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AUTOMATIC WASTE SORTING SYSTEM

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*Abstract:*The Automatic Waste Sorting Machine aims to revolutionize the way we manage and recycle waste by automating the sorting process using advanced sensor technology. In an aera where waste management is becoming an increasingly significant global concern, the project focuses on providing an innovative solution to improve the efficiency of waste sorting, reducing human labor, and ensuring more accurate and sustainable recycling practices. By integrating sensors such as inductive, capacitive, and ultrasonic sensors with Arduino microcontrollers and servo motors, the machine is designed to automatically sort three types of waste materials—plastic, metal, and glass—into their respective bins. The system uses inductive sensors to detect metal objects, capacitive sensors to detect plastic and glass, and ultrasonic sensors to monitor the position of waste within the sorting system. The machine is programmed to sort the materials based on the sensor readings, directing them to different bins through mechanical actuators. The objective of this project is not only to automate waste management in households and industrial settings but also to lay the groundwork for future innovations in waste sorting systems that can identify a wider range of materials and handle larger volumes of waste. This report outlines the design, working, methodology, and results of the Automatic Waste Sorting Machine, discussing its components, programming, challenges, and future potential improvements

I. INTRODUCTION

Waste management and recycling are crucial aspects of environmental sustainability. With the increasing global population and urbanization, the amount of waste generated has skyrocketed, leading to pressing concerns about its disposal and environmental impact. Traditional waste sorting is often carried out manually, which is not only time-consuming but also prone to errors. Moreover, manual sorting is expensive and labor-intensive, creating a demand for automated waste management solutions that can streamline the process, reduce human error, and promote recycling on a larger scale.

The Automatic Waste Sorting Machine is an innovative solution designed to address these challenges. By integrating a range of sensors and microcontroller-based systems, the project automates the process of waste segregation into different bins. The system can detect metal, plastic, and glass objects, segregating them into individual waste bins based on their material type. This sorting mechanism not only makes the recycling process more efficient but also reduces the need for manual labour, making waste management systems more cost-effective and accurate.

The integration of sensors like inductive, capacitive, and ultrasonic into a machine controlled by Arduino microcontrollers opens up a new realm of possibilities for future applications. The machine is designed to sort three types of waste, with the potential to be adapted for additional types of materials. The aim of this project is to explore how automation can be leveraged to improve waste management, reduce waste contamination, and promote a more sustainable and eco-friendly approach to recycling.

II. LITERATURE SURVEY

Waste management, particularly the sorting of recyclable materials, plays a crucial role in reducing the environmental impact of solid waste. Proper waste segregation not only reduces landfill waste but also enhances recycling efforts, contributing to environmental conservation. While manual sorting is still prevalent, automation offers a more efficient and accurate alternative. This literature survey explores the current state of automatic waste sorting technologies, reviewing existing systems, their capabilities, and the advancements in sensor technologies and robotics used for waste segregation.

1. Waste Sorting and its Importance

Waste sorting refers to the process of categorizing waste materials into separate groups to be recycled, reused, or disposed of in an environmentally-friendly manner. According to a study by Gassama et al. (2020), the failure to separate waste at the source significantly reduces the quality of recyclables and increases the cost of waste treatment. Effective waste sorting enables higher-quality recyclables and a more efficient waste management system, significantly contributing to environmental sustainability.

***2.* Manual vs. Automated Waste Sorting**

Traditionally, waste sorting is carried out manually, with workers physically sorting different types of waste into categories. While this approach can be effective, it is labor-intensive, prone to human error, and inefficient in terms of time and cost. Manual sorting also exposes workers to hazardous materials, making it a risky process. To address these challenges, automated waste sorting systems have been developed that employ a combination of sensor technologies, robotics, and machine learning algorithms to automate the process of detecting and sorting materials.

3. Sensor Technologies for Waste Sorting

Modern automated waste sorting systems often rely on various sensor technologies to detect the materials in waste. The sensors used in waste sorting are typically categorized based on the physical properties they measure, including electromagnetic fields, capacitance, and distance.

