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IOT based Smart Agriculture

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Abstract: Agriculture plays a crucial role in the economic development of agrarian nations. In India, approximately 70% of the population relies on farming, contributing nearly one-third of the country's total capital. However, persistent challenges in agriculture continue to hinder national progress. The most effective way to address these issues is through the adoption of smart agriculture by transforming conventional farming practices using modern technologies. This project is designed to enhance agricultural efficiency through automation and IoT-based solutions. Key features include a GPS-enabled, remotely controlled robot capable of performing essential tasks such as weeding, spraying, soil moisture monitoring, deterring birds and animals, and field surveillance. Additionally, the system incorporates intelligent irrigation management that leverages real-time field data for precise control and decision-making. Another integral component is smart warehouse management, which ensures optimal storage conditions by regulating temperature and humidity, along with providing theft detection. All operations are managed remotely via smart devices or computers connected to the internet, with functionality enabled through the integration of sensors, Wi-Fi or ZigBee modules, cameras, actuators, microcontrollers, and a Raspberry Pi.

Keywords: IOT, automation, Wi-Fi, Smart Agriculture

I. INTRODUCTION

Agriculture is regarded as the foundation of human life, serving as the primary source of food and essential raw materials. It plays a vital role in the economic development of a country and offers significant employment opportunities to a large portion of the population. The advancement of the agricultural sector is crucial for improving a nation's overall economic condition. However, many farmers still rely on traditional farming practices, resulting in reduced crop and fruit yields. In contrast, areas where automation and modern machinery have been implemented have witnessed substantial increases in productivity. This underscores the need to integrate scientific innovations and advanced technologies into agriculture to enhance yield.

Many research studies highlight the use of wireless sensor networks to gather data from various sensors and transmit it to a central server using wireless protocols. These networks monitor environmental parameters, aiding in field supervision. However, merely tracking environmental factors is not sufficient to significantly boost crop yield. Several other critical factors also impact productivity. These include insect and pest infestations, which can be mitigated through proper pesticide and insecticide application; damage caused by wild animals and birds during crop growth; and theft risks during the harvesting stage. Post-harvest storage also poses challenges due to environmental and security issues.

To comprehensively address these problems, it is essential to develop an integrated system capable of managing all aspects of agricultural productivity—from cultivation to harvesting and post-harvest storage. This paper proposes a smart agriculture solution that not only monitors field data but also controls various field operations, providing enhanced flexibility and efficiency.

The proposed system leverages automation and IoT technologies. Its key features include a GPS-enabled, remotely operated robotic unit that performs tasks such as weeding, spraying, soil moisture sensing, bird and animal deterrence, and field surveillance. It also incorporates a smart irrigation system that operates based on real-time field conditions. Furthermore, the system includes smart warehouse management with features such as temperature and humidity regulation and theft prevention. All these functions can be remotely monitored and controlled through smart devices or computers connected to the internet, with the system architecture comprising sensors, Wi-Fi or ZigBee modules, cameras, actuators, microcontrollers, and Raspberry Pi.

II. LITERATURE REVIEW

The declining water table, depletion of rivers and reservoirs, and increasing environmental unpredictability have created an urgent need for efficient water utilization in agriculture.

To address this, temperature and soil moisture sensors can be strategically deployed to monitor crop conditions, as described in [1]. An algorithm using threshold values for temperature and moisture can be embedded into a microcontroller-based gateway, enabling precise irrigation control. Such systems can be powered by solar panels and equipped with a two-way communication interface via cellular or internet connectivity, allowing real-time data access and irrigation scheduling through a web interface [2].

Advancements in Wireless Sensor Networks (WSNs) have significantly enhanced monitoring and control capabilities in precision agriculture, particularly in greenhouse environments [3]. Research indicates a continuous decline in agricultural productivity, which can be countered by integrating technology to not only boost yields but also reduce labor requirements. Various studies have introduced systems that leverage technological innovation to support farmers and improve crop output.

