infrared sensors, plus a camera to find waste and put it into bins on its own. It also sends messages when the bins are full which makes waste collection better.

The system mostly uses sensors and those sensors might not always recognize complicated biomedical waste.

It also doesn't sort waste into the biomedical waste groups that hospitals use. So, there is a need, for a system that uses image processing and deep learning to give more accurate waste sorting.

[2] Smart Waste Segregation System through Image Processing

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I find it exciting that the researchers have proposed a waste segregation system that uses MobileNetV2 and image processing techniques to sort five types of general waste. This system uses an ESP-32 CAM, conveyor belt, and servo motor to perform automatic waste segregation.

But the system is capable of segregating general waste and is unable to segregate biomedical waste based on the categories used in hospitals. There is also the problem of visual similarity among waste items. Thus, an improved AI-based system for biomedical waste segregation is needed.

[3] Automatic Waste Sorting System, with Image Processing

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The authors proposed a waste segregation system that uses a neural network trained on images of recyclable and non-recyclable waste. This waste segregation system can automatically classify waste with a precision of eighty-nine percent. However, the waste segregation system can only separate two types of waste. Does not handle biomedical waste classification.

III. RESEARCH GAP

Several research gaps have been identified from the literature, Firstly, many of the datasets that are publicly available to deal with waste are specifically built for municipal waste and not biomedical waste. Secondly, biomedical waste may have objects that appears visually similar, have contaminants, occlusions and varying lighting conditions. Thirdly, training accuracies do not always indicate overfitting, especially when there is an inadequate number of samples. Fourthly, most of the researches focuses only on the accuracy of classification without proof of physical segregation.

IV. PROPOSED WORK

The proposed work focuses around the development of a prototype for the automated identification and segregation of biomedical waste using image processing and deep learning. The system will employ a camera- based classification mechanism and an ESP-32 controlled mechanical segregation mechanism.

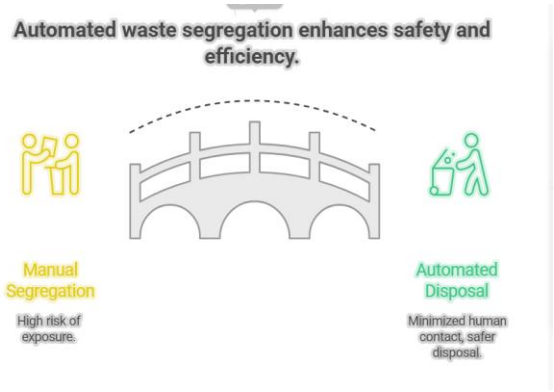
First, a dataset containing images of the chosen biomedical waste categories will be compiled. The images will subsequently be preprocessed in order to develop a CNN-based EfficientNetB0 model for the classification of waste. The four categories which have been identified for the proposed system are Yellow – infectious and anatomical waste, Red – contaminated recyclable plastic waste, White – sharps, and Blue – glassware and broken glassware.

During operation, a camera will capture an image of the incoming biomedical waste sample at the input

chamber, and the image will be processed on a laptop. The processed image will then be passed through the EfficientNetB0 trained model in order to classify the waste. The classification results will be sent on to the ESP-32 microcontroller.

Using the information regarding the waste category, the microcontroller shall operate the TB6600 driver and NEMA-23 stepper motor to rotate the four-compartment bin platform, in order to align the appropriate bin with the input chamber. The rotation will be performed with the help of a bearing and central shaft mechanism. The MG996R servo motors will be operated to allow for entry of the waste into the specified bin.

The overall prototype will be tested using a set of biomedical waste samples. The results will be assessed with the aid of the correct bin positioning, successful waste segregation, classification accuracy, and the response time of system. The proposed work aims to provide an effective solution for automated biomedical waste segregation.



V. OBJECTIVES

1. To design an automatic biomedical waste segregation system which can segregate biomedical waste using image processing and deep learning techniques.
2. To classify biomedical waste into four predefined categories using a CNN – based EfficientNetB0 model:
   Yellow: - Infectious and anatomical waste
   Red: - Contaminated recyclable plastic waste
   White: - Sharps waste
   Blue: - Glassware and broken glassware waste
3. To capture waste images of the waste using a camera and perform image classification on a laptop.

VI. BLOCK DIAGRAM

The proposed system Automated Biomedical Waste Classification and Segregation using Image Processing is designed to recognize and sort biomedical waste automatically with minimum human intervention. An image of a biomedical waste item is captured by a camera, which is then processed by CNN based model to identify the waste category. Based on the output, the ESP-32 microcontroller drives the stepper motor to rotate the bin to the right compartment and activates the servo motor to open the trap door. This system improves the accuracy of waste segregation, reduces human interaction with hazardous biomedical wastes, reduces infection risks, and offers an efficient, cost-effective solution to biomedical waste management.

