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Smart and Inexpensive Implementation of GARBAGE DISPOSAL SYSTEM for Smart Cities

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Abstract: ***With the growth in urbanization and consumption of resources the problem of trash and waste production has also gone up. This is becoming a cause of concern and especially in developing countries where there are no or very less efficient waste management systems in place. Due to the problem of littering and inefficient garbage disposal systems overflow of garbage is common which leads to air and land pollution. The systems currently in-place in developing countries are not efficient and garbage collection trucks have no way to get the real-time information of garbage cans and because of the wide span of a city many garbage cans remain empty and others don't get collected thus it leads to overflow.***

The goal of this project is to solve the problem of overflowing of garbage, littering, and inefficient garbage disposal systems with the help of device created using the Internet of Things (IoT) to provide efficient routes and trash separation, thus reducing the cost and increasing time efficiency. The device will also help in separating the metallic and non-metallic waste into separate bins, further considering the most filled garbage bins and providing an efficient route with their locations.

Index Terms: IoT, Smart Garbage Container, Python, Arduino, Flask micro-framework.

I. INTRODUCTION

According to the article published in "downtoearth.org" more than 377 million urban people live in 7,935 towns and cities and generate 62 million tons of municipal solid waste per annum. Only 43 million tons (MT) of the waste is collected, 11.9 MT is treated and 31 MT is dumped in landfill sites [1].

After observing the garbage spilled on the roads in spite of the availability of municipality bins we looked into the problem. The garbage was spilling out of these bins everywhere, the root of the problem was inefficient garbage collection. To cover a big city with a large population takes time. The waste is not collected properly on time causing the garbage spill, which can attract mosquitoes and spread diseases and make the living areas nearby a risk to people's health.We focused on affordable and easy to build a system that can help address this issue. The primary objective of our project is to separate metal and non-metal garbage from the rest of the garbage and also helps us to keep a check on the current state of garbage bin.

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Other sensors like heat and temperature sensors, ultrasonic sensors help provide data to measure the state of the bin which is sent to the cloud for analysis. This helps determine an efficient path for the garbage collection route.

II. DESCRIPTION AND GOALS

A. *Description*

This project aims to optimize waste collection and ultimately reduce the garbage spillage and make cities cleaner. The GPS module is used to fetch latitude and longitude data and used to track the status of the garbage containers.

It will use the ultrasonic distance sensor to measure how much the container is filled. We will also measure temperatures inside the container. Sensors installed in the container collect data, this information along with the GPS coordinates of the bin is sent to the cloud for further analysis. A list of filled containers that are to be collected is sent to drivers, with the help of Google maps an efficient route connecting all the collection points is also made available to plan an efficient path. For security purposes and proper management, the system is installed with an RFID module. The vehicle owner has to flash his RFID card so that relevant details can be logged in. It will help to log the activity of collectors.

B. *Goals of the project*

The goal of this project is to provide a potential solution to solve the rising problem of mismanagement of waste by providing real-time data to garbage collectors and to separate garbage by default inside the garbage bin. Furthermore, this project is developed to keep the cost of implementation low and is supposed to work with existing infrastructure. It also aims to reduce the consumption of fuel and resources by providing only those locations where waste needs to be collected.

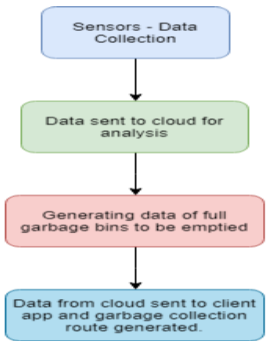

Fig.1. Control Flow Diagram (control flow diagram describes the flow of the project from data collection to route generation)

The metal and non-metal types of garbage are separated into two separate bins. This will help to recycle metal waste easier because time consumption in separating the metal waste is reduced and separation is done at the time of collection.

III. FEATURES

The project has various features that help in the proper management of the waste.

