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SMART DUST BIN BASED ON ULTRASONIC SENSOR AND ARDUINO

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ABSTRACT

Waste collection in towns and campuses is usually organised on a fixed route and a fixed schedule, without any knowledge of how full each bin actually is. As a result, some bins overflow and spread litter and odour around them, while others are emptied when they are nearly empty, wasting fuel and labour. Public bins also require people to touch a dirty lid, which discourages their use and spreads germs. This paper presents a smart dust bin based on an ultrasonic sensor and an Arduino UNO that opens its lid without contact, measures its own fill level, and reports that level to a cloud dashboard so that collection can be planned on actual need.

The bin uses two HC-SR04 ultrasonic sensors. One sensor faces outward at the front of the bin and detects a hand or object within about 25 cm, after which the Arduino drives an SG90 servo motor to lift the lid and closes it again after a short delay. The second sensor is mounted under the lid facing down into the bin and measures the distance to the top of the waste. From the known depth of the bin, the controller converts this distance into a fill percentage, which is shown on a small LCD and indicated through green, yellow, and red LEDs.

Connectivity is provided by an ESP-01 Wi-Fi module connected to the Arduino through a serial link, with an optional SIM800L GSM module for locations without Wi-Fi coverage. Every few minutes, and immediately when the fill level crosses 80 percent, the bin sends its identity, fill level, and battery voltage to a cloud platform. The dashboard lists all bins with their fill status and location, and a notification is sent to the collection supervisor when a bin needs to be emptied.

Particular attention was given to the electrical design, since a bin in a public place must run for long periods on its own supply. The servo motor draws a high current pulse of several hundred milliamperes when it starts, so it is supplied from a separate regulated rail with a bulk capacitor to avoid resets of the controller. The system is powered by a 7.4 V lithium ion pack that can be charged from a small solar panel through a charge controller, and the Arduino places the ultrasonic sensors and Wi-Fi module in low power states between readings to extend battery life.

A prototype built on a 30 litre bin was tested with different types of waste. The fill level measurement was accurate to within about 1.5 cm for solid waste with a reasonably flat surface, and the lid opened within 0.4 s of a hand being detected. The average current draw of about 38 mA gave an estimated battery life of more than five days without sunlight. Future work includes weight sensing, odour detection with a

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gas sensor, route optimisation for collection vehicles, and separation of wet and dry waste.

I. INTRODUCTION

The amount of solid waste generated in Indian cities has grown rapidly with population and changing consumption habits. Municipal bodies spend a large part of their budget on collecting and transporting this waste, and much of the effort goes into trucks travelling fixed routes and stopping at every bin, whether it is full or not. Overflowing bins are a common sight near markets, bus stands, and colleges, where the waste spills on the road, attracts animals, and creates health hazards for the people living nearby.

Most public bins are simple containers with a lid that must be pushed or lifted by hand. Many people avoid touching the lid and throw waste near the bin instead of into it, especially when the lid is dirty. After the Covid period, contactless operation of shared facilities has become a clear expectation among users. At the same time, the collection staff have no way to know the condition of a bin until they reach it, which makes it difficult to prioritise bins that fill quickly or to reduce trips to bins that fill slowly.

Embedded electronics offer a simple answer to both problems. An ultrasonic sensor measures distance by timing the echo of a short burst of sound, and it can detect a hand in front of the bin or the height of waste inside it without touching anything. A servo motor can lift a lid through a precise angle under the control of a microcontroller. The Arduino UNO is easy to program, widely available, and well suited for such sensor and actuator tasks, and a low cost Wi-Fi or GSM module can connect it to a cloud service.

This paper describes a smart dust bin based on ultrasonic sensing and an Arduino UNO. The bin opens its lid when a hand approaches, measures its own fill level, displays the level locally, and reports it to a cloud dashboard that alerts collection staff when emptying is due. The design also addresses the electrical questions that decide whether such a bin works reliably in the field, including servo current, supply decoupling, battery sizing, solar charging, and low power operation.