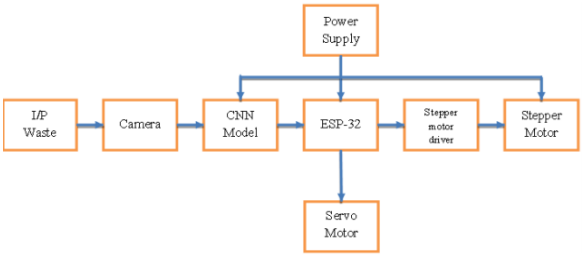


Fig 1. Block Diagram of Proposed System

VII. HARDWARE CIRCUIT DESIGN

The hardware circuit of the proposed waste segregation system revolves around the ESP32-WROOM-32 microcontroller. The hardware circuit connects to a stepper motor driver, a NEMA 23 stepper motor, two servo-motor connectors, status LEDs, a buzzer, a switching input and external power-conversion circuitry. The ESP32-WROOM-32 serves as the control unit directing the movement of the segregation mechanism whenever the ESP32-WROOM-32 receives a classification command from the image-processing system. The ESP32-WROOM-32 is a choice for this design.

The stepper motor driver supplies the interface that lets the NEMA 23 stepper motor spin the multi-compartment waste container. Servo motors give motion for the waste-entry mechanism. A buzzer displays operating conditions. Alerts the user to important events. Limiting resistors protect the indicator LEDs while the external power supply and voltage converter provide the power needed for the

hardware circuit. The stepper motor driver keeps the NEMA 23 stepper motor running

The hardware architecture blends embedded control with actuation to run automated waste segregation. Proper power regulation, grounding, motor-driver interfacing and electrical protection are essential, for the operation of the hardware circuit.

The hardware architecture will handle power regulation. Grounding well.

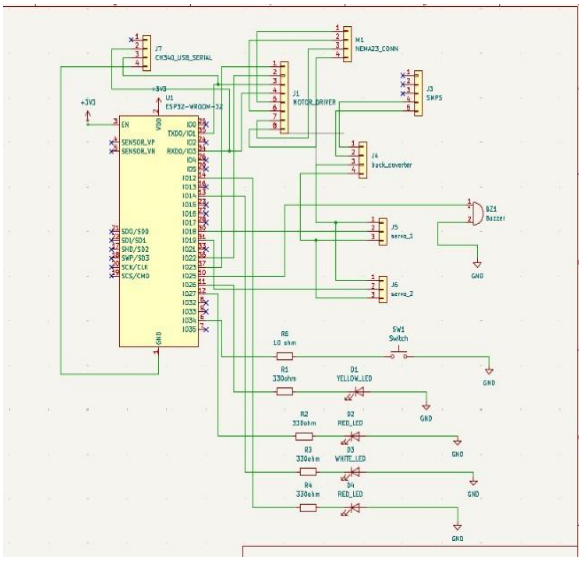
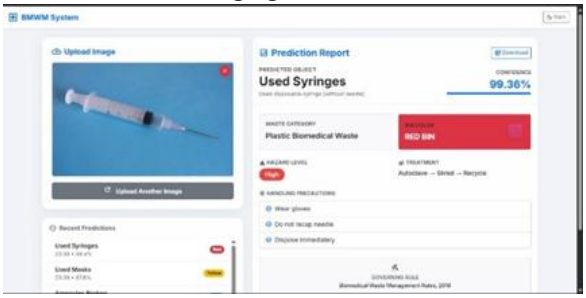
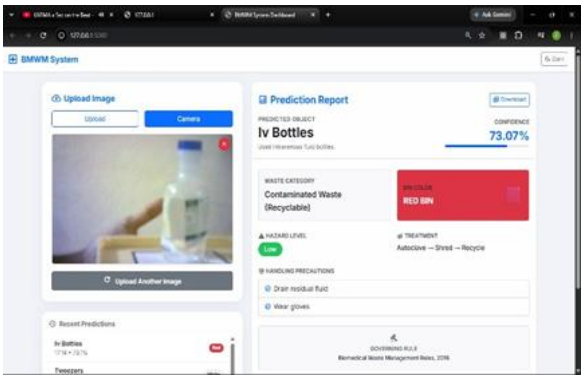


