Design and Development of a Smart Waste Bin

Michael E., Otaru C. O., Liman A. D., Bomoi M. I., Awotoye B.

Abstract: For years, waste bin has been part of our lives; this has necessitated many inventions and innovations to make it automated. In this light, much research was channeled towards the opening and closing of the bin when the presence of human is sensed. However, this may be considered less smart since the bin will operate when the presence of human is sensed even though there is no intention to use it. To avert this ill, this paper presents the design and development of a smart waste bin. The objective of this paper is to develop a smart waste bin that detects the presence of man at a particular distance (1 meter for usage so as not to spill the dirt) and obeys voice command to open or close the lid. This is achieved by the use of PIR, ultrasonic module, voice recognition module, Arduino and servo motor. Results gotten after testing the developed system shows that the performance of the waste bin attains a better level of smartness compared to existing waste bin.

Index Terms: Arduino, PIR, Servo motor, ultrasonic module, voice recognition module and waste bin.

1 Introduction

WASTE is generated every day, from domestic, industrial, commercial and institutional establishments such as hospitals, market just to mention a few [4]. Solid waste management, monitoring and disposal are very important issues for most countries. Efficient waste management and disposal is required to maintain safe and green environment [5]-[6]. As a result, this necessitates the need for waste bins with lids to contain unpleasant sights and odors and to minimize contamination. In recent years, many inventions and methods have been developed using technology to automate waste bins and to encourage proper waste disposal [7]. In 2010 [4], Maher et al worked on RFID and Integrated Technologies for Solid Waste Bin Monitoring System. His method used RFID, GPS, GPRS integrated with low cost camera for solid waste monitoring and management. In the work, the RFID is attached to each bin in order to monitor and track the bin during collection process. The camera takes pictures of the bins before and after collection. Data from the truck network are recorded and forwarded to a control server through the GPS GPRS system. The limitation of this work is the manual operation of the lid of the bin which may expose users to contamination. In 2014, Joan et al [1] worked on Solar Powered Electronic Trash Can which has a magnetic sensor to scans the waste; classify it to either metallic or nonmetallic waste. The control system opens the particular Can where such type of waste is to be disposed and then closes automatically after 10 seconds. However, despite all the fabulous operations of the trash can, its limitation is that the bin will operate automatically when any material passes in front of the scanner even if not intended as waste. Also, the use of multiple controllers makes the design expensive. So as to encourage proper waste disposal, Seeman et al [2] in 2016 worked on the Survey of Wi-Fi Trash Can.

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In his work, users are granted access to WIFI for ten minutes each time the Can is used. Arunkumar et al [3] in 2016 worked on Smart Garbage Collecting Bin for Municipal Solid waste, each of the bins are mounted with an infrared sensor to detect if the bin is full. The sensor gives an indication to the ARM 7 microcontroller if it is full which the sends an SMS to the garbage collection truck of the location of such bin. But these designs failed to automate the opening and closing of the lid of the waste bin. However, to ensure the automation of the lid of the waste bin when it needed, this paper presents a Smart Waste Bin which opens and closes on voice command from the user

2 METHODOLOGY

The automation of the waste bin is achieved via the use of a power supply, Controller (Arduino Uno), voice recognition system, PIR sensor, servo motor and ultrasonic sound sensor. A block diagram of the control circuit is shown in Figure 1.

