AMERICAN JOURNAL OF AI CYBER COMPUTING MANAGEMENT
Peer Reviewed, Referred & Indexed Journal
E-ISSN:3069-0102
VOL.6, NO. 2(2) (2026)

A Smart Bin System with Full - Detection and Automatic Garbage Collection

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Abstract: Rapid urbanization has made waste management problems worse. Traditional garbage pickup systems work on set schedules, which means that they don't take into account how full the trash cans are. This can cause them to overflow, which is bad for health and makes waste collection less efficient. This project offers an IoT-based garbage monitoring system that uses an ESP32, an ultrasonic sensor, an IR sensor, a servo motor, an LCD display, a buzzer, and the Blynk IoT platform to solve these problems. The ultrasonic sensor keeps an eye on how full the trash can is all the time. The ESP32 sends an up-to- notification to the person using it via a Blynk IoT mobile app and sounds a buzzer when the trash bin reaches a certain level. An IR sensor detects people near the trash can and opens the door automatically with a servo motor so that people can throw away their trash without touching it. An LCD screen shows the current level of garbage and the status of the system.

I. INTRODUCTION

Rapid urbanization and population growth have significantly increased the generation of solid waste across cities and towns. Managing this waste in an efficient, hygienic, and environmentally friendly manner has become one of the major challenges faced by municipal authorities. Improper waste disposal and irregular collection practices lead to overflowing dustbins, foul odors, breeding of insects and rodents, and the spread of infectious diseases. These issues not only affect public health but also degrade the overall quality of urban living.

Conventional waste management systems primarily depend on manual monitoring and fixed garbage collection schedules. In such systems, garbage trucks collect waste at predetermined intervals without considering the actual fill level of the dustbins. As a result, some bins overflow before collection, while others are emptied unnecessarily despite being partially filled. This approach leads to inefficient use of manpower, fuel, time, and financial resources. Moreover, manual handling of waste increases the risk of contamination and poses health hazards to sanitation workers.

The emergence of the Internet of Things (IoT) has opened new possibilities for developing intelligent and automated waste management solutions. IoT enables the integration of sensors, microcontrollers, and cloud-based platforms to monitor real-time data and facilitate remote access and control. By adopting IoT-based systems, waste collection processes can be optimized, operational costs can be reduced, and overall cleanliness can be improved. Smart waste management systems play a crucial role in the development of sustainable and smart cities.

The Smart Bin System with Full Detection and Automated Waste Management is designed to address the limitations of traditional garbage collection methods by providing real-time monitoring and automation. The system uses an ultrasonic sensor to continuously measure the garbage level inside the dustbin. When the garbage reaches a predefined threshold level, the system automatically generates alerts through a buzzer and sends notifications to the concerned user or authority via the Blynk IoT mobile application. This ensures timely waste collection and prevents overflow conditions.

In addition to garbage level monitoring, the system incorporates an IR sensor to detect the presence of a user near the dustbin. This enables automatic opening and closing of the dustbin lid using a servo motor, allowing contactless waste disposal. Such a feature significantly enhances hygiene and reduces the risk of spreading germs. The current garbage level and operational status of the system are displayed on an

Received: 15-03-2026 | Accepted: 21-04-2026 | Published: 27-04-2026 | www.ajaccm.com

LCD screen, providing clear and instant visual feedback.

Overall, the proposed system offers a reliable, cost-effective, and efficient solution for modern waste management. By combining automation, real-time monitoring, and IoT connectivity, the Smart Bin System contributes to improved sanitation, reduced environmental impact, and better utilization of resources. This project supports the vision of smart cities by promoting cleaner surroundings, enhanced public health, and sustainable urban development.