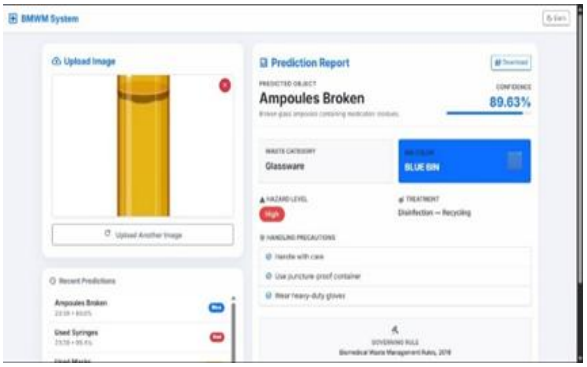
Fig. Circuit Diagram Design

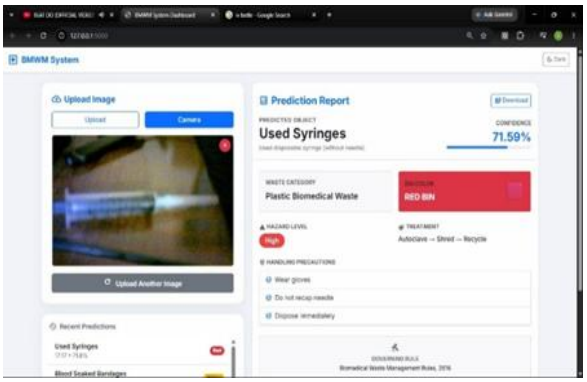
VIII. RESULT

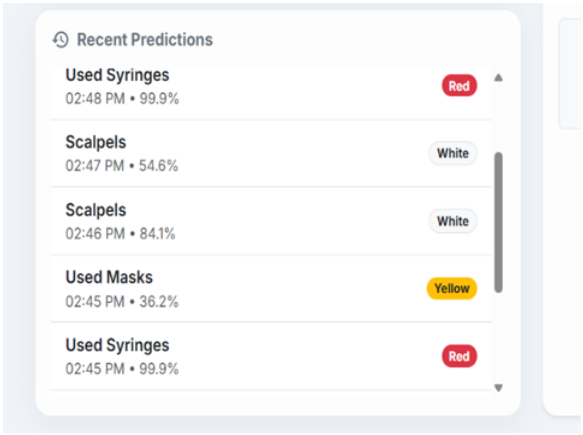
Biomedical Waste Segregation Software Interface:



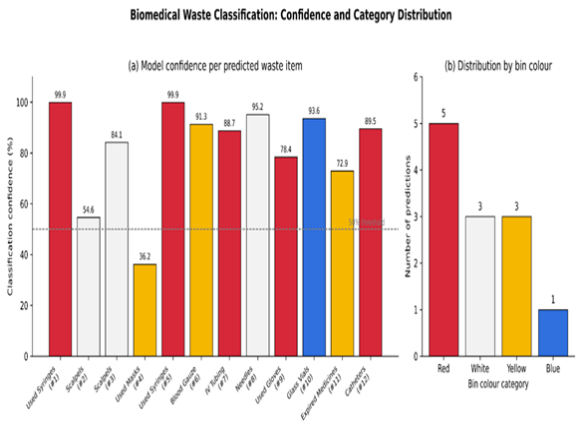




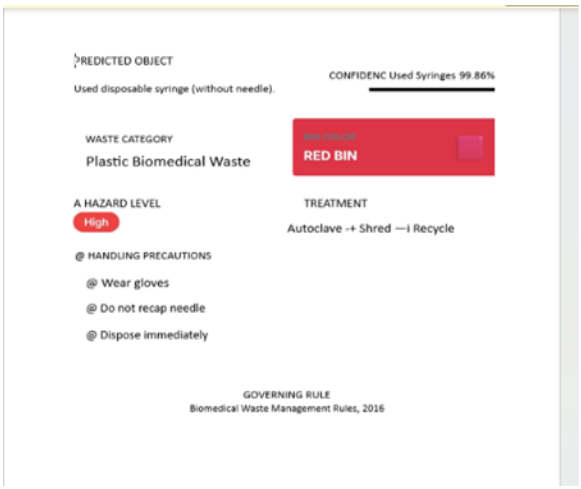




Predicted Output



Graph Analysis



Predicted Report



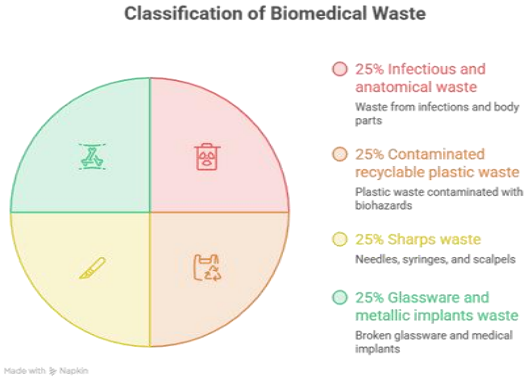


IX. EXPECTED OUTCOMES

- The biomedical waste will be categorized correctly and in real-time into four categories:

Infectious & anatomical waste, contaminated recyclable plastic waste, Sharps waste, and Glassware & metallic implant waste.