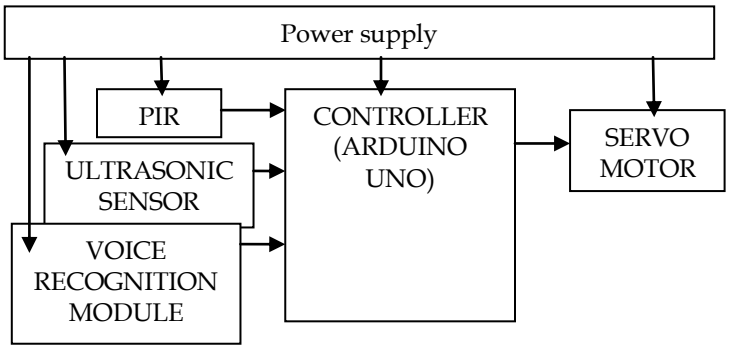

Figure 1. *Block diagram of the Smart Waste Bin*

2.1 Power supply

The power supply as shown in Figure 2 was achieved by stepping down voltage from 230V AC to 15V AC. The 15V AC generated by the transformer (TR1) is then converted to DC via the use of a rectifier (BR1). Afterwards, 1000uf capacitor (C1) is used to filter off ripples. 12V voltage regulator (7812) is used to generate standard 12V and 5V voltage regulator (7805) is used to generate 5V. The 12V generated is to power the Arduino Uno and the 5V is to power the servo motor, PIR, ultrasonic module and the voice recognition module.

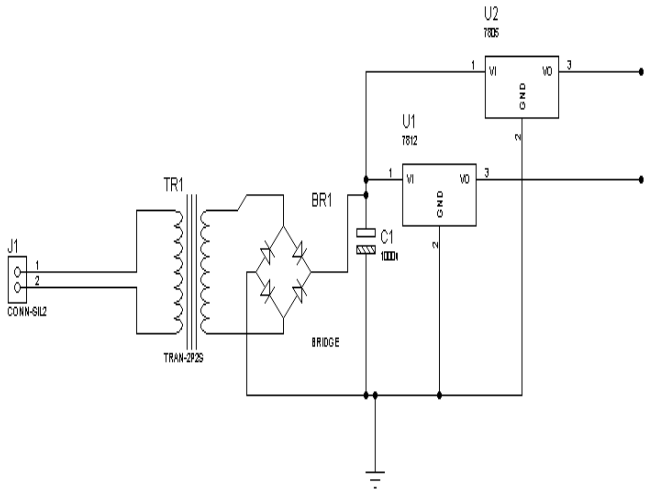

***Figure 2**. Circuit diagram of the power supply*

2.2 Ultrasonic Module

The 5V driven Ultrasonic module HC-SR04 as shown in Figure 3 was used in this project. This module can measure from 2cm to 400cm with an accuracy of 3cm. As a result, it is chosen to measure the distance between the user and the bin so that waste is properly disposed without spilling to the ground. The device has four pins which are V_{cc}, Ground, Trigger and Echo. As shown in Figure 4 V_{cc} and the Ground are used to power the module while Trigger and Echo are connected to the Arduino Uno to operate it. To use the TTL (transistor transistor logic) device, a pulse 10usec wide is sent to the trigger pin. Automatically, the module will transmit eight 40KHz burst. If an obstacle is detected the burst will be reflected back and the Echo pin goes high for the time taken to send and receive the burst. Figure 4 shows the circuit diagram.

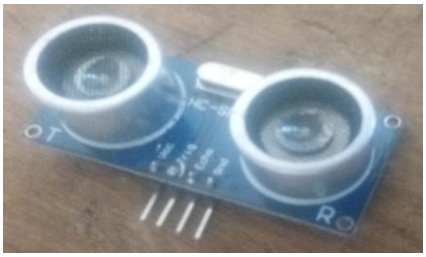

***Figure 3**. Pictorial view of ultrasonic Module*

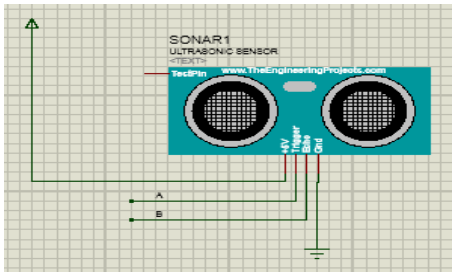

***Figure 4.** Proteus design of the Ultrasonic Module.*

2.3 Passive infrared sensor (PIR)

This module as shown in Figure 5 is made up of pyroelectric sensor which detects INFRA-RED radiation as a result of heat generation from humans. This device consists of three pins which are V_{cc}, Ground and output. The V_{cc} and the Ground is used to power the module with 5V while the output goes high when it detects motion. The module was used to ascertain that the object affront the waste bin is human. Figure 6 shows the circuit description of a PIR on proteus.

