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Implementation of an Automated Plastic Recycling System for 3D Filament Production

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Abstract - Plastic pollution has become a serious global issue, harming both natural ecosystems and human health. To help address this problem, the Smart Recycling of Plastic system is designed to convert discarded plastics into interlocking blocks that can serve as an eco friendly substitute for concrete. The project aims to solve the challenges of manual production, such as inefficiency, uneven quality, and excessive material waste, by automating the process of making plastic filaments. Once plastic bottles are cut into strips, an ESP32 microcontroller manages the next steps extrusion, cooling, and spooling — while sensors provide real-time monitoring to maintain quality.

Key Words: ESP32 Microcontroller, real-time monitoring,3D filament,3D printing.

1.INTRODUCTION

The project title “Implementation of an Automated plastic Recycling System for 3D printing filament Production” aims to enhance plastic waste management by integrating modern technologies such as the Internet of Things (IoT). Conventional recycling methods are often inefficient and lack real time supervision, leading to poor results. This proposed system utilizes various sensors to detect and classify different types of plastic waste, while a microcontroller—such as an Arduino, ESP32, or Raspberry Pi—controls the automation process and transmits collected data to a cloud platform. Through IoT connectivity, both users and waste management authorities can monitor recycling activities in real time via a web dashboard or mobile application. The system can also send notifications when bins are full, and data analytics tools can be used to optimize collection routes and improve overall recycling efficiency. The primary goal is to make plastic recycling more intelligent, automated, and environmentally sustainable. Plastic waste poses a significant environmental challenge because it is non-biodegradable and often disposed of improperly. Traditional recycling systems rely heavily on manual operations, which are slow, labor-intensive, and lack continuous monitoring. The system includes multiple sensors— such as weight, ultrasonic, and infrared—to identify, measure, and classify plastic materials. A microcontroller processes the sensor data and automates the sorting procedure. The information is then uploaded to a cloud server through IoT modules like Wi-Fi, enabling remote access and monitoring via online platforms or mobile apps. Ultimately, this project aims to develop a low-cost, scalable, and automated recycling system that minimizes human effort while improving recycling rates and promoting environmental awareness. By combining IoT automation, smart data monitoring, and real time communication, the system contributes to a more sustainable approach to managing plastic waste.

1.1 MOTIVATION

Plastic waste has emerged as a major environmental concern, with millions of tons generated annually and much of it polluting oceans, landfills, and the atmosphere through incineration. Although awareness of sustainability has increased, traditional recycling systems remain inefficient, labor-dependent, and poorly managed. In many cities, inadequate segregation and delayed collection add to the challenge. This project is motivated by the urgent need to transform plastic waste management through modern technology. By integrating the Internet of Things (IoT) and automation, it aims to enable real-time monitoring, intelligent waste identification, and data-based decision-making to enhance recycling efficiency and minimize manual effort. The initiative is founded on the belief that advanced technology can effectively address environmental issues.

1.2 OBJECTIVES

To design and implement an IoT-based system that can identify, categorize, and track plastic waste using integrated sensors such as weight, infrared (IR), and ultrasonic sensors.

To automate the processes of plastic segregation and disposal through the use of microcontrollers and actuators, thereby minimizing manual involvement and enhancing operational efficiency.

2. METHODOLOGY

The block diagram illustrates the overall architecture of the Automated Plastic Recycling System for 3D Printing Filament Production, highlighting the key hardware components and their interactions with the ESP32 microcontroller. At the center of the system is the ESP32, which functions as the main control unit responsible for data processing, sensor monitoring, and actuator control.

