DESIGN AND DEVELOPMENT OF SMART WASTE BIN FOR EFFECTIVE WASTE COLLECTION AND MANAGEMENT

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Abstract – In modern cities, waste management has become a problem as waste is being generated faster than it is being managed and this is leading to serious environmental pollution. Most conventional trash bins in place are not being emptied efficiently enough which leads to the overflow of waste and the breed of pests, insects and the dreadful diseases they cause and spread.
This project proposes a smart trash bin as the solution to these problems. The intelligent waste bin consists of two systems. The automated lid system is the first part and it is responsible for the opening and closing the cover-lid of the bin without the need for physical contact between the user and the bin. This prevents the user from coming in contact with waste-borne germs, bacteria and viruses. The second is the communication system which will be responsible for informing the waste management authorities about the capacity of the bin so the bin can be emptied as soon as possible. The smart bin opens when the incoming trash is at a distance of 20cm (or less) closer to the bin while the bin refuse to open at a distance greater than this threshold and when the bin is 95% full. Also, the waste management personnel are notified through the communication system attached to the smart bin when it bin is 95% full so that the bin could be emptied. This prevents trash overflow from the bin and ultimately makes the environment cleaner and more eco-friendly.

Keywords: *Smart bin, Arduino Nano, Ultrasonic sensor, Servo motor, GSM module,*

I. Introduction

In the last few years, urbanization, population and industrialization has increased at a tremendous rate and with it, the rate of waste production has increased as well [1][2].The overflow of waste leads to environmental pollution which causes the area affected to look unsightly[3]. The foul odour of the open waste makes the region unconducive for those who live nearby. All of this can lead to a repulsive and unhygienic environment that allows for the breeding of pests, pathogens and insects that spread all kinds of terrible diseases [4]. The current global situation around the covid-19 epidemic, as well as the modifications and restrictions that come with it, has necessitated the need to minimize physical contact with people and objects particularly with dirty surfaces[5]. In most cases people dispose waste indiscriminately because of the need to avoid contact with dirty lid of such waste bin. Aside the possibility of flooding due to the blockage of drainage by waste products, air pollution and diseases could result from accumulated wastes[6]. These general environmental pollution caused by indiscriminate waste disposal are all symptoms of poor waste management, which is why the smart waste bin is being developed to improve waste collection and management[7][8]
This project proposes a smart trash bin as the solution to coming in contact with trash bin lids. Figure 1 shows the processes involved in the operation of the smart bin.

Figure 1: Operation of the smart bin

The smart bin will automatically open upon sensing oncoming trash and will shut its lid after a few seconds. This takes away the need for contact with the waste bin thereby eliminating the risk of contracting germs and bacteria capable of spreading disease. This also ensures the lid remains closed when not in use which ultimately helps to contain the smell of the trash within it. Also, the smart bin will not be opened to receiving trash when the bin is full, as a result, overflow will be prevented, and an SMS text message will be sent to the appropriate authorities via the GSM module incorporated in the design, alerting them that the bin is at full capacity and should be emptied as soon as possible.
Waste management will become more effective as smart trash bins are designed and implemented, and cities will become cleaner, healthier, and more environmentally friendly, which is a positive step toward achieving sustainable smart cities[7].

II. Related Works

Sathyakala et al[9] proposes a smart trash bin system that would ensure garbage collection is done only when needed to reduce garbage collection costs and prevent waste overflow. The proposed system uses an infrared sensor to measure the waste level of the bin and a PIC

microcontroller as an interface through which the hardware is programmed. The PIC microcontroller is a powerful microcontroller but the Arduino Nano is just as powerful, efficient, cost-effective and much easier to use and program.

Sohag & Podder (2020) [1]proposes a smart bin which is similar to the one developed in this project. However, an Arduino Uno board was used instead of the Arduino Nano board used in this work. Though the two microcontroller offers the same functionalities but the Nano board used in this work is smaller and cheaper.

Bhatt et al. (2019)[10] proposed a smart bin that uses an ultrasonic sensor to detect oncoming trash. Based on the sensors reading and the predefined parameters coded into the microcontroller, the servo motor placed on the lid of the bin opens it for the trash to be collected and then closes it automatically after a few seconds. The bin uses a less efficient microcontroller instead of the Arduino nano microcontroller used in this work.

A. S. et al [11]proposed a smart bin that uses a PIC board for a microcontroller, an ultrasonic sensor for waste level detection and a GSM module for its communication system. This system also has an android compatible mobile application on the client end. Through the application, the user can locate the nearest available bin to use and the fastest route to it.

