Design and Construction of an Automatic Waste Sorting Machine

A Thesis

by

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Submitted to the

DEPARTMENT OF MECHANICAL ENGINEERING

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In partial fulfillment of the requirements for the award of the degree of Bachelor of Science in Mechanical Engineering

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Declaration

We do hereby solemnly declare that the work presented here in this project report has been carried out by us and has not been previously submitted to any University/Organization for the award of any degree or certificate

We hereby ensure that the works that have been prevented here do not breach any existing copyright. We take full responsibility in case of any conflict regarding the originality and authenticity of the content presented.

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[Authors]

Abstract

Sorting waste is an important first step in recycling. This project focuses on designing and building an automatic sorting machine that separates metal and non-metal objects with manual help. The system consists of a conveyor belt to move objects, an infrared sensor to detect general objects, and an inductive sensor to identify metallic objects. All components are controlled by an Arduino UNO microcontroller, which processes sensor signals and activates a servo motor to sort objects into designated bins.

The total time taken to sort a single item is approximately 4 seconds (1s detection + 2s actuation + 1s counting). After successful fabrication and testing, the machine met the design goals. The device offers a practical, low-cost solution for small-scale recycling facilities, educational purposes, and local waste management system.

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Notation

BCE	Before Common Era
DC	Direct current

Chapter 1

Introduction

1.1 Introduction

From the beginning of the human civilization, people used various methods of waste disposal to get rid of unwanted material. Sometimes it was buried in the land, thrown in the sea, fed to the animal or burnt. Getting rid of unwanted material is always a major concern for the modern society. Trash has played a tremendous role in history. The Bubonic Plague, cholera and typhoid fever, to mention a few, were diseases that altered the populations of Europe and influenced monarchies. They were perpetuated by filth that harbored rats, and contaminated water supply. When wastes are not properly managed then it may cause serious hazard, as seen in 1350. "Black plague" erupted and more than 25 million people from all over Europe fall victim to it in just five years. There is an increasing rate of waste generation in Bangladesh and it is projected to reach 47,064 tons per day by 2025. The Waste Generation Rate (kg/cap/day) is expected to increase to 0.6 in 2025. A significant percentage of the population has zero access to proper waste disposal services, which will in effect lead to the problem of waste mismanagement [1-3].

The total waste collection rate in major cities of Bangladesh such as Dhaka is only 37%. When waste is not properly collected, it will be illegally disposed of and this will pose serious environmental and health hazards to the people of Bangladesh. This is not the only problem in Dhaka city but also for other big cities around the world [4-5].

In today's society, there are landfills filled with plastic, glass, metal, and all sorts of waste. Much of it could be recycled, but it ends up in landfills. This is becoming more and more of an issue since our earth's resources are limited. Metals are often debated when discussing recycling since it takes more natural resources and energy to make metal from more than simply re-process recycled metal. Metal recycling saves 95% more energy than making new metal from ore deposits. One way to make it easier for people to recycle metal would be if it was made automatic, saving time and energy. By doing so the number of metals that end up in landfills and therefore are not recycled could be reduced. With so much concern recently about being greener and economically friendly, waste management has become a very important

topic. People and companies are starting to realize that the things they use and the way they dispose of them can make a big impact on our world. Proper management of waste plays a vital role in a global environment. That is why a waste sorting system is designed which can be used in houses, offices, and industries as a part of a smart waste management system [6].

1.2 Problem Statements

Poor waste management - ranging from non-existing collection systems to ineffective disposal -causes air pollution, and water and soil contamination. Open and unsanitary landfills contribute to contamination of drinking water and can cause infection and transmit diseases. Improper disposal can lead to adverse health outcomes, for example through water, soil and air contamination. Hazardous waste or unsafe waste treatment such as open burning can directly harm waste workers or other people involved in waste burning and neighboring communities.

The problem statement for an automatic waste sorting machine is the need to develop a system that can efficiently and accurately segregate different types of waste materials from a mixed waste stream, minimizing manual labor, improving recycling rates, and reducing the amount of waste sent to landfills, while overcoming challenges like inconsistent waste composition, complex material identification, and potential contamination issues. Current waste sorting processes are time-consuming, labor-intensive, and prone to human error. Improper waste segregation can lead to contamination of recyclable materials, reducing recycling efficiency. Waste stream complexity and high operational costs contribute to manual sorting. Potential solutions include sensor technology, automated sorting mechanisms, and advanced algorithms. Sensor technology can identify materials based on properties, automated mechanisms use conveyor belts or robotic arms, and advanced algorithms improve recognition accuracy and adapt to changing waste streams.

1.3 Objective

The objectives of this project are:

- To study about waste sorting mechanism.
- To design a model which can sort different kinds of waste.
- To construct a project based on the design.
- To collect and analyze the related data.

Chapter 2

Literature Review

2.1 Introduction

In the present world, there are plenty of scientific innovations and sophisticated technologies that have simplified human life and raised the standard of living. Scientists are busy with research and development works. Day-by-day scientists come up with better ideas that make the life of the common man more automated. As an attempt to develop an automated set-up in whatever area possible that would further simplify human life and make it easier, we ended up with a very relevant area of concern - sorting. Various other places where sorting comes into play predominantly are airports, seaports, small-scale industries, supermarkets, etc. However, due to the restricted reach of automation in sorting in these sectors, the thought of automated sorting in such fields ought to be considered with much importance. Thus, to extend the advantages of automated sorting in large sectors to the above-mentioned sector, a notion of automation has been thought to be implemented in small-scale sectors [7-8].

A literature survey is a proof essay of sorts. It is a study of relevant literature materials about a topic we have been given.