II. RELATED WORK

"Smart Waste Bin with Real-Time Monitoring System"

This paper presents IoT innovation project of a smart waste bin with real time monitoring system which integrates multiple technologies such as solar system, sensors and wireless communication technologies. The aim of this project is to provide an efficient and cost-effective waste collection management system hence providing clean, healthy and green environment. This study proposed a new framework that enables remote monitoring of solid waste bin in real-time via Wi-Fi connection, to assist the waste management activity. The system framework is based on wireless sensor network [WSN] contains three segments: renewable energy source, WSN and control station. Within this framework there are four developed subsystems: solar power system, smart waste bin, short messaging service [SMS] notification system and real-time monitoring system that are interrelated to each other to perform as an efficient, cost-effective waste management system that yield to a green and healthy living environment.

"Municipal solid waste management in Malaysia"

Rapid economic development and population growth, inadequate infrastructure and expertise, and land scarcity make the management of municipal solid waste become one of Malaysia's most critical environmental issues. The study is aimed at evaluating the generation, characteristics, and management of solid waste in Malaysia based on published information. In general, the per capita generation rate is about 0.5–0.8 kg/person/day in which domestic waste is the primary source. Currently, solid waste is managed by the Ministry of Housing and Local Government, with the participation of the private sector. A new institutional and legislation framework has been structured with the objectives to establish a holistic, integrated, and cost-effective solid waste management system, with an emphasis on environmental protection and public health. Therefore, the hierarchy of solid waste management has given the highest priority to source reduction through 3R, intermediate treatment and final disposal.

"Integrated Sensing and Communication Technologies for Automated Solid

Waste Bin Monitoring System"

This research deals with the real time solid waste bin monitoring system by integrating different sensing and communication technologies. The system is divided into three segments and based on Wireless Sensor Network (WSN). The first segment consists of bins with sensor node installed in it, the second segment contains the gateways and the third segment is the base station. The sensor nodes can measure and transmit the waste conditions such as waste level, weight, temperature and humidity inside the bin in every access of the bin. The gateways can receive and forward the bin data to the base station. The base station stores the bin data and facilitates the opportunities to use the data for management purpose. The developed system is capable to response and update the specific bin status in real time which in turn can help to minimize collection route and fuel cost to make the environment clean and healthy.

"Real time solid waste bin monitoring system framework using wireless sensor network"

This paper presents a new framework that enables the remote monitoring of solid waste bin in real time, via ZigBee-PRO and GPRS, to assist the solid waste management process. The system is designed to monitor the status of the bin as soon as someone throw waste insight it. The system framework is based on a wireless sensor network, contains three levels: smart bin, gateway and control station that stores and analyze the data for further use. In this way, the waste collection route can be optimized by feeding the collected data into a decision support system and hence able to reduce operation costs and emissions.

"RFID based e-monitoring system for municipal solid waste management"

With the increase of population of a country, proper management of cumulative of Municipal Solid Waste

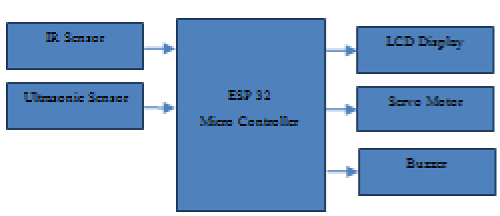
(MSW) becomes more acute for maintaining green environment. In conventional approach a number of trucks collect the MSW and then transport and transfer these MSW in a pre-specified location, but all the above jobs are not properly monitored. It is very important to monitor the trucks and record the information related to the collecting time and area from a central location to ensure the job well done. This project exploits the tremendous power of RFID technology and presents the development of an electronic monitoring (e-monitoring) system to overcome the above problem in the conventional approach. The proposed e-monitoring system is an embedded system that consists of RFID technology interfaced with PIC micro-controller and a web based computerized software. It has been tested in the laboratory environment as well as in the field environment. The test results show that the system functions properly and is working real time. Municipal authority can monitor the SW collecting status through the system and can generate different reports to improve the performance of their service. The prototype developed in this project can be further improved and used for commercial purpose.