Inductive Sensors: Inductive proximity sensors are widely used to detect metal objects in waste. These sensors detect changes in the magnetic field caused by conductive materials, especially metals. According to Reisman et al. (2017), inductive sensors are particularly effective in sorting metals such as aluminum, iron, and steel, which are commonly found in waste streams. In the context of waste sorting, inductive sensors are used to identify metals and direct them to the appropriate recycling bin.

Fig: inductive sensor

Capacitive Sensors: Capacitive sensors are used to detect non-metallic objects based on their dielectric properties. These sensors measure the changes in capacitance when an object with a different dielectric constant, such as plastic or glass, comes near. Salah et al. (2021) explain that capacitive sensors can be fine-tuned to detect specific materials like plastic and glass, enabling more efficient waste segregation. The capacitive sensor's sensitivity can be adjusted to ensure accurate detection, especially when materials like plastic are difficult to distinguish from other materials.

Fig: capacitive sensor

Ultrasonic Sensors: Ultrasonic sensors are frequently used in waste sorting systems to measure the distance between the sensor and the material. These sensors emit sound waves and measure the time it takes for the wave to bounce back, determining the distance to the target object. Huang et al. (2019) highlight the importance of ultrasonic sensors in sorting systems, as they allow the system to detect the position of materials within the system, ensuring that they are properly positioned for sorting.

Fig: ultrasonic sensor

Optical Sensors: Optical sensors, such as cameras and spectrometers, are also gaining popularity in automated waste sorting. These sensors analyze the physical appearance and color of materials to identify specific types of waste, such as plastic bottles or paper. According to Cohen et al. (2020), optical sorting systems are particularly useful in sorting complex waste streams, including mixed plastics and paper products, based on visual cues.

Fig: optical sensor

Microcontroller ATMEGA328: Arduino UNO is an open source prototyping platform based on ATmega328 microcontroller. It consists of 14 digital input/output (I/O) pins, six analogue inputs, a USB connection for programming the on-board microcontroller, a power jack, an ICSP header and a reset button. It is operated with a 16MHz crystal oscillator and contains everything needed to support the microcontroller.

4. Challenges and Future Directions

While automated waste sorting systems have made significant progress, several challenges remain that need to be addressed for widespread adoption.

Sensor Limitations: Sensors such as capacitive and inductive types have their limitations, especially in detecting complex materials. Capacitive sensors may struggle to distinguish between similar materials with similar dielectric properties. Similarly, inductive sensors may fail to detect non-ferrous metals or objects that are too small to affect the electromagnetic field.

System Integration: Integrating various sensors, actuators, and robotic arms into a cohesive system remains a technical challenge. Ensuring that all components work seamlessly together requires careful calibration and synchronization.

Cost and Scalability: The cost of deploying automated waste sorting systems can be prohibitively high, especially for small-scale applications. Reducing the cost of sensors and actuators and improving the scalability of the system will be key to making these systems more accessible.

Handling Complex Waste Streams: Current systems are primarily designed to sort a few basic materials. However, the complexity of waste streams—especially in urban and industrial settings—requires the ability to sort a larger variety of materials, including mixed plastics, organic waste, and electronic waste (e-waste)

III.WORKING

The working of the Automatic Waste Sorting Machine involves several key steps, which are detailed below:

Initialization: When the machine is powered on, the system initializes by setting the servo motors to their home positions. This ensures that all components are in a known state before starting the sorting process. The sensors are calibrated during initialization to ensure accurate material detection

Material Detection: As waste enters the detection area, the inductive sensor detects metal objects by sensing changes in the magnetic field caused by the metal.

The capacitive sensor identifies plastic and glass objects by measuring the change in capacitance when the material approaches. The sensor is fine-tuned to distinguish between plastic and glass based on their dielectric properties.

The ultrasonic sensor continuously measures the distance of the object from the sensor. This helps the system determine whether the object is within the sorting range and ready to be moved.