2.2 Literature Review

In this study, an automatic waste sorter machine was made. This machine can sort metal trash, plastic bottles, or both, which are sorted the waste will be put in different bins according to type. In this machine, Arduino Mega 2560 is used as the main brain, which will work according to the input obtained from the PIR sensor, LDR sensor, inductive proximity sensor, capacitive proximity sensor, and ultrasonic sensor. Testing on automatic waste sorter machines is carried out using five types of waste, namely cans, non-transparent plastic bottles that contain water, transparent plastic bottles, transparent plastic, and report books. From the test results obtained the automatic waste sorter machine can detect waste entering the trash can according to its type by 72%. Whereas 28% experienced a detection error, which was the biggest error that occurred in the detection of transparent empty plastic bottles.

A crucial prerequisite for recycling forming an integral part of municipal solid waste (MSW) management is sorting of useful materials from source-separated MSW. The morphological composition of the waste generated in Russia was studied. Theoretical bases of management of the waste sorting conveyor have been developed taking into account failures such as uneven loading and uneven sorting of waste. The calculation of the waste material balance was based on solving the system of Euler equations and flow control. Control laws are defined to control the flow and density of waste on the conveyor. A relay-contact scheme for automatic sorting of waste to extract various fractions of recyclable waste, such as metal, plastic, paper, glass and organic matter from MSW was developed. The synthesis of a finite state of a machine control system for waste sorting is implemented on a programmable logic device Omron [9-10].

Researchers have been exploring automated sorting techniques to improve the overall efficiency of recycling process. This paper reviews recent advances in physical processes, sensors, and actuators used as well as control and autonomy related issues in the area of automated sorting and recycling of source-separated MSW. We believe that this paper will provide a comprehensive overview of the state of the art and will help future system designers in the area. In this paper also present research challenges in the field of automated waste sorting and recycling. [11]

The main idea of this project is to design and implement a machine that sorts, and classifies three different types of materials which are iron, aluminum, and plastic. Then guide materials to different carts to prepare for the material recycling process. Materials are gravity-fed from the hopper to the conveyor. Then the entered materials are scanned by sensors (inductive and magnetic) that are connected to a programmable logic controller (PLC) which gives the order to air pistons that are located at the edges of the conveyor to move each type of materials to specific cart. [12]

In this paper, a cost-effective Automated Waste Segregator system for the segregation of waste at the household level is implemented. The proposed segregator system segregates the waste into three types, viz., metallic, wet and dry, and in addition, separating dry waste further into paper and plastic. Here, Arduino Uno board is used as the main controller and various sensors are used to detect each type of waste, which is segregated and thrown into the respective bins. Using this

automatic waste segregator system, the separated wastes can be sent directly for recycling [13],

Sorting tasks include the removal of fungus-infested grains, the enrichment of copper content in copper mining or the sorting of plastic waste according to the type of plastic. Sorting decisions are made based on information acquired by one or more sensors. A particular strength of the technology is the flexibility in sorting decisions, which is achieved by using various sensors and programming the data analysis. However, a comprehensive understanding of the process is necessary for the development of new sorting systems that can address previously unresolved tasks. This survey is aimed at innovative researchers and practitioners who are unfamiliar with sensor-based sorting or have only encountered certain aspects of the overall process [14].

In this research, we propose a novel application of the Vision Transformer (ViT) model for classifying 12 types of household garbage. Our approach leverages deep learning-based image classification capabilities to enhance waste categorization's precision and efficiency. The ViT model performs better than established models such as VGG16 and MobileNetV2. Empirical results show that the ViT model achieves an impressive accuracy of 95%, significantly surpassing the accuracy rates of the other models. This advancement addresses the limitations observed in previous research and contributes to more effective waste management practices by providing a reliable and accurate method for garbage classification. Our study introduces a robust and highly accurate Vision Transformer model for household garbage classification, highlighting its potential to revolutionize waste management systems. By outperforming traditional models, the ViT model sets a new benchmark in the field, paving the way for enhanced recycling processes and environmental sustainability [15].

2.3 Summary

From the literature discussed above, we gained a lot of knowledge and we were inspired to do this project. We were able to do it with everyone's tireless work.

Chapter 3

Theoretical Model

3.1 Introduction

In this chapter, we will discuss our system methodology, system description, block diagram, circuit diagram, working principle, and instrument cost analysis.

3.2 Materials and Methodology

To build an automatic waste sorting machine, you would need materials like: conveyor belts, sensors (including near-infrared, magnetic, and capacitive), actuators (like pneumatic cylinders or servo motors), sorting chutes, control system (microcontroller like Arduino), power supply, mechanical components (bearings, shafts, gears), housing structure, and depending on the complexity, vision systems for image analysis; essentially, a system to transport waste, detect different materials using sensors, and direct them to separate collection bins based on the detected type.

Key components and their functions:

- **Sensors:**
    - **Near-infrared (NIR) sensors:** Detect plastic types based on their spectral characteristics.
    - **Magnetic sensors:** Identify ferrous metals
    - **Capacitive sensors:** Detect the presence of conductive materials like aluminum
- **Actuators:**
    - **Pneumatic cylinders:** Can be used to push waste into designated chutes
    - **Servo motors:** Precisely control the movement of sorting mechanisms
- **Sorting chutes:** Separate waste streams based on detected material type
- **Control system (microcontroller):** Processes sensor data and directs

actuators to sort waste accordingly.

Considerations when choosing materials:

- **Sensor accuracy:** Choose sensors with high accuracy for the specific materials you want to sort.
- **Durability:** Components should withstand wear and tear from continuous waste processing.
- **Sorting capacity:** Design the system to handle the volume of waste expected.

The Methodology of this project are:

- The first step is to construct the different parts of the prototype and make sure that the different parts and components fit in the construction.
- The next step is to program the sensors and motors using a simulation program.
- The last stage is to test the prototype using different materials to see if the sensors and motors are properly functioning.

3.3 D Model of the Waste Sorting Machine

As Shown in Fig. 3.1, description of the automatic trash construction and software. All the plastic parts are produced with a 3D printer with PLA plastic (Polylactic acid) and designed in Solid Edge. 3D printer is a machine that constructs a physical object from a digital modeling file that is created from a modeling software such as Solid Edge. The concept behind a 3D printer is to compile layer-by-layer until the component is formed.