III. IMPLEMENTATION

The proposed system introduces an IoT-enabled smart garbage monitoring solution using the ESP32 microcontroller. An ultrasonic sensor measures the distance between the garbage surface and the sensor to calculate the fill level of the dustbin. An IR sensor detects human presence, allowing automatic opening of the dustbin lid using a servo motor.

When the garbage level reaches the maximum limit, the ESP32 activates a buzzer alert and sends a notification to the Blynk IoT application. The garbage level percentage and system status are displayed on an LCD screen. This system enables real-time monitoring and improves waste collection efficiency.

Block diagram



Working

The Smart Bin System operates by integrating multiple IoT components with the ESP32 microcontroller to enable intelligent waste management. The ultrasonic sensor continuously measures the fill level inside the bin, and once it crosses a set threshold, the ESP32 activates a buzzer and simultaneously sends a notification to the user via the Blynk IoT platform. An IR sensor detects human presence near the bin, prompting the servo motor to automatically open the lid for hygienic, contactless disposal. The LCD display provides real-time updates on the bin's status and garbage level, ensuring transparency. Together, these components create an automated, efficient, and user-friendly waste monitoring solution that reduces overflow, improves collection efficiency, and promotes cleaner urban environments.

HARDWARE REQUIREMENTS

ESP-32

ESP32 is the SoC (System on Chip) microcontroller which has gained massive popularity recently. Whether the popularity of ESP32 grew because of the growth of IoT or whether IoT grew because of the introduction of ESP32 is debatable. If you know 10 people who have been part of the firmware development for any IoT device, chances are that 7−8 of them would have worked on ESP32 at some point. So what is the hype all about? Why has ESP32 become so popular so quickly? Let's find out.

Before we delve into the actual reasons for the popularity of ESP32, let's take a look at some of its important specifications. The specs listed below belong to the ESP32 WROOM 32 variant.−

- Integrated Crystal− 40 MHz
- Module Interfaces− UART, SPI, I2C, PWM, ADC, DAC, GPIO, pulse counter, capacitive touch sensor
- Integrated SPI flash− 4 MB
- ROM− 448 KB (for booting and core functions)
- SRAM− 520 KB
- Integrated Connectivity Protocols− WiFi, Bluetooth, BLE
- On−chip sensor− Hall sensor
- Operating temperature range− −40 − 85 degrees Celsius
- Operating Voltage− 3.3V
- Operating Current− 80 mA (average)

With the above specifications in front of you, it is very easy to decipher the reasons for ESP32's popularity. Consider the requirements an IoT device would have from its microcontroller (μC). If you've gone through the previous chapter, you'd have realized that the major operational blocks of any IoT device are sensing, processing, storage, and transmitting. Therefore, to begin with, the μC should be able to interface with a variety of sensors. It should support all the common communication protocols required for sensor interface: UART, I2C, SPI. It should have ADC and pulse counting capabilities. ESP32 fulfills all of these requirements. On top of that, it also can interface with capacitive touch sensors. Therefore, most common sensors can interface seamlessly with ESP32.

Secondly, the μC should be able to perform basic processing of the incoming sensor data, sometimes at high speeds, and have sufficient memory to store the data. ESP32 has a max operating frequency of 40 MHz, which is sufficiently high. It has two cores, allowing parallel processing, which is a further add-on. Finally, its 520 KB SRAM is sufficiently large for processing a large array of data onboard. Many popular processes and transforms, like FFT, peak detection, RMS calculation, etc. can be performed onboard ESP32. On the storage front, ESP32 goes a step ahead of the conventional microcontrollers and provides a file system within the flash. Out of the 4 MB of onboard flash, by default, 1.5 MB is reserved as SPIFFS (SPI Flash File System). Think of it as a mini−SD Card that lies within the chip itself. You can not only store data, but also text files, images, HTML and CSS files, and a lot more within SPIFFS. People have displayed beautiful Webpages on WiFi servers created using ESP32, by storing HTML files within SPIFFS.