Sorting Process: Once the material is detected, the system processes the sensor readings and determines the type of material. Based on the material type, the corresponding servo motor is activated to move the waste to the appropriate bin.If metal is detected, the pipe servo directs the material to the metal bin.If plastic is detected, the pipe is moved to the plastic bin.If glass is detected, the material is directed to the glass bin.If glass is detected, the material is directed to the glass bin.

Servo Control: The servo motors are controlled using PWM (Pulse Width Modulation) signals from the Arduino Uno. The servo motors move to specific angles based on the input from the sensors, ensuring that each type of waste is directed to its respective bin.

The system is designed to return the servo motors to their initial positions after each sorting cycle to ensure the system is ready for the next round of waste detection.

End of Process: After the waste is sorted, the system waits for the next item to be detected. The process repeats for each piece of waste that enters the system.

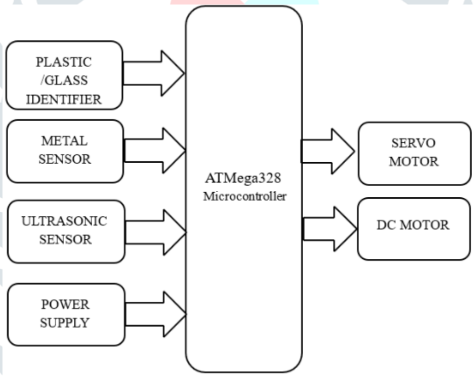


Fig: block diagram

5.METHODOLOGY

The development of the Automatic Waste Sorting Machine involved several stages, including system design, component selection, programming, and testing. Below is a detailed overview of the methodology followed:

Design and Component Selection: The first step was to define the requirements and design the system. The machine was designed to use inductive sensors for metal detection, capacitive sensors for plastic and glass detection, and ultrasonic sensors to measure distance. The mechanical structure was designed to hold the sensors and motors in place while ensuring smooth operation.

Components like Arduino Uno, servo motors, sensors, and power supply were selected based on their suitability for the application and their compatibility with the Arduino platform.

Mechanical Design: The frame of the machine was constructed using a combination of 3D printed parts and laser cut parts. The frame holds the sensors and servos in place and provides the necessary support for the sorting mechanism. The V-gate and pipe mechanisms were designed to move the waste to the respective bins based on the sensor readings.

Programming: The Arduino Uno was programmed to control the servo motors and process the sensor inputs. The code was written in the Arduino IDE and used standard libraries to interface with the sensors and motors.

The system was programmed to initialize the servos, detect materials, and sort them using a series of conditional statements based on sensor values. The system was also programmed to handle errors and perform initialization routines.

Testing and Calibration: The system was tested with different types of waste materials to ensure that the sensors could accurately detect metal, plastic, and glass. Calibration of the sensors was an important part of the process, as the sensitivity of the sensors needed to be adjusted to accurately differentiate between different materials.The system was iteratively tested, and adjustments were made to the code and hardware to improve accuracy and efficiency.

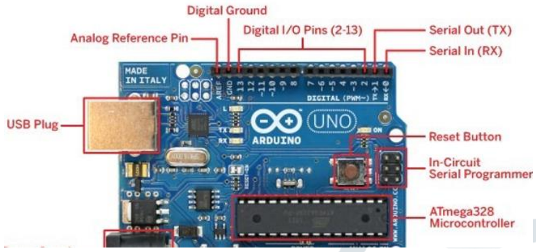
What is Arduino?

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, turn it into an output - activating a motor, turning on an LED. We can tell your board what to do by sending a set of instructions to the microcontroller on the board.

About Arduino: The new prototype board, the Arduino, created by **Massimo Banzi** and other founders, is a low-cost microcontroller board that allows even a beginner to do great things in electronics. An Arduino can be connected to all kind of lights, motors, sensors and other devices; easy-to-learn programming language can be used to program how the new creation behaves. Using the Arduino, you can build an interactive display or a mobile robot or anything that you can imagine. David A. Mellis, the lead software developer of Arduino, states that this little board has made it possible for people to do things they wouldn't have done otherwise.