Figure 3.1: CAD Model of waste sorting Machine

3.4 Block Diagram

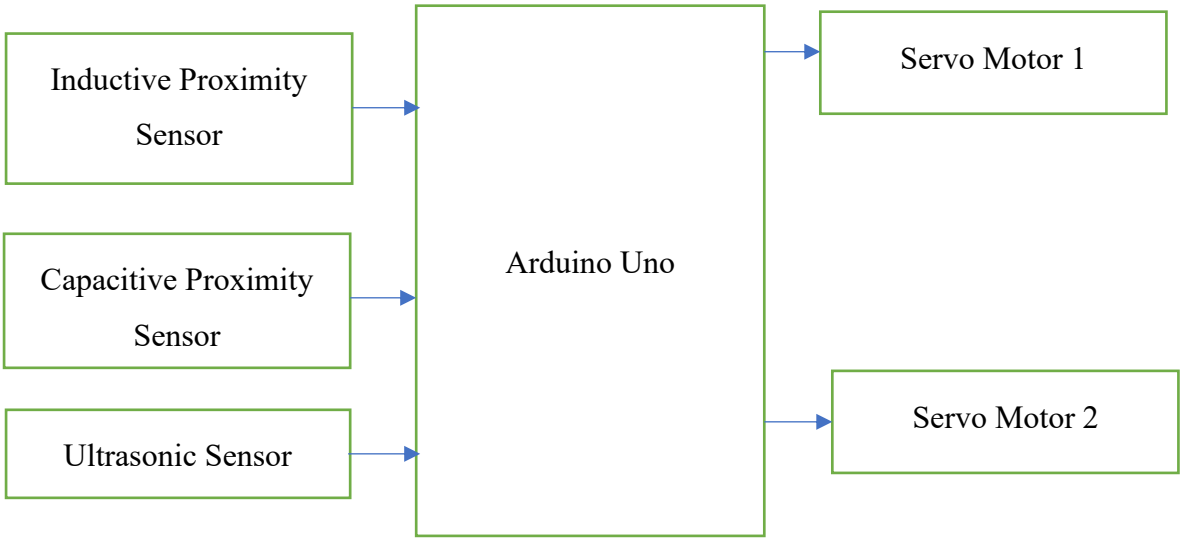


Figure 3.2: Block Diagram

This flexible drilling machine is initially started by connecting wires to the motor and then pairing the machine with a power supply. The machine consists of D.C. motors for rotating the drill bit and chuck, moving the connecting arm up and down, and giving it a full 360° rotation.

3.5 Circuit Diagram

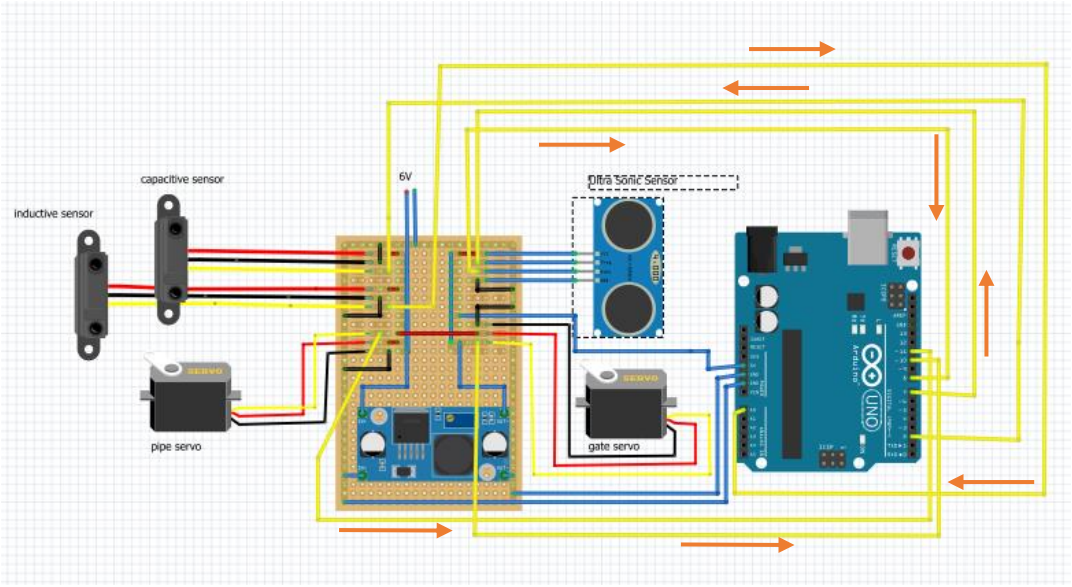


Figure 3.3: Schematic Diagram

As seen in the figure above, the electronic components have been soldered in a prototyping board. The general schema is the following: We utilized one 6V power supply which drives all the components. With this 6-volt provision, we powered the two servos, inductive sensor and the capacitive sensor. Next, we used a step-down converter to convert the 6V to 5V with which we can drive the Arduino via the 5V pin and power the ultrasonic sensor. When soldering one has to be careful and connect all the components to the same ground.

3.6 Complete Project Image



Figure 3.4: Final Project Prototype

3.7 Working Principle

The goal of this project is to sort three different types of waste: Plastic, Metal, and Glass. The waste is directed by the pipe into their respective waste bins. Sorting wastes of different sizes and shapes is not possible, but the performance is better with objects of cylindrical shape or cubic shape with limitations of the size (in terms of height) of Coca-Cola Cans (waste should be limited to a maximum of 300 gm). Objects smaller than 2 cm may pass undetected; larger than 10 cm may jam the conveyor.

The restrictions are due to the design constraints of our waste sorting machine, modifying the size of the sorting machine (e.g. Gate, Pipe diameter) will make it more adaptable to different shapes, sizes, and weights of the wastes.

The capacitive sensor is very sensitive in detecting plastic waste, anything inside/around the plastic object affects the accuracy of the sensor.

