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Smart Agri sphere: IOT-Powered Farming with Intelligent monitoring and sustainable Energy

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Abstract: Smart farming in rural areas faces challenges such as animal intrusions, irregular irrigation, and lack of reliable energy. This paper presents **Smart Agri Sphere**, an IoT-based system integrating intelligent monitoring, intrusion detection, and sustainable power generation. The system uses an **ESP32** with **ultrasonic, IR, sound, LDR, and soil-moisture sensors** to automate field surveillance and irrigation. Intrusions trigger a **buzzer, deterrent lights, andi instant Telegram alerts**. A **Zn/Cu bio-electrochemical cell**, powered by agricultural waste juice, provides a renewable off-grid energy source for sensor operation. The integrated design improves crop protection, reduces water usage, and supports sustainable farming. Results indicate accurate detection, efficient irrigation control, and stable micro-energy generation.

Keywords: Smart farming, IoT, intrusion detection, bio-electrochemical cell, ESP32, sustainable agriculture.

I. INTRODUCTION

Agriculture plays a vital role in sustaining livelihoods, yet farmers face continuous challenges such as animal intrusions, improper irrigation, high labour dependency, and lack of sustainable energy sources. Traditional methods fail to prevent crop damage effectively and are often expensive or unreliable. Smart farming technologies have emerged as a solution by enabling automation through IoT-based sensing and monitoring. Smart Agri Sphere aims to provide a unified system capable of intrusion detection, automated irrigation, and renewable micro-energy generation through Zn/Cu electrochemical cells using agricultural waste juice.

II. METHODOLOGY

The proposed Smart Agri Sphere system integrates IoT-enabled monitoring, automated crop protection, smart irrigation, and sustainable micro-energy generation into a unified architecture. A multi-sensor detection framework consisting of ultrasonic, IR, PIR, sound, and LDR sensors is interfaced with an ESP32 microcontroller to provide continuous real-time field monitoring. These sensors collectively detect motion, boundary breaches, ambient noise abnormalities, and variations in light intensity, enabling accurate identification of animal intrusions.

When an event is detected, the system activates deterrent mechanisms such as a buzzer and LED illumination while simultaneously sending instant alerts to the farmer through the Telegram IoT platform. For irrigation management, a soil-moisture sensor continuously assesses water content, and

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the ESP32 automatically triggers a relay-driven DC pump whenever moisture levels fall below a predefined threshold, thereby ensuring efficient water utilization.

To support deployment in rural and off-grid regions, a Zn/Cu bio-electrochemical cell powered by agricultural waste juice is employed as a renewable energy source, generating sufficient micro-power for sensors and low-energy modules. All data related to intrusion events, soil moisture, and energy output is processed by the ESP32 and transmitted to the IoT platform, enabling remote monitoring, real-time decision-making, and future expansion toward predictive analytics. This integrated methodology provides a scalable, low-power, and cost-effective smart farming solution tailored for sustainable agricultural applications.

