Design and Implementation of a Mobile-Controlled System for Virtual Mode Medical Waste Segregation

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Abstract. Medical waste remains a major hurdle in hospitals, outpatient centers and other healthcare facilities because of the need for appropriate segregation so that storage can be separated by type and impact on the environment can potentially be reduced. This technical paper presents a solution for separating medical waste which is managed with the operation of mobile and robot functions jointly by an android app. It is a quite complex process and still partially manual system, which ends up in two problems: this produces waste and sometimes it can be danger to the workers doing the work. The traditional segregation methods for such waste are laborious leading to improper disposal and increased health hazards as they can often be interpreted wrongly. The traditional waste segregation method practiced by ragpickers is slow and not perfect. One of the main aims of this project is to propose a better method by which medical waste is sorted in India where much of the waste-separation labor is carried out by workers employed in the informal sector. The waste pickers have long worked to sort hazardous hospital waste, some of it laden with potentially toxic levels of heavy metals, by hand. Based on newer technological innovations like robotics and mobile technology, it now seems possible to design an automated system that improves effectiveness and reliability of medical waste management. Such a system could be implemented a robotic arm together with the mobile control system and would aid in waste segregation, reduce human intervention and abide disposal regulations for medical waste.

Keywords: Medical Waste, Waste Sorting, Automated Waste Sorting, Robotics, Mobile Based Automation.

1 Introduction

The surging development of medical waste in large-scale hospitals and health enterprises brings great challenges to waste disposal, and it becomes increasingly paramount to strictly fulfil the regulatory requirements on waste disposal to minimize the adverse effects of contaminative disposal. Conventional way of waste segregation is laborious, there is a possibility of human error in segregating waste and healthcare workers are exposed to risk of injury from hazardous and potentially infectious waste. In India, a large proportion of medical waste is sorted by hand by informal workers, adding to health hazards. Furthermore, the COVID-19 pandemic drew attention to contactless medical waste in action, where front-line health care professionals and others are exposed to infectious waste to a greater extent in the course of caring for patients. The dread of really catching it amounted quite often to doctors refusing to deal with patients or cutting short visits to them and in some cases to loss of interest and unnecessary deaths. This work will attempt to enhance the efficiency, safety

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and accuracy of waste management steps by developing a mobile operated virtual mode health care waste separation control framework integrating automation, robotics and online monitoring.

For ensuring the proper collection, transportation, and disposal of medical waste including hazardous ones like glassware, used needles, plastic, plastic material, medical gloves, and expired drugs.3 Hospital rely on Biomedical Waste Management System. But current waste disposal and transport techniques are inconvenient and put workers at risk of biohazards. Poor separation of the waste at the point of waste generation can cause inefficient recycling and dumping of both recyclable and non-recyclable wastes back into the overall utilization value of waste. State-of-the-art waste-to-energy and waste-to-fuel technologies offer new avenues, processing infectious waste into synthetic gas, biofuels and compost. But for these methods to work as efficient and sustainable solutions, advanced waste separation at the point of generation will be needed.

In the project, a robotized waste segregation system is introduced which includes conveyor belt and smart bin operations which can be control through a mobile interface thus providing real time monitoring and minimising manual effort in waste disposal. And also based on RTOS (Real-Time Operating System) technique, the system can provide non-blocked sentence/output data processing, which can be transmitted to the connected devices synchronically. collection, storage and transportation of medical waste with the least level of health threat for the workers.

Moreover, with the rise of COVID-19 and future pandemics, the system will facilitate virtual waste management support, minimizing direct contact of hospital personnel with contaminated waste and proper and safe disposal of medical waste. The fusion of robotics and on the go-controlled engagement would transform the medical waste disposal system to a more safe, efficient and more environment friendly disposal technique.

2 Literature Survey

Both management and separation of medical waste are important in healthcare facilities with regard to public health, environmental considerations and safety of healthcare workers. Many researches have investigated technical developments for medical waste handling. For instance, A. R. C. et al. (2023) presented a Arduino based UV controllable incubation system to enhance the sterilization methods for preventing contamination of clinical waste. The aim of this procedure is to avoid contamination and ensure safe and secure handling while preserving medical waste. To increase the efficiency in hospitals, Gupta et al. (2023) presented an intelligent approach to tackle biomedical waste by a sophisticated machine learning model to carry out automatic segregation of categories of medical waste. Also, Selvakarthi et al. (2023) discussed IoT-enabled sensing technologies for waste monitoring and tracking, increasing the precision and promptness of waste separation in hospitals.

