INTELLIGENT WASTE DISPOSAL ROBOT WITH CLOUD CONNECTIVITY AND ADVANCED DETECTION MECHANISM

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Abstract: *This paper describes cutting-edge solution designed to revolutionize waste management through automation and intelligent design. By leveraging Wi-Fi connectivity, the robot seamlessly integrates with the cloud, enabling remote monitoring and control. Core components like GPS ensure precise location tracking, while ultrasonic sensors allow for real-time obstacle detection, ensuring smooth navigation in diverse environments. The waste handling system incorporates servo and gear motors, which are managed efficiently by a microcontroller, ensuring the robot performs complex tasks with precision.Safety and efficiency are at the heart of this system. An automatic shutdown feature is activated when no water is detected, preventing damage and conserving resources. Methane levels are monitored using a gas sensor, addressing potential safety hazards. Infrared (IR) sensors assess garbage levels, allowing for timely interventions and optimal waste management. The system's user-friendly design integrates with the Local web server, offering users the ability to monitor and control the robot remotely. This adaptability makes the robot suitable for various settings, from urban environments to industrial waste facilities.*

Keywords*: Wi-Fi connectivity, GPS, ultrasonic sensors, servo and gear motors, microcontroller, gas sensor, Local web server*

I.INTRODUCTION

The **Solar-Powered** River Garbage Cleaning Robot is an innovative solution aimed at addressing the escalating issue of waterway pollution. Powered by renewable solar energy, this robotic system operates autonomously on the surface of rivers, collecting and removing debris and waste that contribute to environmental degradation. Its primary objective is to tackle river pollution caused by plastics, organic waste, and other pollutants, offering an efficient and sustainable approach to cleaning waterways while reducing reliance on traditional energy sources. Equipped with advanced technology, the robot integrates **sensors, cameras**, and **GPS** systems to navigate autonomously and detect pollutants. These **sensors** enable the robot to identify and target areas with high concentrations of waste, ensuring precise and efficient cleaning operations. The **cameras** and **GPS** systems enhance navigation, allowing the robot to move seamlessly through complex waterway environments while avoiding obstacles such as boats, vegetation, and riverbanks.

II.FUNCTIONAL OVERVIEW

The proposed graduation project is designed to efficiently address [specific problem or domain] by leveraging cutting-edge technologies and systematic methodologies. The system follows a modular approach, where each component is responsible for a specific function, ensuring streamlined operation and high reliability. The project encompasses various functionalities, including [mention core functions, e.g., data collection, processing, user interaction, automation], designed to optimize performance and enhance user engagement. A well-structured architecture, combined with seamless integration of multiple technologies, ensures smooth workflow and operational effectiveness.

The system operates through a structured workflow, beginning with data acquisition from relevant sources. This data is then processed using [mention relevant technology, e.g., machine learning algorithms, cloud-based processing], ensuring accuracy and efficiency. A centralized database securely stores the processed information, enabling quick retrieval and analysis. Additionally, user interfaces such as [mention UI elements like dashboards, control panels] facilitate interaction, allowing users to access insights and perform necessary actions with ease. The integration of automation further reduces manual effort, enhancing overall productivity.

To ensure smooth operations, the system employs various security and compliance measures, including data encryption, access control, and regular audits. These features help protect sensitive information and maintain data integrity. Moreover, real-time monitoring and feedback mechanisms allow continuous evaluation and improvement of the system's performance. The use of cloud-based services and scalable infrastructure ensures that the project can handle increasing workloads without compromising efficiency.

The project demonstrates adaptability across multiple applications, ensuring long-term viability and innovation. By incorporating advanced methodologies such as [mention technologies like AI, blockchain, IoT], it guarantees flexibility and responsiveness to changing industry demands. The comprehensive design ensures that the system remains robust, reliable, and user-friendly, making it a valuable asset in addressing contemporary challenges and enhancing efficiency within its target domain.Componenrs Required:

1.Hardware Components:

Microcontroller/Processor: ESP32 CAM BOARD , ESP32 micro controller

Sensors: IR sensors, Ultrasinic sensors, gas sensors, Uv sensor

Actuators: servo motors, gear motors, dc motors.