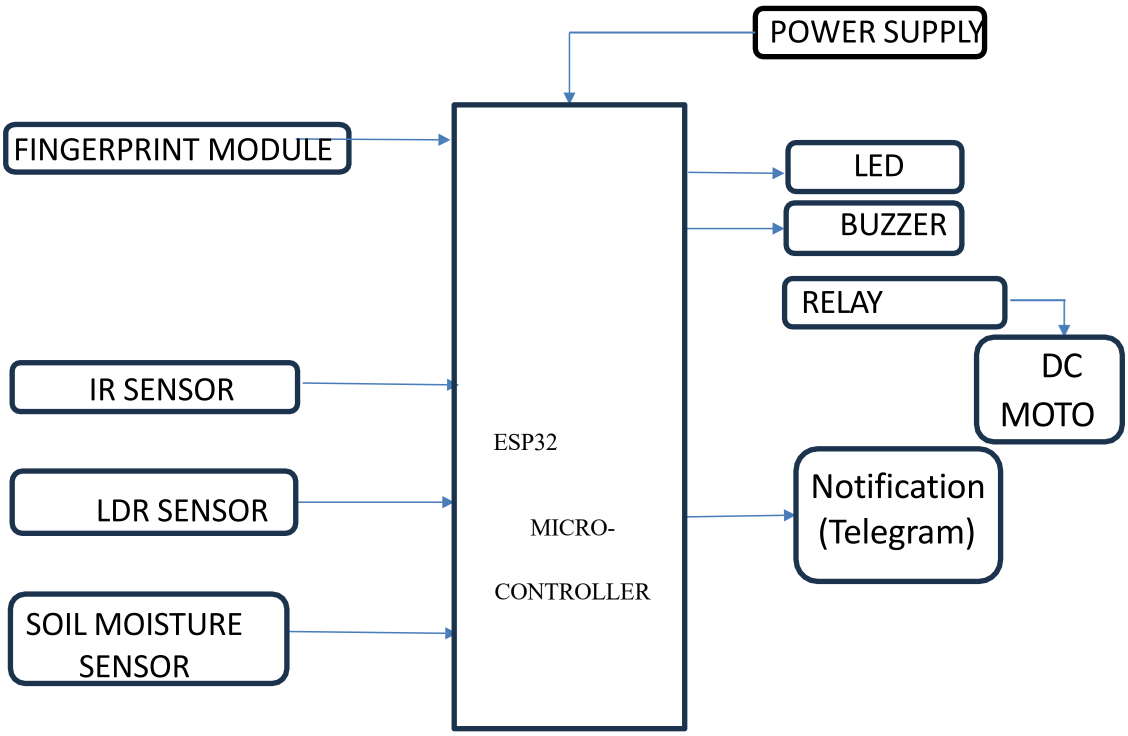

Figure1: IOT Based Smart Farming

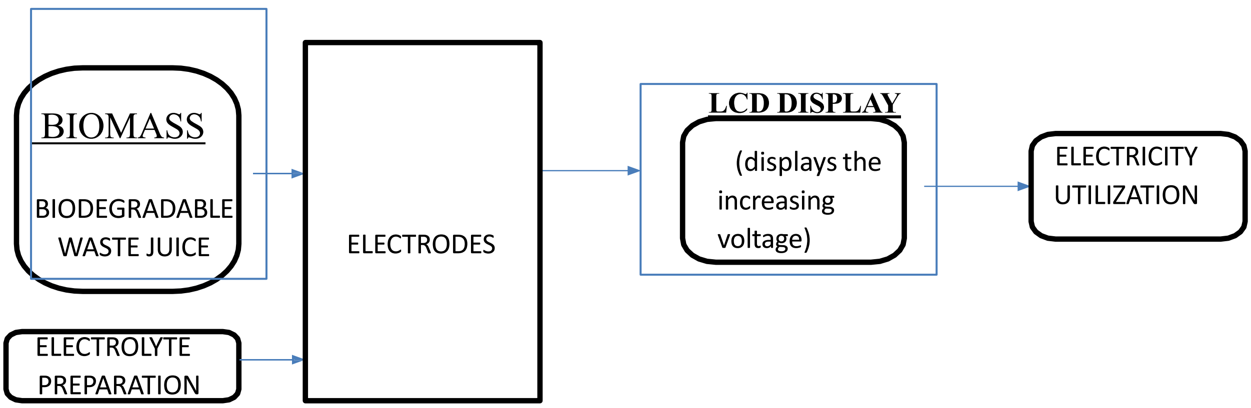

Figure 2: Generation of Sustainable energy

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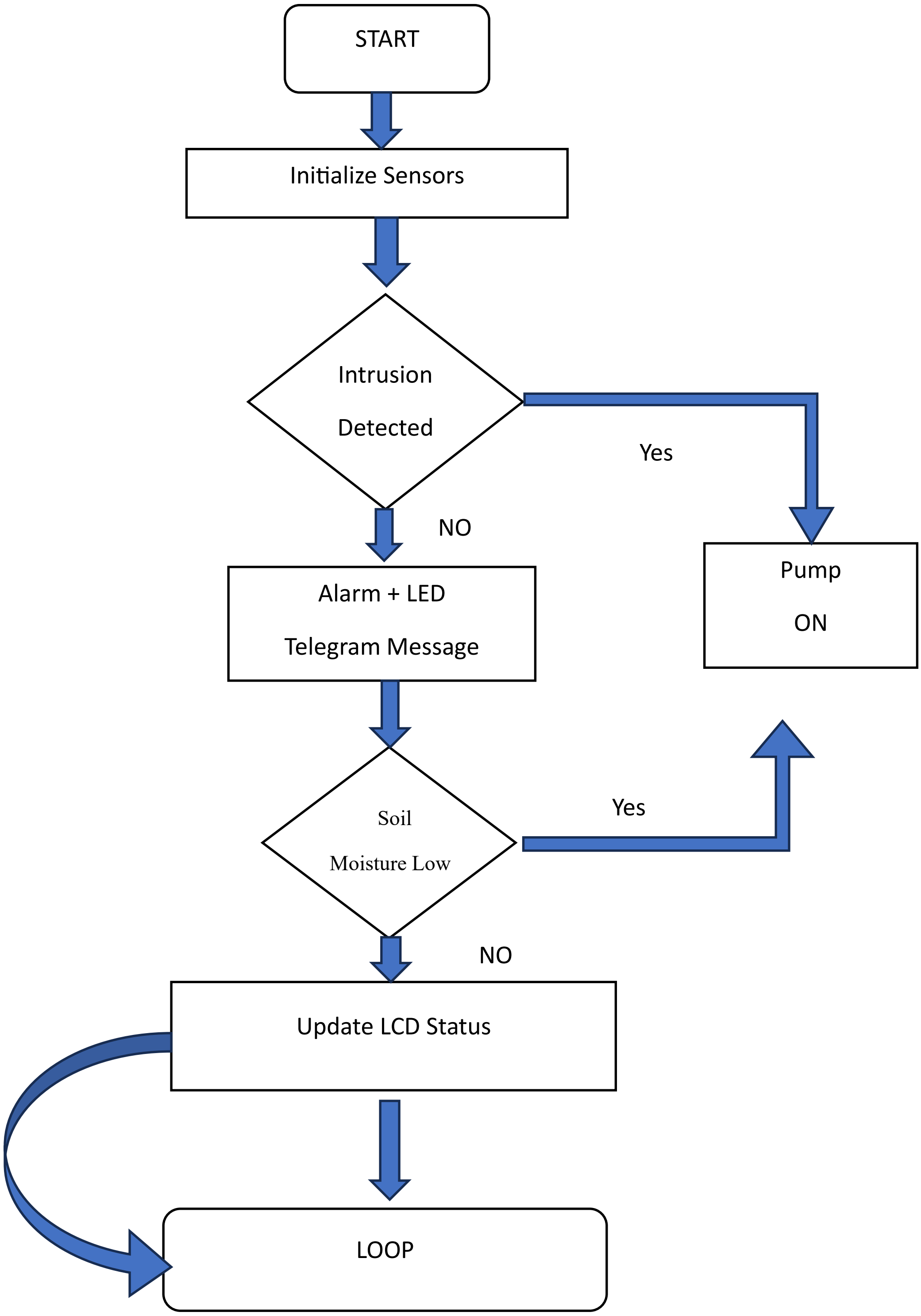

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III. RESULT

Figure 3: Smart Agriculture System

The Smart Agri Sphere system was successfully implemented and tested under controlled field conditions. The intrusion detection module demonstrated reliable performance, with ultrasonic and IR sensors accurately identifying movement within a 2–3meter range. Whenever an intrusion occurred, the buzzer and LED deterrent activated instantly, and the Telegram alert was delivered to the farmer within 1–2 seconds, ensuring timely response.

The smart irrigation unit effectively monitored soil moisture levels and activated the water pump automatically when the soil humidity dropped below the threshold. This resulted in up to 40% reduction in water usage, as water was supplied only when required. The LCD module displayed real-time status updates, improving system clarity and usability.

The bio-electrochemical Zn/Cu cell produced a stable output voltage between 0.8–1.1 V per cell, confirming its suitability as a renewable micro-power source for low-energy components. Multiple cells connected in series were able to power LEDs and small sensor modules, validating the feasibility of sustainable energy integration.

Overall, the integrated system performed efficiently, providing accurate detection, optimized irrigation control, fast IoT alerts, and reliable renewable energy generation, making it highly suitable for rural agricultural applications.

IV. CONCLUSION

This research presents an integrated IoT-based approach for intelligent agriculture, combining intrusion prevention, smart irrigation, and renewable micro-energy generation. The system

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demonstrates effective real-time monitoring, automated response mechanisms, and eco-friendly power sourcing using biomass-driven electrochemical cells. The results indicate strong potential for improving crop yield, reducing labor dependency, and promoting sustainable agricultural practices. Future enhancements include AI-driven crop prediction, solar-hybrid energy systems, and mobile-app-based dashboards**.**

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