There have been other creative proposals that address the real-time classification and segregation of wasted products. Hermawan et al. (2023) proposed a COVID-19 medical waste classification system, based on YOLOv5, and implemented it on a Raspberry Pi to categorize and separate medical waste collected in pandemic situation. Belsare and Singh (2022) developed an IoT-enabled system that sorts medical waste into dry and wet waste as it is generated automatically and enhances process efficiency by minimizing human intervention. Meanwhile, Tasnim et al. (2022) developed a voice-controlled robotic arm for garbage classification by utilizing YOLOv3 object detection, which enables automatic and long-distance garbage sorting. V et al. (2021) proposed BIOBIN, implemented and fully automated COVID-19 pandemic specific, biomedical waste safe disposal system to avoid segregation and create a safe working environment for medical staff.

The combination of LoRa and TensorFlow boosts smart waste management, offering real-time surveillance, automatic classification, and the optimized collection. LoRa bins with IoT sensors monitor the amount of waste, and AI models use historical data to help sort through the waste and remove some of the work from people who have more important things to do in their lives than to sort through trash. Predictive analytics stave off overflows and optimize disposal schedules, meaning less landfill waste. This flexible approach saves resources, contributes to a sustainable future and creates cleaner cities. Singh et al. (2019) described a waste segregator designed for smart cities to support waste management and recycling. Further, Raundale et al. (2017) investigated IoT applications in the biomedical waste facilities in 17 the developing world, highlighting the opportunity of IoT for enhancing the efficiency of waste sorting and management. These technology-based advances, such as the earlier work of Folianto et al. s (2015) Smart bin system highlight the increasing importance of automation and real time monitoring in the field of medical waste management to guarantee safer and sustainable practices.

3 Existing System

At present, the segregation of medical waste is primarily carried out through manual sorting performed by hospital staff, through the use of vibrantly coloured bins, into specific types including infectious, pathological, sharps and general waste. This way is very easy to cause human error, and the trash is not sorted properly, effectively aggravating the pollution and increasing the infection risk for both workers and patients. Although there are some partially automated solutions including barcode and RFID enabled tracking systems, the cost for such solutions is high and the infrastructure is not well established. Third, lack of computerized data recording means that the type and volume of waste generated cannot be tracked effectively, complicating compliance with biomedical waste management rules.

What is more, the present system does not have real-time monitoring and remote control, so as to not be able to realize effective tracing of waste disposal processes. Depending on manual documentation causes inconsistent data and inefficiency in the waste facilities. Poor segregation also causes problems with the subsequent waste management processes, recycling and incineration and environmental pollution and may have legal implications. The increasing medical waste, particularly during pandemics and higher utilization of healthcare services, require more sophisticated and automated technology. Radio frequency Identification (RFID) embedded mobile virtual mode-controlled waste segregation can overcome these drawbacks and increase accuracy, efficiency and real-time tracking, thus ensuring safety and sustainable medical waste management.

4 Methodology

Appropriate separation and dumping of medical waste help healthcare facilities to prevent human hazards and environmental contamination. Traditional manual sorting methods have a few drawbacks including the redundancy of contamination, low levels of accuracy and may prove to be quite inefficient. This paper describes a technique where waste segregation is automated with the help of real-time data, robotic automation with RTOS and mobile-operating based robot system. This smart bin uses sensors (RFID, IR and image recognition) to detect and separate waste which then is taken care of by a robotic arm. The waste was separated into specific bins by the robotic arm that uses AI algorithms. It supports real-time operation, allows task prioritization and ensures smooth functioning. The system can be remotely monitored and managed through a smartphone application, making it possible to manage waste in an energy-efficient way and minimise human exposure to EBM. Fig 1 shows the Proposed Block Diagram.

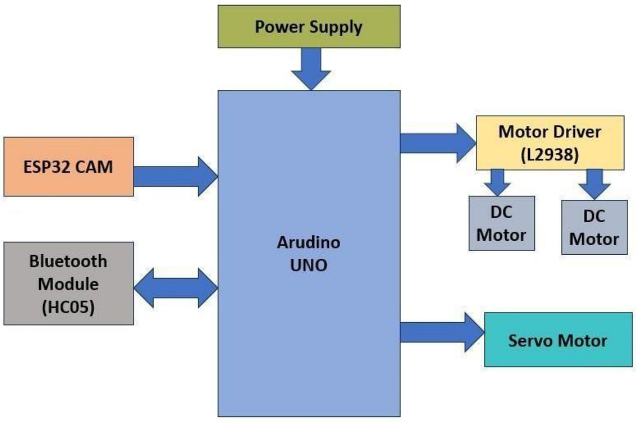

Fig. 1. Proposed Block Diagram.

