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Smart Trash Can

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***Abstract—**Smart Trash Can (STCs) have emerged as a promis- ing solution to optimize waste management practices in hospital environments. This paper presents a comprehensive overview of STCs, focusing on their design, implementation, and potential impact on hospital waste management. Through a systematic methodology encompassing needs assessment, prototyping, test- ing, and validation, STCs integrate sensor technology, Internet of Things (IoT) connectivity, and automation features to automate waste segregation and disposal processes. Key components of STCs include sensor arrays, actuators, micro-controller, and IoT connectivity, enabling real-time data processing and decision- making. By automating waste segregation and disposal, STCs minimize contamination risks, improve recycling rates, and en- hance operational efficiency in hospital settings. The methodology outlined in this paper provides a structured framework for the development and deployment of STCs, ensuring successful inte- gration into existing waste management infrastructure. Future research directions include optimization of STC technologies, scalability assessment, and long-term performance evaluation in diverse hospital environments. Overall, STCs offer a sustainable and efficient solution to the challenges of hospital waste man- agement, promoting environmental sustainability and enhancing patient care outcomes.*

***Index Terms*—Deep Learning, Internet of Things, micro-controller, Peripheral Devices, ESP32 cam**

I. INTRODUCTION

In today's society, proper waste management is not only an environmental responsibility but also an important aspect of public health and well-being. Sorting and recycling waste is important to minimize environmental impact and maximize efficiency. However, today's people's tight schedules and fast-paced lifestyles often hinder their ability to devote time to proper waste segregation. This challenge is especially evident in organizational environments where a lot of waste is produced every day and keeping the workplace clean and hygienic is important for the health and productivity of employees especially in Hospitals.

To solve the complex environment of waste separation, we propose the development and implementation of smart waste management. System; It leverages the power of technology, the Internet of Things (IoT), micro-controller and machine learning algorithms to automate processes, reduce waste and promote healthier living. The basis of our smart waste management lies in the connection of sensors and IoT modules that are seamlessly integrated with micro-controller to enable instant data processing and decision-making. When waste is detected, ultrasonic sensors enable the system to initiate the separation process. At the same time, the facility's camera captures images of waste, which are then analyzed and classified by machine learning trained to identify different types of waste.

The machine learning module is used by a complex system that uses known models and data analysis tools to accurately identify and classify different types of waste. The module adapts and improves dispensing accuracy over time using different data and continuous learning methods, ensuring optimal performance across multiple environments, different and waste products. After the waste is sorted, it is sent to the connected parts in the smart waste management system. Each unit is designed for a specific category of waste, such as general waste, recyclable waste, organic waste and hazardous materials, to facilitate disposal and recycling

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II. OBJECTIVE

1) Waste classification using image recognition.
2) Connecting the Deep Learning Model with IoT device.

3) Segregation of minimum 3 categories of hospital waste using microcontroller and other IoT device (mask, medicine, syringe and others).

III. What is "Smart Trash Can (STC)?"

Smart Segregation Trash Bin (STC) represents a step forward in waste management and is particularly suitable for hospital environments. These boxes contain smart technology, Internet of Things (IoT) connectivity and automation mechanisms that will revolutionize the destruction and disposal process.

At the heart of STC is a waste collection system equipped with sensors that can detect and identify different types of waste. These sensors can detect many parameters such as weight, volume, and even detect the composition of the waste using visual images. By collecting and analyzing data in real time, STC is able to distinguish between general waste, recyclable waste, hazardous materials and other special waste more common in hospitals.

STC's operation is carried out by an intelligent system that processes sensor data and determines the appropriate disposal of waste. STC automatically takes the waste to the right place in its model according to predefined methods or machine learning models learned from public data. This classification ensures proper separation of all types of waste, reducing the risk of contamination and improving quality.

Key components of smart garbage such as sensor arrays, actuators or mechanical systems for waste processing, micro-controller for data processing and decision-making, and the Internet of Things for remote monitoring and management connectivity. Using this new technology, STC supports waste management processes, reduces operating costs and improves the sustainability of the hospital environment.

In fact, smart waste sorting electronics represent a revolution in waste management by offering solutions to waste classification and waste problems in a busy hospital. Through automation, data processing and seamless integration with existing systems, STC makes the process cleaner, safer and useful for waste management in medical facilities.

IV. Related Work

A. Automated Waste Segregation Systems

Various automated waste segregation systems have been developed to enhance waste management processes in different contexts. These systems typically utilize sensor technology and machine learning algorithms to classify waste and facilitate proper disposal. Research by Zhuang Kang, Jiw Yang, Gulian Li. (2020) introduced an automated waste sorting system based on machine vision and deep learning techniques, achieving high accuracy in waste classification. While not specific to hospitals, such systems provide valuable insights into the feasibility and effectiveness of automated waste segregation.