3.8 Components List

Hardware Part:

- Arduino Uno
- Inductive Sensors
- Capacitive Sensor
- Ultrasonic Sensors
- Motors
- Step Down Converter

Arduino Uno

In a nutshell, the Arduino Uno is an open-source microcontroller board based on the ATmega328P microcontroller. Various expansion boards shields, and other circuits can be interfaced with the board's digital and analog input/output pins. A type B USB cable is required to program the board using the Arduino IDE (Integrated Development Environment). It has 6 Digital pins and 12 Analog pins. An external 9-volt battery can be used to power it, or a USB cable can be used. It is also similar

to the Arduino Nano and Leonardo. It can be downloaded from the Arduino website and distributed under the Creative Commons Attribution-Share Alike 2.5 license. Various layouts and production files are also available.

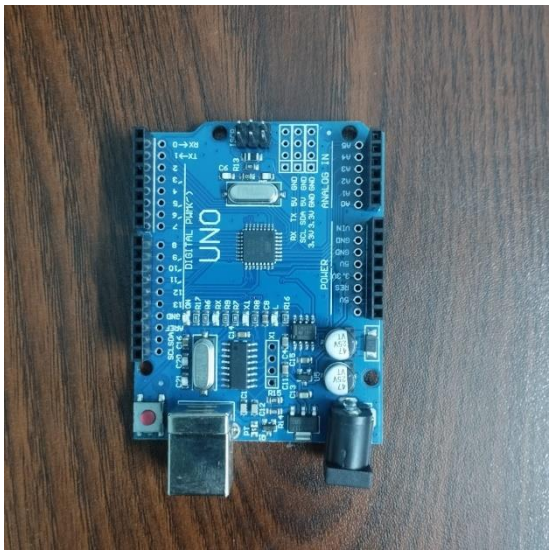


Figure 3.5: Arduino Uno

This initial release of the Arduino Software was given the name "Mega" for its Italian meaning. Arduino Uno was the first of a series of USB-based Arduino boards, and the Arduino IDE and Uno together were the first releases of Arduino software. A bootloader is already preprogrammed into the ATmega328, allowing programmers to upload new code without an external hardware programmer.

It is the first board not to include the FTDI USB-to-serial driver chip while using the STK500 protocol as its communication protocol. The USB-to-serial converter uses the Atmega16U2 (Atmega8U2 up to version R2) as an analog input.

Specifications:

Operative Voltage: 5V and 3.3V

Input Voltage: 5-12V (5V model) and 3.3-12V (3.3V model)

Digital I/O Pins: 14 Pins (6 are PWM output pins)

Analog Input Pins: 6 pins

DC Current per I/O Pin: 40 mA

Flash Memory: 32 kB (0.5 kB is taken by bootloader)

SRAM: 2 Kbytes

EEPROM: 1 Kbytes

Clock Speed: 16 MHz (5V model) and 8 MHz (3.3V model)

Table 3.1: ARDUINO Uno Configuration

Pin Group	Pin Name	Description
POWER SOURCE	VCC, GND, and RAW	VCC- Linked to +5V or +3.3V GND– Linked to Ground RAW– Linked to Unfettered power supply 5+V to +12V
Communication INTERFACE	UART Interface (RXD, TXD) SPI Interface (MOSI, MISO, SCK, SS) TWI Interface (SDA, SCL)	UART (Universal Asynchronous Receiver Transmitter) Interface can be used to program PRO MINI SPI (Serial Peripheral Interface) Interface can be used to program PRO MINI TWI (Two Wire Interface) Interface can be used to attach peripherals.
INPUT-OUTPUT PINS	PD0 to PD7 (8 pins of PORTD) PB0 to PB5 (6 pins of PORTB) PC0 to PC6 (7 pins of PORTC) ADC6 and ADC7 (2 extra pins)	They oblige various dedications, but they can be classified as data I/O pins.
ANALOG to DIGITAL CONVERTER	ADC0, ADC1, ADC2, ADC7	They can be used for analog input and feature 10-bit resolution.
PWM	OC0A, OC0B, OC1A, OC1B, OC2A, OC2B	It delivers PWM outputs and 8-bit tenacity.
RESET	RESET	Resets the controller.
EXTERNAL INTERRUPTS	T0 and T1	Hardware interrupts are provided by these two pins.
ANALOG COMPARATOR	AIN0 and AIN1	An internal comparator connects these two pins.

Inductive Sensor

An inductive sensor is a non-contact device that detects metallic objects using electromagnetic induction. It's often used in industrial applications to monitor the position, movement, or distance of metallic objects.



Figure 3.6: Inductive sensor

How inductive sensors work

- An electric current passes through an inductor, which creates a magnetic field.
- When a magnetic field changes, a current flows through a circuit with an inductor.
- When a metallic object interacts with the magnetic field, eddy currents are induced in the object.
- These eddy currents extract energy from the sensor's magnetic field, which changes the signal level in the sensor.
- The change in signal level then switches the output stage in binary sensors.

Applications

- Machine tools
- Coolants and lubricants
- Welding applications
- Wet areas and the food and beverage industry
- Material handling
- Refrigerated warehouses

Advantages

- Non-contact detection, Versatile, and Suitable for harsh environments.

Disadvantages

- Can produce errors due to temperature and exposure to other fields

Capacitive Sensor

A capacitive sensor is a non-contact device that detects objects by using an electrical field. It can detect solids, liquids, and even non-metallic objects.



Figure 3.7: Capacitive sensor

How it works

1. The sensor emits an electrical field.
2. When an object enters the field, it changes the electrical potential of the field.
3. This change is detected by the sensor and reported to an oscillator.
4. The oscillator changes its signal level, which is compared to a threshold.
5. If the signal level exceeds the threshold, the output stage is switched.

Uses

- Capacitive sensors are used in many industries, including food, chemical, semiconductor, wood, paper, and glass.
- They can be used to detect flow, pressure, liquid level, spacing, thickness, and more.
- They can be used in key, dimmer, and X-y tablets.

