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System design for waste management using Blynk app

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Abstract

In the present era of information and technology, the most important problem faced by the municipal authorities is the garbage collection from various parts of the city. We need is to have a monitoring system that gives information about garbage in different localities immediately to the concerned person. The aim of this work is to design a cost effective and portable system, that enable its use for making cities clean using smart technology. The design has been carried out to cater to the current waste management situation and optimize by providing an affordable waste management solution as the main objective. The designed system also has an automatic opening of the latch of the bin when someone is detected nearby, makes announcement, moves on Radio Frequency (RF) controlled trolley and sends information regarding the level of the bin to the person incharge for collection. The trolley design specifications are also discussed in the present study.

This work introduces a groundbreaking Smart Waste Management System that harnesses the power of the Internet of Things (IoT) to revolutionize waste collection and disposal. Overall, this system not only addresses the pressing issue of efficient waste disposal but also promotes sustainability and community engagement through its display of data on blynk app. It represents a promising step towards cleaner, greener, and smarter urban environments.

Keywords: IoT; Waste Management; RF-Controlled Trolley; Blynk App; Community Engagement.

1. Introduction

In an era where urbanization is rapidly increasing, efficient waste management has become a paramount concern for cities worldwide. The traditional methods of garbage collection are often inefficient and lack real-time monitoring capabilities, leading to overflowing bins and unpleasant (dirty) streets. To address these challenges, an innovative solution has emerged, the IoT-Based Garbage Monitoring System, leveraging cutting-edge technologies such as the ESP32 microcontroller, the Blynk mobile application, a timer system, and an RF-controlled trolley.

This groundbreaking system represents a fusion of the Internet of Things (IoT), wireless communication, and automation to revolutionize the way it manages and monitors garbage collection. The ESP32, a microcontroller, renowned for its versatility and connectivity capabilities, serves as the central brain of the system. It is equipped with sensors to detect garbage levels within bins and communicates this data wirelessly to the cloud.

The Blynk mobile app acts as a user-friendly interface, allowing both residents and Concerned authorities who collect waste, to access real-time information about garbage levels, schedule pickups, and receive alerts when bins reach their full capacity. This user-friendly application enhances transparency, enabling timely and efficient waste collection while minimizing unnecessary trips.

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To optimize routes and conserve resources while collecting garbage/waste, a timer system is integrated into the IoT solution. It allows for the scheduling of collecting garbage at specific times, ensuring that resources are allocated efficiently and reducing the environmental impact associated with collection of garbage.

Furthermore, the RF-controlled trolley represents the physical embodiment of automation in waste management. When bins reach their capacity or when scheduled times arrive for collection, the trolley autonomously navigates to the designated location using RF signals. This not only minimizes human intervention but also reduces labour costs while maintaining the city's cleanliness.

2. Literature review

In essence, a literature review serves as an exploration, evaluation, and synthesis of pertinent literature within a specific research field. It sheds light on the evolution of knowledge within that domain, emphasizing prior research, established insights, emerging trends, and the current state of understanding on the subject.

Adil Bashir et al. [1] introduced a sensor-based approach to prevent garbage overflow in residential areas, replacing manual or loader-based methods. This efficient method optimizes vehicle and manpower utilization. B. Chowdhury and M. U. Chowdhury [2] devised an RFID-based smart trash system where users pay based on the weight of trash thrown into bins. This encourages waste reduction among residents. Fachmin Folianto et al. [3] developed a data collection system using sensors and wireless networks, reducing power consumption and operational time. This improved decision-making for litter bin providers and cleaning contractors. Dr. K. R. Nataraj and Meghana K.C. [4] focused on cleanliness awareness, utilizing an IR sensor to detect trash levels and a gas sensor for toxic gases. An alarm is triggered when the bin is full. R.M.Sahu et al., [5] introduced a system using RFID, GPS, and GIS for solid waste bin monitoring. Lokuliyana, et al., [6] proposed an IoT-based waste management framework with optimization algorithms. T. N. b. M. Ishak and S. b. Abdullah [7] designed a smart system assessing waste bin levels via sensory systems and IoT connectivity. Andrei Brozdukhin et al., [8] utilized moisture and ultrasonic sensors for waste level measurement and image processing for trash index calculation. S. D. Satyamanikanta and M. Narayanan [9] developed a garbage collection system with real-time bin status notification. Chun-Yen Chung et al. [10] deployed LoRaWAN communication for garbage sorting and developed a monitoring interface. Bhamidi Rama & K Raajasekhar [11] created an automated smart waste management system using IoT and sensor-based circuitry, ensuring efficient waste collection and notification. These works collectively showcase innovative approaches for improving waste management through technology and automation.

