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An IoT-enabled Waste Management Solution

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Abstract: ***The proposed system provides real-time monitoring of garbage levels in smart bins using an Arduino Uno microcontroller, a Wi-Fi module, and ultrasonic sensors. Before being implemented, the smart bin prototype is modelled using proteus professional simulation software. The experimental results demonstrate the effectiveness of a potential waste management and control solution.***
Keywords: Smart City, Waste Management, IoT, Arduino.

I. INTRODUCTION

This study provides real-time garbage monitoring in smart bins using IoT enabled solid waste management systems for smart cities. The following are the major contributions of this work:

1) Reduces human intervention in the process of waste segregation.
2) The system provides real time monitoring of garbage level in smart bins using Arduino Uno Microcontroller, a Wi-Fi Module and ultrasonic sensors.
3) The simulated results produced using Proteus professional simulator gives a promising solution for waste management control.

The rest of the paper is organized as follows: Section 2 presents the related work of IoT based smart waste management. Description of the system architecture in presented in Section 3, Experimental results are discussed in Section 4. Finally, Section 5 concludes our work with highlights of future directions.

II. RELATED WORK

The urban cities are highly populated because of the inflow of rural migrants to these cities for their livelihood. In case of an overpopulated city and its surroundings, the lack of waste management and control effects the environmental cleanliness along with some health issues. In order to provide a proper sanitisation and a solution to waste monitoring and control to each society, the use of IoT based garbage bins were brought forward [1].

Several research projects have been carried out related to the IoT based smart bin designs. A study on IoT based smart waste management system using WSN and embedded Linux board is presented in [2], where they could process data regarding the status of garbage bins being filled or empty and forward the information to the concerned authorities in waste management. An intelligent disposal system design was introduced in [3] which uses solar energy to charge the system and the amount of waste accumulated inside the bin is monitored using the presence sensors.

A smart bin system was proposed which collects and transmit data through a wireless mesh topology and correspondingly identifies the fullness of the bin. This system utilizes a duty cycle technique which helps in reducing the overall power consumption and to maximize the operational time. The results occupied showed that the system could well manage the litter bin utilization and the work could be optimized using the operators [4]. A Smart Waste Management System (SWMS) is designed in [5] which follows the IoT technology and consists of collectors of public garbage with an embedded technology. This technology is used in public places for the monitoring of real time level of garbage bins and based on the level, an optimized path is generally selected which is in term sent to the garbage collecting vans for reasonable fuel usage and cost. A system using K-Query scheduling technology based on IoT is designed in [6] for waste management which is composed of microcontroller module, a GPS module and an ultrasonic sensor. The installation of the modules is inside the trash cans and the monitoring is done by the sensors. Another system named Intelligent collector is proposed in [7] which provides an updated information about the level of residues present in the compartments through sensors installed inside and also about the landfills. For the working, a Sonar device like HC-SR04 is used by the authors. An IoT based Low-cost agriculture farm monitoring system design is proposed in [8] which uses Losant platform of IoT cloud for continuous measurement of soil moisture level of the plants. This gives an alert to the farmers if the moisture content of a particular plant is low through an email or a SMS. The sensors provide a real time data visualization which could be operated and accessed from any part of the world.

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III. SYSTEM DESIGN

In smart cities, waste management is an important service for maintaining a hygienic [9] environment and disease-free society for the people. Figure 2 shows an illustration indicating main building blocks of the proposed smart city garbage collection management system. The system comprises of four main entities, namely, Smart Bins, Garbage Collecting Vehicles, Waste Collection Authority, and a Central Database.

1) *Smart Bin:* It is an intelligent edge-node with unique identification and it is placed in public area as a garbage storage point near waste resources. Each smart Bin is equipped with two ultrasonic sensors (HC-SR04). First ultrasonic sensor is located on the front side of the Smart Bin, it detects personnel within a certain range to facilitate automatic opening of the bin. The other ultrasonic sensor is positioned inside the bin to determine the current waste level [10] of the smart bin. Every Smart Bin provides the following information to the central database of the system: level of the bin in percentage, location of the bin.

