Design and Implementation of Automated Waste Segregator with Smart Compression

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Abstract

This study entitled "Design and Implementation of Automated Trash Bin with Smart Compression" aims to design and implement an efficient system that will help to properly segregate wastes. Two Arduino Uno are interconnected to each other along with the all the components needed to achieve the desired output. Push buttons are used to determine what kind of waste is going to be disposed. LEDs was used to indicate if the input is correct. The Stepper Motor is responsible for the rotation of the trash bins that are attached on a circular metal plate. Ultrasonic sensor was used to determine if paper or plastic bins are needed to be compressed. Compression was made possible using Linear Actuator leading to a maximized space for the trash bin. LEDs will also serve as indicator the bins are already full. It will help the Local Government Units and the community in obtaining a greener environment and aiding the problem on solid waste management in this country.

Keywords: Arduino Uno, Push Button, LEDs, Ultrasonic Sensor, Linear Actuator, Stepper Motor

I. INTRODUCTION

Worldwide material consumption has expanded rapidly, as has material footprint per capita, seriously jeopardizing the achievement of ensuring sustainable consumption and production patterns or Sustainable Development Goal 12 under UNESCO Sustainable Development Goals. Urgent action is needed to ensure that current material needs do not lead to the over extraction of resources or to the degradation of environmental resources, and should include policies that improve resource efficiency, reduce waste and mainstream sustainability practices across all sectors of the economy. In 2017, worldwide material consumption reached 92.1 billion tons, up from 87 billion in 2015 and a 254 per cent increase from 27 billion in 1970, with the rate of extraction accelerating every year since 2000. This reflects the increased demand for natural resources that has defined the past decades, resulting in undue burden on environmental resources. Without urgent and concerted political action, it is projected that global resource extraction could grow to 190 billion tons by 2060 [1].

Unsurprisingly, the Philippines generates more solid waste as population increases, living standards are enhanced, and urban and rural areas are being developed. According to a report by the Senate Economic Planning Office (SEPO), the country's waste generation steadily increased from 37,427.46 tons per day in 2012 to 40,087.45 tons in 2016. Meanwhile, solid wastes produced by Philippine cities are expected to increase by 165 percent to 77,776 tons by 2025 [2].

Unplanned open dumping at landfill sites made by municipal is a common method of disposal of waste. Human health, plant, animal life and aesthetic value of the environment are affected due to this method. The economic value of the waste generated is not realized unless it is recycled completely. Several advancements in technology have also allowed the refuse to be processed into useful entities such as Waste to Energy, where the waste can be used to generate synthetic gas (syngas) made up of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam; Waste to Fuel, where the waste can be utilized to generate biofuels [3].

Solid waste management remains the most pressing urban environmental challenge in the country. The percentage weight of MSW fractions in the Philippines states that out of 100%, 27.78% of waste collected are recyclables. The 8.70% of it are papers, 10.55% are plastics, 4.22% are metals and 2.34% are glass [4].

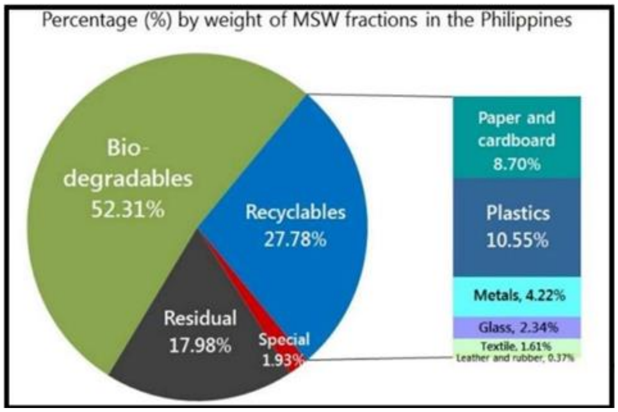

Figure 1. Percentage of Municipal Solid Waste

Though public and other private sectors are there to segregate waste, it is much better if the waste is already sorted from its source. With this, the quality of material of all the recyclable waste collected will remain with higher value [5].

The solution needed for increasing the utilizable resources is through setting up automated bins which can identify the type of garbage dumped into the bin. This helps negate the effects of human negligence and reduce the chances of available recyclable materials getting contaminated. Automated trash bins are prototype of municipal waste segregator, which can segregate the dumped waste immediately, leading to more recyclable paper. The Smart bin can be programmed to send information about the dumped garbage, such that respective action can be taken. Various sensors and motors are interfaced with microcontroller in this system [6].

Objectives of the Study

To identify the hardware and software needed to design a proper waste management system which will be able to segregate paper, plastic, metal, and glass automatically along with its smart compression and determine the system's process that will give an efficient output. To assemble, test, and evaluate the system in terms of functionality, accuracy, and reliability.