II. LITERATURE SURVEY

Research on smart waste management systems has grown along with the wider interest in smart cities. Early work focused on fitting sensors to bins so that their fill level could be known remotely, and several types of sensors have been compared for this purpose. Infrared distance sensors are cheap but are affected by sunlight and by the colour of the waste, while load cells measure weight but do not indicate how much volume remains. Ultrasonic sensors have been favoured in many studies because they measure distance over a range of a few centimetres to a few metres, are not sensitive to colour, and are easy to interface with microcontrollers. Researchers have reported that irregular waste surfaces, soft materials such as cloth, and condensation on the sensor can cause occasional wrong readings, and have suggested taking several readings and using the median value to improve reliability.

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Contactless or touch free bins have been studied mainly from the point of view of hygiene and user acceptance. Designs described in the literature use ultrasonic, infrared, or capacitive proximity sensors to detect a hand or foot near the bin and a servo or geared DC motor to lift the lid. Studies of user behaviour have found that people are more willing to use a bin that opens automatically, particularly in hospitals, food courts, and offices. Some designs add a voice message or light to encourage correct disposal. Researchers have also pointed out mechanical issues, such as the torque needed to lift heavier lids, wear in the hinge, and the need to stop the motor if the lid is blocked, which affect the long term reliability of such bins. Placement of the sensor so that it is not triggered by people walking past has also been discussed.

The communication of bin status to a central server has been handled in different ways depending on the location of the bins. Campus and indoor deployments commonly use Wi-Fi modules such as the ESP8266, while street bins spread across a city have used GSM text messages, GPRS data, ZigBee mesh networks, or low power wide area networks such as LoRa and NB-IoT. Studies comparing these options show a trade off between data rate, range, power consumption, and running cost. Cloud platforms and simple web dashboards have been used to show a map of bins with their fill levels, and several studies have linked these dashboards to route planning algorithms that generate a collection route covering only bins above a set level, reporting reductions in distance travelled and fuel used.

Power supply design is a recurring concern in the literature on field deployed bins. A bin placed on a street has no mains supply, so it must run on batteries, often charged by a small solar panel. Researchers have measured the current consumed by sensors, controllers, and radios and have shown that the radio and the actuator dominate the energy budget. Techniques such as duty cycling the sensors, putting the controller into sleep mode between readings, and sending data only when the fill level changes significantly have been used to extend battery life from days to weeks. Studies involving servo driven lids note that the inrush current of the motor can cause supply dips that reset the controller, and recommend a separate supply rail or large decoupling capacitors.

More recent studies have added further functions to smart bins, including gas sensors to detect the smell of decomposing waste, temperature sensors to detect fires inside the bin, weight sensors to estimate the mass collected, and cameras or inductive sensors to separate dry and wet or metal and plastic waste. Some work has used the data from many bins to predict when each bin will become full, based on its fill rate over previous days. While these features increase cost and complexity, they show the direction in which the field is moving. The system described in this paper takes a practical middle path, combining touch free lid operation and ultrasonic fill level sensing on an Arduino UNO with Wi-Fi or GSM reporting, a careful supply design, and a cloud dashboard that supports collection planning.

III. SYSTEM ANALYSIS

The smart dust bin is analysed as four functional blocks: sensing, control and actuation, power supply, and communication with the cloud. The sensing block contains two HC-SR04 ultrasonic sensors, one facing outward to detect a user and one

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facing down into the bin to measure the height of waste, each triggered by a 10 microsecond pulse and returning an echo pulse whose width is proportional to distance. The control block is an Arduino UNO that computes distances, converts the inner reading into fill percentage using the known bin depth, and drives an SG90 servo through a 50 Hz PWM signal to open the lid to about 100 degrees. Local indication is given through a 16x2 LCD and three LEDs. The power block consists of a 7.4 V lithium ion pack, a 5 V buck regulator for the logic, a separate 5 V rail with a 1000 microfarad capacitor for the servo, and an optional solar charge controller. The communication block uses an ESP-01 module over serial to send data to a cloud platform, with a SIM800L GSM module as an alternative. The servo draws a starting current of about 500 mA, the ultrasonic sensors about 15 mA each while ranging, and the ESP-01 up to 170 mA during transmission, so the supply is sized for these peaks while the firmware keeps the average current low. A voltage divider on the battery lets the Arduino report its charge state, so that a bin with a weak battery can be serviced before it stops working.