Finally, for transmitting data, ESP32 has integrated WiFi and Bluetooth stacks, which have proven to be a game-changer. No need to connect a separate module (like a GSM module or an LTE module) for testing cloud communication. Just have the ESP32 board and a running WiFi, and you can get started. ESP32 allows you to use WiFi in Access Point as well as Station Mode. While it supports TCP/IP, HTTP, MQTT, and other traditional communication protocols, it also supports HTTPS. Yep, you heard that right. It has a crypto−core or a crypto-accelerator, a dedicated piece of hardware whose job is to accelerate the encryption process. So you cannot only communicate with your web server, you can do so securely. BLE support is also critical for several applications. Of course, you can interface LTE or GSM or LoRa modules with ESP32. Therefore, on the 'transmitting data' front as well, ESP32 exceeds expectations.

With so many features, ESP32 would be costing a fortune, right? That's the best part. ESP32 dev modules cost in the ballpark of ₹ 500. Not only that, the chip dimensions are quite small (25 mm x 18 mm, including the antenna area), allowing its use in devices requiring a very small form factor.

One very big advantage with ESP32, which has aided its quick adoption and massive popularity, is the provision for programming the ESP32 within the Arduino IDE.

Now, I should point out here that Arduino is not the only IDE that helps you compile code for ESP32 and flash it into the microcontroller. There is ESP−IDF which is the official development framework for ESP32, which provides much more flexibility in terms of configuration options. However, it is hardly as intuitive and user−friendly as the Arduino IDE, and if you are starting out with ESP32, Arduino IDE is ideal to get your hands dirty. Also, with the number of supporting libraries built for ESP32 in Arduino, courtesy of the huge developer community, there's hardly any functionality of ESP32 which can't be realized with the Arduino IDE. ESP-IDF is more suitable for the more advanced and experienced programmers, who need to stretch ESP32 to its limits. If you are one of those, you are looking for the ESP−IDF Getting Started Guide. Others can follow along.

IR SENSOR

The IR sensor or infrared sensor is one kind of electronic component, used to detect specific characteristics in its surroundings through emitting or detecting IR radiation. These sensors can also be used to detect or measure the heat of a target and its motion. In many electronic devices, the IR sensor circuit is a very essential module. This kind of sensor is similar to human's visionary senses to detect obstacles.

IR Sensor

The sensor which simply measures IR radiation instead of emitting is called PIR or passive infrared. Generally in the IR spectrum, the radiation of all the targets radiation and some kind of thermal radiation are not visible to the eyes but can be sensed through IR sensors.

In this sensor, an IR LED is used as an emitter whereas the photodiode is used as a detector. Once an infrared light drops on the photodiode, the output voltage & resistance will be changed in proportion to the received IR light magnitude.

ULTRASONIC SENSOR

Ultrasonic sensors are electronic devices that calculate the target's distance by emission of ultrasonic sound waves and convert those waves into electrical signals. The speed of emitted ultrasonic waves traveling speed is faster than the audible sound. There are mainly two essential elements which are the transmitter and receiver. Using the piezoelectric crystals, the transmitter generates sound, and from there it travels to the target and gets back to the receiver component.

To know the distance between the target and the sensor, the sensor calculates the amount of time required for sound emission to travel from transmitter to receiver. The calculation is done as follows:

D = 1/2 T * C

Where 'T' corresponds to time measured in seconds

'C' corresponds to sound speed = 343 measured in mts/sec

Ultrasonic sensor working principle is either similar to sonar or radar which evaluates the target/object attributes by understanding the received echoes from sound/radio waves correspondingly. These sensors produce high-frequency sound waves and analyse the echo which is received from the sensor. The sensors measure the time interval between transmitted and received echoes so that the distance to the target is known.

Ultrasonic Sensor Specifications

Knowing the specifications of an ultrasonic sensor helps in understanding the reliable approximations of distance measurements.