1. Smart Bin can separate garbage based on its properties. To provide garbage extraction to some extent, the bin automatically separates garbage based on its ferrous properties.
2. Smart Bin can measure the level of garbage in the bin. Using the ultrasonic sensors, we measure the level and send the data to the cloud. So, that collector has real-time data of the bin's capacity.
3. To provide the location of the bin it is equipped with a GPS module and provides the location data to the client.
4. The Bin is connected to the cloud and sends data of its location, conditions, and capacity for analysis to keep the client updated in real-time.
5. For logging and security, an RFID logging system is developed. So, that admin can track the garbage collection and log the data for future use.

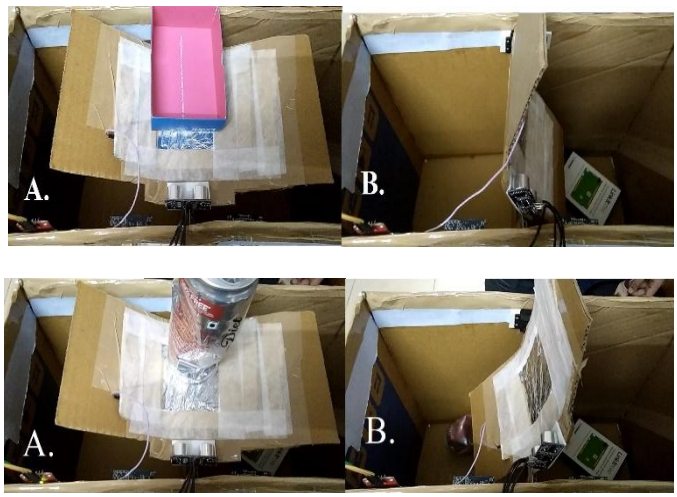

Fig. 2. Trash Separation (*In the given figure, the Trash Separation module is putting an object to the respective part of the bin based on its properties. (A.) An object is placed on the platform. (B.) It determines the type of object and rotates accordingly*.)

A. *Experimentation*

We experimented with lots of different techniques and sensors to get the correct data.

- To measure the capacity of the bin we experimented with Infrared sensors and ultrasonic sensors. As the infrared sensors work for short distances ultrasonic sensors worked better for the use case. Ultrasonic sensors calculate the distance of the object from the sensor [2].
- For separation of trash, we looked into different sensors that could recognize the material of the object. We experimented with an RGB color sensor to separate the plastics. [3] We used a capacitive touch sensor that worked best to separate the ferrous material from the trash. This turned out to be a good feature as ferrous material is reused and recycled often.
- For security purposes, we used RFID Module (MFRC-522) sensor to log the user.
- To track the interior of the bin we used Temperature and Humidity sensors.

IV. TECHNICAL SPECIFICATION

A. *Hardware Specifications:*

- **Arduino Uno R3 ATmega328 -** Arduino Uno is a microcontroller board based on the ATmega328P. 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. [4]
- **LinkIt One MT2502A -** The LinkIt ONE development kit includes a development board, a Wi-Fi and Bluetooth antenna, GSM (2G) antenna and GPS/GLONASS antenna as well as a Li-battery. It is based on MediaTek MT2502A chipset. The MediaTek MT2502A is a feature-rich and extremely powerful single-chip solution for high-end GSM/GPRS (2G) capabilities. It also features a highly integrated Bluetooth transceiver which is fully compliant with Bluetooth specification v4.0. [5]
- **SparkFun Capacitive Touch Breakout - AT42QT1010 -** The AT42QT1010 is a dedicated, single-button capacitive sense chip. The chip handles monitoring a conductive area for touch. As long as touch is detected, the AT42QT1010 keeps the output line high. Otherwise, the line is kept low. It works with a power source (1.8V--5V) and ground for the AT42QT1010 to work. Additionally, a PAD pin is available if you would like to create your external electrode. [6]
- **Ultrasonic Distance Sensor –** The ultrasonic distance sensor is used to measure the bin capacity. The specification of the sensors used are as follows:
  - Power Supply: +5V DC
  - Power Supply: +5V DC
  - Quiescent Current: <2mA
  - Working Current: 15mA
  - Effectual Angle: <15°
  - Ranging Distance: 2cm – 400 cm/1" - 13ft
  - Resolution: 0.3 cm
  - Measuring Angle: 30 degree
- **Temperature and Humidity Sensor (DHT-11) –** To monitor the internals of the bin DHT-11 sensor is used with the following specifications:
  - Power Supply: 3 to 5V
  - Max current use during conversion: 2.5mA (while requesting data)
  - Humidity readings: 20-80% with 5% accuracy
  - Temperature readings: 0-50°C ±2°C accuracy
  - Sampling rate: No more than 1 Hz (once every second)