***Figure 5.** Pictorial view of PIR module*

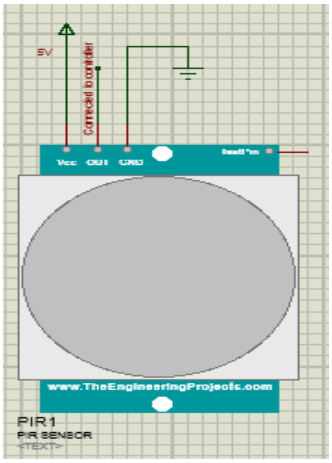

***Figure 6.** Proteus view of PIR module*

2.4 Voice recognition module

The module VR3 produced by Elechouse as shown in Figure 7 is an easy-control speaking recognition board. The 5V powered module which supports eighty voice commands in all, could take seven voice commands at the same time. Though the board could be interfaced with any controller via serial port or general input pins, however, for this work serial port is used. Preceding recognition, the module was trained by following the instructions as specified by the manufacturer in the data sheet. This module was chosen to achieve the voice operation of the work. The specification of the module is specified in Table 1.

***Table 1**: Electrical Specification of voice recognition module VR3*

S/N	PARAMETER	ELECTRICAL CHARACTERISTICS
1.	Voltage	4.5-5.5V
2.	Current	Less than 40mA
3.	Digital interface	5V TTL for UART interface and GPIO interface
4.	Analog interface	3.5 mm mono-channel microphone + microphone interface
5.	Size	31mm x 50mm
6.	Recognition accuracy	99%

***Figure 7**. Pictorial view of VR3 voice recognition module.*

2.5 Controller

The controller used as shown in Figure 8 is Arduino Uno R3. The micro controller board is made with ATMEGA328 which has 14 digital input and output pins, 6 analog inputs, 16Mhzceramic resonator, USB connector and many more. However, because of the different modules within it, this controller was chosen to reduce cost and time of design. The controller serves as the central processing unit of the whole design. It is interfaced to the input sensors (Ultrasonic sensor, PIR, voice recognition module V3) and the actuator which is the servo motors. The specification of the controller is seen in Table 2

***Figure 8**. Pictorial view of Arduino controller*

***Table 2:** Specification of Arduino Uno R3 controller*

S/N	PARAMETERS	ELECTRICAL CHARACTERISTICS
1.	Micro-controller	ATMEGA328
2.	Operating Voltage	5V
3.	Recommended input voltage	7V-12V
4.	Input voltage limit	6V-20V
5.	Digital input output pin	14
6.	Analog pins	6
7.	DC current at input output pin	40mA
8.	Flash memory	32kB
9.	SRAM	2kB
10.	EEPROM	1kB
11.	Clock speed	16MHz

2.6 Servo Motor

This serves as the actuator which opens and closes the lid of the waste bin. The servos used have a torque of 1.8kgf.cm. The three pin device is powered with 5V as shown in the circuit diagram in Figure 9

