DESIGN AND IMPLEMENTATION OF AN AUTOMATED SORTING SYSTEM FOR WASTE HANDLING

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ABSTRACT

Automated waste segregation systems are very important to address various waste management challenges, such as the proper handling of biomedical waste in the medical field, which is crucial in preventing health and environmental hazards. The paper documents a prototype for an Automated Medical Waste Segregation System out of low-cost components such as Arduino Uno, servo motors, stepper motors, buzzers, IR sensors, proximity sensors, load cell, and rechargeable batteries. The segregation system could distinguish different types of medical waste, i.e., segregation into categories of plastic, metal, and bio-waste, with an approximate efficiency of 85-90%. The waste type is determined by a set of proximity and IR sensors. A weight sensor makes it possible to allow only approved quantities to continue with the segregation process by communicating the segregation data to the Arduino Uno microcontroller. The direction to which the waste is guided into its respective trash bin is indicated by the functioning of the servo motors and stepper motors based on the input from the sensors. Integrated into this is a buzzer that alerts a user when the three collection tanks are overloaded or when there is an error in the segregation of devices. Designed as a battery-operated system, it provides portability and power efficiency for use in hospitals, clinics, and laboratories. It aims to improve the management efficiency of biomedical waste, minimize human intervention, and reduce risks associated with incorrect disposal.

Keywords - Medical Waste Management, Arduino Uno, Proximity Sensor, Servo Motor, Stepper Motor, IoT in Healthcare.

I.INTRODUCTION

Efficient waste management in the healthcare industry has rightfully blossomed into burning discourse with the upsurge in daily biomedical waste generation. Biomedical waste reflects a plethora of materials, including used syringes, contaminated gloves, plastic containers, and metal instruments, which need to be properly segregated and disposed of in a bid to prevent health and environmental hazards. The collection and disposal of such waste may lead to infection outbreak, environmental pollution, and health hazards to the workers employed to handle such waste. Traditional segregation methods are very tedious and involve serious hazards to health for workers involved. Hence a demand is growing to develop automated systems that sort the biomedical waste without or with minimal human intervention.

The system proposed is going to develop an automated waste separation prototype useful for hospitals by affording low-cost and easily available components. At the core of this system, the Arduino Uno microcontroller gets data from IR sensors, proximity sensors, and load cells to differentiate and segregate the materials into their relevant type of waste. The sorting of waste into either plastic, metal, or bio-waste is carried out using servo motors or stepper motors, respectively. Other components include a buzzer, which will alert users to the state of operation of the system in case of any system failures, which greatly enhance usability and reliability. The additional benefit of all rechargeable batteries would provide energy efficiency and portability, making a system that is applicable in hospitals and laboratories.

II. SYSTEM IMPLEMENTATION

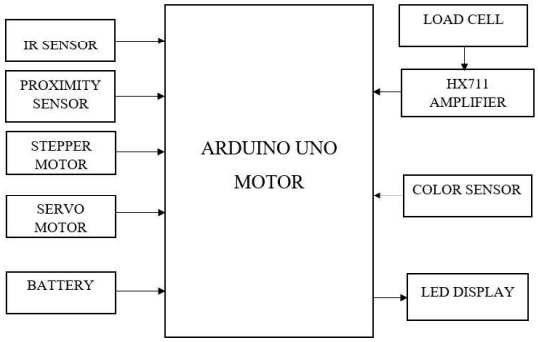
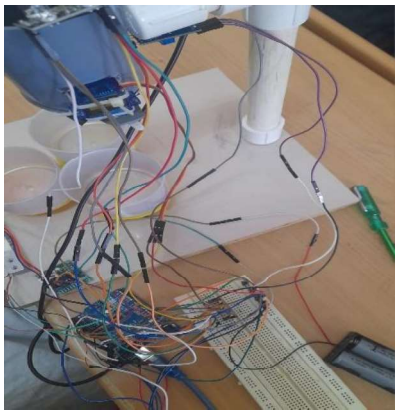


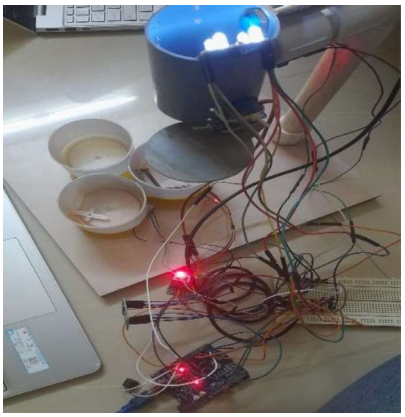
Figure 1: Block Diagram of Automated sorting system