Power Supply: 15V Rechargable battery

Communication Modules: ESP32 board's Wifi module

Display Units: LED's

Other Supporting Components: Resistors, capacitors, transistors, Motor drivers etc

2. Software Components:*

Programming Language: Html, CSS , JavaScript

Integrated Development Environment (IDE): Arduino IDE, CC Studio.

Libraries and Frameworks: WiFi.h, WebServer.h, ESP32Servo, TinyGPS++.h, SoftwareSerial.h

The above components form the backbone of the project

II.BLOCK DIAGRM OF PROJECT.

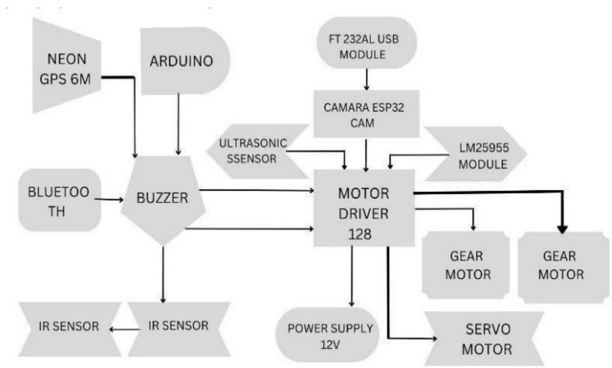

Fig 1:Block diagram Of Project

The provided block diagram showcases the comprehensive design of an integrated system, likely for an automated or robotic application. Each component has a unique role, and their interaction forms a cohesive and efficient operational workflow. Here's an expanded explanation of the system:

Central Microcontroller (Arduino)

The Arduino serves as the brain of the system, acting as a central hub that processes data from various inputs and controls outputs. It receives signals from sensors like GPS, IR sensors, ultrasonic sensors, and modules like the ESP32-CAM, then makes decisions to execute appropriate actions. The microcontroller is programmable, allowing flexibility in implementing custom logic for various applications such as navigation, waste management, or surveillance.

Navigation and Localization (NEO-6M GPS Module)

The NEO-6M GPS module provides real-time location data. This feature is crucial in applications like autonomous navigation, where precise geographical positioning is required. For example, in a garbage cleaning robot, it helps the system identify its current position and follow a pre-defined path or return to a home base for recharging and unloading.

Communication and Alerts (Bluetooth Module and Buzzer)

The Bluetooth module enables wireless communication between the system and external devices, such as smartphones, computers, or tablets. This allows users to monitor the robot's status, send commands, or receive real-time updates. The buzzer provides audible feedback or alerts for various events, such as obstacle detection, low battery, or task completion, enhancing user interaction and system reliability.

Object Detection and Monitoring (IR Sensors, Ultrasonic Sensor, and Camera ESP32-CAM)

- IR Sensors: These sensors detect nearby objects or obstacles, providing a basic level of environmental awareness. They might also be used to measure the level of garbage or identify objects blocking the robot's path.
- Ultrasonic Sensor: This sensor measures the distance to objects using sound waves, offering more accurate obstacle detection compared to IR sensors. It helps in navigation and avoiding collisions.

- ESP32-CAM: This module adds advanced capabilities like real-time image or video capture. It may be used for surveillance, object recognition, or remote monitoring, providing visual data to users or enhancing the robot's decision-making capabilities.

Actuation (Motor Driver L298, Gear Motors, and Servo Motor)

- Motor Driver L298: This module interfaces between the Arduino and the motors, enabling the microcontroller to control motor speed and direction. It is essential for driving high-current motors that the Arduino cannot power directly.
- Gear Motors: These provide the main driving force for the system, enabling movement or heavy-duty actions. For instance, they could drive the robot's wheels or power a mechanical arm for garbage collection.
- Servo Motor: This motor is used for precise, angular movements, making it suitable for fine-tuned operations such as controlling a robotic arm or other mechanical components that require exact positioning.