3. Setting up the system

In the current system, the setup mainly utilizes IR sensors, ultrasonic sensors, and the ESP32 microcontroller. One of the ultrasonic sensors is responsible for gauging the waste level within the bin, while the IR sensor detects the presence of a person approaching the bin for waste disposal. The lid's movement is controlled by a servo motor linked to it. The ultrasonic sensor used under the top of the lid will sense the level of the bin and the loudspeaker connected to it always says only to deposit dry waste. DC motors are used along with an L293D motor driver to move the bin on the trolley. Within this system, pertinent data concerning the bin's waste level is transmitted to the relevant authorities. The Internet of Things (IoT) is leveraged to collect and monitor this data, and the Blynk app. serves as the platform for storage and oversight.

The following components are used in this work.

3.1. ESP32 with IoT Controller

The ESP32 as shown in figure 1 stands as a robust microcontroller endowed with built-in Wi-Fi and Bluetooth capabilities. It finds widespread application in IoT projects, enabling the connection of devices to the internet seamlessly.

Figure 1 ESP32 with IoT Controller

3.2. IR Proximity Sensor

An IR proximity sensor as shown in figure 2 relies on infrared light to detect the presence or absence of an object within its sensing range. It frequently serves in tasks such as obstacle detection and proximity sensing. The sensor has a maximum range of 40-50 cm indoors and 15-20 cm outdoors.

Figure 2 IR Proximity Sensor

3.3. Ultrasonic Sensor

An ultrasonic sensor as shown in figure 3 operates by emitting sound waves and measuring the time it takes for these waves to return. It proves invaluable for distance measurement and object detection across a wide spectrum of applications, including robotics and automation. It has a range of appx. 70 cms or 21 meters.

Figure 3 Ultrasonic sensor

3.4. RF Transmitter and Receiver

In the transmitter part, a data encoder and Radio Frequency (RF) transmitter is present as shown in figure 4. To control the robot, four push button switches are connected to the encoder, with a common ground connection. When a button is pressed, the encoder receives a digital LOW signal and converts it into serial data. This serialized data is then transmitted via the RF transmitter.

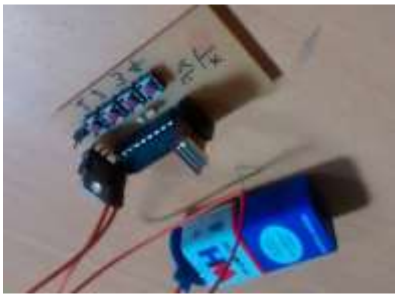

Figure 4 RF Transmitter and Receiver

On the receiving end, an RF receiver is used to capture the transmitted data, which is then sent to an HT12D decoder. The decoder takes this serial data and transforms it back into parallel form. Subsequently, these decoded signals are directed to the L293D Motor driver IC. Depending on the received data, the robot's two DC motors operate in various directions like forward, reverse, left, right, allowing it to control the robot's movements using the remote.

3.5. SG Servo Motor (5V)

The SG Servo motor as shown in figure 5 belongs to the category of motors capable of precise rotation. Frequently used in fields like robotics and automation, it plays a pivotal role in controlling the position of objects with great accuracy.

Figure 5 SG Servo Motor (5V)

3.6. ISD1820 Audio Rec. & Player

The ISD1820 as shown in figure 6 represents an integrated circuit equipped with the ability to both record and play audio. Its utility comes to the fore in applications demanding sound recording and playback functionalities.

Figure 6 ISD1820 Audio Rec. & Player

3.7. Motor driver (L293D)

The L293 as shown in figure 7 ensures efficient and safe motor operation by providing both direction and speed control, making it an indispensable component for the mobility and manoeuvrability requirements.

