IoT Based Smart Rewarding System for Intelligent Trash Management

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Abstract. Most Indian cities find it tough to manage waste. Officials in Indian cities have been under increasing pressure to manage waste as populations surge. A significant portion of the garbage such as those collected from streets to open plots come from dumping waste without using designated dustbins when residents throw away garbage. This poses a serious health risk and is a threat to urban sanitation. In our work, we have proposed an IoT based smart dustbin system that can control city cleanliness and waste operation in a smarter way. The real-time waste collection system utilizes sensors to detect waste in real time and transmits the data to a central control unit directly through wireless communication, which reduces operation-related costs for collecting waste. Load cells and RFID readers are integrated in the rubbish bin for waste weight measurement. RFID-tagged receptacles are unlocked by users and they earn reward points for proper disposal of waste, encouraging responsible recycling. This would work wonders in not only dump management, but also an infi-nite number of diseases that are connected with dumped dirt on roads.

Keywords: waste management, IoT, smart dustbin, RFID, reward system, real-time monitoring, Wi-Fi.

1 Introduction

Waste management has gradually become a growing problem in urban areas with the increasing generation of waste products and contemporary poor methods for their disposal. Traditional disposal systems typically result in over-filled garbage bins, littered streets, and extreme health hazards to those living in the city. To solve these problems, IoT and RFID based intelligent waste management are being developed.

The proposed work aims to design a smart dustbin that self opens after it sees the garbage coming near, weighs the amount of waste and gives reward point against it. RFID is used for user identification, and a backend can obtain the fill level with other IoT sensors such as ultrasonic, and weight. It enables better bin rounds and prevents the need for overflow of wheeled bins. Associate waste management with incentive mechanism, to encourage the user's responsible behavior and build green recycling culture of household refuse.

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IoT and RFID are also considered to be enablers in process automation, data-driven decision support, and efficiency enhancement in waste management which are highlighted in previous studies. This move is also part of smart city dreams as it advocates for sustainable and clean waste disposal.

2 Literature Study

The rapid urbanization has brought us the problems on waste control under ever mounting pressure. The traditional system of collection and disposal is over burden, lacking in segregation and frequently degrades the environment. In response, IoT-based applications were proposed for smart waste management that could take full advantage of the sensors, communications and automation platforms.

2.1 IoT in Smart Waste Management

There are number of researches that have shown the effectiveness of IoT in waste monitoring and management systems. Kumar et al. [1] introduced a system based on the Internet of Things (IoT), using sensors and communication modules, to have optimal waste collection. Likewise, Sosunova and Porras [2] carried out a review of literature on IoT-based systems for smart cities, with focus on sustainability and efficiency. Balashanmugam [3] implemented an IoT based smart dustbin system and demonstrated the possibility of real-time waste monitoring at home level.

2.2 Segregation and Automated Waste Collection

Garbage separation is still a problem in developing countries. Kadus et al. [4], and Gimonkar [5] have proposed waste segregation IoT models that can automatically categorize the trash hence minimizing manual work. Mapari et al. [6] proposed an automatic waste segregation and monitoring system that sends the current status of the garbage bins in real-time, while Chowdhury and Chowdhury [7] studied RFID enabled real-time waste management as a precursor for smart systems. Leo et al. [8] advanced greater degrees of separation via IoT automatic monitoring, in addition to an increased waste classification accuracy.

2.3 Smart Bin Monitoring and IoT Architectures

Several researchers also devoted to smart dustbin and monitoring systems. Haque et al. [9] presented a high-efficient collection system with the assist of IoT and smart bins to reduce non-effective collecting trips. Kanade et al. [10] proposed a smart garbage monitoring system with the Internet of Things (IoT) integration for online alerts on filled up bins. Pavithra et al. [11] developed an IoT-based automatic smart waste management system constructed by Chaturvedi et al. [12] integrated IoT and RFID technology to enhance the efficiency of monitoring. Patole et al. [13] have also confirmed the use of IoT for level monitoring of garbage.

2.4 IoT for Smart Cities and National Initiatives

Malapur, and Pattanshetti [14] proposed IoT-oriented waste management applications targeting smart city paradigms, while Alwis et al. [15] developed incentive mechanisms on a smart disposal system. Hassan et al. [16] developed a less expensive arduino-based automated sorting recycle bin that is cheap for resource-restricted areas.