Power Management (Power Supply and LM2596 Module)

- The system operates on a 12V power supply, which provides energy to all components.
- The LM2596 module is a DC-DC step-down voltage regulator, ensuring components that require lower voltage levels (e.g., Arduino or sensors) receive stable power. This protects sensitive parts from overvoltage damage and ensures efficient energy usage.

USB Module (FT232RL)

The FT232RL USB module provides a connection between the Arduino and external devices, such as a computer, for programming or data transfer. This feature allows easy uploading of control code or debugging of the system, ensuring that the robot can be updated or reprogrammed as needed

FLOW CHART

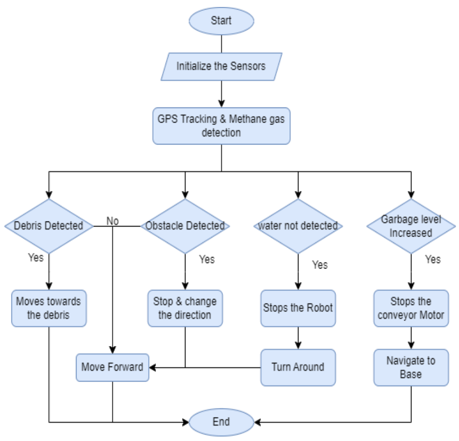

Fig 2 : Flow Chart of operational workflow

The flowchart outlines the operational workflow of an autonomous robot system, such as a waste management or river-cleaning robot. Each block or decision diamond represents a specific action or condition in the robot's logical sequence of operations. Here's a detailed explanation of the flowchart:

1. Start: The process begins when the robot is powered on. This initial step sets the system in motion and prepares it for operation.

2. Initialize the Sensors: At this stage, the robot activates and calibrates its onboard sensors, including IR sensors, ultrasonic sensors, GPS module, and gas sensors. Sensor initialization ensures accurate data collection for navigation, obstacle detection, and environmental monitoring.

3. GPS Tracking & Methane Gas Detection: The robot starts tracking its location using the GPS module while simultaneously monitoring methane levels through the gas sensor. This dual functionality ensures that the robot stays within its designated operating area and detects harmful gas emissions that might indicate a hazardous environment.

4. Condition 1: Debris Detected

- Yes: If debris is detected by the IR or ultrasonic sensors, the robot moves toward the debris to collect it.
- No: The robot continues its normal operation, scanning for additional debris.

5. Condition 2: Obstacle Detected

- Yes: If an obstacle is detected by the ultrasonic sensors, the robot stops and changes its direction to avoid a collision.
- No: The robot continues on its current path.

6. Condition 3: Water Not Detected

- Yes: If the system determines that there is no water (possibly using float sensors or other water-detection methods), the robot stops operation and turns around to return to its designated area.
- No: The robot continues its tasks in the water.

7. Condition 4: Garbage Level Increased

- Yes: If the waste storage compartment is full, as detected by IR or weight sensors, the robot stops the conveyor motor and navigates back to the base for emptying. This ensures efficient operation without overloading.
- No: The robot continues collecting debris.

8. End: The operation concludes once the robot completes its task, reaches its base, or encounters a critical issue requiring manual intervention.

V .WORKING

1.ESP 32 Cam

ESP32 is a low-power and low-cost system on a chip microcontroller that is integrated with Wi-Fi & Bluetooth. This development board is manufactured simply by ESPressif. Several variants have been launched & announced since the release of this ESP32 board. These boards have different CPUs & capabilities, and all of them can share a similar SDK & are mostly code-compatible.

The ESP32 CAM module is an ESP32-based low-cost full-featured microcontroller with an integrated small-size OV2640 camera module & microSD card socket. This module integrates Bluetooth, WiFi, and BLE Beacon with two 32-bit high-performance LX6 CPUs. The frequency adjustment range of this module ranges from 80MHz to 240MHz. It adopts a stage pipeline architecture, a Hall sensor, an on-chip sensor, a temperature sensor, etc. This type of module is appropriate for industrial wireless control, home smart devices, wireless monitoring & IoT applications which require a camera with superior functions like image recognition & tracking.