- The sensing range lies between 40 cm to 300 cm.
- The response time is between 50 milliseconds to 200 milliseconds.
- The Beam angle is around $5^{0.}$
- It operates within the voltage range of 20 VDC to 30 VDC
- Preciseness is ±5%
- The frequency of the ultrasound wave is 120 kHz
- Resolution is 1mm
- The voltage of sensor output is between 0 VDC – 10 VDC
- The ultrasonic sensor weight nearly 150 grams
- Ambient temperature is -25^0C to $+70^0$C
- The target dimensions to measure maximum distance is 5 cm × 5 cm

The ultrasonic sensor pin diagram is:

SERVO MOTOR

Servo Motor Introduction: A servo motor is an electric motor that adjusts its position, speed, or torque in response to controller inputs.
The term servo comes from the Latin word serves, meaning servant or slave. This reflects the historical use of servo motors as auxiliary drives that assist the main drive system However, modern servo motors

Received: 15-03-2026 | Accepted: 21-04-2026 | Published: 27-04-2026 | www.ajaccm.com

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are capable of providing high performance and precision as main drives in various applications.

A servo motor consists of three main components:

- **A motor:** This can be either a DC motor or an AC motor depending on the power source and the application requirements. The motor provides the mechanical power to rotate or move the output shaft.
- **A sensor:** This can be either a potentiometer, an encoder, a resolver, or another device that measures the position, speed, or torque of the output shaft and sends feedback signals to the controller.
- **A controller:** This can be either an analog or a digital circuit that compares the feedback signals from the sensor with the desired setpoint signals from an external source (such as a computer or a joystick) and generates control signals to adjust the motor’s voltage or current accordingly.

The controller employs a closed-loop feedback system, adjusting the motor’s movement to closely align with the desired setpoint, maintaining strict accuracy.

The controller can also implement various control algorithms, such as proportional-integral-derivative (PID) control, fuzzy logic control, adaptive control, etc., to optimize the performance of the servo motor.

How Does a Servo Motor Work?
The basic working principle of a servo motor involves the controller receiving two types of input signals:

- A setpoint signal: This is an analog or digital signal that represents the desired position, speed, or torque of the output shaft.
- A feedback signal: This is an analog or digital signal that represents the actual position, speed, or torque of the output shaft measured by the sensor.

The controller compares these two signals and calculates an error signal that represents the difference between them.The error signal is then processed by a control algorithm (such as PID) that generates a control signal that determines how much voltage or current should be applied to the motor.The control signal is sent to a power amplifier (such as an H-bridge) that converts it into an appropriate voltage or current level for driving the motor.The motor then rotates or moves according to the control signal and changes its position, speed, or torque, and sends a new feedback signal to the controller.The process repeats until the error signal becomes zero or negligible, indicating that the output shaft has reached the desired setpoint.

LCD

LCD is a flat display technology, stands for "Liquid Crystal Display," which is generally used in computer monitors, instrument panels, cell phones, digital cameras, TVs, laptops, tablets, and calculators. It is a thin display device that offers support for large resolutions and better picture quality. The older CRT display technology has replaced by LCDs, and new display technologies like OLEDs have started to replace LCDs. An LCD display is most commonly found with Dell laptop computers and is available as an active-matrix, passive-matrix, or dual-scan display. The picture is an example of an LCD computer monitor.

The Liquid Crystal library allows you to control LCD displays that are compatible with the Hitachi HD44780 driver. There are many of them out there, and you can usually tell them by the 16-pin interface.

Output of the sketch on a 16x2 LCD

The LCDs have a parallel interface, meaning that the microcontroller has to manipulate several

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interface pins at once to control the display. The interface consists of the following pins:

- A **register select (RS) pin** that controls where in the LCD's memory you're writing data to. You can select either the data register, which holds what goes on the screen, or an instruction register, which is where the LCD's controller looks for instructions on what to do next.
- A **Read/Write (R/W) pin** that selects reading mode or writing mode
- An **Enable pin** that enables writing to the registers
- 8 **data pins (D0 -D7)**. The states of these pins (high or low) are the bits that you're writing to a register when you write, or the values you're reading when you read.