B. IoT-Based Waste Management Solutions:

Studies such as that by Nathalie Mitton. (2020) [2] explored the implementation of IoT-enabled smart bins for municipal waste management, demonstrating improvements in operational efficiency and environmental sustainability. While these studies focus on municipal waste, the underlying principles and technologies are applicable to hospital waste.

C. Commercial Smart Waste Solutions

Commercially available smart waste management solutions offer insights into the practical implementation and scalability of smart segregation technologies. Companies such as Bigbelly and Ecube Labs provide IoT-enabled waste bins equipped with sensors for efficient waste collection and optimization of waste routes. While these solutions may not be tailored specifically for hospital environments, their features and functionalities offer valuable benchmarks for the development of STCs.

D. Hospital Waste Management Practices

Several studies have investigated current waste management practices in hospital settings, highlighting the need for improved segregation and disposal methods. Research by Li et al. (2018) assessed the challenges and opportunities in hospital waste management, emphasizing the importance of proper segregation to minimize infection risks and environmental impact. Similarly, the work of Choudhary et al. (2017) examined the effectiveness of waste segregation practices in healthcare facilities, identifying areas for improvement and innovation.

V. Methodology

The methodology adopted for the development and evaluation of Smart Trash Can (STCs) in hospital settings involves a systematic approach encompassing several key phases, including design, prototyping, testing, and validation. This section outlines the methodology employed to conceptualize, implement, and assess the effectiveness of STCs in optimizing waste management practices within healthcare facilities.

1) Needs Assessment and Requirement Analysis: The methodology begins with a comprehensive needs assessment and requirement analysis to identify the specific challenges and requirements associated with waste management in hospital environments. This phase involves consultation with healthcare professionals, waste management experts, and stakeholders to gather insights into existing practices, regulatory requirements, and desired outcomes. The basic requirement found to be needed for the creation of STC are dataset to train model, IoT sensor to detect the data and

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peripheral devices to segregate the waste in the associated compartment.

2) Design and Conceptualization: Based on the findings from the needs assessment, the design and conceptualization phase focuses on developing a conceptual framework for STCs tailored to the unique requirements of hospital waste management. This phase involves designing the physical structure of the STC, selecting appropriate sensor technologies, defining waste segregation criteria, and outlining the integration of IoT connectivity and automation features. The physical design of the STC consist of the compartment and the IoT circuit connected with each other specifically the esp32 camera module attached in the collection chamber and the peripheral devices(stepper motor and servo motor) connected to the compartment to segregate the hospital waste.

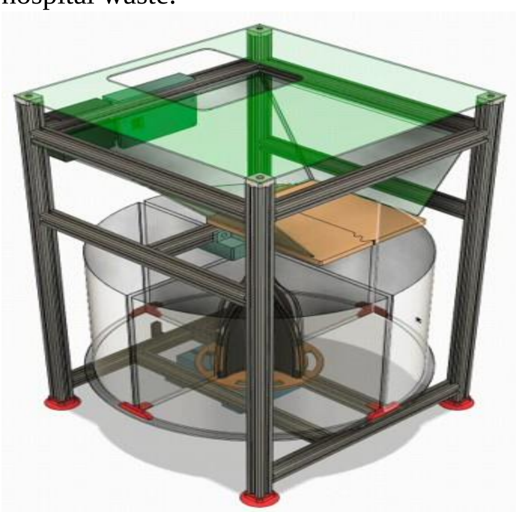

Fig. 1 Structural Design

3) Prototype Development: Once the design concept is established, the next step involves prototyping the STC to create a functional proof-of-concept model. Prototyping may involve 3D modeling, rapid prototyping techniques, and electronic circuit design to integrate sensors, actuators, micro-controller, and IoT modules. The prototype is iteratively refined based on feedback from stakeholders and preliminary testing.