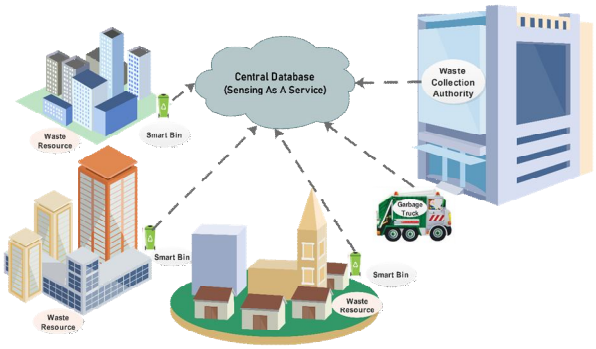


Fig. 2 Smart city garbage collection management

2) *Garbage Collecting Vehicles:* These collect waste from the smart bins and are connected with the central database from where it gets information about the filled smart bin. Garbage collection vehicles gather waste from the smart bins and transport it to the dumping sites for further treatment.
3) *Central Database:* It serves as the storage point and information center that contains details of smart bins, garbage collecting vehicles including their locations. Level status of Smart Bins is stored in the database and its status is updated after each event.

IV. HARDWARE REALIZATION

An integrated Arduino program is developed to synchronize the operations of all the sensors based on IoT [11]. Smart Bin has automatic lid opening feature to avoid littering of waste due to the external factors like unusual weather conditions and animals. An ultrasonic sensor located on the front side of the Smart Bin detects personnel within a certain detection range, the lid opens automatically. A servo motor is placed in the upper portion of the Smart Bin for automatic opening. Waste may be disposed in the Smart Bin, and the lid will remain open till the person remains in detection zone. The lid will close automatically after the person leaves the detection range. The electrical connection between all the components are simulated in Proteus software and are depicted in figure 6. Working of our model is described as follows:

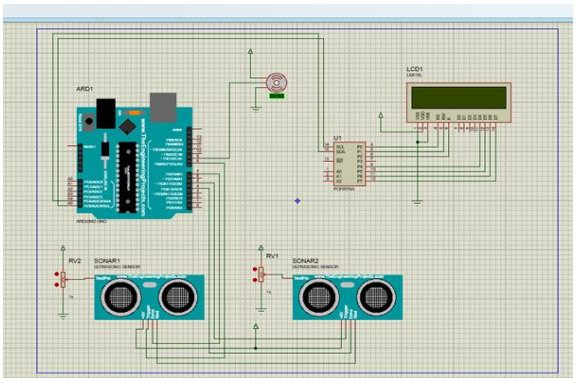


Fig. 6 Interconnection between components in Proteus

1) *Arduino IDE:* Arduino IDE is an open-source software which makes it easy to write a code and upload it on the Arduino board. It runs on Linux, Windows, Mac OS X. The software consists of a text editor for writing and compiling codes. The Arduino board is connected to the computer through an USB cable. Where it can be connected to the Arduino (IDE) Integrated Development Environment and uploads it to the board get executed and gives output from the devices such as LEDs, sensors, or motor. With an addition of methods and functions Arduino code is written in C++ and C programming language. C++ is Object Oriented (OOPS) language but C is not.
2) *Arduino Uno:* Arduino Uno is an ATmega328 based microcontroller board (refer figure 7), which is an open-source electronics platform. It contains 20 input and output pins, a USB connection, a reset button, LEDs, a 16 MHz resonator, an in-circuit system programming header and a power jack. This Uno ("Uno" means one in Italian) board is the first reference model in the USB Arduino boards series. It is the heart of the complete project.

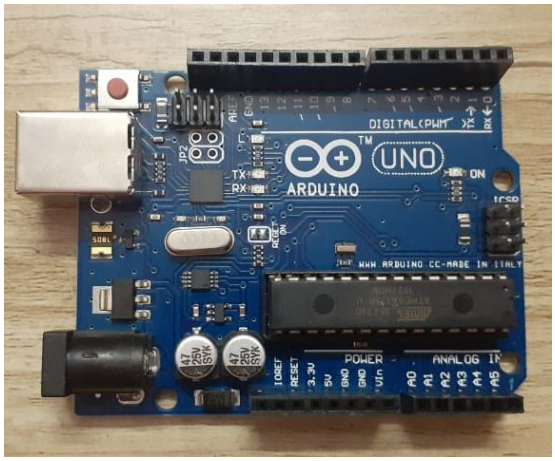


Fig. 7 Arduino Uno

3) *HC-SR04 Ultrasonic:* An ultrasonic sensor is a distance sensor and as its name suggests it uses Ultrasonic waves and can detect objects from a range of 2 cm to 400 cm. It consists of a control circuit, a receiver and 2 ultrasonic transmitters as can be seen from figure 8. It is used to measure level of the waste and also to sense if somebody's approaching the trash towards the dustbin.