- They can be used to create fingerprint images.
- They can be used to measure the abrasion of brake discs.
- They can be used in touchscreens.

Other features

- Capacitive sensors can be flush-mounted or non-flush-mounted.
- They can have various shapes, sizes, and construction materials.
- They can have an adjustable sensing range.

Ultrasonic Sensor

It is a device that uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. High-frequency sound waves reflect across boundaries to produce distinct echo patterns. Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. The transducer of the sensor acts as a microphone to receive and send the ultrasonic sound. Our sensors, like many others, use a single transducer to send a pulse and to receive the echo. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse. This process is a key aspect of ultrasonic sensor work.



Figure 3.8: HC-SR04 Ultrasonic Distance Sensor Module

Specifications:

- Power & Logic Voltage: DC 5V
- Current during measurement: 15mA
- Ultrasonic Frequency: 40 KHz
- Measuring Angle: 15º
- Trigger Input Signal: 10uS high pulse
- Sensor dimensions (excluding header): 45.5 x 20 x 15.5mm
- Weight: 8.7g.

Applications

- Used to avoid and detect obstacles with robots like biped robot, obstacle avoider robot, path finding robot etc.
- Used to measure the distance within a wide range of 2cm to 400cm
- Can be used to map the objects surrounding the sensor by rotating it
- Depth of certain places like wells, pits etc can be measured since the waves can penetrate through water

Motor

This High-Torque MG996R Digital Servo features metal gearing resulting in extra high 10kg stalling torque in a tiny package. The MG996R is essentially an upgraded version of the famous MG995 servo, and features upgraded shock-proofing and a redesigned PCB and IC control system that make it much more accurate than its predecessor. The gearing and motor have also been upgraded to improve dead band width and centering. The unit comes complete with 30cm wire and 3 pin 'S' type female header connector that fits most receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum and Hitec. This high-torque standard servo can rotate approximately 120 degrees (60 in each direction). You can use any servo code, hardware or library to control these servos, so it's great for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. The MG996R Metal

Gear Servo also comes with a selection of arms and hardware to get you set up nice and fast!



Figure 3.9: Servo Motor MG996R

Specifications (Manufacturer):

- Power Supply: 4.8V to 7.2V
- Weight: 55g
- Dimension: 40.7 x 19.7 x 42.9 mm approx.
- Operating Speed: 0.17sec / 60 degrees (4.8V no load)
- Operating Speed: 0.14sec / 60 degrees (6.0V no load)
- Stall Torque: 9.4 kg-cm at 4.8V
- Stall Torque: 11 kg-cm at 6V
- Gear Type: All Metal Gears
- Connector Wire: Heavy Duty, 11.81" (300mm)

Step Down Converter

The DC/DC step-down voltage regulator is capable to convert voltage between 3.2V and 40V into a smaller voltage between 1.25V and 35V. It is capable of driving a 3A load.

We have adjusted this step-down converter for our requirements, respectively the 6V from the power supply has been converted to 5V which feeds the Arduino Uno; this has been done via the potentiometer for voltage adjustment.



Figure 3.10: LM2596

Specifications:

- Input voltage: 3.2V - 40VDC
- Output voltage: 1.25V - 35VDC
- Max. output Current: 3A
- Dimensions: 43mm x 21mm x 14mm(l) x (w) x (h)
- Weight: 12 g

Chapter 4

Data & Calculation

4.1 Power usages & Efficiency of the machine.

A. Power Consumption

Example Setup:

- Motor: 12V, 2A
- Arduino + Sensors: 12V, 0.5A
- Total current = 2.5 A
- Voltage = 12 V

Power:

$$\text{Power} = V \times I$$

= 12 V × 2.5 A

= 30 W

If you run it for 1 hour:

Energy used = 30W × 1hr

= 30 Wh

B. Separation Efficiency

Sorting efficiency is calculated using the formula:

$$\textbf{Efficiency} = \frac{Correctly\ Sorted\ Items}{Total\ Target\ Items} X\ 100$$

Experimental Data:

❖ **For Metal:**

- Total items input: 90
- Metal items in input: 30
- Correctly separated metals: 24

Efficiency = (24/30) × 100

= 80.0%

❖ **For Glass or Others:**

- Total items input: 90
- Glass items in input: 30

- Correctly separated metals: 26

Efficiency = (26/30) × 100
= 86.7%

❖ **Average efficiency across tests: 83.35%**

C. Throughput (Waste Processing Rate)

- Waste processed in 30 minutes = 10 kg

Throughput = (10kg/30min) × 60 = 20 kg/hour

4.2 Source of Waste

During the test runs, waste samples were gathered from:

- **Local residential households** – bottle caps, wire pieces.
- **University workshop lab** – scrap iron nails, bent rods.
- **Canteen bins** – plastic spoons, food wrappers, some aluminum foil.

4.3 Environmental Impact

The automated sorting machine helps reduce environmental damage in the following ways:

- **Reduces landfill metal content**, which can leak heavy metals into soil and groundwater
- **Encourages recycling,** which saves raw materials and energy
- **Minimizes human contact** with hazardous waste, improving worker safety
- **Supports cleaner surroundings**, especially in small communities or institutions

4.4 Instrument Cost Analysis

Serial No	Components	Price
01	Arduino Uno	1200
02	Inductive Proximity Sensor	880
03	Capacitive Proximity Sensor	2200
04	Ultrasonic Sonar Sensor	110
05	Servo Motor MG 996 R	1500
06	Connector	200
07	Mseal	100
08	T Connector	120
09	Basket	300
10	Plywood Board	900
11	PVC Board	400
12	Rod	500
13	Pipe	250
14	LM2596	300
15	Battery	270
16	Battery Case	60
17	Switch	10
18	Wire and Others	1000
Total		**10300 BDT**

Table 4.1: Cost analysis of instruments

Chapter 5

Results & Discussion

5.1 Introduction

In this chapter here we discuss our project result analysis and outcome, advantages, limitations, application, and discussion of our system.