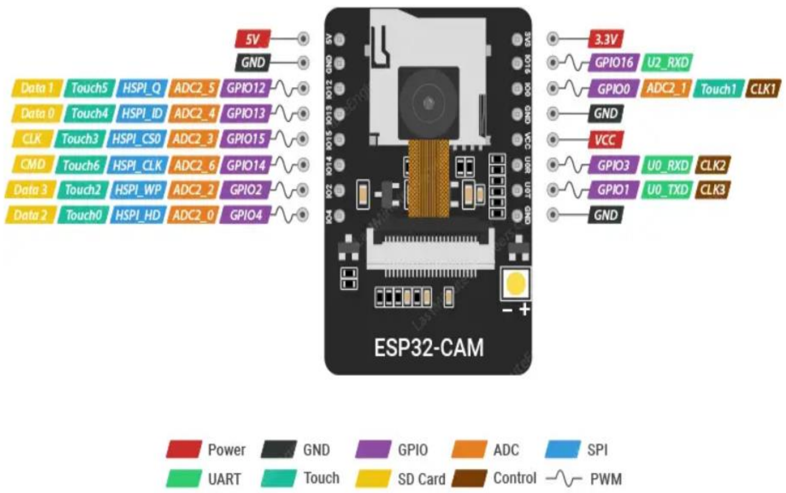

Fig 3:ESP32 Cam Pin Configuration

- Power Pins: ESP32 Cam includes two power pins; 5V & 3V3, so this module is powered through the 3.3V/5V pins. The VCC pin of this module usually outputs 3.3Volts from the on-board voltage regulator but it can be configured to 5V output with the Zero-ohm link close to the VCC pin.
- GND is the ground pin of the module.
- GPIO Pins: This module includes 32 GPIO pins in totality but many of them are internally used for the camera & the PSRAM. So this module has only 10 GPIO pins which can be assigned for different peripheral duties like; ADC, SPI, UART, and Touch.
- UART Pins: The ESP32-S chip includes two UART interfaces; UART0 & UART2. But simply the RX pin of UART2 like GPIO 16 is broken out to make UART0 usable UART only on the ESP32-CAM. These pins are used mainly for flashing & connecting to different UART devices like fingerprint sensors, GPS, distance sensors, etc.
- MicroSD Card Pins: These pins are used to interface the microSD card. These pins can also be used as regular inputs & outputs if you do not use a microSD card.
- ADC Pins: There are two ADC2 pins only on the ESP32-CAM which are broken out but these pins are internally used by the WiFi driver and they cannot be used whenever Wi-Fi is enabled.
- Touch Pins: These modules include seven capacitive touch-sensing GPIOs. Once a capacitive load like a human finger is close to the GPIO, then this module notices the change within capacitance.
- SPI Pins: The ESP32-CAM includes one SPI (VSPI) only in slave & master modes.

- PWM Pins: The ESP32-CAM includes ten channels of PWM pins which are controlled through a PWM controller. So the output of PWM can be used to drive LEDs & digital motors.

GPS MODULE

The NEO-6M GPS module that can track 22 satellites and identify locations anywhere in the world. It can serve as a great launch pad for anyone looking to get into the world of GPS.

They are low power (suitable for battery operated devices), affordable, easy to interface and extremely popular with hobbyists.

Hardware Overview

2.NEO-6M GPS Chip

At the heart of the module is a GPS chip from U-blox – NEO-6M. The chip measures less than a postage stamp but packs a surprising amount of features into its tiny frame.

Fig 4: NEO-6M GPS Chip

- It can track up to 22 satellites over 50 channels and achieve the industry's highest level of tracking sensitivity i.e. -161 dB, while consuming only 45 mA current.
- Unlike other GPS modules, it can perform 5 location updates in a second with 2.5m horizontal position accuracy. The U-blox 6 positioning engine also has a Time-To-First-Fix (TTFF) of less than 1 second.