2.5 AI and Advanced IoT Technologies

The integration of deep learning and AI into IoT waste has been particularly studied recently. Sheng et al. [17] developed a LoRa IoT framework with TensorFlow smart waste classification models. Vijayakumar et al. [18] presented RFID and sensor-based IoT based garbage collection in Bharadwaj et al. [19] associated IoT waste automation to national programs such as Swachh Bharat Abhiyan. Ishaq et al. [20] used IoT to monitor biomedical waste, dealing with sustainability and safety issues.

2.6 Emerging Research and Future Trends

The latest collaborations are using AI and smart automation to better manage waste. Alourani et al. [21] developed a sorting system which used combined IoT and AI technologies to achieve more accurate waste separation. Addas et al. [22] threw the concept of Waste Management 2.0 into the market in which IoT would be attached to eco-friendly and efficient solutions at city level.

3 System Implementation

3.1 Hardware Requirements

3.1.1 RC522 RFID Unit

RC522 RFID Unit the RC522 RFID Module is a low cost MFRC522 based RFID Reader Module that is support read and write Mifarestrauss. It operates at 13.56MHz frequency, popularly used as HF RFID readers and writers MIFARE® is an NXP Semiconductors-owned trademark, and is being licensed to several companies including STMicroelectronics. This module can read and write information to RFID card and tag from the distance of 3 to 5cm. It communicates to microcontrollers over SPI, I2C or UART. Fig 1 shows RC522 RFID Module.

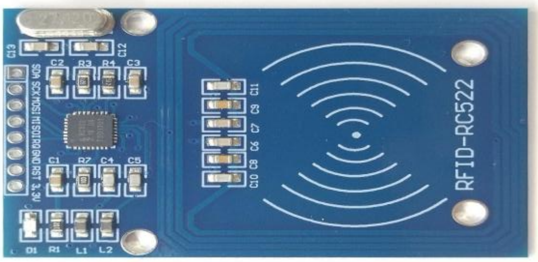

Fig. 1. RC522 RFID Module.

3.1.2 Ultrasonic Sensor (HC-SR04)

Ultrasonic sensors use the programmed way of how long a high-frequency sounds take to travel out away from the sensor to an object in front of the sensor and reflect back to the sensor. Upon reading such sensors, the sensors are used to detect the distance of objects and accurate location of any threats or obstacles. A few technical characteristics are: detection range between 20 mm and 400 cm, working frequency of 40 kHz, accuracy of ±1 cm, and a beam width around 15 degrees. Fig 2 shows Ultrasonic Sensor (HC-SR04).

Fig. 2. Ultrasonic Sensor (HC-SR04).

3.1.3 Arduino NodeMCU ESP8266

The NodeMCU ESP8266 is an open-source platform for IoT development, equipped with a low-power, 32-bit microcontroller and integrated Wi-Fi capabilities. This can transmit and receive data over wireless networks, making it ideal for remote sensor applications, IoT projects, and home automation systems. Some key technical specifications include an operating voltage of 3.3V, a clock speed of 80 MHz, and multiple GPIO pins for interfacing sensors and actuators. The device supports communication through I2C, SPI, UART, and PWM, allowing developers to connect a wide variety of peripherals. Fig 3 shows NodeMCU ESP8266.

Fig. 3. NodeMCU ESP8266.

3.1.4 I2C LCD Display (16x2)

An I2C LCD display is a liquid crystal panel module that supports an I2C (Inter-Integrated Circuit) communication medium, hence simplifying pins for control. The module works at 5V and the screen size is 16 characters x 2 lines (16x2). It is suitable to display textual information or custom characters, and it is equipped with backlight to make it visible. Its minimal wiring makes it an ideal choice for spread beaming projects such as Arduino's and embedded systems where less wiring is a priority. Packet to the pellet This lib uses the arduino hardware I2C implementation to transmit/receive data. Fig 4 shows I2C LCD Display (16x2).

Fig. 4. I2C LCD Display (16x2).