Power Supply: The schematic of a +12V regulated DC power supply, a reliable device for average current demands of approximately 1 amp, is shown fig 2. This circuit protects against short circuits and thermal overload and is anchored by the LM7812 integrated circuit, a three-terminal voltage regulator (see Fig.2). A mainstay of the LM78XX family, the LM7812 is a positive voltage regulator that can handle a variety of voltage requirements. Variants that operate at a steady 5 volts include the LM7805. The LM79XX family, its equivalent, deals with negative voltages. A transformer (Tx=Primary 230V, Secondary 12V, 1Amp step-down converter) is used to convert 230V mains to 12V. The bridge rectifier, which converts AC to DC, is made up of four 1N4007 or 1N4003 diodes.

Use a 1000uF, 25V capacitor to effectively filter voltage fluctuations and ensure a clean DC output. Its integration into the circuit is straightforward, allowing for easy assembly. The LM7812 voltage regulator requires an input voltage above 12V to function optimally. To prevent overheating and ensure stable performance, attaching a heat sink is essential. This setup enhances voltage regulation, minimizes ripple, and improves overall circuit reliability. Proper filtering and cooling mechanisms contribute to efficient and long-lasting electronic operation.

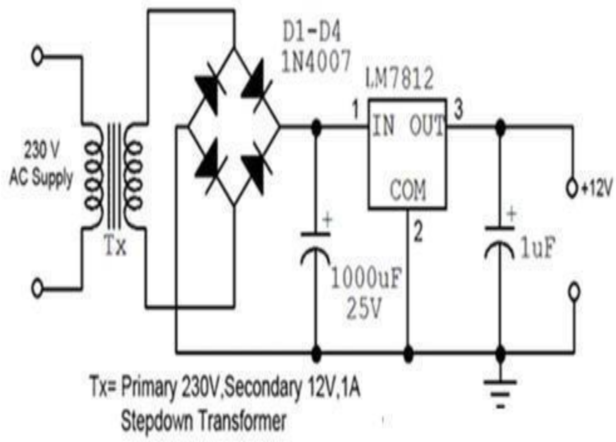

Fig. 2. Power supply.

Arduino UNO: The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The board is programmed with the Arduino IDE through a Type-B USB cable and a 7-20VDC power supply is required for terminals P5 (and consequently all toolheads), fed by a 9V or a USB powerbank. It differs from other versions in that it does not have an FTDI chip for serial communication and instead features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. Onboard bootloader allows connection/upload of the firmware with a USB-UART adapter. The site uses the Arduino UNO as one of the most popular development platforms and what you'll find below is your Arduino UNO program to prototype your ideas whether you are a hobbyist, teacher or an expert in prototyping and embedded applications.

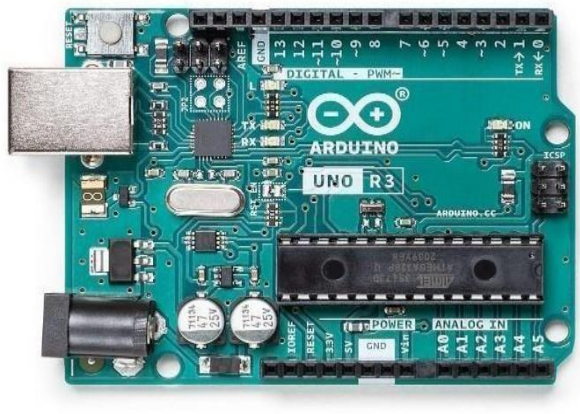

Fig. 3. Arduino UNO

4.1 Specifications of Arduino UNO

- Microcontroller: ATmega328P (brain of the board)
- Input Voltage: 7V – 12V (recommended)
- Digital Pins: 14 (used for input/output, 6 support PWM)
- Analog Pins: 6 (used for sensors)
- Clock Speed: 16 MHz (controls processing speed)
- Communication: USB, Serial, I2C, SPI
- USB Port: Type-B (for programming and power)

Fig. 4. Bluetooth Module.