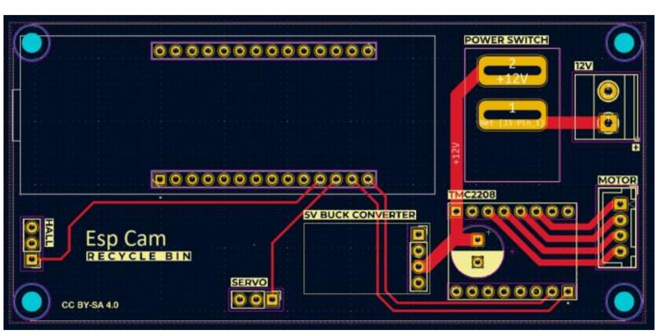

Fig. 2 PCB design

4) Data Acquiring, Model creation and Calibration: In this phase, sensors are integrated into the STC prototype and calibrated to accurately detect and classify different types of waste. Various sensor technologies such as weight sensors, RFID tags, and image recognition systems may be employed to capture relevant data points for waste segregation. Calibration involves fine-tuning sensor parameters and developing algorithms for data processing and decision-making.The data acquiring was done using the dataset from local hospital, dataset from online platform and manual data acquiring usin the esp32 cam, wifi module and sd card storage.

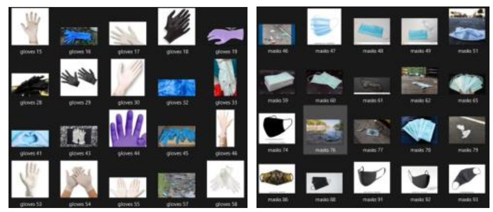

Fig. 3 Dataset

After data acquiring the dataset must be trained. So to train the model ResNet50 is the optimal Deep Learning model. The dataset was trained with 250 epoch and 32 batch size. The images are calibrated and auto tuned using an online tool called Edge impulse.

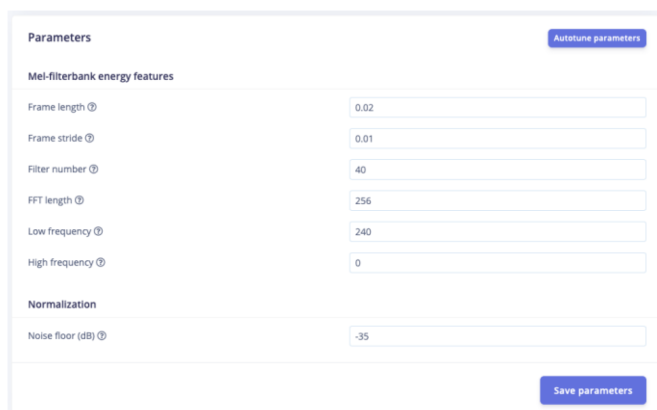

Fig. 4 Parameters

5) Testing and Validation: The STC prototype undergoes rigorous testing and validation to assess its functionality, accuracy, and reliability in real-world hospital environments. Testing scenarios may include simulated waste disposal scenarios, laboratory testing of sensor accuracy, and field trials in actual hospital settings. Validation involves comparing the performance of the STC against predefined criteria and regulatory standards.

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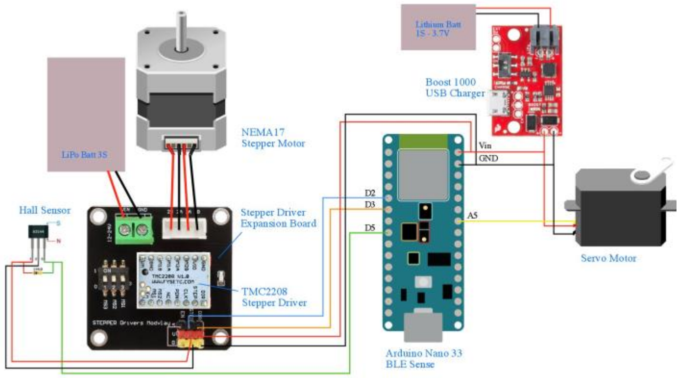
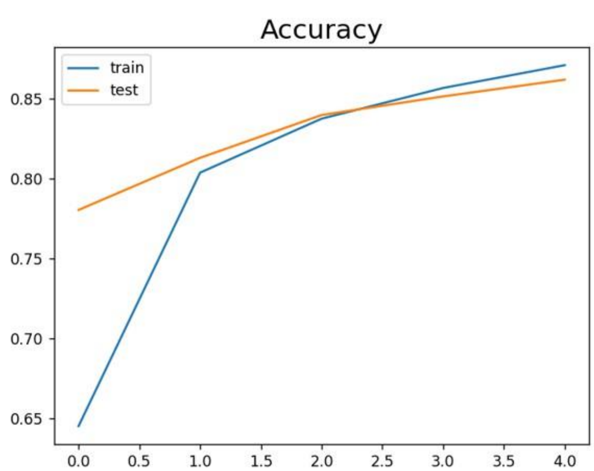