III. Social significance

In urban cities, most conventional trash bins in place are not being emptied efficiently enough and this leads to the overflow of waste and the breed of pests, insects and the dreadful diseases they cause and spread.

The conventional trash bins require physical contact to use, this is no longer ideal especially at this period of global pandemic due to the covid-19 outbreak, which necessitated minimum or no physical contact with people or object. Therefore, this project will further prevent the spread of diseases.

IV. Methodology

The major components used in this project are an Arduino Nano microcontroller board, two ultrasonic sensors, a servo motor, a GSM module (SIM800L) and a liquid crystal display (LCD).

Other materials like jumper wires, Vero board, hot glue and so on were crucial to the achievement of the project.

The system is in two parts which are;

i. The automated trash collection system,
ii. The bin communication system

The two systems are connected to the same Arduino Nano board. The automated trash collection system involves an ultrasonic sensor (HC-SR04) that uses a technique similar to echolocation, which bats use to detect nearby objects, to detect oncoming trash as shown in Fig. 2.

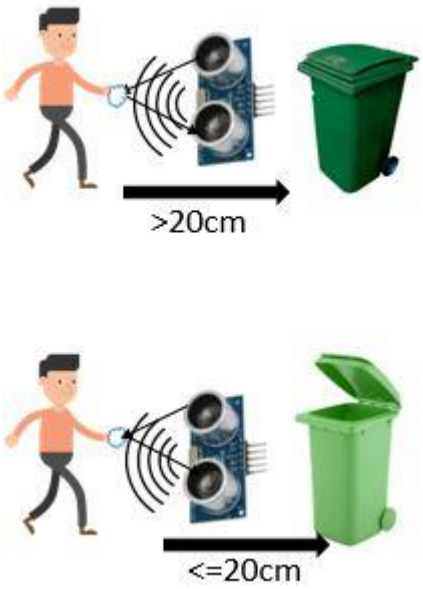

Figure 2: Automatic opening of the bin lid

The ultrasonic sensors measure the distance between the incoming trash and the bin, then promptly feeds the received data (in form of measured distance) to the Arduino Nano. The Arduino Nano then compares the distance measured by the sensor to the set threshold of 20cm that has been programmed into it. If the distance measured is less than or equal to 20cm, the Arduino Nano energize the servo motor to open the lid but if the distance between the bin and the object is greater than 20cm, the bin stays shut as shown in the figure 2. The system was programmed with such a small threshold distance to prevent the bin from opening unnecessarily when people pass by it. It is expected that the user would walk up to the bin and extend the trash towards it. The smart waste management system involves another ultrasonic sensor present inside the bin that measures the height of the trash in the bin. With this sensor present, the capacity of the bin can be measured and displayed on the liquid crystal display (LCD) in real-time

V. RESULTS

As soon as the trash level in the bin measures up to 70%, a text message will be sent to the appropriate personnel telling them the bin is almost full. However, the bin will continue to collect more trash but when the trash level measures up to 95%, another message will be sent to the appropriate personnel, telling them that the bin is full. At this point, the bin shuts down and stops opening to collect more trash till the trash collection personnel arrive to empty it. Once the bin is empty, the process starts again and the cycle continues until the waste in the bin is 95% of its capacity, then the lid of the bin refuse to open for more trash to come in. This is depicted in the flow chart in figure 4.

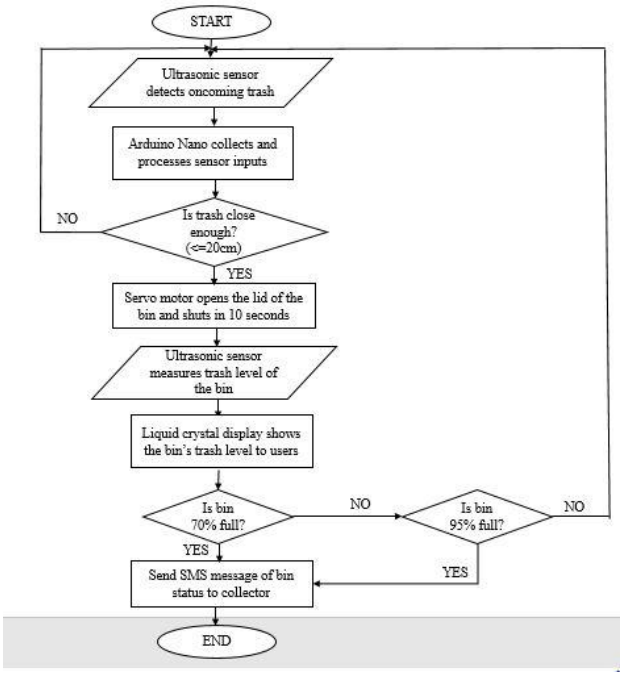

Fig. 4: Flowchart of the smart bin system

For the automatic lid system of the bin, the Arduino Nano, ultrasonic sensor and servo motor work together.