4.2 Bluetooth Module (HC05)

Communication device: The project's foundation is wireless communication between a mobile phone and a microcontroller. However, a micro controller by itself cannot speak directly to an Android smartphone. The Bluetooth Serial module can communicate with other Bluetooth devices that have the serial port and operates without a drive. The diagram of Bluetooth module is shown in fig 4.

- The master and slave must communicate with each other.
- The password needs to be accurate.

ESP32 CAM: The ESP32-CAM is a small camera module with the ESP32-S chip, designed for wireless image processing and transmission. It also integrates a friendly RTC real time clock and a n OV2640 camera. It also has several GPIO pins for peripheral connection, which is more suitable for projects. With a Micro SD card slot built in, it supports storage of images or any other data type that you may desire; useful for surveillance, AI vision, smart automation, etc. Featuring built-in Wi-Fi and Bluetooth connectivity, the ESP32-CAM allows remote access and real-time data transmission, which is otherwise challenging for applications requiring embedded vision. ESP32 CAM Show in fig 5.

Fig. 5. ESP32 CAM.

Motor Driver (L2938): The L293 and L293D devices are quadruple high current half H drivers. With a supply voltage from 4.5V to 36V, both the L293 and L293D can control a current of up to 1A per channel. These ICs can drive inductive loads such as DC motors, bipolar stepper motors, relays, and solenoids in positive-supply applications. The units both have TTL compatible inputs, making them easy to use with microcontrollers and much more. They're sturdy enough for robotics, automation, and motor control projects!

motors require electronic controllers to adjust current flow. These are known for their reliability, efficiency, and suitability for dynamic environments and are used in robotics, automotive and industrial automation. Fig 6 Show the Motor driver.

Fig. 6. Motor driver.

DC Motor: A DC motor is an electromechanical device that converts direct current into rotational motion, making it ideal for various applications requiring speed and torque control. While rare, unique designs like the ball bearing motor and Faraday's homopolar motor exist. The two main types are brushed and brushless motors brushed motors use mechanical contacts for commutation, whereas brushless. Fig 7 shows the DC Motor.

Fig. 7. DC Motor.

Servo Motor: Servo Motor A servo means servomechanism, so it's a type of motor with precise control over position, velocity, and acceleration. Fig. 8 is a diagram of the servo motor. The control circuit alters the movement of the motor by comparing the rotation angle of the motor to the signal of the position feedback device. If the rotation of the motor varies from the predetermined desired position, the control circuit will adjust the motion of the motor in accordance with the difference in the feedback signal, so that the position of the motor becomes closer to the desired position as time passes.

Fig. 8. Servo Motor.

Accordingly, the servo motor has excellent stability and precision. About Servo Motors Servo motors are great electronic devices specifically designed for robotics and automation applications due to their high-speed response and quick acceleration and deceleration. Since accurate position control can be accomplished with a feedback signal, the servo motor can rapidly and accurately reach the target position. For this reason, servo motors are used in applications like industrial automation, robotics and automatic equipment where fast response times and precise control of the highlight position are required.

5 Results and Discussion

The increasing volume of medical waste necessitates efficient and automated segregation methods to minimize environmental and health risks. This model focuses on the design and implementation of a mobile-controlled system for virtual-mode medical waste segregation. Utilizing IoT-based technology, the system enables real-time monitoring and categorization of medical waste through a mobile interface. By integrating smart sensors, it enhances accuracy in waste classification and disposal management. This innovation aims to improve hospital waste management practices, ensuring regulatory compliance and promoting environmental sustainability. For working of mobile controlled system for virtual mode medical waste segregation, initially once the power supply is connected to the kit. Then the kit starts initializing as shown in fig.9.

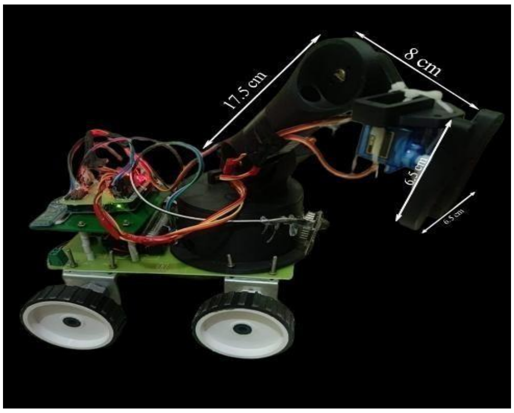

Fig. 9. Experimental setup.