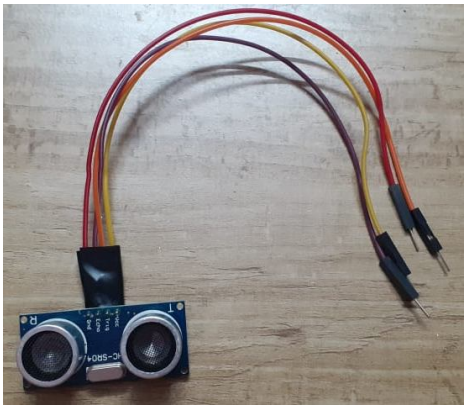


Fig. 8 HC-SR04 Ultrasonic

4) *Servo Motor:* A servo motor is an electronic device which is a linear or rotary actuator that grants for exact control of linear or angular position, linear or angular velocity and acceleration. It is based on closed- loop mechanism. Servo motor has various applications such as in robotics, positioning the antenna, automatic opening of doors etc.
5) *ESP8266 Wi-Fi Module:* ESP8266 is a Wi-Fi microchip, which is very low in cost. It helps in sending data from hardware to the cloud or application. It can be seen in figure 9.

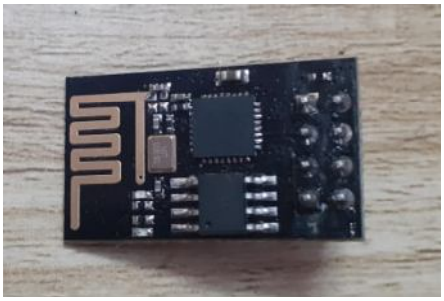


Fig. 9 ESP8266 Wi-Fi Module

After setting up all the components according to the schematic and doing all the connections, the code is uploaded on Arduino IDE and the circuit is provided with 9V power supply and the system is then turned on. The ultrasonic sensor sends and receives ultrasonic waves when they hit any object. Thus, when any object approaches towards the lid of the bin it sends signals to Arduino, which in this project is used as a Controller. When Arduino gets the data, it analyzes the distance between the object and the bin. If this distance less than 30 cm, Arduino commands the servo motor and the lid of the bin opens up as the servo motor rotates 90 degrees from its original position. After the given time interval, the lid of the bin may automatically close.

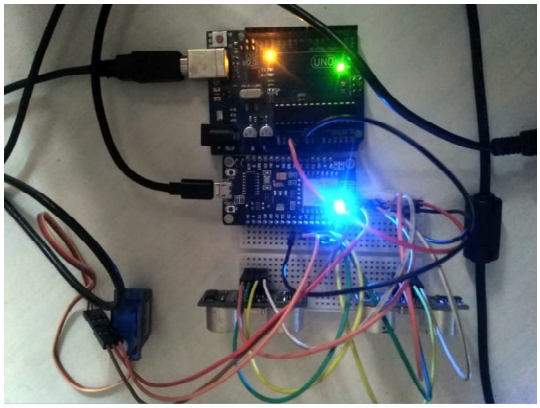


Fig. 10 Interconnection between various components

Similarly, an ultrasonic sensor is attached to check the trash level in the bin. ultrasonic sound is emitted by sensor; it is reflected by the garbage inside the smart bin. The time interval between the transmitted signal and received reflected sound waves is used to calculate the level of filling in the bin. The calculated numeric data representing the percentage filling of bin is displayed on the LCD and the data will be analyzed by Arduino and through the ESP8266 Wi-Fi Module the notification will be sent.