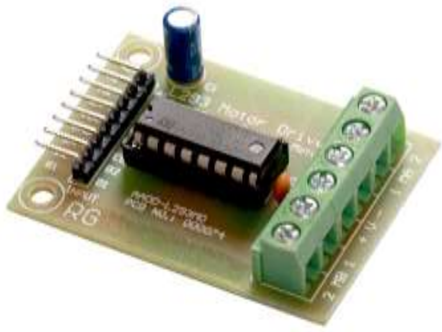

Figure 7 Motor driver (L293D)

3.8. The 200 RPM DC motors with 65mm plastic wheels

The 65mm plastic wheels as shown in figure 8 are attached to these motors, ensuring smooth movement over various surfaces.

Figure 8 200 RPM DC motors with 65mm plastic wheels

In this work, these motors can be controlled by the ESP32 microcontroller to drive the trolley autonomously to designated collection points. They enable the trolley to move forward and backward, making it versatile for navigation. Their RPM rating can be adjusted to control the trolley's speed, ensuring efficient garbage collection. These motors are essential for the overall functionality and contribute to its IoT capabilities by enabling remote control and precise movement to optimize garbage collection processes.

4. Methodology

The System operates seamlessly by utilizing a range of components and functionalities. To begin, an ultrasonic sensor continuously gauges the distance to the garbage bin, offering real-time data on its fill level. This data is then processed through wireless transmission. The ESP32 microcontroller receives this information and encodes it using the HT12E encoder, preparing it for transmission via RF communication. On the receiving end, the RF receiver and HT12D decoder work in unison to decode and interpret the data, making it readily accessible for further analysis. This decoded data is seamlessly integrated with the Blynk IoT platform through the ESP32's Wi-Fi connection. Users will be able to monitor the status of the garbage bin in real-time via the user-friendly Blynk mobile app, showing graphical indicators and charts. When the fill level exceeds the predefined thresholds, the system will promptly issue alerts or notifications to users, ensuring timely collection of the waste. Additionally, the system boasts the option for remote control through a servo motor, activated by an IR proximity sensor, allowing users to conveniently operate the bin's lid. For added efficiency, a timer function is implemented to automate waste collection and a trolley to move the bin using a remote which is operated by the concerned person. Overall, this IoT-driven solution streamlines waste management practices, facilitating informed decision-making and enhancing user convenience and engagement. The block diagram of the proposed model is shown in figure 9.