5.2 Result Analysis

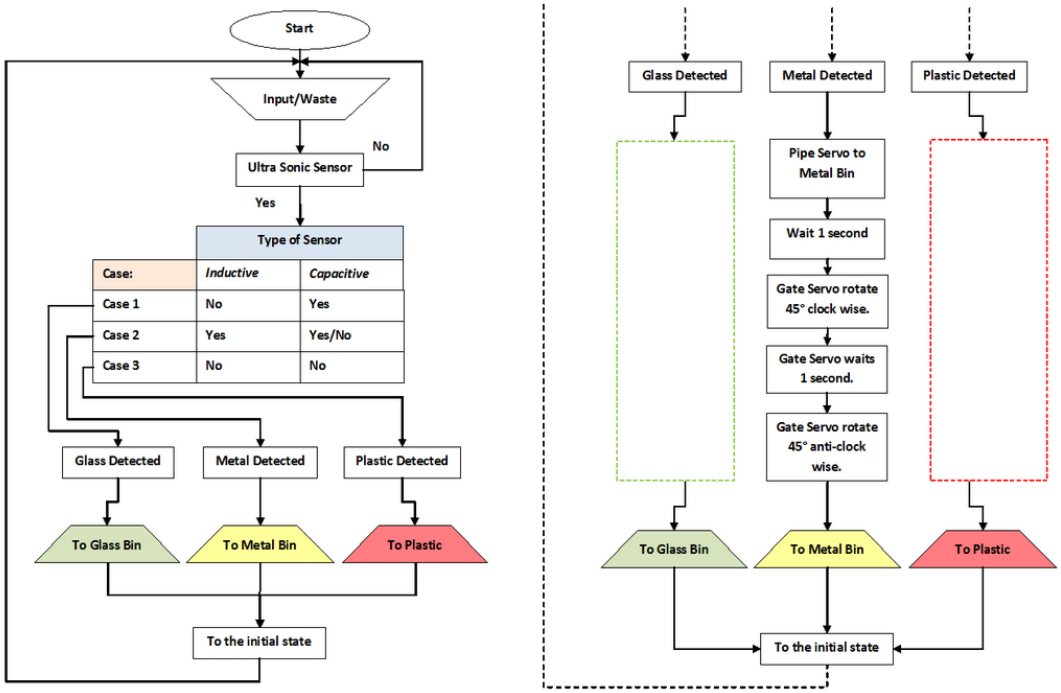


Figure 5.1: Working Flow Chart

To do the sorting of three different types of materials we have used three sensors. Based on these sensors values we can distinguish the type of material. We have 3 cases: Metal detected, Plastic Detected, Glass detected. As we can notice in the flowchart those three cases correspond to those specific state combinations of the sensors.

The programming is divided into these sections:

1. Initialization of the system

2. Object and Material Detection

3. Servos Movements

1. Initialization

Comment: In startup Gate and Pipe servo will go to a prescribed position, this procedure will be repeated in each start-up or reset. This part of the code will be executed only once in startup.

- Read the values for the actual position of the two Servo motors.

If Pipe position! = to the zero position

-move pipe to the zero position

-move gate and then bring it back to the initial position (This is done intentionally each system startup/reset; no matter if it is in the zero position or not)

If Pipe position == the zero position

-move gate and then bring it back to the initial position (This is done intentionally each system start-up/reset; no matter if it is in the zero position or not)

-Initialize sensors

2. Object and Material Detection

if (Inductive Sensor<=250 && Capacitive Sensor == 1 && Ultrasonic Sensor Distance<=14 cm)

-Plastic Detected: To Plastic Bin (step 3)

if (Inductive Sensor<=250 && Capacitive Sensor! =1 && Ultrasonic Sensor Distance<=14 cm)

-Glass Detected: To Glass Bin (step 3)

if (Inductive Sensor>=250) {

-Metal Detected: To Metal Bin (step 3)

3. Servos Movements

If Plastic Detected:

-Move Pipe Servo to Plastic Bin

-Delay

-Move Gate Servo from position 0 to 1

-Delay

-Move Gate Servo from position 1 to 0

If Glass Detected:

-Move Pipe Servo to Glass Bin

-Delay

-Move Gate Servo from position 0 to 1

-Delay

-Move Gate Servo from position 1 to 0

If Metal Detected:

-Move Pipe Servo to Metal Bin

-Delay

-Move Gate Servo from position 0 to 1

-Delay

-Move Gate Servo from position 1 to 0

In the following section the code will be provided.

5.3 Advantages

There are certainly many advantages of our project and some of the major ones have been given below:

- **High efficiency and throughput:**

Can sort large volumes of waste quickly and accurately, minimizing manual labor and time spent on sorting.

- **Improved recycling quality:**

Accurately separates different materials, leading to cleaner recycled streams and higher value for recycled products.

- **Reduced landfill waste:**

By effectively separating recyclable materials, less waste ends up in landfills.

- **Cost savings:**

Can potentially reduce labor costs associated with manual sorting.

- **Reduced environmental impact:**

Contributes to sustainable waste management by maximizing recycling potential.

- **Flexibility:**

Can be designed to sort a variety of materials, including plastic, paper, metal, glass, and more.

- **Improved worker safety:**

Eliminates the need for workers to manually handle potentially hazardous waste.

- **Advanced technology:**

Can incorporate sensors and image recognition for precise sorting, even with complex waste streams.

5.4 Limitation

This project has some disadvantages. These are –

- **Accuracy issues with complex waste:**

Sorting machines can struggle to accurately identify and separate items with similar appearances, mixed materials, or unusual shapes, leading to misclassification and contamination in recycling streams.

- **Cost and maintenance:**

Implementing an automated waste sorting system can involve significant upfront costs for the equipment and ongoing maintenance to ensure optimal functionality.

- **Waste stream variability:**

New packaging designs or changes in waste composition can require system adjustments, making it difficult to adapt to evolving waste streams.

- **User education needed:**

Effective operation relies on proper waste segregation by users, which may require ongoing education to ensure they dispose of items correctly.