One notable development is a remote sensing and irrigation control system utilizing a distributed WSN, as proposed by Y. Kim. This system supports variable rate irrigation through real-time in-field sensing and site-specific control of a precision linear move irrigation setup. It comprises five sensor stations distributed across the field, each gathering environmental data and transmitting it to a base station via GPS. The base station then processes the data and triggers irrigation as needed, based on a pre-existing database. This approach presents a cost-effective wireless solution for remote precision irrigation management [4].

Further studies on WSNs for agriculture have focused on measuring soil parameters such as temperature and humidity. Sensors were embedded beneath the soil surface and communicated with relay nodes using low-duty-cycle protocols to extend system lifespan. These systems employed microcontrollers, UART interfaces, and sensors for data collection, which was periodically buffered and transmitted. However, challenges included high system costs and RF signal attenuation due to subsurface sensor placement [5].

III. SYSTEM OVERVIEW

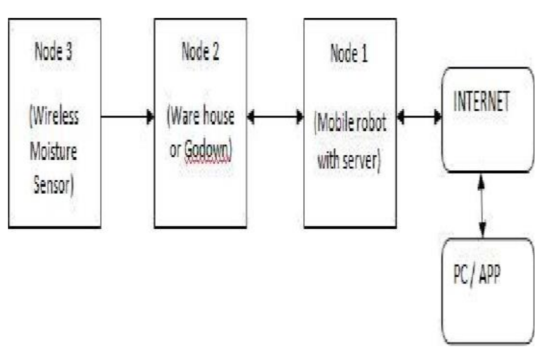

Figure I : System overview

The paper is divided into four sections: nodel, node2, node3, and PC or mobile app to control the system. In the current system, each node is integrated with various sensors and devices and connected to a central server via wireless communication modules. The server sends and receives information from the user via internet connectivity. The system has two modes of operation: automatic and manual. In auto mode, the system makes its own decisions and controls the installed devices, whereas in manual mode, the user can control system operations via the Android app or PC commands.

IV. ARCHITECTURE OF THE SYSTEM

Node l :

Node 1 is a GPS-enabled mobile robot that can be controlled remotely via a computer or programmed to navigate autonomously within a designated field area using coordinates provided by the GPS module.

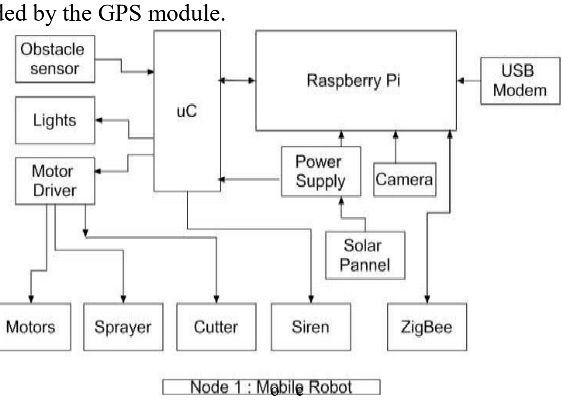

Figure 2: Node 1

This remote-controlled robot is equipped with various sensors and devices such as a camera, obstacle sensor, siren, cutter, and sprayer. It is capable of performing several tasks including surveillance, scaring birds and animals, weeding, and spraying.

Node 2:

Node 2 is a warehouse system that integrates multiple sensors and devices, such as a motion detector, light sensor, humidity sensor, temperature sensor, room heater, and cooling fan, all interfaced with an AVR microcontroller. The motion detector detects any movement in the warehouse when the security mode is activated. Upon detection, it alerts the user via a Raspberry Pi, enabling theft detection.