- **RFID Module (MFRC-522) –** To log the user activity and provide security RFID module is used with the following specification:
  - Voltage: DC 3.3V
  - Operating Current :13-26mA
  - Idle Current :10-13mA
  - Operating Frequency: 13.56MHz
  - Module Interface SPI Data Transfer Rate: Max. 10Mbit/s
  - Card reading distance : 0〜30mm
- **Servo Motor –** To separate the garbage placed on the platform a servo motor is used to rotate the platform. Following are the specification of servo motor used:
  - Stall torque: 8.5 kgf·cm (4.8 V), 10 kgf·cm (6 V)
  - Operating speed: 0.2 s/60º (4.8 V), 0.16 s/60º (6 V)
  - Operating voltage: 4.8 V to 7.2 V

B. *Software Specification:*

Cloud IoT Server: UBI Dots / Thingspeak / Azure is an IoT cloud platform that allows the sensor data to be easily converted into useful information. It also makes the analysis of data easier. Thingspeak / Azure offer APIs that allows to read and write data to the various attributes: data sources, variables, and event. It also supports theft detection using the developer's GPS data. The APIs are easy to use and develop further functionality.

Client Web App: Here, we are using Python to get data from IoT Cloud servers using their APIs and we are using python to connect our web-app with the database.

1. Flask: We used the flask framework to develop the client web app. As it is easy to use and requires little to no setup.

2. SQLAlchemy: SQLAlchemy is an ORM that facilitates database creation and makes it more versatile and platform-independent. ORM makes the development of the application database type independent. [7]

3. Requests: Requests python module allows to interact with REST services using APIs. Requests python module is used to fetch data from the cloud using its REST APIs.

V. ARCHITECTURE

A. *Hardware Design*

The embedded system comprises of two modules.

Module-1: This module consists of a micro-controller, ultra-sonic sensors that are used to measure the capacity if bin and temperature and humidity sensors. The data from the sensors and latitude and longitude positions from the GPS module are sent via Microprocessor to the Cloud IoT server e.g.: Thingspeak / Azure. This data is received using python requests module and IoT Cloud APIs which can be further used to provide an efficient route for garbage collection.

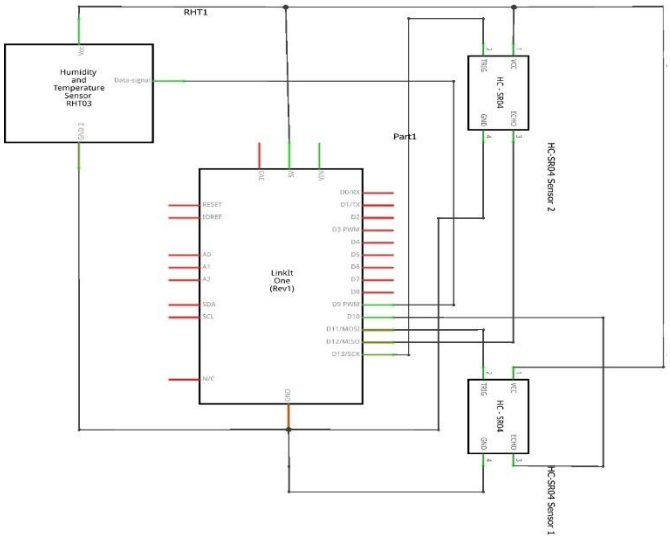

Fig.3. Module 1: Circuit Diagram (*Circuit diagram of module -1 with LinkIt One, Ultrasonic distance sensors, and DHT11-Temperature and Humidity sensors*)

Here given figure (Fig. 2) shows the circuit diagram of Module – 1. It shows the circuit between microcontroller LinkIt One, Ultrasonic distance sensor and Temperature and humidity sensor. It uses the inbuilt GPS and WIFI module of Linkit One to compute the location and send data to the cloud respectively.