3.Position Fix LED Indicator

There is an LED on the NEO-6M GPS module that indicates the status of the 'Position Fix'. It will blink at different rates depending on which state it is in:

- No blinking – it is searching for satellites.
- Blink every 1s – Position Fix is found (the module can see enough satellites).

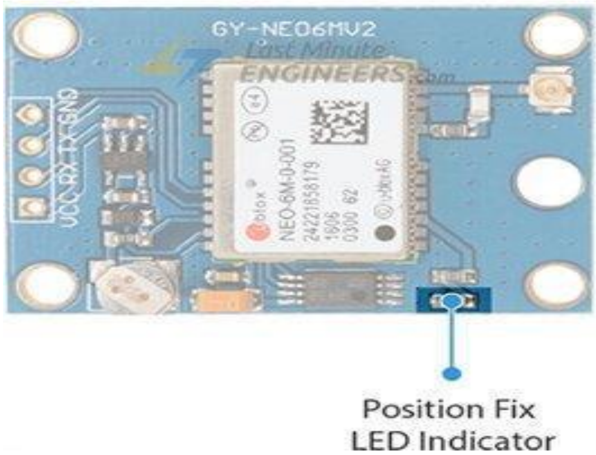

Fig 5: Position Fix LED Indicator in NEO-6M GPS module

4. LDO Regulator

The operating voltage of the NEO-6M chip ranges from 2.7 to 3.6V. But the good news is, this module comes with MICREL's MIC5205 Ultra-Low Dropout 3V3 regulator.

The logic pins are also 5-volt tolerant, so we can easily connect it to Arduino or any 5V logic microcontroller without using a logic level converter.

Fig 6: LDO Regulator in NEO-6M GPS module

5. Battery & EEPROM

The module is equipped with HK24C32 Two Wire Serial EEPROM. It is 4KB in size and is connected via I2C to the NEO-6M chip.

The module also houses a rechargeable button battery that acts as a super-capacitor.

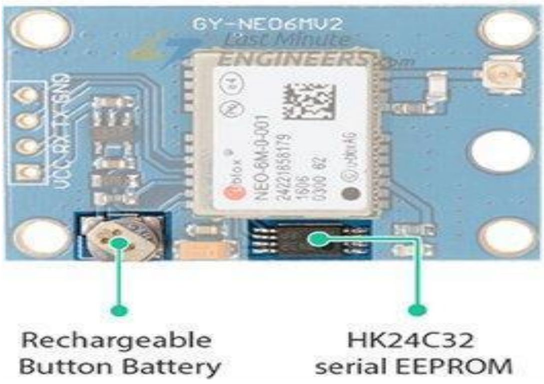

Fig 7: Battery & EEPROM in NEO-6M GPS module

6.Antenna

The module comes with -161 dBm sensitivity patch antenna for receiving radio signals from GPS satellites.

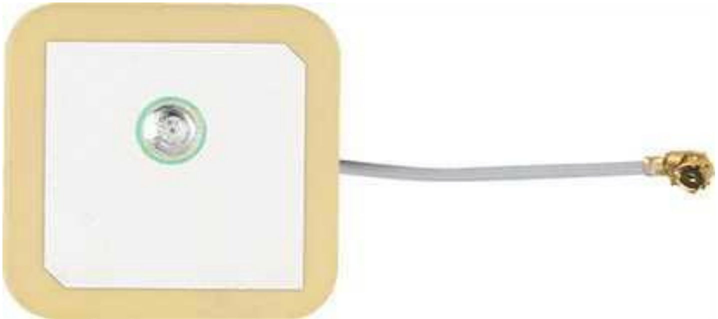

Fig 8: Antenna

You can snap-fit this antenna into the small U.FL connector located on the module.