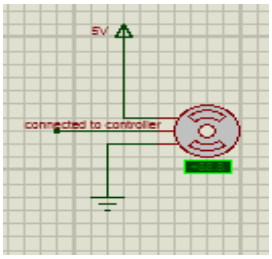

***Figure 9**. Proteus view of servo motor.*

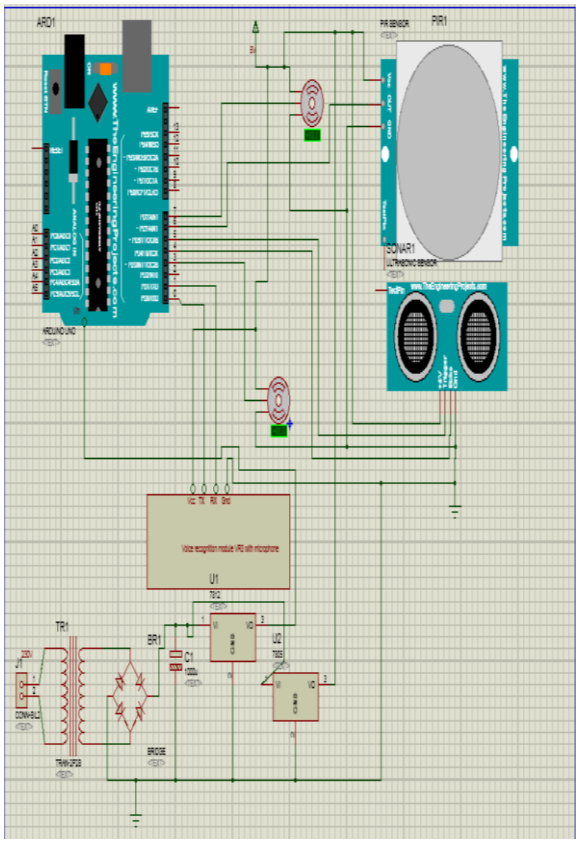

***Figure 10**. Complete circuit diagram*

2.7 Mode of operation

The transformer (TR1) is supplied with 230V AC through J1 as shown in Figure10. This voltage is stepped down to 15V and then converted to DC by the rectifier BR1. The capacitor C1 filters off the ripples and supplies power to 7812 and 7805 voltage regulators which regulate the 15V DC to 12V DC and 5V DC respectively. These voltages are used to power the system. When active, the controller sends control signal through pin 5 to the trigger pin of the ultrasonic module so as to scans for obstacles affront it at most at a distance of 1 meter. If any is found, the PIR check for thermal infrared radiation to ensure that the object before it is human. Furthermore, the system waits for the voice command ("Bin open"). If the voice command is received, the controller sends a control signal to the actuators (the two servo motors) to move to an angle of 90^{O} opening the lid of the waste bin. The system then expects the close command ("Bin close") while still sensing the presence of the individual at the same distance. However if the close command is not received to aid the closing of the lid of the waste bin after 20 seconds, the controller automatically sends the control signal to move the actuator to an angle of 0^{o} closing the waste bin. This automatic closing also happens when the individual is further away from the waste bin (more than 1 meter) even though the close command is not declared.

3 Result

The design was developed, tested with the lid of the waste bin initially closed and the results obtained are showed in the Table 3 and Table 4 below.

***Table 3.** Experimental Result of the opening operation of the waste bin*

S/N	Ultrasonic Module distance reading with object (cm)	PIR Logic	open command	State of waste bin
1.	≤ 100	0	0	0
2.	≤ 100	0	1	0
3.	≤ 100	1	0	0
4.	≤ 100	1	1	1
5.	> 100	0	0	0
6.	> 100	0	1	0
7.	> 100	1	0	0
8.	> 100	1	1	0

***Table 3:** Experimental Result of the closing operation of the waste bin*

S/N	Ultrasonic Module distance reading with object (cm)	PIR Logic	close command	Time after opening (sec)	State of waste bin
1.	≤ 100	1 to 0	-	-	1 to 0
2.	≤ 100	1	0	<20	1
3.	≤ 100	1	0	>20	0
4.	≤ 100	1	1	-	0
5.	> 100	-	-	-	0

Key:
PIR: Logic=1 when human is sensed, Logic=0 when human is not sensed
Open command: Logic =1 when given, Logic=0 when not given
Close command: Logic =1 when given, logic=0 when not given
State of waste bin: Logic=1 when opened, Logic=0 when closed.
Note '–' is don't care condition.

4 DISCUSSION

- The Table 3 above shows that the only conditions which will aid the opening of the waste bin are that the body affront the bin must be human within the range of 1 meter and that the open voice command should be given.
- In Table 4, the first row shows when a human was there before and then replace by an object; the bin which was opened initially closed immediately.
- The second row shows a human within the maximum distance when no close command was given under 20 seconds, the bin remained open.
- The third row shows that when the bin is opened and the user is within using range but no close command is given, the bin will close after 20 seconds with or without the command.
- The fourth row indicates that the bin will close as soon as the close command is given.
- The fifth row shows that the bin will close automatically when the user leaves the 1 meter range.

5 CONCLUSION

The bin worked smartly as expected. It sensed the presence of a user within 1 meter radius so as to avoid garbage spill and opens at the voice command “Bin open”. The bin closes if the user walks away from the operating range or when the close command (“Bin close”) is given or when its 20 seconds past the instant of opening and no close command is given.

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