ECOMATIC (AUTOMATED ROBOT FOR CLEANING SURROUNDINGS AND WASTE COLLECTION WITH SEGREGATION)

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Introduction:

The growing need for sustainable waste management has motivated the development of innovative solutions that combine automation, efficiency, and environmental consciousness. The proposed automated robot for cleaning surroundings and waste collection with segregation is designed to maintain hygiene in public spaces, promote recycling, and reduce labour dependency. It incorporates features such as autonomous navigation, waste segregation, and smart monitoring to address modern waste management challenges.

Objectives:

The primary objectives of this project are designed to address the challenges of urban waste management by leveraging automation and sensor intelligence to improve cleaning efficiency and waste segregation accuracy. These objectives are:

1. **Design and Fabrication of an Autonomous Cleaning Robot Platform**

    - To develop a mobile robotic platform capable of independent movement, equipped with DC geared motors controlled via L298N motor drivers for precise navigation and speed control.

    - Construct a rigid yet lightweight frame using acrylic or aluminium materials to ensure portability and durability in indoor and semi-outdoor environments.

    - Integrate a mechanical brush mechanism powered by a dedicated motor to simulate manual sweeping, capable of collecting diverse types of litter including dry debris and wet waste.

2. **Intelligent Waste Segregation System Using Sensor Integration**

    - Implement a soil moisture sensor that detects moisture content to differentiate between wet and dry waste. This sensor is critical for enhancing the sorting mechanism, ensuring waste is appropriately classified and routed.

    - Use servo-controlled gates (SG90 servo motor) that dynamically open or close based on sensor inputs to direct waste into designated compartments or bins, reducing manual sorting efforts and increasing processing speed.

3. **Centralized Microcontroller-Based Control Architecture**

    - Employ NodeMCU ESP8266, a low-cost, Wi-Fi-enabled microcontroller, as the central processing unit. It provides seamless sensor integration, motor control, and communication capabilities.

    - Develop efficient firmware using the Arduino IDE to implement real-time sensor data acquisition, PWM motor speed modulation, and decision-making algorithms based on conditional statements.

4. **Autonomous Navigation and Obstacle Avoidance**

    - Use ultrasonic sensors (HC-SR04) for reliable detection of obstacles within a certain range. This prevents collisions, allowing the robot to navigate dynamically changing environments.

    - Include infrared (IR) sensors (TCRT5000) to follow predefined black/white line paths, ensuring the robot can maintain a guided route through various locations.

5. **Contactless Interaction for Enhanced Hygiene**

    - Design a gesture-controlled disposal gate activated by ultrasonic proximity sensing. This contactless mechanism prevents direct human contact with the waste disposal system, reducing the risk of contamination and improving public acceptance.

6. **Modular and Scalable Design**

    - Aim for a modular hardware and software architecture that can be easily upgraded or expanded with additional sensors, actuators, or communication modules.

Methodology:

The ECOMATIC project development follows a structured, iterative approach encompassing conceptual design, hardware selection and integration, software development, testing, and optimization.

1. **Mechanical and Structural Design**

    - Chassis Fabrication: Use lightweight acrylic sheets or aluminium frames to create a robust base that supports all mechanical and electrical components without compromising manoeuvrability.

    - Brush Assembly: Attach a rotating brush driven by a geared DC motor mounted at the front of the robot. The brush's speed and direction are

controlled independently to effectively sweep debris into the collection chamber.

- Collection Compartment: Design a central waste storage bin sized appropriately for the robot's operational duration. The bin includes servo-actuated gates for segregating wet and dry waste.
- Waste Bin Gates: Integrate SG90 servo motors to open and close gates based on waste type, ensuring clean and efficient waste routing.

2. Embedded System Integration

- Microcontroller: Use the NodeMCU ESP8266 to handle multi-sensor data acquisition, motor control, and wireless communication. It supports PWM for motor speed control and GPIO pins for sensor interfacing.
- Motor Drivers: Use L298N or L293D H-Bridge drivers to control the direction and speed of DC motors driving the wheels and the brush motor.
- Sensors Integration:

  o Ultrasonic Sensors (HC-SR04): Used for dual purposes:

  ▪ Obstacle detection with real-time distance measurement to avoid collisions.

  ▪ Gesture detection near the disposal area to trigger automatic lid/gate opening. o Soil Moisture Sensor: Measures the moisture level of the collected waste, allowing classification into wet or dry categories.

  o IR Sensors (TCRT5000): Detect line contrast on the ground to guide the robot along predefined cleaning paths using line-following algorithms.

- Motors:

o DC Geared Motors: Provide the propulsion and steering of the robot with differential drive (independent control of left and right motors).

o Servo Motor: Controls the opening and closing of segregation gates.

o Brush Motor: Dedicated motor to rotate the sweeping brush for efficient debris collection

Result and Conclusion:

The robot will autonomously clean public spaces, segregate waste, and minimize the labor required for waste management. It will also optimize waste collection by reducing operational costs, enhancing recycling rates, and improving environmental sustainability. Real-time monitoring and GPS tracking will enable efficient route management and waste collection, while the alerting system will ensure timely maintenance and waste disposal.

Future Scope:

- Solar Power Integration
- IoT-Enabled Remote Monitoring and Control
- AI-Based Visual Waste Classification
- Voice and Mobile App Interaction
- Enhanced Ruggedness and All-Terrain Capability
- Scalability and Modular Expansion
- Data Analytics and Predictive Maintenance