Once the kit is powered on, the waste segregation process begins. The vehicle is navigated toward the waste using mobile commands to the vehicle from the mobile by pressing the buttons for left moving of vehicle we have to press left, for right moving of vehicle we have to press right, for forward moving of vehicle we have to press the up button, for backward moving of vehicle we have to press the down button, to control and move the vehicle towards the waste by seeing the video from the mobile screen as shown in fig.10 Once the waste is found it is picked by giving the pressing the pick button in the mobile then the waste is picked by vehicle as shown in fig.11.

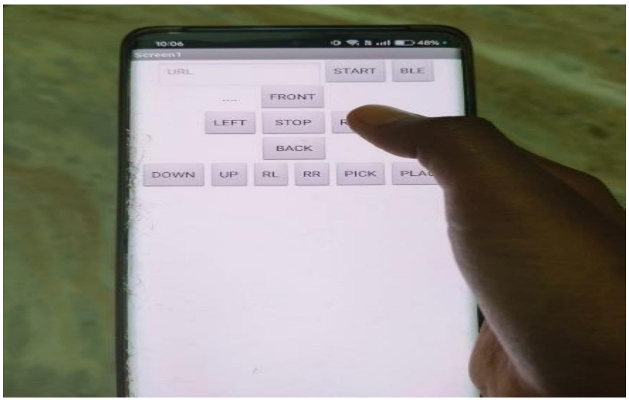

Fig. 10. Controlling the vehicle through mobile.

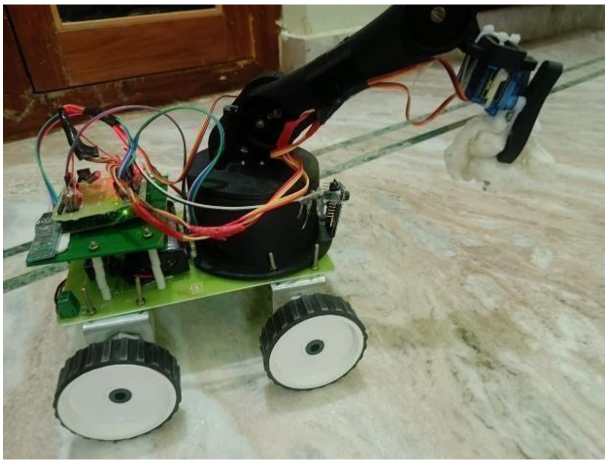

Fig. 11. Waste material collected by vehicle.

After the waste material is collected from the room it has to be put in the dustbin by giving the commands using the mobile interface, the vehicle is navigated toward the waste, where it collects the material. After collection, the vehicle is directed to the dustbin for disposal to control and move the vehicle towards the waste by seeing the video from the mobile screen as shown in fig.12, the vehicle will move towards the dustbin and by pressing the drop the waste material is drop at the dustbin as shown in fig.12.

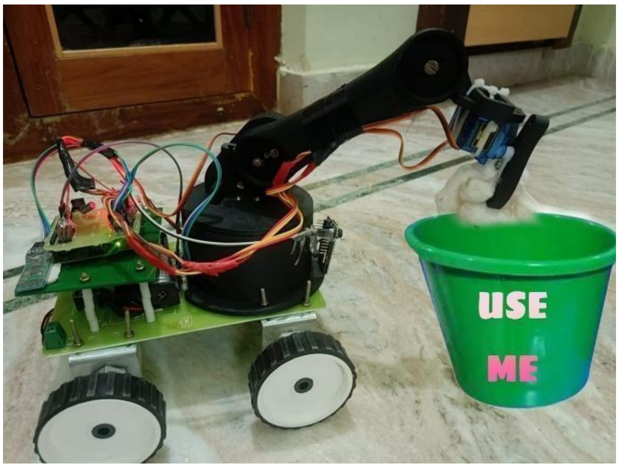

Fig. 12. Waste material dropped into the dustbin.

6 Conclusions

The robotic arm is used in automatic e-waste segregation, which separates e-waste, wet waste, and metal garbage. The motor-powered arm is activated and the waste is dispensed onto the appropriate containers when the sensors are triggered. Because it incorporates a robotic arm and an automated system, this method is more inventive and more effective. In terms of improving the cleanliness of our society, this research makes progress. In the future, artificial intelligence and a crusher could be used to improve the efficiency and sophistication of this system.

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