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Tree Health Monitoring and Management System using IoT

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Abstract- **This paper explores innovative approaches to environmental and tree health monitoring using IoT, machine learning, and advanced communication systems. A LoRaWAN-based sensor system for urban trees collects real-time data on soil moisture, temperature, and humidity, improving tree management. Another study focuses on an IoT system for coconut trees, enhancing remote agricultural decision-making. A heterogeneous neural network (HNN) predicts the Urban Tree Health Index (UTHI) with high accuracy, automating tree assessments. Lastly, a hybrid edge computing and LoRa architecture enables real-time forest monitoring, addressing challenges like deforestation and climate change. Together, these technologies promote sustainable forestry and tree health management.**

Index Terms: **LoRaWAN, HNN, UTHI, edge computing, remote sensing, ThingSpeak.**

I. INTRODUCTION

The collection of research papers explores innovative approaches to environmental monitoring and tree health assessment using advanced technologies such as the Internet of Things (IoT), LoRaWAN, and machine learning. A LoRaWAN-Based Environmental Sensor System for Urban Tree Health Monitoring discusses the development of a low-power, wireless sensor system designed to monitor various environmental parameters affecting urban trees. The study highlights the integration of soil temperature, moisture sensors, and air temperature/humidity sensors to assess tree health, demonstrating the effectiveness of LoRa technology in urban settings. IoT Based Smart Coconut Tree Health Monitoring System for Sustainable Agriculture in India presents a novel wireless sensor network that enables continuous monitoring of coconut tree health. This system leverages IoT technology to provide real-time data on soil moisture and other critical parameters, aiming to enhance agricultural practices and sustainability in coconut farming. Urban Tree Health Assessment using Heterogeneous Neural Network: A Novel Approach introduces an Urban Tree Health Index (UTHI) developed through a heterogeneous neural network model. This model utilizes both dynamic and static features to evaluate tree health, offering a more efficient and automated assessment method compared to traditional manual inspections. LoED: LoRa and Edge Computing based System Architecture for Sustainable Forest Monitoring proposes a hybrid architecture that combines LoRa technology and edge computing for real-time forest monitoring. The architecture aims to address challenges such as population growth and environmental degradation by monitoring soil, water quality, and climate conditions to support sustainable forest management.

II. LITERATURE REVIEW

This section of the manuscript highlights various research works undertaken to eradicate the problems faced by farmers and tree growers nationally and internationally.

The domain of Internet of Things has opened up extremely productive ways to cultivate soil and raise livestock for farmers and growers. Prospering on this fruitful usage of IOT in agriculture [2], smart monitoring based farming applications (discussed below) capable enough to deliver 24/7 visibility into soil and crop health are on demand.

The Kaa open-source IoT Platform (promoting the development of smart farming systems) is one of the crucial middleware technology platfporms meant for tying together different sensors, connected devices, and farming facilities.

Kaa provides a quick start set of ready-to-use components with smart farming applications like Sensor based field and resource mapping, Remote equipment monitoring, Remote crop monitoring, Predictive analytics for crops and livestock, climate monitoring and geo-fencing[11] etc.

FarmBeats- is another end to end IOT platform for agriculture that enables seamless data collection from various sensors, cameras and Drones. FarmBeats's system design accounts for weather related power and internet outages [12].

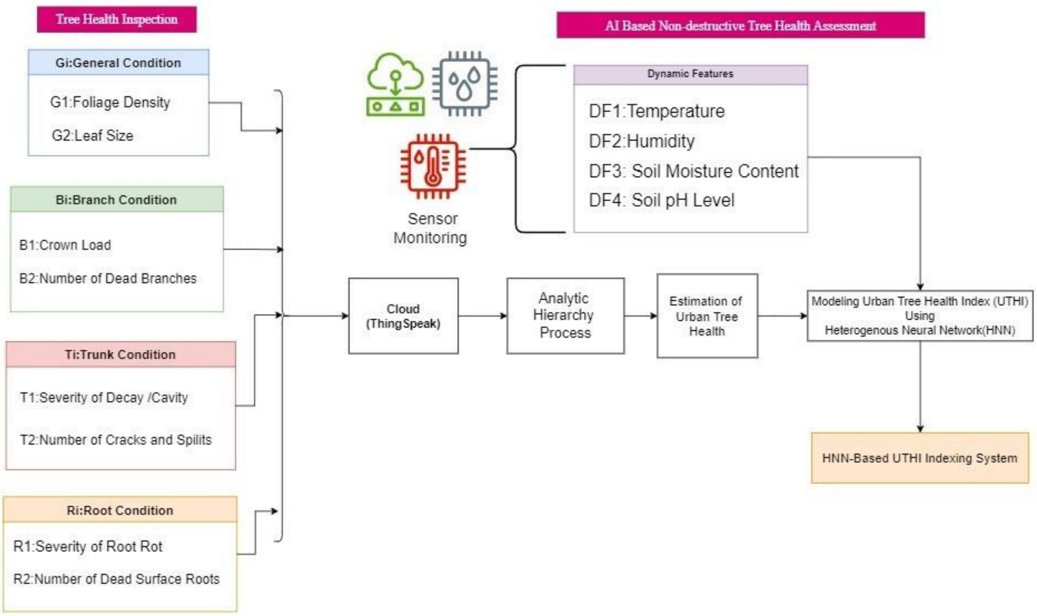
IoT based sensor technologies are driving towards development of sustainable, environment friendly smarter cities catering to digital transformation around the world. South Korea ranked top owing to its readiness for sustained IoT adoption among countries in Asia Pacific region [13].