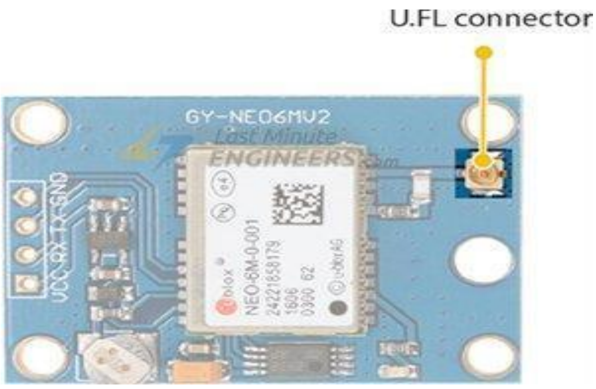

Fig 9: U.FL connector

The patch antenna is great for most of our projects. But if you want to get more sensitivity and accuracy, you can also snap-on any 3V active GPS antenna.

U.FL connectors are small, delicate and are not rated for strain. To prevent damage to the U.FL connection, you can thread the U.FL cable through the mounting hole.

7. HC-SR04 ULTRASONIC SENSOR:

The HC-SR04 Ultrasonic Distance Sensor that can report the range of objects up to 13 feet away. An HC-SR04 ultrasonic distance sensor actually consists of two ultrasonic transducers. One acts as a transmitter that converts the electrical signal into 40 KHz ultrasonic sound pulses. The other acts as a receiver and listens for the transmitted pulses.When the receiver receives these pulses, it produces an output pulse whose width is proportional to the distance of the object in front.

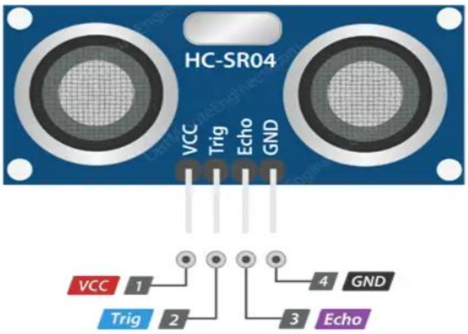

Fig 10: HC-SR04 Ultrasonic Sensor Pinout

8. IR SENSOR

IR Sensor Module has built-in an IR transmitter and IR receiver that sends out infrared light and looks for reflected infrared light to detect the presence of any obstacle in front of the sensor module. It is used to find obstacles and short & medium-range communication.

There is onboard a potentiometer to adjust the detection range. There is an Obstacle Detection LED indicator on the module board. IR sensor transmits digital data (logical 1 and 0) in the form of infrared light. When the sensor gets logical 1 means LED ON and logical 0 means LED OFF. The sensor has a very good and stable response even in ambient light or in complete darkness.

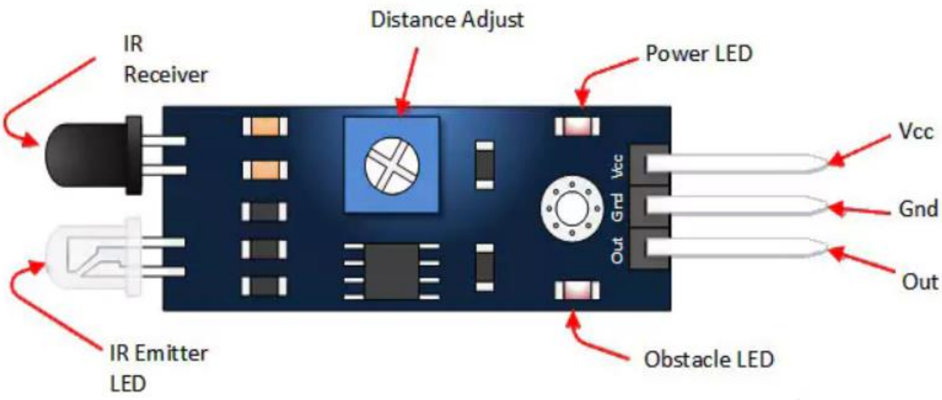

Fig 11: IR Sensor Pinout

1.ARDUINO IDE:

The Arduino IDE provides a user-friendly interface for programming Arduino boards, making it accessible to beginners and experienced developers alike. It supports a wide range of Arduino-compatible boards, including the popular Arduino Uno, Nano, Mega, and others, as well as third-party boards based on the Arduino platform. The IDE is available for Windows, macOS, and Linux operating systems, allowing users to develop Arduino projects on their preferred platform.