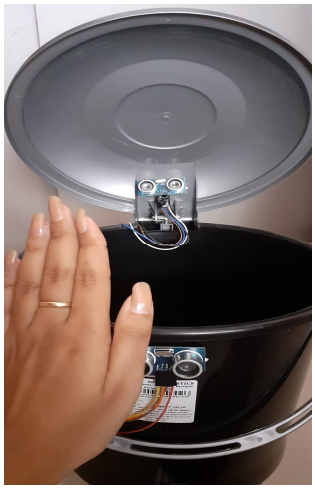


Fig. 11 Lid opens up when object approaches the bin

V. CONCLUSION

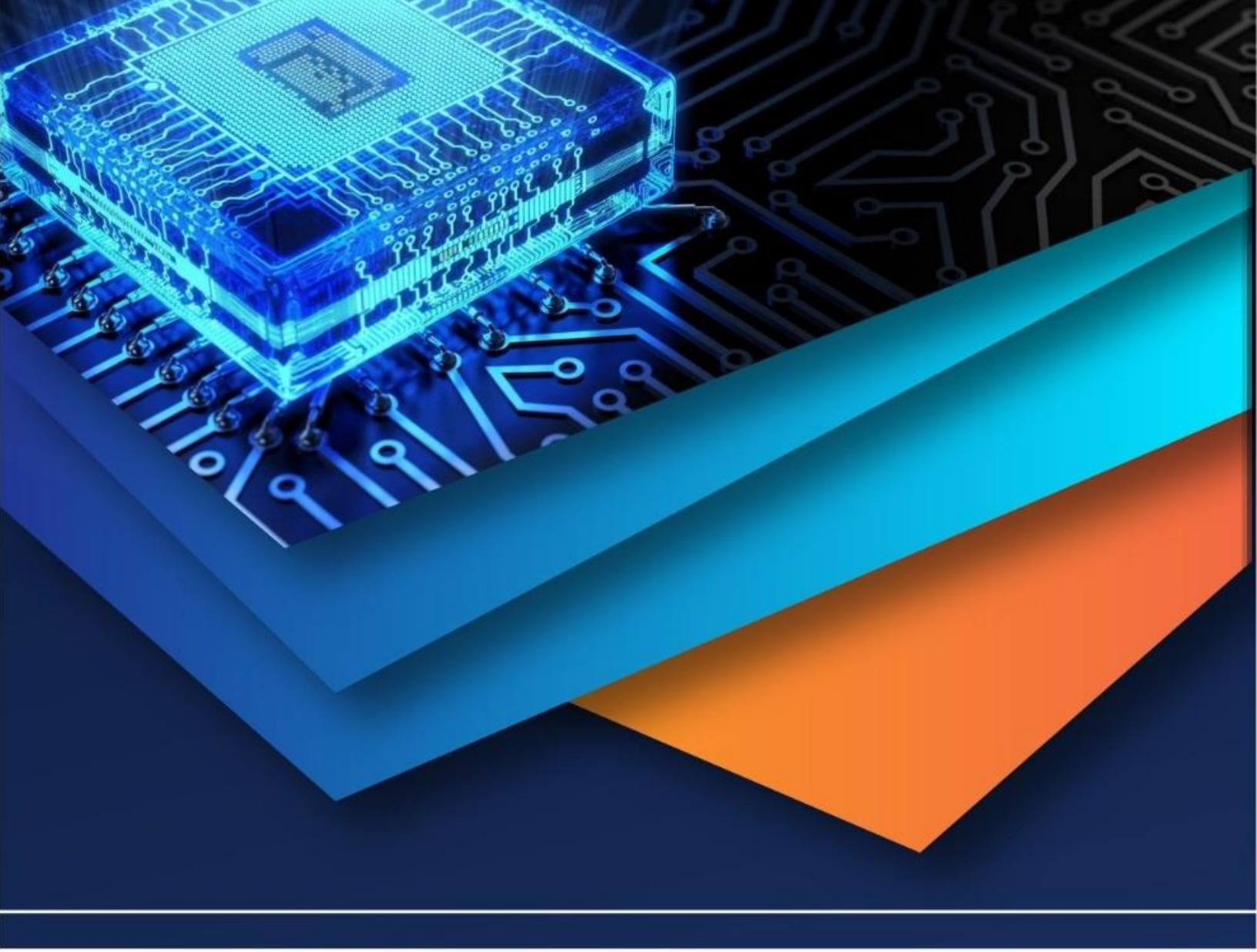
The main objective of the project is to minimize human efforts and resources with the help of technology. To sum up everything that has been stated, a Smart Dustbin is an efficient device. It has a very less complex circuit. It helps in monitoring the garbage level and thus can help to reduce overflowing of garbage bins. It consumes extremely little power, making it both economical and environmentally friendly. One disadvantage of this research is its inability to identify liquid waste. The work described in the paper has a simple design and has a low production cost too.

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