- **Space constraints:**

Depending on the scale of the system, significant space may be required for the sorting machine and associated infrastructure.

- **Sensor limitations:**

Sensors used to identify waste materials may not always be able to accurately detect certain materials, especially when dealing with contaminated or obscured items.

- **Contamination issues:**

Even with advanced sorting technology, some level of contamination within the recycled materials may still occur.

- **Potential for breakdowns:**

Mechanical components of the sorting machine can experience malfunctions, leading to disruptions in the sorting process and requiring repairs.

5.5 Application

This project has applications in many fields due its necessity. We have selected a few of them and they are given below:

- **Municipal Solid Waste (MSW) Management:**

Sorting household waste to separate recyclables like plastic bottles, aluminum cans, newspapers, and cardboard, allowing for higher recycling rates in cities.

- **Construction and Demolition Waste Recycling:**

Sorting construction debris like wood, metal, concrete, and drywall to recover reusable materials, minimizing waste sent to landfills.

- **Industrial Waste Processing:**

Separating different types of industrial waste, such as plastic scrap, metal shavings, and electronic waste, to facilitate efficient recycling and reuse.

- **Organic Waste Separation:**

Identifying and separating organic materials like food scraps for composting, creating valuable fertilizer, and reducing landfill waste.

- **Electronics Recycling:**

Sorting electronic components like plastics, metals, and precious metals from discarded electronics to recover valuable materials.

5.6 Discussion

The waste when exposed to our automatic waste segregator and monitoring system. The proposed system would be able to monitor the solid waste collection process and management of the overall collection process. It would provide in-time solid waste collection. The technologies which are used in the proposed system are good enough to ensure the practical and perfect for solid waste collection process monitoring and management for green environment. The waste segregator as the name suggests, segregates the waste into three major classes: plastic, organic, and metallic. The proposed system would be able to monitor the solid waste collection process and management of the overall collection process. The inlet section is provided with an open and close mechanism to regulate the flow of waste onto the conveyor. The inductive proximity sensor is used to detect metallic waste. A blower mechanism is used to segregate dry and wet waste. The timing and movement of the conveyor belt is controlled by Arduino Uno. Continuous and unnecessary operation of any particular section is thus avoided

Chapter 6

Conclusion

6.1 Conclusion

An automatic waste sorting machine represents a significant advancement in waste management by utilizing advanced technology to efficiently identify, categorize, and sort various waste materials, significantly reducing manual labor while maximizing resource recovery from waste streams, contributing to a more sustainable and environmentally friendly approach to waste management through increased recycling and reduced landfill reliance; as technology evolves, these machines are expected to become even more accurate and capable in their waste sorting capabilities. By implementing sustainable waste management practices, such as waste reduction, recycling, composting, and the use of modern landfills and waste-to-energy facilities, we can reduce our impact on the environment and conserve resources for future generations.

This work describes the design and production of an automatic solid waste sorting machine with a smart digital counter. The machine was designed using a microcontroller (Arduino Uno) to control the conveyor system which consists of the conveyor support, driving unit, and the driven unit. The sorting mechanism consists of the inductive sensor, infrared Sensor, and the actuating system using a servo motor. The conveyor system helps in the conveyance of objects towards the sorting chute. The actuating system receives a signal from the microcontroller and the device does the sorting of the objects based on their characteristics while the digital counter counts the number of metallic objects dropping into the designated cart. The time taken for the inductive sensor to sense an object, the waiting period for the servo motor to be actuated and the time taken for the counter to count after a metallic object is sensed are 1s, 2s, and 1s respectively. After its development, it was tested and observed to meet the design requirements.

6.2 Future Recommendation

Automatic Sorter Machine for Smart Waste Management System can be deployed to solve our existing problem as well as bring about a change in our daily life by meeting our demands.

A. Sorting More

Types of Materials The developed Automatic Sorter Machine for Smart Waste Management System can sort only four waste materials. If more sensors are used then it will be possible to sort more types of materials (Such as Transparent and nontransparent plastics, thick and thin papers, Semiconductors and Conductors, Rubber materials, Organic, etc.).

B. Reduction of Cost

Companies that are manufacturing and distributing trash bins throughout the world, currently producing manual trash bins. If a large-scale production of an Automatic Sorter Machine for a Smart Waste Management System is possible then the price of this product will be cheaper than the present manufacturing cost. It will be cheaper because the mechanical structure is very simple and the sensors will be industrial-grade.

C. Increasing Response Time

The response time of the electromechanical system is relatively fast. But it can be made faster by using an industrial-grade servo motor. The microcontroller and servo motor used in the presently developed Automatic Sorter Machine for Smart Waste Management System are properly synchronized. When the industrial-grade servo motor is used, then the system should be synchronized to perform smoothly and faster.

D. Health Service

A special type of sensor could be used to sort out the organic parts of the waste. When the organic parts of the waste are sorted out then they may be tested automatically to find out the food habits of the user and analyze it for the improvement of the user's diet. Another application of sorting out the organic parts of the waste is, that the organic parts may help to diagnose several diseases of the user. Thus, the health issues of the user of the Automatic Sorter Machine for Smart

Waste Management System will be insured to some extent.

E. Primary Recycling and Reusing Unit

A primary recycling and reusing plant may be installed with the automatic sorter machine. This will ensure that a home user will practice recycling and reusing. The primary plant may consist of only paper or plastic recycling units. This will ensure a healthier lifestyle and guarantee cost minimization for the home or industrial users.