ARDUINO UNO BOARD: The 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 a AC-to-DC adapter or battery to get started.. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few Rupees and start over again.

"Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards.



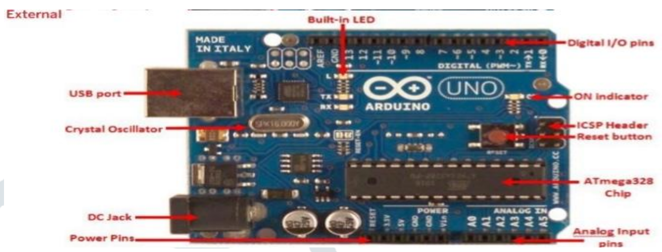


Fig: Arduino uno board

Component Explanations:

- ***Analog input Pins:*** Pins (A0-A5) that take-in analog values to be converted to be represented with a number range 0-1023 through an Analog to Digital Converter (ADC).
- ***ATmega328 chip:*** 8-bit microcontroller that processes the sketch you programmed.
- ***Built-in LED:*** In order to gain access or control of this pin, you have to change the configuration of pin 13 where it is connected to.
- ***Crystal Oscillator:*** clock that has a frequency of 16MHz
- ***DC Jack:*** where the power source (AC-to-DC adapter or battery) should be connected. It is limited to input values between 6-20V but recommended to be around 7-12V.
- ***Digital I/O pins:*** Input and output pins (0-13) of which 6 of them (3, 5, 6, 9, 10 and 11) also provide PWM (Pulse Width Modulated) output by using the analogWrite() function. Pins (0 (RX) and 1 (TX)) are also used to transmit and receive serial data.
- **ICSP Header:** pins for "In-Circuit Serial Programming" which is another method of programming.
- ***ON indicator:*** LED that lights up when the board is connected to a power source.
- ***Power Pins:*** Pins that can be used to supply a circuit with values VIN (voltage from DC Jack), 3.3V and 5V.
- ***Reset Button:*** A button that is pressed whenever you need to restart the sketch programmed in the board.
- ***USB port:*** Allows the user to connect with a USB cable the board to a PC to upload sketches or provide a voltage supply to the board. This is also used for serial communication through the serial monitor from the Arduino software.

Table: technical specification

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA

DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Sensors & comparators:

Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. A Sensor converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into a signal which can be measured electrically.

Criteria to choose a Sensor: There are certain features which have to be considered when we choose a sensor. They are as given below

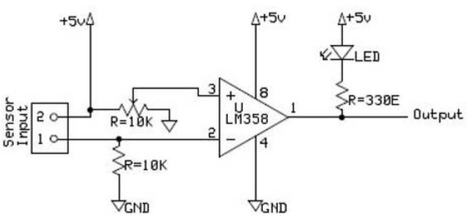
Accuracy
Environmental condition - usually has limits for temperature/ humidity
Range - Measurement limit of sensor
Calibration - Essential for most of the measuring devices as the readings changes with time
Resolution - Smallest increment detected by the sensor
Cost
Repeatability - The reading that varies is repeatedly measured under the same environment

IR sensor:

Level Sensing circuit (IR transceiver): The sensor circuit mainly consists of two blocks i.e. IR transmitter and IR receiver. The transmitter transmits the IR rays continuously and received by the receiver. When the beam is broken a high to low signal produced, that signal is fed to the microcontroller. These circuit are unaffected by sunlight and other artificial lights; range of this circuit is about 5 meters without any lenses. Range can be extended further by using lenses or reflector with sensors.

Fig: IR sensor

Comparator circuit: The LM358 consist of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltage. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. Application areas include transducer amplifier, DC gain blocks and all the conventional OPAMP circuits which now can be easily implemented in single power supply systems. Here we using LM358 as a comparator circuit.



COMMUNICATION:

Communication is the activity of conveying information through the exchange of messages, or information. The system which is to displays the next station information. To establish the communication between the station and Train we using RF communication system.