Module-2: The primary function of this module is to separate the trash based on material properties. This function helps in the overall recycling process making it more efficient. It achieves this by determining the property of material based on its ferrous properties and conductivity. It consists of a Capacitive Touch Breakout Sensor in conjunction with a servo motor which is controlled by Arduino UNO R3 microcontroller. The Capacitive Touch Breakout Sensor is connected to a platform upon which the object placed will get examined based on its properties. If it is a recyclable metal object the motor will rotate accordingly and place the object in the respective bin. An RFID module and notification LEDs are used for user logging and management purposes. It can be used to track when the trash was collected and the state of the garbage container. The following diagram shows the circuit diagram of both the module.

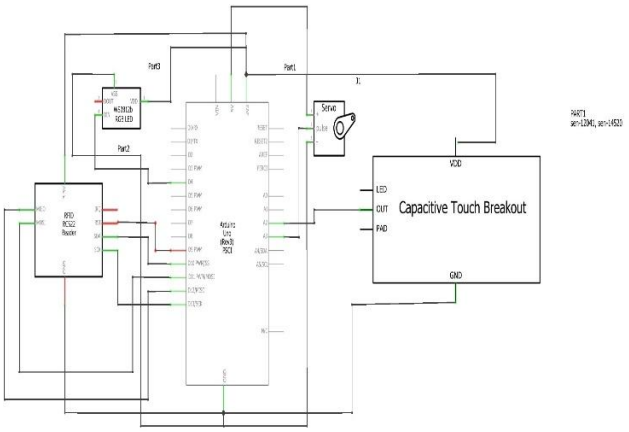

Fig.4. Module 2: Circuit Diagram (circuit diagram of module-2 (trash segregation) with servo motor and RFID module for logging and security purposes)

B. *Software / Web App Design*

To provide the user with an interface for monitoring the status of the garbage container and provide the efficient route marking full garbage bins a web-based application is provided. The web-based application built using HTML, CSS. JavaScript, jQuery.

The data collected by various sensors and modules are updated to the cloud which analysis the data acts as a server for our client web-app. The web-app fetches the data from the IoT Cloud. This data is then used by the app to show the status of various bins to the client. Using the data from the cloud and Google Maps APIs it calculates an efficient path for the garbage collectors. This path only considers the containers that are currently more than 80% filled. The web app is responsive so that it can be used on any mobile device as well as a computer.

The user (garbage collectors/municipality administration) can log in to the web-app to check the status of the bin. The app provides a route to collect the waste so that visit to the waste containers that are not full can be prevented.

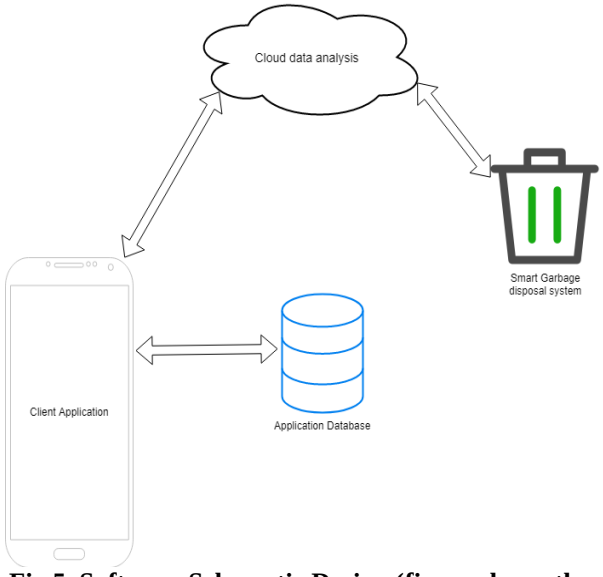

Fig.5. Software Schematic Design (figure shows the model of the application. Client application fetches user details from database and garbage container sends all the info collected to cloud. Where analyzed data gets sent to user by REST APIs.)