Related Work

Andres Torres-García et al. (2015) aims to present an Intelligent Waste Separator (IWS) which can replace the traditional way of dealing with waste; the proposed device receives the incoming waste and places it automatically in different containers by using a multimedia embedded processor, image processing, and machine learning to select and separate waste [7].

Mariah Rayah D. Bondad et al. (May 2018) uses Arduino microcontroller, ultrasonic sensor, and a servo motor to build an automatic lid opening trash bin with content monitoring capability. For future research, they can integrate the system with segregation using additional sensors [8].

Fun with Trash made by student of Seoul National University named Ryeol Jang et al. (2016) is a system that has smart sensor system that can identify what trash has been put inside. The system has an ultrasonic sensor that can detect the waste then a photo is captured by a camera sensor that can recognize the type of trash (paper, glass, can, plastic). then it is compared against entries in a database and if it is sorted properly and correctly in the right bin, the user if informs and the bin will be opened. Points are added to the user's account if he/she has correctly segregated the trash [9].

Sneha M P et al. (2014) proposed a system that sorts wastes into three different categories, metal, dry, and the wet waste. And the system can segregate only one type of waste at a time with an assigned priority for the wastes. By the experimental result, it shows that the waste has been successfully segregated into a glass, metallic, wet, and dry waste using the segregator [10].

Swati Sharma and Saranjitg Singh (2018), they proposed a management system of smart dustbin where it uses IoT as a hardware and ionic framework as our software ensures the cleaning of dustbin soon when the garbage reaches its maximum. If the dustbin is not cleaned in specific time, then the record sent to the higher authority. In our case, the admin who can take an appropriate action against to the concerned employee [11].

II. METHODOLOGY

Conceptual Framework

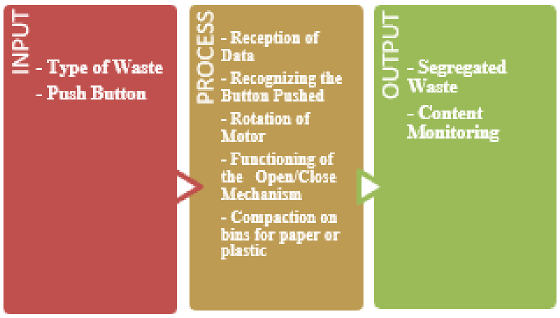

Figure 2. IPO Chart of the Automated Waste Segregator

Figure 2 shows the Input-Process-Output Chart of the Automated Waste Segregator. The waste that is placed in the open/close mechanism of the trash bin will be one of the input parameters of the system. Another is the push buttons that the user will demonstrate based on the provided instructions. The instructions are to be set by the prospect client. These data are transmitted to Arduino Uno. The data will be interpreted and will send command to the stepper motor. When the desired rotation of the stepper motor is achieved, the open/close mechanism where the waste is initially placed will then do its function to drop the waste in the desired container. As a result, the waste is properly segregated. The ultrasonic sensor will be used to monitor if the container is full, and LED will be the indicator.

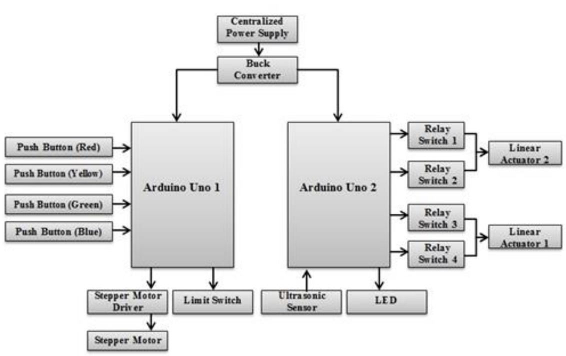

Figure 3. Block Diagram of Automated Waste Segregator

Figure 3 shows how the components are interconnected to the two Arduino uno to build an efficient system. Buck converter is connected from a 24V Power Supply to the Arduino Uno. Push Buttons, Micro Step Driver, Limit Switch, Ultrasonic Sensor are connected to Arduino Uno 1. All the Relays and LEDs are connected to Arduino Uno 2.