Waspmote Plug & Sense – enabled tracking of environmental parameters such as farming, vineyards or greenhouses. It was made applicable in countries like Italy, Slovenia, Indonesia, Switzerland, Australia and others for a variety of crops [13].

Others like Link Labs, Thingworx keep providing IoT architectures to benefit the agricultural industry enabling monitoring of crops, climate etc[14].

Farmers in Brazil are using unmanned tools like drones, to collect, analyze and transmit real-time crop intelligence to monitor the usage of chemicals, and irrigate dry fields in order to improve the yields. Information received over the mobile handsets of farmers is helpful to make real time data-based decisions about resource utilization by means of analyzing vast generated data. Large numbers of farmers are now Deploying "Precise Agriculture" Technology Using Field Sensors for monitoring farm operations.
It was expected that by 2020, around 20 billion Internet connected devices are going to use techniques like advanced computing, complex analysis, and artificial intelligence, etc. to monitor the farming activities.According to industry body NASSCOM, majority of the IoT start-ups in the country started focusing on smart agriculture with innovations ranging from smart irrigation, agri-drones, robotic harvesting to the production monitoring and agrisensors as well.

III. PROPOSED SYSTEM



System Architecture

1. Proposed IOT based tree health monitoring system is useful for remotely monitoring the health of trees at any place in the world by means of a hand held mobile phone [1].
2. Proposed IOT system is a low power consumption dual powered system that can even work on solar power to ensure continuous usage without any power break.

3. Proposed IOT system provides high quality security aspects through wireless sensor networks.
4. Data generated through proposed system can be remotely monitored for analysis based on cloud Computing. A brief description clearly illustrating the reasons for choosing few modules is specified below:

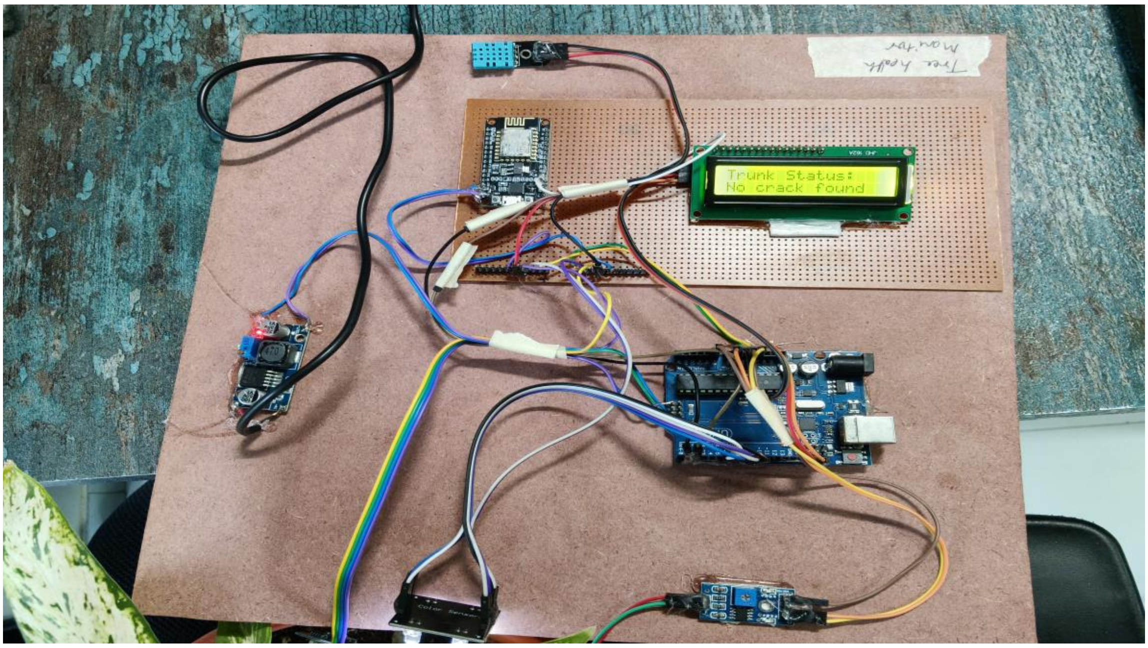
a) Raspberry Pi 3 Embedded Board, with a quadcore ARM Cortex-A53 processor is known to Pi 1 board and operates at 80% faster than Raspberry Pi 2 board in parallelized tasks.