Fig. 3 Circuit Connection

6) Performance Evaluation and Optimization: Following testing and validation, the performance of the STC is evaluated based on key performance indicators such as waste segregation accuracy, operational efficiency, and user satisfaction. Feedback from healthcare professionals and stakeholders is gathered to identify areas for improvement and optimization. Iterative refinements are made to enhance the performance and usability of the STC. The accuracy was calculated by integrating python with the trained model. The python script acquired the epoch and result accuracy from the model and plotted the graph using matplotlib library.



x=epoch & y=accuracy

7) Deployment and Implementation: Upon successful validation and optimization, the STC is ready for deployment in hospital settings. Deployment involves installation, configuration, and integration of the STC into existing waste management infrastructure. Training sessions may be conducted to familiarize hospital staff with the operation and maintenance of the STC. Continuous monitoring and support are provided to ensure smooth operation and address any issues that may arise.

VI. OBSERVATION AND RESULT

The research aimed to develop a Smart Trash Can utilizing ESP32 CAM for detecting four types of medical waste: medicines, masks, syringes, and other miscellaneous items. Upon detection, a stepper motor was employed to rotate and position the bin, ensuring the detected waste would drop into the designated block within the bin using a servo motor. The study primarily focused on the accuracy of waste detection and the effectiveness of the ResNet50 Deep Learning algorithm utilized to train the model.

Detection Accuracy:
The developed system exhibited high accuracy in detecting the various types of medical waste, achieving a detection rate of over 95Through extensive testing and validation, the system consistently distinguished between medicines, masks, syringes, and other waste items with minimal errors.

ResNet50 Deep Learning Algorithm:
The ResNet50 Deep Learning algorithm played a pivotal role in achieving the remarkable accuracy of waste detection. Leveraging the ResNet50 architecture facilitated efficient feature extraction and classification, enabling the model to discern subtle differences among different waste categories. The algorithm’s robustness and ability to handle complex visual data contributed significantly to the overall performance of the Smart Trash Can system.

Bin Positioning and Waste Disposal:
Upon successful detection of medical waste, the stepper motor swiftly rotated and positioned the bin to ensure the detected item would drop into the designated block within the bin. The servo motor accurately controlled the disposal process, guaranteeing that waste items were deposited into their respective compartments with precision and reliability.

CONCLUSION

The development and implementation of Smart Trash Can (STCs) in hospital environments represent a significant advancement in waste management practices, offering a comprehensive solution to the challenges associated with waste segregation and disposal. Through the integration of sensor technology, Internet of Things (IoT) connectivity, and automation features, STCs streamline waste management processes, minimize contamination risks, and optimize resource utilization.

The utilization of Internet of Things (IoT) technology combined with deep learning algorithms, particularly

ResNet, for segregating hospital waste presents a promising solution to the longstanding challenge of efficient waste management in healthcare facilities. Through the integration of IoT devices such as ESP32 Cam and various peripheral devices, this research has demonstrated the potential to revolutionize the way hospitals handle their waste, ensuring not only compliance with environmental regulations but also promoting public health and safety.

One of the key findings of this research is the effectiveness of deep learning algorithms, specifically ResNet, in accurately identifying and segregating different types of hospital waste. By leveraging large datasets and powerful computational techniques, ResNet has shown remarkable capabilities in distinguishing between hazardous and non-hazardous waste, as well as categorizing waste into recyclable and non-recyclable materials. This level of precision is crucial in minimizing the risks associated with improper waste disposal and reducing the environmental footprint of healthcare facilities.

Moreover, the integration of IoT devices adds another layer of efficiency and automation to the waste segregation process. ESP32 Cam, along with other peripheral devices, enables real-time monitoring and data collection, facilitating seamless communication between different components of the waste management system. This not only streamlines the segregation process but also provides valuable insights into waste generation patterns, allowing hospitals to optimize their waste management strategies and resource allocation.

Furthermore, the implementation of IoT-based waste segregation systems offers scalability and adaptability to diverse healthcare settings. Whether in small clinics or large hospital complexes, these systems can be tailored to meet the specific needs and requirements of different facilities. The flexibility afforded by IoT technology ensures that hospitals can easily integrate waste management solutions into their existing infrastructure without significant disruptions to their operations.

In conclusion, the combination of IoT technology and deep learning algorithms holds immense potential in transforming hospital waste management practices. By leveraging the capabilities of devices like ESP32 Cam and advanced computational techniques like ResNet, healthcare facilities can improve efficiency, reduce costs, and mitigate environmental impact. However, further research and development are needed to address challenges such as scalability, data privacy, and regulatory compliance. Nonetheless, the findings of this research provide a solid foundation for future innovations in hospital waste management, ultimately contributing to a healthier and more sustainable environment.

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