One of the key features of the Arduino IDE is its simplicity and ease of use. The IDE includes a text editor with syntax highlighting and auto-completion features, making it easy to write and edit code in the Arduino programming language, which is based on Wiring and C/C++. Users can write sketches (Arduino programs) using familiar programming constructs such as functions, variables, loops, and conditional statements.

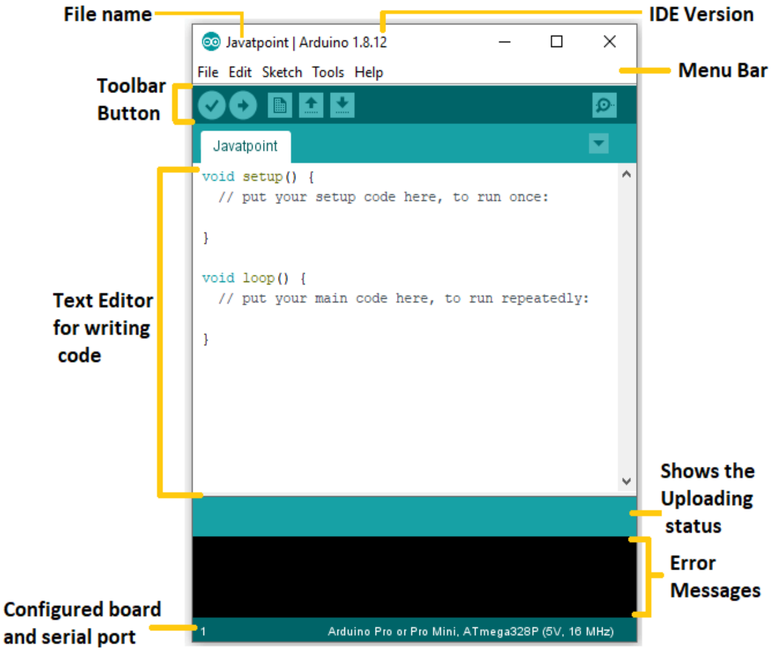

Fig 12: Arduino IDE

2. HTML (HYPERTEXT MARKUP LANGUAGE)

Purpose: HTML is used to define the structure of a webpage. It provides the basic layout, content, and organization of your page.

3.CSS (CASCADING STYLE SHEETS)

Purpose: CSS is used to style HTML elements by setting properties like colors, font sizes, margins, and layout. It enhances the visual presentation of the content defined in HTML.

3.Server-Side Communication

The backend is responsible for processing data, handling business logic, and interacting with databases.It is typically built using languages like Python (Flask, Django), Node.js, PHP, etc. API Communication (RESTful APIs): RESTful APIs allow the frontend to send HTTP requests to the server. The server processes the request and responds with data (usually in JSON format)

A simple web server on an ESP8266 or ESP32 board using the Arduino IDE. The server handles HTTP requests, serves dynamic HTML content, and provides basic interaction between a web page and the device. The Arduino board connects to a Wi-Fi network and acts as a web server, allowing users to interact with the device through a web browser.

4. LOCAL WEB SERVER:

The provided HTML code creates a comprehensive and responsive dashboard for monitoring and controlling a garbage robot, combining real-time sensor data visualization, live camera streaming, and joystick-based motor control. The dashboard features a clean grid layout with sections for sensor readings, a live camera feed, and joystick controls, all styled with CSS for a modern, mobile-friendly interface. Sensor data such as gas levels, TDS readings, garbage bin status, GPS coordinates, and operational mode are fetched from the ESP32 module every two seconds and displayed dynamically. The joystick interface, implemented using the NippleJS library, allows users to control the robot's movement with commands like forward, backward, left, and right, while a stop command is triggered when the joystick is neutral. A live camera feed from the ESP32-CAM is integrated through an iframe for real-time visuals. Additionally, the dashboard features a toggle button for changing the robot's mode and a sound alert system to notify users when the garbage bin is full, accompanied by a visual warning message. The communication between the dashboard and the robot is facilitated through HTTP requests to the ESP32 modules.