3.1.5 Servomotor (SG90)

The SG90 Servo motor is a mini size, low power consumption three pole motor, giving 1.5Kg/cm torque. It's a kid of miniature which is ideally used in robotics. It is controlled via PWM signals and has a working range of 0-180 degrees. Key motor specs: voltage range is 4.8V-6V, torque 1.8 kg-cm (approximately), response time 0.1 seconds/60 degrees. The servomotor reduces the load through a transmission and feedbacks the speed of the motor to help mannerism the model or equipment. Fig 5 shows Servomotor (SG90).

Fig. 5. Servomotor (SG90).

3.1.6 HX711 + Load Sensor

The HX711 is a precision 24-bit analog-to-digital converter (ADC) designed for weigh scales and industrial control applications to interface directly with a bridge sensor. With a load cell, this can be used to measure weight. The HX711 amplifies and digitally decodes the weaker signals from the load cell and serves the converters to readily readable digital form for as a microcontroller. It is primary due to work on a 5V supply, and talking on a two-wire interface. Schema of the sensor Work a load cell can work as force sensor or weight sensor from 0 up to the rated capacity of the load cell, which typically varies from few grams to several kilograms, according to the specific load cell utilized. Fig 6 shows HX711 & Load Sensor.

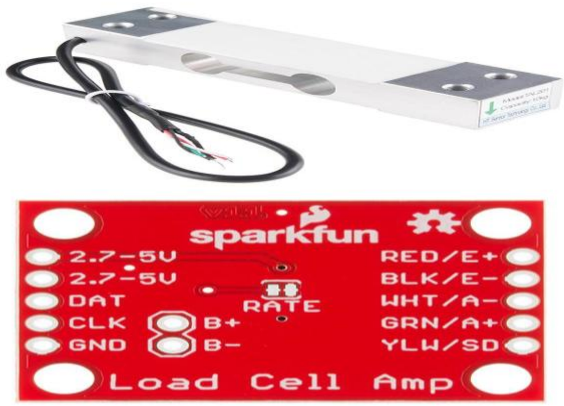

Fig. 6. HX711 & Load Sensor.

3.2 Software Requirements

3.2.1 Arduino IDE

One thing for sure, the Arduino software platform is the easiest path to code in any form in an Arduino boards and is still user focused IDE where developers of all skills levels can write their project codes, and test them, and apply to a project etc with less stress.

3.2.2 Firebase

Firebase is a cloud-based platform to store sensor data (e.g., bin level and user identification details from RFID) in cloud to support real-time update and user interaction for data synchronization between devices. Backed with powerful database management and user authentication functionalities, it offers a perfect solution to monitor the status of bins, the activities of users and to send notifications in real-time, enabling seamless waste management. With powerful security measures, easy mobile and web app integration and offline access to data, Firebase guarantees the safety and availability of essential data. It is highly automation-enabled using Cloud Functions, provides the capacity for long data retention and historical analysis, and can be easily scaled for growth of your systems. Furthermore, Firebase's analytics services that provide insights to improve operations and Firebase Hosting which facilitates deployment of web-based monitoring applications. All of this combined makes Firebase a robust, scalable platform for IoT-enabled waste management systems.

3.2.3 Blynk

Blynk itself is a cloud platform that allows you to provide updates and build mobile apps to check on the status of your IoT devices in real-time. In such a scenario, Blynk notifies users or local administration with an alert when the trash is at a predefined level, initiating actions e.g., emptying of the bin. This system can be made more efficient and accessible by providing an easy way to track bin status and other sensor readings to a user in a mobile app interface.

4 Methodology

The architecture of the Smart Garbage Collector System consists of several sensors and modules for proper garbage management such as ultrasonic sensors, RFID readers, load cells, Blynk for notification, Firebase for storing data and user interactions. Ultrasonic sensors are used to measure the dustbin’s fill level; notifications are then sent via Blynk once the dustbin becomes full and that the system is being updated. The bin opens automatically when someone approaches. Those with the tags are to open the dustbin The RFID used to open the dustbin, a load cell to measure the weight and display to corresponding user and then rewarded according to weight. The user identity and points are monitored through the RFID system, and the data can also be saved to Firebase, for live monitoring and record keeping. The reward system updates the user's points with Firebase, and Blynk, using its mobile application, sends real-time notifications to the users about their points and the actual state of the bin. Once bin is full, ultrasonic sensors sends real time notification to authorities using Blynk, later all data is stored in Firebase for better waste management. Fig 7 shows System Implementation.