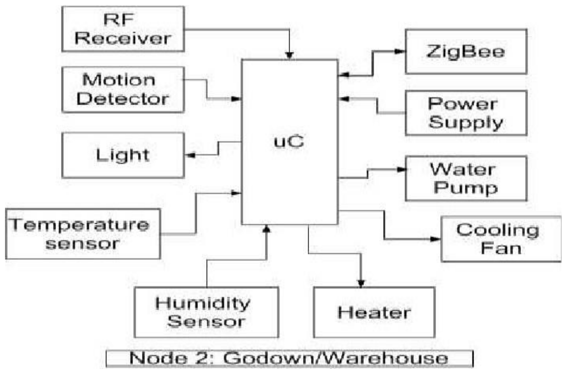

Figure 3: Node 2

The temperature and humidity sensors monitor environmental conditions, and if the values exceed thresholds, the room heater or cooling fan automatically adjusts to maintain optimal conditions. Additionally, Node 2 controls a water pump based on the soil moisture data received from Node 3.

Node 3:
Node 3 is a smart irrigation system that automates water pump control based on real-time field data. In auto mode, the system automatically turns the water pump on or off to maintain the required soil moisture level. In manual mode, users can control the water pump remotely via a mobile device or computer. This node continuously monitors soil moisture levels and sends the data to Node 2, which processes it to control the water pump's operation.

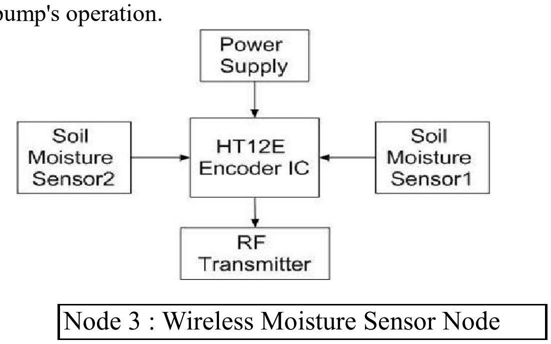

Figure 4: Node 3

In Node 3, the moisture sensor sends data via the HT12E Encoder IC and an RF transmitter. This transmitted data is then received by Node 2, where it is processed by the microcontroller to manage the operation of the water pump.

Hardware Used:

- **AVR Microcontroller Atmega 16/32:** This low-power 8-bit microcontroller features 8K bytes of self-programmable flash memory, 23 I/O lines, and a 10-bit ADC, ideal for sensor data processing.

- **ZigBee Module:** Used for wireless communication between Node 1 and Node 2, ZigBee operates at a low power consumption and provides a communication range of about 50 meters, which can be extended using high-power modules or a network of devices.

- **Temperature Sensor LM35:** A low-cost temperature sensor whose output voltage is directly proportional to temperature in Celsius. It provides accurate temperature readings within a range of -55°C to +150°C.

- **Moisture Sensor:** This sensor measures the soil's water content by using electrical resistance. It communicates moisture data to the microcontroller for water pump control.

- **Humidity Sensor (DHT11):** A basic, low-cost sensor for measuring temperature and humidity. It provides digital output without the need for ADC conversion, though it updates data every 2 seconds.

- **Obstacle Sensor (Ultrasonic):** An ultrasonic sensor that measures distance by emitting sound waves and analyzing the time it takes for the waves to return after hitting an obstacle. It helps in obstacle detection for the mobile robot and as a motion sensor for theft detection in the warehouse.

- **Raspberry Pi:** A compact computer used for networking and controlling the automation system remotely. It supports internet connectivity and facilitates remote operation of the system. The Pi model used is the Pi 2 Model B, equipped with a quad-core ARM Cortex-A53 CPU and 1GB of RAM.

Software Used:

- **AVR Studio Version 4:** This software is used for writing, compiling, and debugging embedded C programs for microcontrollers, generating .hex files for burning into the microcontroller.

- **Proteus 8 Simulator:** A simulation software used for testing microcontroller designs and embedded systems before hardware implementation, reducing the risk of damage due to design errors.

- **Dip Trace:** An EDA/CAD tool for creating schematic diagrams and printed circuit boards (PCBs). It provides features such as an auto-router, 3D preview, and component editor.

- **Singapore:** A Hex downloader and fuse bit calculator tool for programming AVR microcontrollers.

- **Raspbian OS:** A Debian-based open-source operating system optimized for Raspberry Pi, offering a wide range of pre-compiled software packages for easy installation and operation.