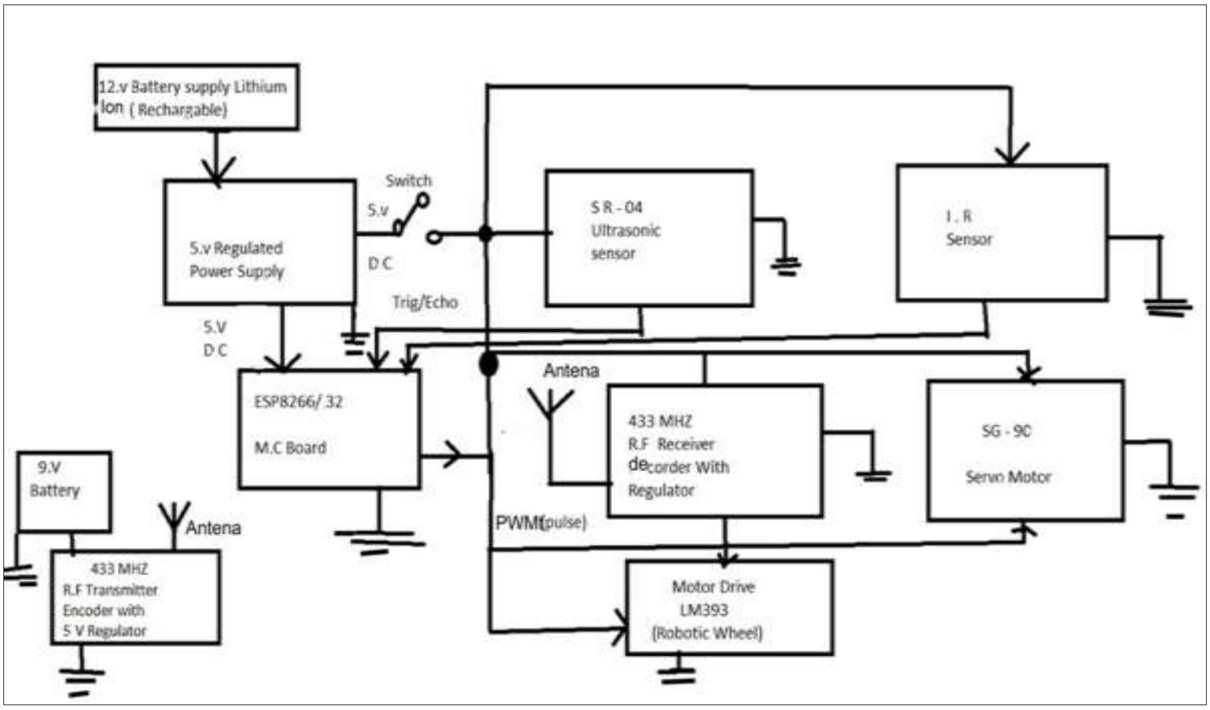

Figure 9 Block diagram of Smart waste management system

With all these components in place, an integrated System is designed. It combines real-time monitoring, precise waste-level measurements, and remote control into one efficient solution. A remote controller is used with 4 switches to move the bin on its wheels. When switch 1 is pressed the bin moves towards left direction, when switch 2 is pressed it moves towards right direction, when switches 1&2 are pressed at a time it moves forward, when switches 3 and 4 are pressed at the same time the bin moves backwards. When none of the switches are pressed the bin stops and remains stable. These wheels are connected through DC motors which are operated using the L293D Motor driver. This motor driver helps to provide the necessary voltage required for the motors. The system operates by sending data wirelessly to the Blynk App, allowing users to monitor and control waste collection schedules conveniently. The timer functionality optimizes routes during collection, reducing operational costs and environmental impact. This work is a smart way of managing waste since there is a movement by Government about Swachhata Pakhwada as a part of the Swachh Bharat Abhiyan.

In summary, this System introduces a transformative approach to waste management, harnessing the power of technology to streamline processes and enhance user engagement. With the inclusion of RF remote capabilities, it further extends the system's reach and convenience, all while promoting sustainable and efficient waste disposal practices.

5. Results

In this work, unit tests are conducted on all modules and obtained the expected results. Testing of each module of a system is called Unit testing. The main purpose of this testing is the Software quality checking. Later, the component testing is conducted on each module to get the expected results, and modules in the system worked properly. The prototype development board is checked to see the implementation of the designed system and its output is developed by the integration of the different modules. The bin was moving using DC motors controlled by remote having four switches as shown in figure 10.

Figure 10 Prototype of designed model

The results obtained on the monitor shows that there is a person near the bin at 14cms, so the hatch of the bin is not opened, and the amount of waste filled in the bin is 33% as shown in the figure 11.

Figure 11 Results displayed on Blynk app.

The output obtained from various sensors is shown on mobile phone using Blynk app. as shown in figure 12. It shows that the bin has opened its hatch up to 90% using servo motor.

Figure 12 Display of output on Blynk app. on mobile.

6. Smart dustbin design Calculations:

Torque plays an important role, and its calculation forms the basis for the complete design for the IoT. Therefore, Torque can be calculated as follows:

$Total\ Torque\ required\ (\tau) = F_{total} \times r$

$\tau = Trorque\ (NM)$.

$F_{total} = total\ force\ (N)$

$r = wheel\ radius\ (M)$

$$Total\ Force\ (F_{total}) = Rolling\ resistance + Acceleration\ Force + Constant\ velocity\ force$$

To calculate Total torque we require following parameters,

Rolling resistance of indoor tile flooring(μ)

Average velocity with which the bin must move (v)

Average acceleration(a)

weight of the bin(W)

Let us fix the average velocity to be 0.68 m/s (This is done based on the velocity of the motors and wheel sizes in the market), rolling resistance be 0.03 and weight of the bin be 10 Kg.

We know that $V_f = U_i + at$------------------------------(6.1)

⇒$0.68 = 0 + a(1)$(let us consider the time t as 1 sec)

⇒$a = 0.68\ m/s^2$

Force required for acceleration:

$F_{acc} = m \times a$

$= 3 \times 0.68\, N$

$= 2.04\, N$

m= mass in Kgs

a = acceleration desired

Force required for constant velocity.