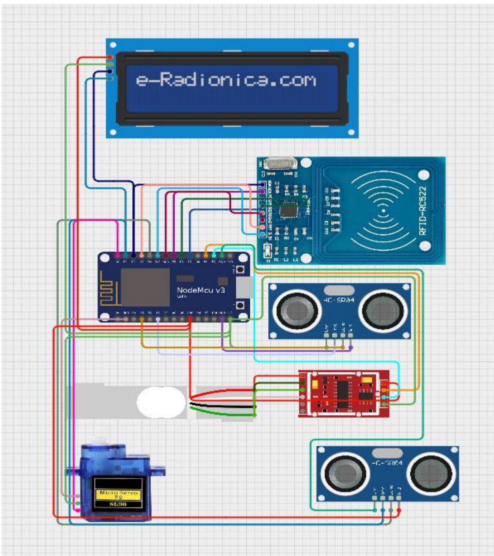

Fig. 7. System Implementation.

5 Result and Analysis

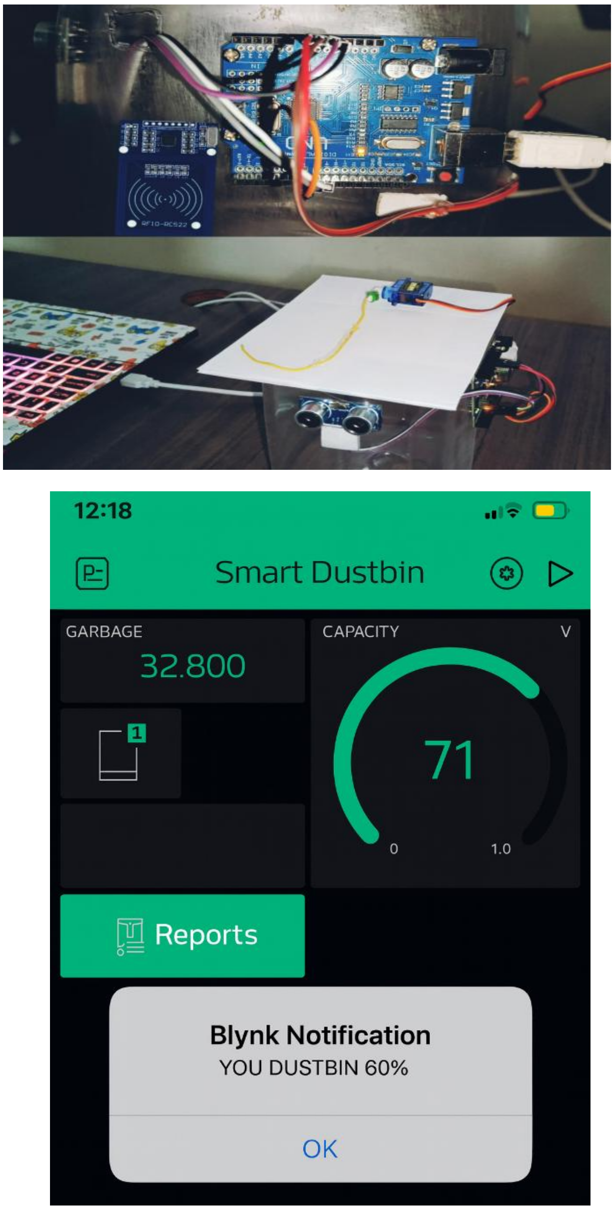

Fig. 8. Kit Structure (X) & Interface (Y).

The design proves evidently a good example of block components being derived and combined for usage in smart trash monitoring. The following (Fig. 8. X) it can be seen an example of one system like that illustrated as assembled and arranged in which a plurality of sensors and devices, such as ultrasonic sensors, RFID readers, load cells, are adapted. When the dustbin is full, notices will be produced and sent by Blynk app, as shown in (Fig. 8. Y) and inform users and authorities immediately. Facilities user data (RFID, rewards points) are managed/stored in Firebase to enable easy tracking and interaction with the system. It could also automatically monitor and collect wastes from distance in time. That's why our new product will have added value to you in an economical and space-saving feature but it provides solution for tidiness and garbage when use at home or commercial settings. By implementing its incentive system for disposing the waste in a proper manner, it is also integrated with Blynk and Firebase, therefore the data will be secured and all operations function properly.

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