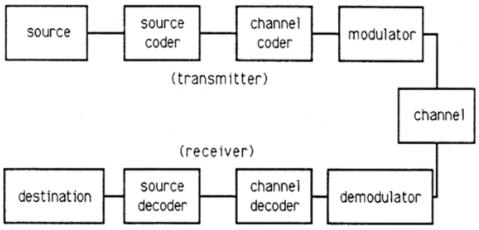


Fig: block diagram of communication system

Transmitter*:* Transmitter is the transmitting part in this block diagram. Using this system we can generate the messages which are to be sent through this system.
Receiver: This is the Receiving part in block diagram of communication system. This can be said as the target to which the information needs to be delivered.
Encoder:Encoder is the second element in the communication system. It performs the encoding of the given data, which means that this system converts the messages in the form of symbols for transmission purpose. In this system, sequences of characters are created in a special format for an effective transmission. This encoding system is used for security purpose.
Decoder: Decoder is used to decode the encoded message and retrieve the actual message. Decoding must be done correctly. If this part is not performed well then, the message which is received might not be correct.This encoding and decoding will be very help full in military and mobile communications.

Channel: This is the main block in the block diagram of communication system. Noisy channel is nothing but the medium through which the message is transmitted. Messages are conveyed through this channel. Different channels have different strengths and weaknesses. Each channel has its own frequency and different applications have different operating frequencies.
Modulation and Demodulation: *Modulation* is a process, in which any one of the characteristics (Amplitude, Phase, and Frequency) of carrier wave is varied in accordance with the message signal. Retrieving the original message signal from the Modulated signal is known as Demodulation.

LCD (16X2) display:
LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.
The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. Click to learn more about internal structure of a LCD.

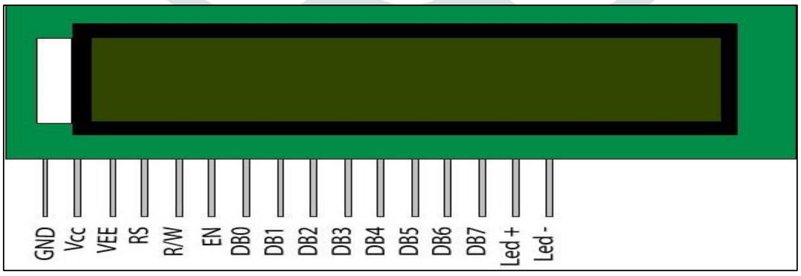


Fig: pin configuration of 2X16LCD

SERVO MOTOR:

What is a Servo Motor?
A **servo motor** is an electrical device which can push or rotate an object with great precision. If you want to rotate and object at some specific angles or distance, then you use servo motor. It is just made up of simple motor which run through **servo mechanism**. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. We can get a very high torque servo motor in a small and light weight package. Doe to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

Fig: servo motor

Working principle of Servo Motors: A servo consists of a Motor (DC or AC), a potentiometer, gear assembly and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from other source, will be processed in feedback mechanism and output will be provided in term of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with potentiometer and as motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

Controlling Servo Motor: All motors have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU.

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

Servo motor works on **PWM (Pulse width modulation)** principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of **DC motor which is controlled by a variable resistor (potentiometer) and some gears**. H igh speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle.

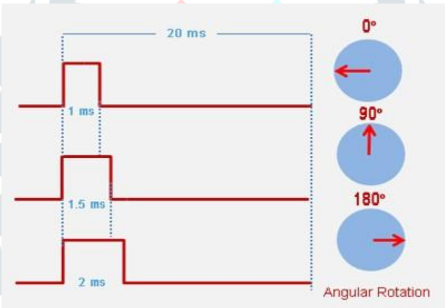


Fig: controlling of servo motor

Lrotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing. This degree of rotation can be controlled by applying the **Electrical Pulse** of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. Pulse of 1 ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2 ms pulse can rotate it to 180 degree.

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume, if you are planning to use more than two servo motors a proper servo shield should be designed.