b) Universal Software Radio Peripheral (USRP) is a family of software-defined radios designed and sold by Ettus Research, a low-cost software hardware platform used by research labs, universities and hobbyists around the world.

c) Most USRPs connect the host through a highspeed link to control its hardware and send / receive data. Some USRP models also integrate host functionality with a built-in processor that allows the USRP device to operate independently.

d) Many products in USRP series are open source hardware. All USRP products are controlled by open source UHD drivers. The USRP is often used with the software package GNU Radio to create complex radio systems defined by software.

IV. IMPLEMENTATION AND RESULT



Implementation of circuit

1. Implementation of Circuit

Each component is wired carefully on a breadboard or prototyping PCB. The DHT sensor’s data pin is connected to a digital pin on the Arduino, while the soil moisture sensor connects to an analog input. The crack sensor is attached to the tree surface and connected to a digital pin. The LCD is interfaced using the I2C protocol, which reduces the wiring complexity. The voltage regulator is integrated to convert higher input voltage (e.g., from a battery) to the 5V required by the Arduino and sensors.The Arduino is programmed using the Arduino IDE with logic to read and process sensor inputs. For each sensor, the program defines safe threshold ranges. For example, if soil moisture drops below a certain value, the system can flag it as "Dry Soil." If a crack is detected by the sensor, the LCD will display a warning like "Crack Detected." The LCD continuously updates in real time. If the NodeMCU is used, it is programmed to send the sensor values to an IoT platform like Arduino IDE using Wi-Fi.

2. Testing and Calibration

The system is tested in different conditions to ensure accuracy and reliability. Soil moisture is measured in both dry and wet soil to calibrate the sensor's analog values. Temperature and humidity readings are verified with standard instruments. The crack sensor is tested with both stable and disturbed surfaces. Based on these tests, thresholds are fine-tuned in the Arduino code for more accurate monitoring.