The application is built using a flask micro-framework based on python and SQLAlchemy as a database ORM. Apart from the IoT server, an SQLite database is maintained to provide a login / sign-in facility to the user. The web-app is responsive and easy to scale, it is platform-independent hence can run on any device with an internet web browser.

C. *Design Constraints*

1. The ultrasonic depth uses high-frequency sound waves to compute the distance by measuring the turnaround time of the wave [8]. The sensor has two openings on its front. One opening transmits ultrasonic waves, (like a tiny speaker), the other receives them, (like a tiny microphone). The only constraint is seldom inconsistent values that are rectified by extensive testing. It is a low-cost solution to measure the capacity of the container, which brings the development cost down.

3. Connection Reliability: Since the connection of the internet is not reliable in rural areas, but the internet is spreading and lots of people are getting access to it. This solution is appropriate for upcoming SMART CITIES.

4. Analysis of data does not take into consideration if there has been a peak when the data was unavailable, as the possibility exists of device malfunction at the peak time.

5. Data Unavailability: There are cases when there is no reading from the device and as we are showing real-time data about the level of material in container and temperature and humidity level it can be implied that sensors are not working.

VI. ISSUES ADDRESSED

A. *Health and Safety*

Smart Garbage Disposal system is a smart way to deal with big cities' problems related to trash and littering. Smart Garbage Disposal system leverages the most innovative technologies to solve this problem and helps to keep cities clean by providing an efficient way to dispose the garbage and also the device installed in the trash can is running on battery causing almost zero elimination of waste and once battery is totally exhausted it can be properly disposed since it is monitored regularly, therefore, no chances of overflow and contaminating the environment. Two separate containers provided for metallic and other waste it helps in properly recycling the waste if possible.

B. *Usability*

The system provides a real-time web interface that provides information about the level of garbage-filled in the container and all the data is updated in real-time and also keeps the log of when and who collected the garbage from the garbage can as RFID is used only garbage collector can open the bin. With the use of RFID, it also gives makes it easy to log the collection process and since the smallest path is being plotted between all the filled containers it helps to reduce the cost as well as the effort of the garbage collectors. These Smart Garbage Containers can be installed at the prime location where people can easily go and drop off their garbage. Humidity and temperature sensor is installed if any chemical waste is dumped or anything that can cause fire all necessary precautions like unauthorized access and overflow of waste all are checked regularly, garbage collectors. The device itself does not need very much human interactions.

C. *Economic and Sustainability*

One of the major components of the project is the wireless transmission of the data whether it is from the embedded device to the mobile device or from the mobile device to the remote server used for data analyses. The primary problem in relying on such data transmission is the cost of transmitting the data. For end-user data supplied from server will be very less as it will be just coordinating of the filled trash cans and then shortest path is plotted by Google maps and data usage on that part is very less but sending data from trash can to cloud server and then

performing calculations to determine the level of container and checking it with limit and also keeping the record about the access and maintenance of container. The cost of a battery that is to be used for powering the device is not very much as it will require only 3.3V to 5V sensors used mainly ultrasonic distance sensor, humidity and temperature sensor are not very costly and can be easily accommodated and by using link it one has reduced product cost as it has inbuilt modules like GPS and WIFI. Similarly, servo motor to be used for rotating the platform for separating the metal from non-metal is also not very costly.

VII. CONCLUSION

The project aimed to develop an IoT device that helps in solving the garbage disposal problems in big cities. The system consists of two modules. The first module solves the garbage separation ferrous/recyclable material from the rest at an early stage so that the cost involved in separating the garbage later can be reduced. The second module gives near real-time information of garbage bin to the client application which determines an efficient route and displays it to the user.

Above project helps provide a potential solution to garbage problem in big cities by providing garbage separation, real-time garbage update and efficient route to collect the garbage.

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