$F_{vel} = w \times v$---------------------------(6.2)

= (3 ×10) ×0.68

= 20.4N

w= weight in (N)

v=Desired velocity in m/s

$F_{total} = R + F_{acc} + F_{vel}$--------------(6.3)

= 0.03+2.04+20.4

= 22.47 N

Therefore,$torque\ required\ (\tau) = F_{total} \times r$ --------(6.4)

$= 22.47 \times 32.5 \times 10^{-3}$

$= 730 \times 10^{-3}$ N-m

= 0.73 N-m

Therefore, as the total torque required is 0.73 N-m a DC motor with 100 rpm and delivering 0.9N-m torque attached with a 65mm diameter wheel would be the correct design for the requirement.

Stress on Chassis

Stress (Chassis) / FOS = Force / Area

Consider, Factor of Safety = 2

Total Force = 22.47 N

Length of Chassis = 180 mm

Width of Chassis = 120 mm

$Area = Width \times Length$-------------------(6.5)

$$Area = 180 \times 120\, mm^2$$

$Area = 216\, cm^2$

Stress (Chassis) / FOS = 22.47 (N) / 216 cm^2

Stress (Chassis) = 22.47 × 2 (N) / 216 cm^2

Stress (Chassis) = 0.208 N / cm^2

Design of smart bin

Mass of Dustbin Plate = 0.2 kg

Weight of Dustbin Plate = mg = 0.2 × 9.81 = 1.962 N

Torque = Weight of Dustbin Plate × Distance (From Centre of Gravity) ------(6.6)

Now, Let's Calculate Centre of Gravity for different Shapes.

1) Semi Circle (Radius = 25 cm)

   Centre of Gravity = 4R/3π

   Centre of Gravity = (4 × 25) / (3 × 3.14) = 10.61 cm

   Torque = 1.962 × 10.61 = 20.81 N-cm

2) Circle (Radius = 25 cm)

   Centre of Gravity = R

   Centre of Gravity = 25 = 25 cm

   Torque = 1.962 × 25 = 49.05 N-cm

3) Rectangle (Width = 25 cm, Length = 75 cm)

   Centre of Gravity = L / 2

   Centre of Gravity = 75 / 2 = 37.5 cm

   Torque = 1.962 × 37.5 = 73.57 cm

4) Triangle (Side = 75 cm)

   Centre of Gravity = b / 3

   Centre of Gravity = 75 / 3 = 25 cm

   Torque = 1.962 × 25 = 49.05 N-cm

It was found that the semi-circle shaped bin cannot be used due to stability issues. Rectangular shaped bin requires higher torque. Triangular shaped bin is not space efficient, and the dust can fit in Corners. Hence, circular bin is preferred which was used in this work.

7. Conclusion

Rapid population and increasing industrialization are the major causes of pollution. The problem of overflow of garbage, leads to unhygienic conditions of sanitation due to lack of information passed on time to the concerned authorities. Advancements in technology are utilized to overcome these problems. This work is initialized to aid the concept of keeping the city smart and will fulfil the mission of Swatch Bharat Abhiyan. It uses a cheap and reliable IoT device as a central control board and is interfaced with sensors like IR, ultrasonic, voice recorder, servomotor, dc motors, and a remote. All the sensors' data are stored in an online database in real time, and notification on the system and on mobiles makes it more efficient and reliable.

Future work

Waste disposal presents a pressing concern with vast potential for future development in several key areas. One such avenue for advancement lies in refining the design of receptacles used for source segregation, exploring new materials and designs adaptable to various waste scenarios and characteristics.

Furthermore, delving into the realms of cost-effectiveness and portability through research can pave the way for broader adoption, making these solutions accessible to a more diverse audience. There is substantial untapped research potential in enhancing the efficiency of waste management models. The current model has been carefully tailored to address existing waste challenges while keeping affordability in focus.

Looking ahead, there's room for system upgrades incorporating an array of sensors. As technology evolves, integrating new sensors into the system can accommodate diverse segregation requirements and offer enhanced functionality. Additionally, the inclusion of features like mapping the shortest route to reach the bin location, coupled with real-time smartphone notifications, can significantly improve user-friendliness, convenience, and overall efficiency. The work can be done on wet waste also.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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