Test for moisture and temperature

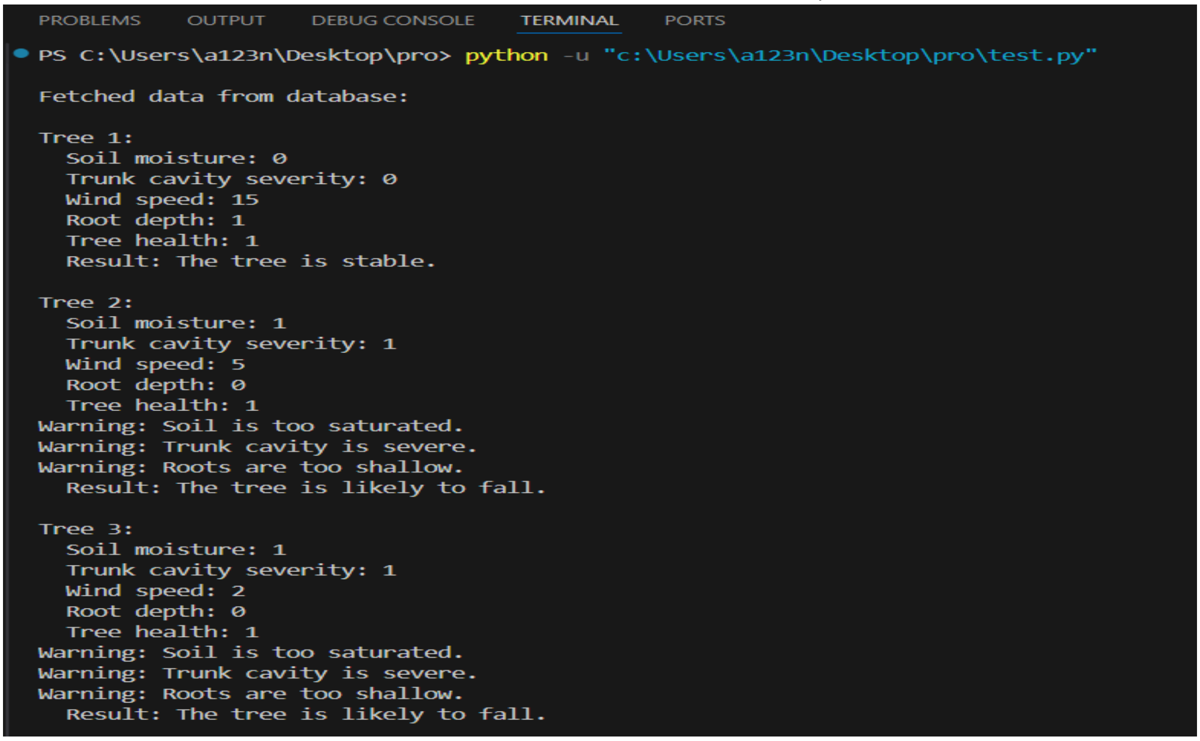
3. Website Login Module

The login page acts as a secure gateway for users to access personalized data and system controls related to tree health monitoring. It ensures that only authorized users, such as researchers, environmentalists, or forest authorities, can view and manage sensor data, system alerts, and reports. The interface follows a clean, modern aesthetic. The design features a prominent login/register toggle box placed over a high-quality background image of a healthy tree integrated with digital monitoring equipment, reinforcing the fusion of nature and technology.

4. Result

The Python script shown in the terminal fetches and processes sensor data related to different trees from a connected database. This back-end logic runs on the operator or developer's system, simulating or retrieving real-time values from sensors deployed near the trees.

The output ends with a final diagnostic result, e.g.:
"The tree is stable."
"The tree is likely to fall."



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PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL    PORTS

PS C:\Users\a123n\Desktop\pro> python -u "c:\Users\a123n\Desktop\pro\test.py"

Fetched data from database:

Tree 1:
  Soil moisture: 0
  Trunk cavity severity: 0
  Wind speed: 15
  Root depth: 1
  Tree health: 1
  Result: The tree is stable.

Tree 2:
  Soil moisture: 1
  Trunk cavity severity: 1
  Wind speed: 5
  Root depth: 0
  Tree health: 1
Warning: Soil is too saturated.
Warning: Trunk cavity is severe.
Warning: Roots are too shallow.
  Result: The tree is likely to fall.

Tree 3:
  Soil moisture: 1
  Trunk cavity severity: 1
  Wind speed: 2
  Root depth: 0
  Tree health: 1
Warning: Soil is too saturated.
Warning: Trunk cavity is severe.
Warning: Roots are too shallow.
  Result: The tree is likely to fall.
```

Result

V. CONCLUSION

The studies collectively highlight the significant advancements in environmental monitoring and tree health assessment through the integration of IoT technologies, machine learning, and wireless communication systems like LoRaWAN.

LoRaWAN-Based Environmental Monitoring: The implementation of a LoRaWAN-based sensor system for urban tree health monitoring demonstrates the effectiveness of low-power, long-range communication in collecting real-time data on critical environmental parameters. The findings indicate strong correlations between various factors affecting tree health, such as soil moisture, temperature, and humidity, which can inform better management practices.

Smart Coconut Tree Health Monitoring: The IoT-based system for coconut tree health monitoring showcases the potential for remote monitoring in agriculture. By providing farmers with real-time insights into soil and environmental conditions, the system enhances decision-making capabilities, ultimately leading to improved agricultural practices and sustainability.

Urban Tree Health Assessment Using Machine Learning: The development of a heterogeneous neural network (HNN) for assessing urban tree health introduces a novel approach to integrating dynamic and static features. The high accuracy of the HNN in predicting the Urban Tree Health Index (UTHI) emphasizes the role of machine learning in automating tree health assessments, which can significantly reduce management costs and improve urban forestry practices.

Edge Computing and LoRa for Forest Monitoring: The proposed architecture combining edge computing with LoRa technology for sustainable forest monitoring illustrates a comprehensive approach to real-time data collection and analysis.

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