SOFTWARE DEVELOPMENT

software installation

Installing ARDUINO IDE

To install the Arduino IDE for Windows, follow these instructions:

1. Download .exe file from website: http://arduino.cc/en/Main/Software/
2. Once the download is complete, double-click the file, and extract it. (Usually the file is downloaded in .zip format)
3. The extracted "Arduino" named folder is to be copy and paste it into C-Drive, and

Open the folder, if you wish create the shortcut of Arduino.exe file on your desktop.

Installing DRIVERS

The next task is to install the drivers for your Arduino board's USB interface.

1. Connect your Arduino to your PC with the USB cable. After a few moments an error message will be displayed, which will say something like "Device driver software not successfully installed." Just close that dialog or balloon.
2. Navigate to the Windows Control Panel. Open the Device Manager and scroll down until you see the ports or Arduino,

3. Right-click *Arduino Uno* under Other Devices and select Update Driver Software. Then, select browse option and update the drivers.

Taking a look Around the IDE

The IDE is divided into three main areas: the command area, the text area, and the message window area.

Fig: window

The Command Area

The command area includes the title bar, menu items, and icons. The title bar displays the sketch's filename. Below this is a series of menu items (File, Edit, Sketch, Tools, and Help) and icons.

The Icons

Below the menu toolbar are six icons. Mouse over each icon to display its name. The icons, from left to right, are as follows:
Verify: Click this to check that the Arduino sketch is valid and doesn't contain any programming mistakes.
Upload: Click this to verify and then upload your sketch to the Arduino board.
New: Click this to open a new blank sketch in a new window.
Open: Click this to open a saved sketch. Save Click this to save the open sketch.
Serial Monitor: Click this to open a new window for use in sending and receiving data between your Arduino and the IDE.

The Text Area

The actual code is written in this block.

The Message Window Area

The message window area is shown at the bottom side. Messages from the IDE appear in the black area. The messages you see will vary and will include messages about verifying sketches, status updates, and so on.

CHALLENGES FACED:

Every project on its own has its difficulties and challenges, for our project challenges are listed below:
Rotating the Pipe: Designing a mechanism, while bettering of the project done last year was a challenge. We wanted to have something that can beimplemented in real life (like having a centralized garbage system in a Building). Countering the problem of the last year project we focused on notmoving the Garbage can and so we went for a design which included a Pipe which rotates in 3 direction of fixed garbage can.
Designing a Gate: Designing a gate where the sensor detects the type of waste and directs it to the pipe, while the pipe rotates in the meantime to therespective garbage can was very tricky. We had several ideas from having an Objection plate while the garbage is held on the plate for detection andhaving a tilting bucket etc. Finally, we went for an idea of V-gate in order to avoid the movement of sensors and have less mechanical moving parts.
Using bearings: The original Idea involved using bearing both for V-gate shaft and Pipe support. As seen we used an 8 mm Radial bearing for Gateshaft on the either side. Also the rotating pipe shaft was to be supported by a thrust bearing, eventually we opted out of this idea as the wooden frameconstructed for the Pipe was more than sufficient to support it. This saved a lot of time and prevented further any future mechanical complications inthe project.
Using only one power supply: It was a challenge to restrict our selves in using only one power supply and having least electronic components aspossible. Therefore, in our design phase, we have considered all the possible ways to use only one power supply efficiently; and we opted for thescheme that is represented in the electronics chapter.
Accuracy of sensors: Sensors are not always accurate, having limitation in their distance of measurement. This affects it's accuracy in detection(particularly when the object is small). We intended to modify the gate design by adding a printed part but it effected the performance of the sensorand so for future implications of the system for better detection, shielded sensors can be used.
Position of Sensors: There are many factors that came in to the picture while deciding the position and location of our sensors. We considered
making a fixed structure for the sensors because we did not want the sensors to be attached to the gate. Also, the distance between the two sensorshad to be considered so that the sensors do not influence each other. This has been done by considering the recommended distance in the datasheetand also by some trial and error we found the optimal locations to place our sensors.
Initialization of the system: In the start-up of the system, we wanted everything to go to the prescribed zero position. However, servos were movingwithout a command given to them (fast and not as commanded). We "fixed" this by considering the actual position of the motors on the system startup. Furthermore, one can consider here other ways of solving this issue, for instance, using different servos, other software solutions like usingEEPROM; or hardware solutions.