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V. EXPERIMENTATION AND RESULTS

Figure 5: experimental setup for Nodel

As illustrated in Figure 5, the experimental setup for Node 1 includes a mobile robot connected to a central server, along with a GPS module, camera, and various sensors. All sensors have been successfully interfaced with the microcontroller, which in turn is connected to the Raspberry Pi. Both the GPS and camera are also linked to the Raspberry Pi. Test results demonstrate that the robot can be controlled remotely through wireless transmission of PC commands to the Raspberry Pi. The Raspberry Pi forwards these commands to the microcontroller, which sends signals to the motor driver to control the robot's movement. Additionally, the GPS module provides the robot's location coordinates.

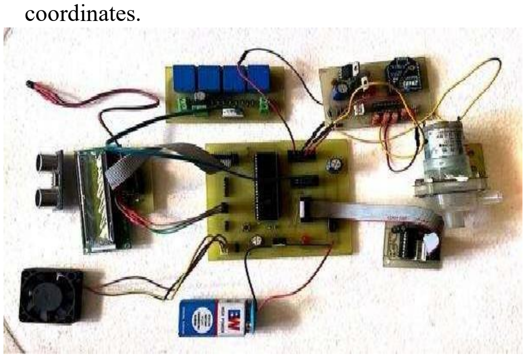

Figure 6: experimental setup for Node2

As shown in the figure above, Node 2 comprises a motion detector, temperature sensor, humidity sensor, cooling fan, water pump, and other devices connected to the microcontroller board. The sensors provide input to the microcontroller, which controls the devices in auto mode based on the sensor data. Additionally, the microcontroller sends sensor readings to the Raspberry Pi, which then forwards the data to the user's smart device via the internet. Test results indicate that when the temperature exceeds a preset threshold, the cooling fan is automatically activated in auto mode. Similarly, if the soil moisture level falls below a predefined threshold, the water pump is turned on. In manual mode, the microcontroller receives control signals from the Raspberry Pi via ZigBee and performs the corresponding actions based on the received commands.

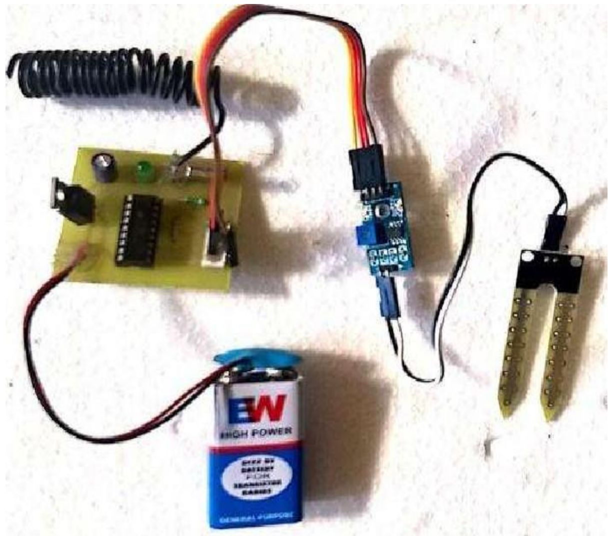

Figure 7: experimental setup for Node3

As shown in the figure above, Node 3 consists of a moisture sensor connected to the HT12E Encoder IC. The moisture sensor transmits data using the HT12E Encoder IC and an RF transmitter to Node 2, where the data is processed by the microcontroller. Based on the received data, the microcontroller controls the operation of the water pump, turning it ON or OFF accordingly.

VI. CONCLUSION

The successful integration of sensors and microcontrollers across all three nodes with the Raspberry Pi has enabled effective wireless communication between the nodes. Experimental tests and observations confirm that this project provides a comprehensive solution to address field activities, irrigation challenges, and storage issues. The use of a remote-controlled robot, a smart irrigation system, and a smart warehouse management system effectively tackles various agricultural concerns. The implementation of such a system in real-world scenarios is likely to enhance crop yield and overall production.

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