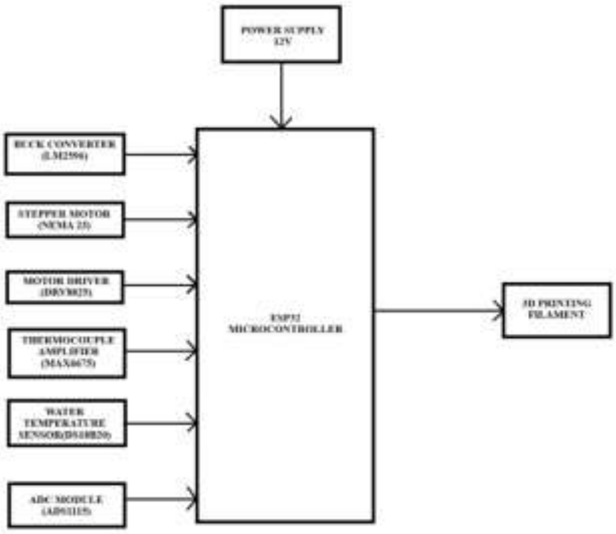

Fig 2.1: Block diagram for 3D printing filament

A 12V power supply provides the primary input power for the system. This voltage is regulated using the LM2596 buck converter, which steps down the 12V supply to safe operating levels required for the ESP32 and other low-voltage components. The stepper motor (NEMA 23) and its DRV8825 motor driver work together to control the extrusion mechanism. The motor driver receives control signals from the ESP32 and precisely adjusts the motor's speed and torque to ensure a consistent filament output.To maintain proper extrusion temperature, a MAX6675 thermocouple amplifier is connected to a K-type thermocouple. This module sends accurate temperature readings to the ESP32, allowing the system to regulate the heating element effectively.

The DS18B20 water temperature sensor monitors the cooling water bath temperature, ensuring the extruded filament solidifies uniformly. Its readings help maintain stable cooling conditions for better filament quality.For additional analog measurements such as load or tension monitoring, the ADS1115 ADC module interfaces with the ESP32, offering high-precision digital conversion of analog signals.Finally, the processed thermoplastic material passes through the controlled extrusion and cooling process, resulting in the production of consistent, high-quality 3D printing filament.

3. HARDWARE REQUIREMENTS

3.1 ESP32 MICROCONTROLLER

The ESP32 microcontroller plays a crucial role in the implementation of an automated plastic recycling system for 3D printing filament production. Its built-in Wi-Fi and Bluetooth enable seamless communication between sensors, actuators, and the monitoring platform. With a fast dual-core processor and multiple GPIO pins, it efficiently handles tasks such as temperature control, motor operation, and real-time data acquisition. Its low-power design supports continuous system operation while maintaining high reliability. The ESP32 also allows remote supervision of filament quality, system performance, and safety conditions, making the recycling process smarter, more accurate, and highly automated for consistent filament output.

3.2 BUCK CONVERTER

The LM2596 buck converter is an essential component in the automated plastic recycling system for 3D printing filament production. It provides a stable and efficient regulated DC voltage needed to power different modules such as sensors, motors, and the ESP32 controller. By stepping down higher input voltages to a safe operating level, it prevents overheating and protects sensitive electronics. Its high conversion efficiency reduces energy loss, making the system more reliable during long operation periods. The adjustable output feature allows precise voltage control, ensuring consistent performance of heating elements, motor drivers, and monitoring units involved in the filament production process.

3.3 MOTOR DRIVER

The DRV8825 motor driver is a key component in the automated plastic recycling system for 3D printing filament production. It is used to control stepper motors that manage plastic feeding, extrusion, and spool winding. The driver supports precise microstepping, allowing smooth and accurate motor movement, which is essential for maintaining uniform filament diameter. It can handle high current loads, ensuring stable operation during continuous processing. The DRV8825 also provides built-in protection against overheating, overcurrent, and voltage spikes, improving system safety. Its adjustable current limiting feature helps optimize motor performance, making the overall recycling and filament production process more efficient and reliable.

3.4 THERMOCOUPLE AMPLIFIER

The MAX6675 thermocouple amplifier is used in the automated plastic recycling system to accurately measure high temperatures during the plastic melting and extrusion process. It works with a K-type thermocouple and converts the sensed heat into a stable digital output that the ESP32 can easily read. This ensures precise temperature monitoring, which is essential for producing consistent, high-quality 3D printing filament. The MAX6675 offers noise-resistant readings, fast response, and reliable performance even in high-heat environments. Its accuracy helps maintain the correct melting point, prevents overheating, and supports safe, efficient, and controlled operation throughout the filament production cycle.

3.5 WATER TEMPERATURE SENSOR

The DS18B20 water temperature sensor is used in the automated plastic recycling system to monitor the cooling water temperature during the filament solidification process. Its digital one-wire interface makes communication simple and reliable with the ESP32 microcontroller. The sensor provides accurate and stable temperature readings, ensuring the cooling bath maintains an ideal range for proper filament shaping. Consistent cooling prevents filament warping, bubbles, and uneven diameter. The DS18B20 is waterproof, durable, and supports long cable runs, making it suitable for continuous industrial use. Its precision helps maintain filament quality and overall system efficiency throughout the production process.