There's also a **display contrast pin (Vo)**, **power supply pins (+5V and GND)** and **LED Backlight (Bklt+ and BKlt-)** pins that you can use to power the LCD, control the display contrast, and turn on and off the LED backlight, respectively.

The process of controlling the display involves putting the data that form the image of what you want to display into the data registers, then putting instructions in the instruction register. The Liquid Crystal Library simplifies this for you so you don't need to know the low-level instructions.

The Hitachi-compatible LCDs can be controlled in two modes: 4-bit or 8-bit. The 4-bit mode requires seven I/O pins from the Arduino, while the 8-bit mode requires 11 pins. For displaying text on the screen, you can do most everything in 4-bit mode, so example shows how to control a 16x2 LCD in 4-bit mode.

BUZZER

An audio signalling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

Buzzer Pin Configuration

The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

IV. RESULT ANALYSIS

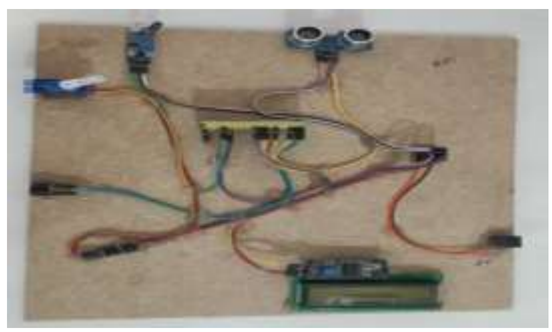

Fig1:project kit

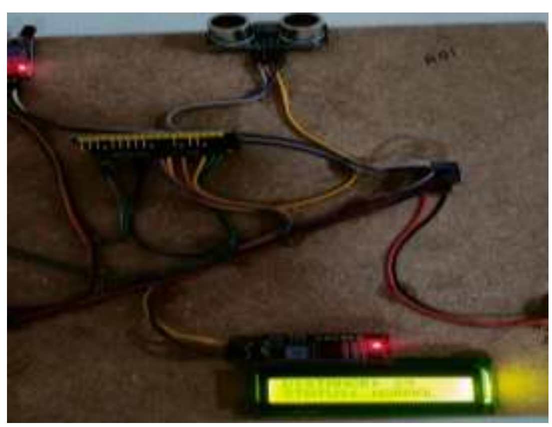

Fig2: dustbin status normal

Received: 15-03-2026 | Accepted: 21-04-2026 | Published: 27-04-2026 | www.ajaccm.com

Fig2: dustbin status full

V. CONCLUSION

The Smart Bin System with Full Detection and Automated Waste Management provides an effective solution to the growing challenges of waste management in urban environments. By integrating IoT technology with sensors and automation, the proposed system overcomes the limitations of traditional waste collection methods that rely on fixed schedules and manual monitoring. Real-time garbage level detection ensures timely collection and prevents overflow, thereby improving cleanliness and hygiene in public and residential areas.

The use of an ultrasonic sensor enables accurate monitoring of the waste level inside the dustbin, while the ESP32 microcontroller efficiently processes sensor data and communicates alerts through the Blynk IoT platform. Instant notifications and buzzer alerts ensure that responsible authorities or users are informed when the dustbin reaches a critical level. Additionally, the inclusion of an IR sensor and servo motor facilitates contactless waste disposal, enhancing user convenience and reducing the risk of contamination.

The LCD display provides continuous visual feedback regarding the system status and garbage level, making the system user-friendly and easy to monitor. Overall, the proposed smart bin system reduces human intervention, optimizes waste collection schedules, saves time and resources, and contributes to a cleaner and healthier environment.

In conclusion, this project demonstrates how IoT-based automation can significantly improve waste management practices and supports the development of smart cities. With further enhancements such as GPS tracking, data analytics, and integration with municipal systems, the smart bin system can be scaled and implemented on a larger level to achieve sustainable and efficient waste management.

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