Existing System

In the existing arrangement, public bins are plain plastic or metal containers with a hinged lid or no lid at all. Users must touch the lid to open it, and many avoid doing so, leaving waste on the ground beside the bin. Collection is carried out on a fixed timetable by vehicles that visit every bin on a route, and the staff have no information about which bins are full until they arrive. Bins in busy places overflow before the next scheduled visit, while bins in quiet places are emptied when they contain very little. Supervisors rely on complaints from residents or photos sent by field staff to learn about overflowing bins. There is no record of how quickly each bin fills, so the number and placement of bins and the frequency of collection are decided by guesswork. Some commercial smart bins exist, but they are costly, imported, and depend on proprietary platforms, which limits their use in colleges and small towns. Even where such bins are installed, their data is rarely used to change the routes or timing of collection vehicles.

Disadvantages of Existing System

- Users must touch a dirty lid, which is unhygienic and discourages use.
- Waste is often dropped beside the bin instead of inside it.
- Collection follows a fixed schedule regardless of actual fill level.
- Busy bins overflow before the next scheduled collection.
- Nearly empty bins are visited, wasting fuel and labour.
- Supervisors learn about overflowing bins only through complaints.
- No data is available on fill rates to plan bin placement.
- Overflowing waste attracts animals and creates health hazards.
- Commercial smart bins are expensive and use closed platforms.
- Bins without a power design cannot run electronics for long periods.

Proposed System

The proposed smart dust bin combines touch free lid operation, fill level measurement, and cloud reporting in a low cost unit built around an Arduino UNO. The front

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ultrasonic sensor is read every 200 ms, and when an object is detected within 25 cm for two consecutive readings the servo lifts the lid, holds it open for four seconds after the hand is withdrawn, and then closes it slowly. The inner ultrasonic sensor is read once every minute when the lid is closed, taking five readings and using the median to reject spurious echoes, and the fill percentage is computed from the distance to the waste and the empty bin depth. The LCD shows the percentage and the LEDs show green below 50 percent, yellow up to 80 percent, and red above 80 percent. The Arduino sends the fill level and battery voltage through the ESP-01 module to a cloud dashboard every ten minutes and immediately when the red level is reached, and the dashboard notifies the collection supervisor. When the bin is full, the lid remains closed and the display asks users to use the next bin.

Advantages of Proposed System

- Lid opens without contact, improving hygiene for all users.
- Fill level is measured automatically using ultrasonic sensing.
- Median filtering gives stable readings despite uneven waste surfaces.
- Local LCD and LED indication show the bin status at a glance.
- Collection staff are alerted when a bin reaches 80 percent.
- Collection routes can be planned on need, saving fuel and time.
- Separate servo supply rail prevents controller resets during lid motion.
- Battery and solar charging allow operation without mains supply.
- Low power operation extends battery life to several days.
- Uses inexpensive and widely available components and open platforms.

IV. METHODOLOGY

The methodology started with the mechanical fitting of the sensors and servo to a 30 litre bin, with the inner sensor fixed at the centre of the lid and the servo horn linked to the lid hinge. Each ultrasonic sensor was tested against a measuring tape at distances from 5 cm to 60 cm, and the conversion factor was adjusted for the speed of sound at the measured room temperature. The bin was then filled in steps with paper, plastic bottles, and mixed waste, and the computed fill percentage was compared with the actual height to estimate error. The current drawn by each part was measured with a multimeter in idle, sensing, transmitting, and lid moving states, and the results were used to size the battery and the solar panel. The Arduino firmware was organised as a loop with timed tasks for user detection, fill measurement, display update, and communication, with the Wi-Fi module switched off between transmissions. Data was sent as HTTP requests to a cloud channel, and a dashboard with alert rules was configured and tested over two weeks of use. During this period the time taken for the bin to fill, the number of lid openings per day, and the battery voltage at the end of each day were recorded for analysis.