The Arduino Nano is a microcontroller board that is quite synonymous to the Arduino Uno but is significantly smaller than the Uno in size, making it all the more suitable for embedded system applications. It is called a microcontroller because it has input and output pins, a processing unit which is the ATmega328P and memory for the storage of instructions. Regarding this project, the Arduino Nano is the brain of the circuit. Being the microcontroller in the circuit, it is responsible for instructing all the other components, telling them what to do and when to act. Therefore, all the other components of the circuit are connected to its pins via jumper wires. The Arduino Nano board has memory where it stores all the instructions for the components connected to it. These instructions are written in the Arduino IDE using the C++ programming language and then sent to the memory in the Arduino.

The ultrasonic sensor measures distance with the use of ultrasonic waves. When the sound bounces off the target object and is reflected back to the sensor, it deduces the distance between the target object and itself by measuring the time that the transmission and reflection took. The following formula can be used to calculate the distance:

$$\text{Distance } L = 1/2 \times T \times C \qquad (1)$$

Where L is the desired distance, T is the time between the ultrasonic wave emission and reception and C is the sonic speed. (The value is multiplied by 1/2 because T is the round trip time (go-and-return) of ultrasonic waves).

The Vcc pin is connected to the 5v pin on the Arduino Nano so that the sensor can draw power. The ground pin is connected to the ground on the Arduino Nano. The trigger pin is responsible for the emission of the sound waves that are expected to travel from the sensor, bounce off the target object and reflect to the sensor so the desired distance can be measured. When the sound waves are reflected back to the sensor, the Echo pin goes high for a set time, which is equal to the time it takes for the wave to return to the sensor. This time is measured and used in calculating the distance between the object and the sensor. The trigger pin and the echo pin are connected to two of the digital pins on the Arduino Nano as they both deal with transmission and reception respectively.

A servo motor is a self-contained electrical device that efficiently and precisely rotates machine parts[12]. It could be either a linear or rotary actuator which gives precise position control in closed-loop applications.

Servo motors typically have three wires namely, power (red), ground (brown) and signal (yellow). The ground pin is connected to ground, the power pin is connected to the power plane and the signal pin is connected to a digital pin on the Arduino.

These components and the connections of the different components causes the automatic opening and closing of the bin.

For the bin communication system, the GSM module (SIM800L), ultrasonic sensor and the Arduino Nano work together to establish communication between the bin and the garbage collection personnel as shown in figure 4.

Fig. 4: Bin communication system

The liquid crystal display shows the user the level of trash in the bin so it is obvious if the bin can take more trash or if it is full.

The SIM800L is a tiny GSM/GPRS module that supports SIMCOM enhanced AT commands and provides 2G GSM/GPRS data. It is simple to interface with the UART of almost all popular microcontrollers because it uses the serial communication method. It has four pins connecting it to the Arduino Nano. The Vcc pin is connected to the 5v pin on the Arduino, the ground pin is connected to ground, the TX and RX pins, which are responsible for the transmission and reception of signal, are connected to two of the digital I/O pins on the Arduino.

The ultrasonic sensor is placed inside the bin, under the lid. The Vcc pin is connected to the 5v pin on the Arduino Nano so that the sensor can draw power. The ground pin is connected to the ground on the Arduino Nano. The trigger pin and the echo pin are connected to two of the digital pins on the Arduino (what are the purpose). The resulting design is shown in the figure 5 The figure 5 shows the final combination of the different components which result in the developed smart bin.

Figure 5: The designed Smart waste bin

VI. Conclusion

The smart bin is crucial in the achievement of smart cities and in realizing a clean and sustainable environment. It can be used for both outdoor and indoor applications. The project will eliminate the need for physical contact with trash bins and improve waste management systems and the logistics involved, thereby reducing environmental pollution, the spread of waste borne diseases and pest infestation and boosting general public health.

VII. Recommendations

The smart trash bin can be enhanced, given the costs are within budget, by

i. Replacing the plug that powers the servo motor with a rechargeable battery, likely a solar powered battery.

ii. Adding a compressor function to the bin so it can contain as much trash as possible per system cycle. Trash like nylon bags and paper tend to take space in the bin and make it seem full when they can simply be compressed, allowing the bin take more trash. The compressor will prevent the bin from filling faster than it should.

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