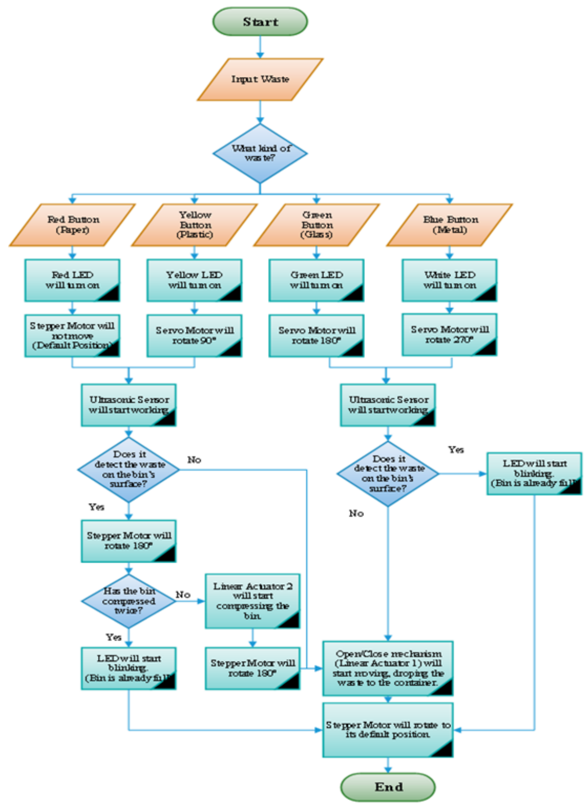

Figure 5. System Flowchart of AWS

Figure 5 below shows the flowchart to be follow on the design and implementation of an Arduino Based Automated Waste Segregator with Smart Compression. The stepper motor will be responsible for the rotation of the bins. There will be a Motor Driver to be use for the stepper motor. Push button will determine the rotation of the bins. Linear Actuator 1 will be used for the compression for paper and plastic bins. Ultrasonic sensor will detect if the paper or plastic bin is ready to be compressed and they can only be compressed twice. once the bin is compressed twice and the ultrasonic sensor detect that waste is on the surface of the bin, it is considered full. Since glass and metals are avoided to be shattered and distorted, they cannot undergo the compression. Once the ultrasonic sensor detects that waste is on the surface of the bin, it is considered as full. Linear Actuator 2 will be responsible for the open and close mechanism. Once a bin is full, the open/close mechanism for that certain bin will start working. For example, if a person pressed the button for a bin which is full, the open/close mechanism will stop working. LED will be the indicator if the paper or plastic bin is on the process of compressing and it will also indicate if the bin is full.

Hardware Used

Arduino Uno R3 Microcontroller

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. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

NEMA 34 Stepper Motor 45kg-cm

They can be found in desktop printers, plotters, 3d printers, CNC milling machines, and anything else requiring precise position control. These are a special segment of brushless motors. They are purposely built for high-holding torque. This high-holding torque gives the user the ability to incrementally “step” to the next position. This results in a simple positioning system that does not require an encoder. This makes stepper motor controllers very simple to build and use.

2H Microstep Driver DQ860MA

Is a two-phase hybrid stepper driver. It is designed to be use for 2-phase hybrid stepper motors with 57mm to 110mm outside diameter and less than 7.8A phase current. The circuit that it adopts is similiar to the circuit of a servo controller which enables the motor to run smoothly almost without noise and vibration. It is widely used in middle and big size numerical control devices such as curving machine, CNC machine, computer embroider machine, packing machines etc.

24V 5A Centralize Power Supply

This 24V power supply can supply a DC voltage of 24V DC, and a current of up to 5A, it features a trim potentiometer to fine tune the output voltage. This will be the power source of the system.

Ultrasonic Sensor HC-SR04

The ultrasonic sensor HC-SR04 uses sonar to determine distance to an object. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package.

Linear Actuator

It is an actuator that creates motion in a straight-line direction, in contrast to the circular motion of a conventional electric motor. Linear actuators can provide both push and pull movements that is possible to lift, drop, slide, adjust, tilt, push or pull objects.

III. RESULTS AND DISCUSSIONS

Stepper Motor

Table 1. Actual vs. Measured Angle of Rotation for Paper (Red Button

Trial No.	Actual Angle of Motor Rotation	Measured Angle of Motor Rotation	Percentage Error (%)
1	0°	0°	0
2	0°	0°	0
3	0°	0°	0
4	0°	0°	0
5	0°	0°	0
6	0°	0°	0
7	0°	0°	0
8	0°	0°	0
9	0°	0°	0
10	0°	0°	0
Average Percentage Error			0

Table 2. Actual vs. Measured Angle of Rotation for Plastic (Yellow Button)

Trial No.	Actual Angle of Motor Rotation	Measured Angle of Motor Rotation	Percentage Error (%)
1	90°	90°	0
2	90°	90°	0
3	90°	90°	0
4	90°	90°	0
5	90°	90°	0
6	90°	90°	0
7	90°	90°	0
8	90°	90°	0
9	90°	90°	0
10	90°	90°	0
Average Percentage Error			0

Table 3. Actual vs. Measured Angle of Rotation for Glass (Green Button)

Trial No.	Actual Angle of Motor Rotation	Measured Angle of Motor Rotation	Percentage Error (%)
1	180°	180°	0
2	180°	180°	0
3	180°	180°	0
4	180°	180°	0
5	180°	180°	0
6	180°	180°	0
7	180°	180°	0
8	180°	180°	0
9	180°	180°	0
10	180°	180°	0
Average Percentage Error			0