SYSTEM ARCHITECTURE

The architecture of the smart dust bin is organised in layers from the physical sensors to the collection staff. The Sensing Layer contains the outward facing ultrasonic sensor for hand detection and the inner ultrasonic sensor for fill level measurement. The Signal Processing Layer converts echo times into distances, applies median

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filtering, and calculates fill percentage. The Controller Layer is the Arduino UNO, which schedules sensing, decides when to open the lid, and prepares data for transmission. The Actuation Layer consists of the servo motor that lifts the lid. The Local Display Layer uses the LCD and the three status LEDs. The Power Supply Layer includes the lithium ion battery, buck regulators, the separate servo rail, and the solar charge controller. The Connectivity Layer uses the ESP-01 Wi-Fi module or the GSM module. The Cloud Layer stores fill data and applies alert thresholds, and the Application Layer presents a bin list, fill trends, and notifications to supervisors.

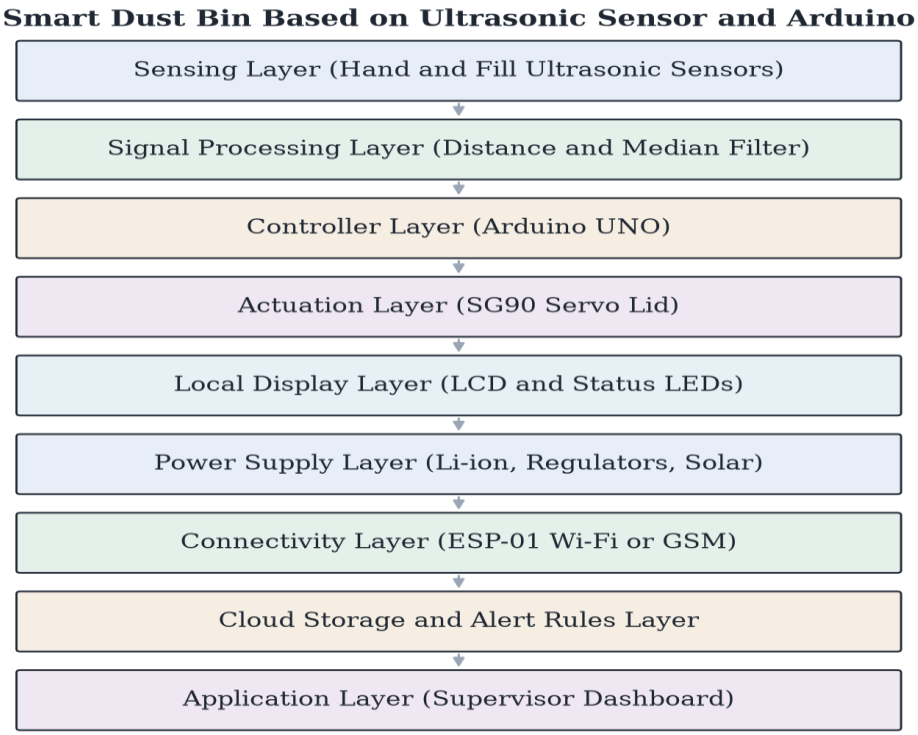
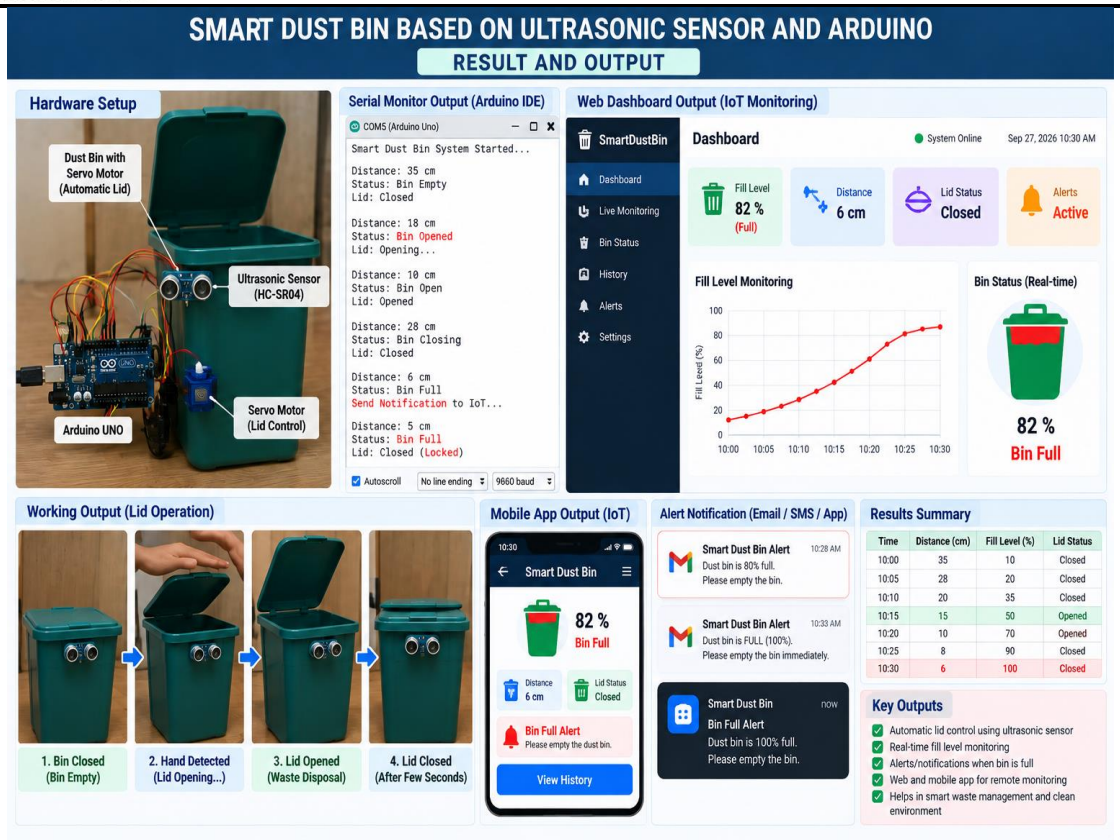