3.6 ADC MODULE

The ADS1115 ADC module is used in the automated plastic recycling system to provide high-resolution analog-to-digital conversion for sensors that require precise measurement. It offers 16-bit accuracy, allowing the ESP32 to read small voltage changes from components such as load cells, pressure sensors, or analog temperature sensors. This precision helps monitor filament thickness, tension, and extrusion stability. The ADS1115 communicates through the I²C interface, making integration simple and reliable. It also includes a programmable gain amplifier, enabling accurate readings even from low-level signals. Its stable performance ensures better process control, contributing to consistent, high-quality 3D printing filament product.

4. SOFTWARE REQUIREMENTS

4.1 EMBEDDED FIRMWARE

Embedded firmware controls the entire automated plastic recycling system by managing sensors, motors, and temperature regulation. It enables real-time data processing, precise motor movement, and stable heating control. The firmware ensures smooth coordination between components, supports remote monitoring, and maintains consistent filament quality throughout the recycling and extrusion process.

4.2 WEB DASHBOARD

The web dashboard in the automated plastic recycling system provides a user-friendly platform for monitoring and controlling the entire filament production process. It displays real-time data such as temperature, motor speed, filament quality, and system status. Through wireless connectivity, users can adjust parameters, view alerts, and track performance remotely. This dashboard improves transparency, ensures efficient operation, and enhances overall system reliability by giving complete visibility and control from any connected device.

5. IMPLEMENTATION

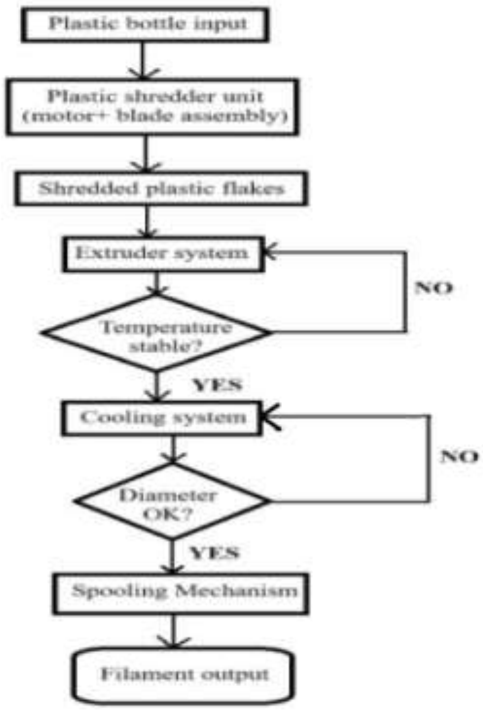

Fig 5.1 Implementation of 3D Printing Filament

The above block diagram 5.1 illustrates the step-by-step process of an automated plastic recycling system used for producing 3D printing filament. The process begins with feeding plastic bottles into a shredding unit, where a motor-driven blade assembly converts them into small flakes. These flakes enter the extruder, which melts the plastic and maintains a stable temperature for smooth extrusion. Once melted, the material passes through a cooling system to solidify and stabilize the filament. A diameter sensor checks filament thickness, ensuring it meets required standards. If correct, the filament is guided to the spooling mechanism, resulting in a consistent filament output**.**

6. RESULTS

The developed system is expected to produce high-quality 3D printing filament from recycled plastic, enabling the creation of durable and practical products. Through real-time monitoring and automated control, it ensures accuracy in operation and minimizes defects during filament production. Moreover, the project supports environmental sustainability by reducing carbon emissions, conserving energy, and promoting efficient recycling practices for a cleaner and greener future.

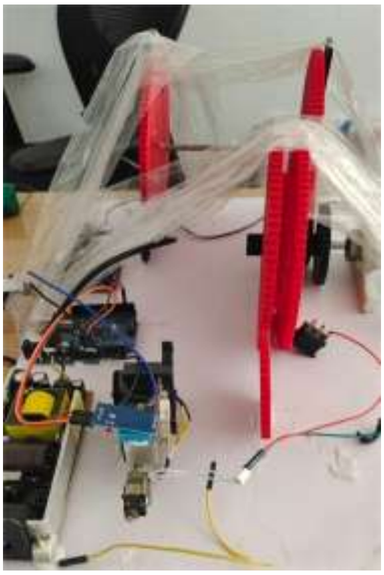

Fig 6.1 3D Printing Model

Fig 6.2 3D Printing Filament Output

7.CONCLUSION

An automated plastic recycling system for 3D printing filament transforms waste into high-quality filament through shredding, controlled extrusion, and sensor-based automation. Using an ESP32 for precise temperature and motor control, it ensures consistent output while promoting sustainability, low-cost production, and accessible manufacturing for makers, educators, and small industries.

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