Table 4. Actual vs. Measured Angle of Rotation for Metal (Blue Button)

Trial No.	Actual Angle of Motor Rotation	Measured Angle of Motor Rotation	Percentage Error (%)
1	270°	270°	0
2	270°	270°	0
3	270°	270°	0
4	270°	270°	0
5	270°	270°	0
6	270°	270°	0
7	270°	270°	0
8	270°	270°	0
9	270°	270°	0
10	270°	270°	0
Average Percentage Error			0

Linear Actuator

Table 5. Response of motor and open/close mechanism when Paper bin is full

Trial No.	Motor Rotation	Open/Close Mechanism	Time Delay
1	180°	ON	15s
2	180°	ON	15s
3	0°	OFF	0s

Table 6. Response of motor and open/close mechanism when Plastic bin is full

Trial No.	Motor Rotation	Open/Close Mechanism	Time Delay
1	180°	ON	15s
2	180°	ON	15s
3	270°	OFF	0s

Table 7. Response of motor and open/close mechanism when Glass bin is full

Trial No.	Motor Rotation	Open/Close Mechanism	Time Delay
1	180°	OFF	0s
2	180°	OFF	0s
3	180°	OFF	0s

Table 8. Response of motor and open/close mechanism when Metal bin is full

Trial No.	Motor Rotation	Open/Close Mechanism	Time Delay
1	90°	OFF	0s
2	90°	OFF	0s
3	90°	OFF	0s

Table 9. Response of motor and compressor when Paper bin is full

Trial No.	Motor Rotation	Compressor	Time Delay
1	180°	ON	15s
2	180°	ON	15s
3	270°	OFF	0s

Table 10. Response of motor and compressor when Plastic bin is full

Trial No.	Motor Rotation	Compressor	Time Delay
1	180°	ON	15s
2	180°	ON	15s
3	0°	OFF	0s

Ultrasonic Sensor

Table 11. Actual vs Measured distance of Ultrasonic Sensor when Paper bin is full

Trial No.	Ultrasonic Sensor Actual Distance	Ultrasonic Sensor Measured Distance	Percentage Error (%)
1	5.10cm	5.15cm	0.98
2	5.30cm	5.37cm	1.32
3	6.40cm	6.44cm	0.63
Average Percentage Error			0.98

Table 12. Actual vs Measured distance of Ultrasonic Sensor when Plastic bin is full

Trial No.	Ultrasonic Sensor Actual Distance	Ultrasonic Sensor Measured Distance	Percentage Error (%)
1	7.20cm	7.28cm	1.11
2	8.50cm	8.54cm	0.47
3	8.80cm	8.86cm	0.68
Average Percentage Error			0.75

Table 13. Actual vs Measured distance of Ultrasonic Sensor when Glass bin is full

Trial No.	Ultrasonic Sensor Actual Distance	Ultrasonic Sensor Measured Distance	Percentage Error (%)
1	5.50cm	5.58cm	1.45
2	7.00cm	7.14cm	2
3	9.60cm	9.66cm	0.63
Average Percentage Error			1.36

Table 14. Actual vs Measured distance of Ultrasonic Sensor when Metal bin is full

Trial No.	Ultrasonic Sensor Actual Distance	Ultrasonic Sensor Measured Distance	Percentage Error (%)
1	6.20cm	6.23cm	0.48
2	7.50cm	7.64cm	1.86
3	8.90cm	9.00 cm	1.12
Average Percentage Error			1.15

Tables 1-14 are the data gathered during the actual testing of the whole system. Stepper motor, Linear Actuator and Ultrasonic Sensor have different tables of data to identify the functionality and efficiency of each component.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Automated Waste Segregator, designed and developed by the proponents, was able to achieve proper waste segregation, maintaining the quality of recyclable wastes and maximizing the capacity of the trash bin as stated in the objectives of the study. The proponents were able to build an Automated Waste Segregator with Smart Compression that can properly segregate four types of waste according to the input push button along with smart compression when the sensor detected that the paper bin or plastic bin is already full. It was also able to notify the user if the bins are already full through the LEDs assigned to each bin. Upon the actual testing, the proponents concluded that the system could provide an efficient output depending on the knowledge of user about the waste that they are going to dispose.

Recommendations

For further development of Automated Waste Segregator, the proponents highly recommend the use of image processing in the system. This will provide a system that is not dependent in human knowledge. Additional sensor like loadcells will also help in monitoring the weight of waste on each bin leading to a more accurate data of waste collected in the area where the system is installed. The future researchers can also use higher holding torque stepper motor so that the system can handle higher amount of waste. Better compression mechanism is also recommended in maximizing the capacity of the trash bins.

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