Tuning and adjusting different parameters of the system: Tuning and adjusting different parameters of the system, and making everything worktogether was rather challenging. We opted for values that are optimal, however, the system response can be increased by changing these parameters(ex. speed of servos, the delays added into the code, etc.). Also, we observed that it will detect more efficiently metals if we only consider the datafrom the inductive sensor, this can be seen in the codes given in the programming section.

CONCLUSION & FUTURE WORK:

In conclusion, the automated waste sorting machine represents a significant advancement in the management and recycling of waste. By utilizing cutting-edge technology, such as sensors, AI, and robotics, it can efficiently sort waste materials with greater accuracy and speed compared to traditional manual methods. This not only reduces the workload and cost of waste management but also contributes to environmental sustainability by ensuring that recyclable materials are properly segregated. The system's potential for scalability, adaptability, and integration with existing waste management infrastructure makes it a valuable tool for cities and industries aiming to reduce their carbon footprint and improve recycling rates. With continued innovation and investment, automated waste sorting could play a crucial role in the global effort toward waste reduction and resource conservation.

References:

[1] "Waste Management: Principles and Practice" by J. M. P. De Silva pg.:45-78 (Covers waste sorting technologies and practices)

[2] "Recycling and Waste Management: A Global Perspective" by David A. W. Smith pg.:102-130 (Discusses automated recycling systems and their efficiencies)

[3] "Handbook of Recycling: State-of-the-art for Practitioners, Analysts, and Scientists" byErnst Worrell and Markus Reuter pg.: 215-250 (Focuses on recycling technologies and automated sorting)

[4] "Waste Management: A Reference Handbook" by David E. Newton pg.: 89-115 (Explores various waste management techniques including automation)

[5] "Sustainable Waste Management: A Systems Approach" by Paul T. Williams pg.: 150-175 (Details on systems thinking in waste management and sorting)

[6] "Automated Waste Sorting: A Review of Current Technologies" by Garcia, M., & Lopez, R.,Journal of Environmental Engineering Vol. 146, No. 3, 2020 pg.: 1-15 (Comprehensive review of automated sorting technologies)

[7] "The Role of Automation in Waste Management: A Review" by Thompson, J., & Patel, S.,Waste Management JournalVol. 95, 2020 pg.: 123-135 (Discusses the impact of automation on waste management systems)

[8] "Sensor Technologies for Waste Sorting: A Review" by Patel, R., & Kumar, S., Sensors and Actuators A: PhysicalVol. 310, 2020 pg.: 1-12 (Focuses on various sensor technologies used in waste sorting)

[9] "Robotic Waste Sorting: Current Trends and Future Directions" by Lee, H., & Kim, J., Robotics and Autonomous Systems, Vol. 134, 2021, pg.: 45-60 (Explores advancements in robotic sorting systems)

[10] "Innovations in Waste Sorting Technologies" by United Nations Environment Programme (UNEP) in 2021 pg.: 10-30 (Overview of innovative technologies in waste sorting)

[11] A Review of Automated Waste Sorting Technologies" by Smith, J., & Jones, A. (2021). Journal of Environmental Management.

[12] Advancements in Waste Sorting Technologies: A Comprehensive Review" by Kumar, R., & Singh, P. (2020). Waste Management Journal.

[13] Advanced Sensor Applications in Waste Management Systems" by M. J. Schut et al.

[14] Sustainable Waste Management: A Systems Approach" by Paul T. Williams

[15] Sensor Technologies for Waste Sorting: A Review" by Patel, R., & Kumar, S. (2020). Sensors and Actuators A: Physical.

[16] Sensors and Transducers" by Ian Sinclair, which covers sensor technologies applicable to waste sorting.

[17] Sensors and Actuators: Engineering System Instrumentation" by Clarence de Silva.