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APPENDIX

```
#include <Servo.h>

Servo Pipe_Servo;
Servo Gate_Servo;

// define the variables
int sensorInd = A0;
int sensorpin = 2;
int indValue;
const int trigPin = 7;
const int echoPin = 8;
int i=0;
float Pipe_Pos=0.0;
float Gate_Pos=0.0;
int n=0;

long duration;
int distance;

float metalDetected;
void setup() {
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);

Serial.begin(9600);
```

```
  Pipe_Pos=Pipe_Servo.read();
  Gate_Pos=Gate_Servo.read();
  Serial.println("Motor_PIPE Position");
  Serial.println(Pipe_Pos);
  Serial.println("Motor_GATE Position");
  Serial.println(Gate_Pos);
  delay (5000);

  Pipe_Servo.attach(11);

  if (Pipe_Pos<90){
   for(i=Pipe_Pos; i<=90; i=i+1){
   Pipe_Servo.write(i);
   delay (15);
   }
  }
   else {
    for(i=Pipe_Pos; i>=90; i=i-1){
    Pipe_Servo.write(i);
    delay(15);
    }
   }
delay (1000); //Delay (wait) for servo pipe to go to the bin.
```

```
 Gate_Servo.attach(10);

     for(n=0; n<=45; n=n+1){  //Choose the right angle for Gate servo
      Gate_Servo.write(n);
      delay(20);
    }
   delay(1000);

     for(n=45; n>=0; n=n-1){
      Gate_Servo.write(n);
      delay(25);
     }
delay(5000);

void loop() {

delay(3000);

digitalWrite(trigPin, LOW);
delayMicroseconds(10);//

digitalWrite(trigPin, HIGH);
delayMicroseconds(30);//it was 1
digitalWrite(trigPin, LOW);

duration = pulseIn(echoPin, HIGH);
```

```
distance= duration*0.034/2;

Serial.print("Distance: ");
Serial.println(distance);

indValue=analogRead(sensorInd);
delay(10);
int sensorstate = digitalRead(sensorpin);
delay(500);
metalDetected = (float)indValue*100/1024.0;
delay(50);
Pipe_Pos=Pipe_Servo.read();
Gate_Pos=Gate_Servo.read();

  if(indValue>=250){
   Serial.println("Metal Detected");
    Pipe_Pos=Pipe_Servo.read();
    Gate_Pos=Gate_Servo.read();
    Serial.println("Motor_PIPE Position");
    Serial.println(Pipe_Pos);
    Serial.println("Motor_GATE Position");
    Serial.println(Gate_Pos);


    Serial.println("Motor to metal bin");
```

```
    delay(100);

    if (Pipe_Pos<90){

     for(i=Pipe_Pos; i<=90; i=i+1){
     Pipe_Servo.write(i);
     delay(15);
     }
    }

     else {
       for(i=Pipe_Pos; i>=90; i=i-1){
       Pipe_Servo.write(i);
       delay(15);

       }
     }

delay(1000); //Delay (wait) for servo pipe to go to the bin.

     for(n=0; n<=45; n=n+1){
     Gate_Servo.write(n);
     delay(20);
    }
```

```
  delay(1000); //Delay (wait) and then bring back the Gate_Servo to its initial position.

   //Bring Back Gate_Servo to initial position
   //So from actual position 2--> n=45; we go backwards up to n=0.

   for(n=45; n>=0; n=n-1){
    Gate_Servo.write(n);
    delay(25);
   }
  }

  else if(indValue<=250 && sensorstate == 1 && distance<=15){ //NO NO state
  delay(100);
  Serial.println("Plastic Detected");

   Pipe_Pos=Pipe_Servo.read();//Read the last value given to Pipe servo
   Gate_Pos=Gate_Servo.read();//Read the last value given to Pipe servo
   Serial.println("Motor_PIPE Position");
   Serial.println(Pipe_Pos);
   Serial.println("Motor_GATE Position");
   Serial.println(Gate_Pos);
   Serial.println("Motor to Plastic Bin");

   delay(100); //We should tune this but just in case to remmeber
   //Wait for some time after the measurements and move servo to
```

```
  if (Pipe_Pos<145){

   for(i=Pipe_Pos; i<=145; i=i+1){
   Pipe_Servo.write(i);
   delay(15);
   }
  }
   else {
    for(i=Pipe_Pos; i>=145; i=i-1){
    Pipe_Servo.write(i);
    delay(15);

    }
   }

delay(1000); //Delay (wait) for servo pipe to go to the bin.

   for(n=0; n<=45; n=n+1){
   Gate_Servo.write(n);
   delay(20);
  }
  delay(1000); //Delay (wait) and then bring back the Gate_Servo to its
   for(n=45; n>=0; n=n-1){  //Choose the right angle for Gate servo
   Gate_Servo.write(n);
   delay(25);
```

```
  }
else if(indValue<=250 && sensorstate != 1 && distance<=14){
  Serial.println("Glass Detected");

   Pipe_Pos=Pipe_Servo.read();//Read the last value given to Pipe servo
   Gate_Pos=Gate_Servo.read();//Read the last value given to Pipe servo
   Serial.println("Motor_PIPE Position");
   Serial.println(Pipe_Pos);
   Serial.println("Motor_GATE Position");
   Serial.println(Gate_Pos);
   Serial.println("Motor to Glass Bin");

   delay (1000)
   if (Pipe_Pos<25){

    for (i=Pipe_Pos; i<=25; i=i+1){
    Pipe_Servo.write(i);
    delay (15);
    }
   }

    else {
      for(i=Pipe_Pos; i>=25; i=i-1){
      Pipe_Servo.write(i);
      delay(15);
```

```
      }
     }
delay (1000); //Delay (wait) for servo pipe to go to the bin.

   //Next rotate the gate servo.//This remains the same for all other cases
   //And control the speed of Gate Servo.

    for(n=0; n<=45; n=n+1){
     Gate_Servo.write(n);
     delay(20);
   }
   delay(1000); //Delay (wait) and then bring back the Gate_Servo to its
    //initial position.

    //Bring Back Gate_Servo to initial position
    //So from actual position n=45; we go backwards up to n=0.
    for(n=45; n>=0; n=n-1){
     Gate_Servo.write(n);
     delay (25);
    }
   Serial.println("Motor_PIPE Position");
   Serial.println(Pipe_Pos);
   Serial.println("Motor_GATE Position");
   Serial.println(Gate_Pos);
}
}
```