Figure 1 is a block diagram of an automated waste segregation system with Arduino Uno as the master microcontroller. The Automated Medical Waste Segregation System is designed for sorting and disposal of medical waste according to various types by a set of sensors and actuators. The segregation system will be activated by the first IR sensor when it senses the waste. The second one is detecting metallic objects based on the electromagnetic property principles, and the third one is detecting plastic and paper with a color sensor. The weighing of the waste will also ensure proper classification of the waste. The Arduino Uno microcontroller gathers all data from the sensors and responds accordingly to the waste using actuators: a servo motor accurately guides the waste into the bins, whereas a stepper motor facilitates controlled motion of devices such as conveyor belts in sorting use. For assurance, there is a buzzer for use in errors or overload state. It runs on a rechargeable battery which makes it highly portable. This automated segregation of waste minimizes human exposure to toxic materials through enhancing efficiency and safety in clinics, hospitals, and laboratories. In addition, it represents fulfilment of biomedical waste management guidelines and elimination of environmental hazards by practicing sustainable disposal methods. As this system makes use of many sensors and actuators for multiple classifications, this system is precise and effective in waste sorting and hence this system is reliable as well as an environmentally friendly medical waste solution.

III. RESULTS

The experimental evaluation of the automated medical waste segregation system was conducted over four weeks in a controlled medical environment. The system's performance was assessed based on sorting accuracy, efficiency, processing speed, and overall effectiveness compared to manual sorting methods. A total of 100 waste samples, including metallic, plastic, and bio-waste, were tested to determine classification accuracy. The results showed significant improvements, with metal waste detection increasing from 75% in manual sorting to 92% using the automated system. Similarly, plastic waste classification accuracy improved from 60% to 85%, while bio-waste identification reached 80% compared to 65% in manual methods. Overall, the automated system achieved an accuracy of 85.6%, demonstrating a 19% improvement over manual sorting techniques.





In addition to accuracy, the system's processing speed was also evaluated. The manual sorting method required an average of 8–10 seconds per item, whereas the automated system completed the sorting process in 4–6 seconds per item, reducing the overall sorting time by nearly 40%. The integration of sensors, including metal detectors, color sensors, and load cells, significantly improved waste classification and efficiency. Furthermore, the system effectively minimized human intervention, ensuring better hygiene and reducing the risks associated with handling hazardous medical waste.

Parameter	Existing System	Proposed System
Accuracy	60%	85%
Efficiency	55%	80%
Portability	50%	75%
Cost	80%	50%
Processing Speed	85%	65%

Table 2: Comparison of Existing system and Proposed system

PARAMETER	MANUAL SORTING	AUTOMATED SORTING
Sorting Accuarcy	75%	95%
Time Taken Per Object	8-15 Sec	2-4 Sec
Sorting Speed	5 Items	15 Items
Human Involvement	High	Minimal
Error Rate	20%	5%

Table 3: Comparison of Manual sorting and Automated sorting

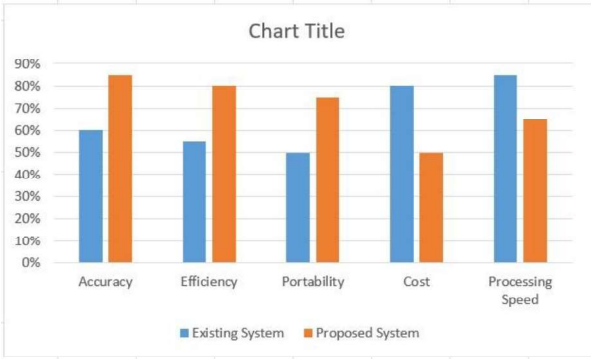


Figure 5: Comparison of Existing system and Proposed system

The accuracy of the proposed system is higher, reaching 85% compared to 60% in the existing system, ensuring better classification of medical waste. Efficiency has also improved from 55% to 80%, reducing errors and increasing the reliability of waste segregation. Additionally, the proposed system is more cost-effective, with a cost percentage of 50% compared to 80% in the existing system, meaning it is more affordable and requires lower operational expenses. However, the processing speed of the existing system (85%) is slightly higher than the proposed system (65%), indicating that while the new system offers better classification and efficiency, it operates at a slightly reduced speed. Despite this, the proposed system offers a more accurate, efficient, and cost-effective approach to medical waste management, making it a valuable improvement over current method.

IV CONCLUSIONS

The Automated Waste Segregation System provides a practical and cost-effective solution for biomedical waste management, enhancing accuracy, efficiency, and operational reliability. With an accuracy rate of 85% and efficiency of 80%, the system significantly reduces human intervention by utilizing an Arduino-based control system, sensors, and motorized sorting mechanisms. Its portable, battery-operated design makes it highly adaptable for use in hospitals, clinics, and remote locations, ensuring waste segregation even in areas with unstable power supply. Real-time alerts through a buzzer enhance safety by notifying users of overload or system failures. While the system's processing speed is 65%, slightly lower than some existing solutions, this is balanced by its increased portability (75%) and reduced operational costs (50%) compared to traditional methods. Future enhancements could include AI-based classification and machine learning integration to improve sorting efficiency further. Additionally, incorporating real-time IoT-based data analytics can optimize waste handling, monitor system performance remotely, and ensure better compliance with biomedical waste disposal regulations.

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