- The system will be able to sort the waste into the appropriate bin with as little human involvement as possible
- The risk level of infection and exposure of the medical and sanitation workers to hazardous biomedical waste is reduced.



X. ADVANTAGES

- Lower human exposure: The system reduces the amount of human interactions with potentially hazardous biomedical waste during the segregation process.
- The system can be used to automate the segregation process: The waste can be identified and redirected to the suitable category automatically with minor human interventions
- Improves the consistency of the segregation: The system ensures consistent segregation based on the pre-defined waste categories.
- Saves time and effort: By separating items it cuts down the amount of work that sanitation workers and healthcare staff must do.
- Easy to implement and low-cost prototype: This system can be built with hardware and software so it is practical, for schools, labs and small projects.
- Reduces the risk of cross-contaminations: With improved segregation, the possibility that the different categories of waste would be mixed up is reduced. This promotes a safe environment.

- Easy to update and modify: The system could be updated and modified by charging the images processing algorithm, hardware specifications or waste categories.

XI. APPLICATION:

- Hospitals: I observe that Hospitals make sure to sort their wastes into different categories by themselves.
- Clinics: I discern that Clinics make use of methods to detect and get rid of wastes and Clinics make the process efficient and safe.
- Laboratories: I ascertain that Diagnostic Laboratories make sure to keep contaminated materials and medical items away from each other and Diagnostic Laboratories reduce the risks involved.
- Medical Colleges: I deduce that Medical Colleges sort laboratory wastes in a certain manner and Medical Colleges train their students on this right from the start.
- Research Laboratories: I comprehend that Research Laboratories sort their wastes in the midst of experiments and Research Laboratories save time to keep things smooth.
- Healthcare Centers: I perceive that Healthcare Centers reduce the process of handling and keep segregation stable and Healthcare Centers reduce mishaps.
- Waste Management Facilities: I admire that Waste Management Facilities collect and process their wastes and Waste Management Facilities take part in the functioning.

XII. LIMITATIONS

- Technology Limitation: - Poorly lit environments, imperfect lighting, occluded objects, or other image quality issues may lead to incorrect recognition and, therefore, disposal of waste.
- Similar classes: - Biomedical waste has several classes that may reassemble each other.
- Limited classes: - The model was trained on a certain number of classes, and there are likely to be other types of biomedical waste that the system cannot recognize.
- Prototype limitations: - The model described in this project in only a prototype; for actual applications, such as a hospital, the computer system would need to be much more powerful and include various safety measures.
- Rotation limitations: - The prototype may need adjustment during rotation or have other mechanical problems.
- Performance variations: - Performance may vary due to a variety of factors, such as dust or other contaminants on the camera lens, lightning, or irregular shapes of different objects.
- The results obtained by using a few laboratory samples may not be accurate enough when actual used in a hospital.

XIII. FUTURE SCOPE

Future Scope of this project includes the following:

- Real-time Operation-

The system can be enhanced to recognize and sort out the waste materials automatically and continuously without manual operation.

- Large waste dataset –

More images of biomedical waste of different classes must be added for the system's reliability process.

- Improve image Processing-

More complex computer -vision models can be used in the system to deal with various image appearances such as object shape, size, color, and lighting differences during data collection.

- Move computation to the edge-

The image processing module can be moved from a laptop to a smaller and portable computer.

- IOT Connectivity-

The system can be connected to an IoT (Internet of Things) engine to track the number and type of waste in each bin.

- Bin-level sensors-

Sensors can be added to each bin to indicate when it reaches a certain level to alert waste-collecting personnel.

- Adaptation for hospitals-

With sufficient improvements and safety tests,the system can be modified and integrated into hospital settings , laboratories, and medical institutions.

- Improved mechanical System – A more robust and reliable mechanical system must be designed and built that allows continuous sorting and heavier waste loads.

XIV. CONCLUSION

The proposed Automatic Biomedical Waste Segregation System offers a solution for improving the way biomedical waste is handled. It uses image processing and deep learning to make the process better. The EfficientNetB0 model is used to recognize types of waste. The ESP32 is responsible for controlling the NEMA-23 stepper motor. The MG996R servo motors to sort the waste. By bringing together software and hardware the system wants to cut down on the need for people to do the work manually. This helps lower the chances of getting hurt. Makes sure the sorting is done the way every time. This project shows how automation can be useful in managing waste in healthcare. In the future the system could be better, by improving how accurately it classifies waste. It could also have safety features and the ability to monitor things in time. This would make the system more dependable when it is used in situations.

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