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VI .RESULT

EXPERIMENTAL SETUP

Fig 13: Image of Robot Cleaning Garbage

Fig 14: Final Project Image

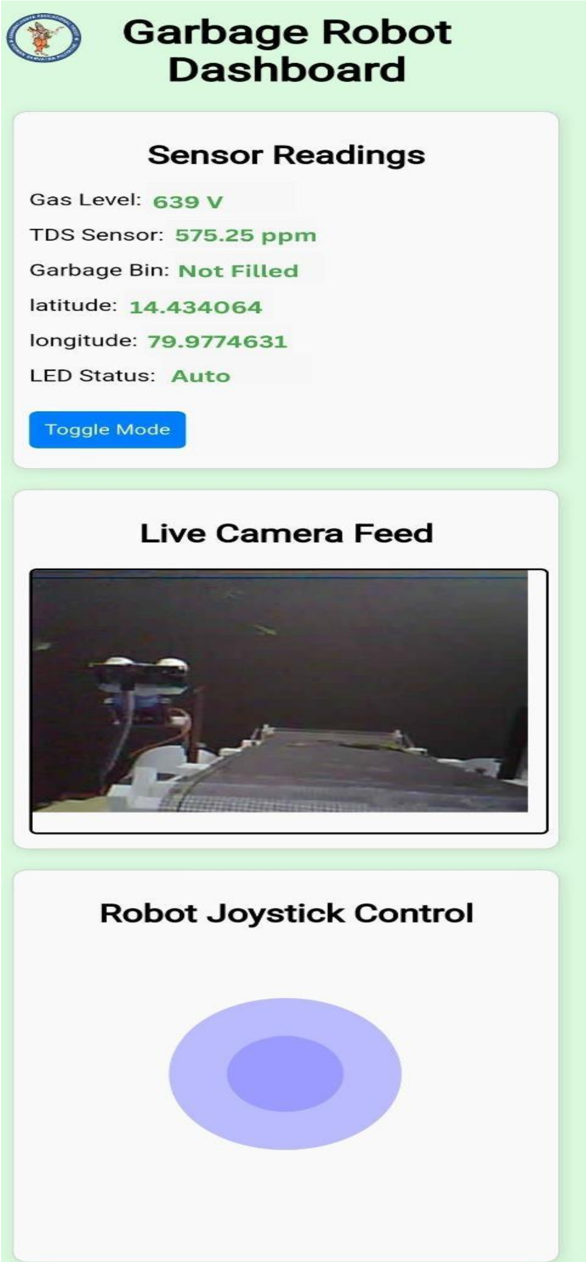

Fig 15: Sensor Readings shown in Local Web server

VII. CONCLUSION

The proposed system, as outlined in the flowchart, represents a significant advancement over the existing systems for waste management and environmental monitoring. Unlike the traditional or existing systems, which often rely on manual labor, limited automation, or external power sources, the proposed system integrates advanced features such as GPS tracking, methane gas detection, and autonomous navigation. These enhancements allow for real-time monitoring, efficient debris collection, and improved safety measures, addressing the limitations of the existing system. Additionally, the use of the ESP32 CAM and cloud integration in the proposed system facilitates remote monitoring and control, enabling users to track operations and environmental conditions seamlessly.

Compared to the existing system, which might have limited precision and operational efficiency, the proposed system is highly adaptive and eco-friendly. The reliance on renewable energy, such as solar power, eliminates the need for external power sources, reducing operational costs and the carbon footprint. Furthermore, the intelligent decision-making capabilities, including obstacle avoidance, debris detection, and waste level monitoring, ensure uninterrupted and efficient operation. These features, combined with its ability to operate autonomously in diverse environments, make the proposed system a robust, scalable, and sustainable solution for addressing waterway pollution and waste management challenges.

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