Fig. 1 System Architecture

V. RESULT AND OUTPUT

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VI. CONCLUSION

This paper presented a smart dust bin based on ultrasonic sensors and an Arduino UNO that opens its lid without contact, measures its own fill level, and reports that level to a cloud dashboard. The system uses two HC-SR04 sensors, an SG90 servo, an LCD with status LEDs, an ESP-01 Wi-Fi module, and a battery supply with optional solar charging, and it shows that a useful smart bin can be built from inexpensive, widely available parts.

The touch free lid addresses the hygiene problem that discourages people from using public bins. In testing, the lid responded within about 0.4 s of a hand being detected and closed automatically after use, and users found the bin easy and pleasant to use. The fill level measurement, supported by median filtering, gave results within about 1.5 cm of the actual waste height for common types of waste, which is sufficient to decide when a bin needs emptying.

The electrical design proved as important as the sensing logic. Supplying the servo from a separate rail with a bulk capacitor removed the resets that occurred in early tests when the lid started moving, and switching the Wi-Fi module off between transmissions reduced the average current to about 38 mA. With a 2200 mAh battery this gives several days of operation without sunlight, and a small solar panel can keep the bin running indefinitely in normal weather.

Future work will add a load cell to record the weight of waste, a gas sensor to detect odour and decomposition, and route planning software that uses the fill data from many bins to generate efficient collection routes. Separation of dry and wet waste

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using simple moisture or inductive sensors and a divided bin is another useful extension. A pilot deployment across a college campus would help evaluate the durability of the hardware and the practical savings in collection effort.

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