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AN INTEGRATED IOT ARCHITECTURE FOR REAL-TIME ANTI-POACHING AND FOREST MONITORING USING A MULTI-SENSOR NETWORK

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Abstract

Illegal logging and forest fires pose serious threats to environmental sustainability, biodiversity and national economies, particularly through the exploitation of high-value species such as Indian Sandalwood and Teak. Conventional surveillance methods relying on manual patrols are often ineffective due to vast forest areas and delayed response times. This paper presents a cost-effective, IoT-based anti-poaching and fire detection system that enables continuous, automated forest monitoring. The proposed design integrates an Arduino Mega 2560 microcontroller with multiple sensors—an ADXL335 accelerometer for vibration and tilt detection, a sound sensor for chainsaw noise identification and a DHT11 sensor for temperature monitoring. Detected anomalies activate local actuators such as a buzzer and submersible water pump for immediate on-site response, while an ESP8266 Wi-Fi module transmits real-time data and alerts to the ThingSpeak cloud platform for remote supervision. The system was rigorously tested under simulated conditions, demonstrating high accuracy, low false-positive rates and reliable wireless communication. Results confirm its capability to detect illegal logging and fire events promptly, providing both deterrence and rapid response mechanisms. This IoT-driven, scalable approach offers a practical pathway toward sustainable forest protection with potential future enhancements in energy autonomy, long-range connectivity and intelligent pattern recognition using machine learning.

Keywords

Internet of Things (IoT), Wireless Sensor Network (WSN), Anti-Poaching, Illegal Logging, Forest Monitoring, Arduino, Real-Time Alert System, Environmental Conservation.

1. Introduction

The illegal exploitation of forests, particularly through the poaching of high-value species such as Indian Sandalwood (Santalum album) and Teak (Tectona grandis), poses a major environmental and economic threat. Beyond the loss of trees, deforestation drives habitat destruction, soil erosion, biodiversity decline, and rising carbon emissions. Economically, illegal timber trade undermines local economies and often finances organized crime.

Indian Sandalwood, priced at INR 12,000–13,000 per kilogram in domestic markets, remains a prime target for smuggling, prompting its classification as a rare species and strict governmental regulation. Traditional forest protection largely depends on manual patrols, which are constrained by large forest areas, resource limitations, and delayed responses. These reactive methods highlight the urgent need for automated and intelligent surveillance capable of continuous monitoring and real-time alerts.

Advancements in affordable sensors, microcontrollers, and wireless networks have enabled the Internet of Things (IoT), which holds transformative potential for forest monitoring. Wireless Sensor Networks (WSNs) can efficiently collect ecological data across vast areas. Prior research has explored accelerometers to detect tree-cutting vibrations, acoustic sensors to identify chainsaw activity, and fire detection using temperature and smoke sensors. Building on these studies, this work presents an integrated IoT-based anti-poaching system that combines tilt, acoustic, and temperature sensors with local actuation and cloud-based monitoring. This multi-sensor design reduces false positives common in single-sensor systems and enhances reliability in detecting poaching events. By utilizing widely available components and open-source platforms, the system ensures cost-effectiveness, scalability, and practical deployment for sustainable forest protection.

2. Literature Review

Over the past decade, technology for forest conservation has advanced considerably. Early efforts relied on satellite-based remote sensing to detect large-scale deforestation. While useful for macro-level analysis, these systems lacked the real-time precision required to prevent individual poaching incidents. The introduction of Wireless Sensor Networks (WSNs) enabled finer and localized monitoring. For instance, [4] proposed a microcontroller-based approach using a 3-axis MEMS accelerometer to detect vibrations during tree cutting, validating the model through simulated cutting events. Similarly, [8] explored WSN nodes with GPS modules to track the continuous location of trees, helping distinguish between natural felling and poaching.

Research has since shifted toward integrating multiple sensors for more reliable detection. A notable study [5] employed tilt, sound, and temperature sensors, with data transmitted via Wi-Fi to the Blynk application. Their system activated alarms such as buzzers and pumps using relay switches, while data were stored on the Blynk server. This reflects the growing emphasis on IoT-enabled multi-sensor fusion. In addition, WSN-based forest monitoring frameworks have been proposed to extend beyond poaching detection, addressing challenges such as animal intrusion, fire monitoring, and deforestation [9]. These systems aim to reduce reliance on manual patrols and create autonomous monitoring networks.

The system presented in this paper advances this trajectory by combining these approaches into a validated prototype with a complete IoT architecture. It prioritizes practical implementation, featuring detailed hardware and software design, robust communication protocols, and real-world testing. Unlike conceptual studies, this work demonstrates a functional, deployable solution for preventing tree poaching through integrated, cost-effective technology.

3. Methodology

The overarching architecture of the anti-poaching system is designed to sense, process, actuate, and communicate. The system can be conceptually divided into four layers: the Sensing Layer, the Processing and Control Layer, the Actuation Layer, and the Communication and Cloud Layer. Figure 1 illustrates the complete block diagram of the system.

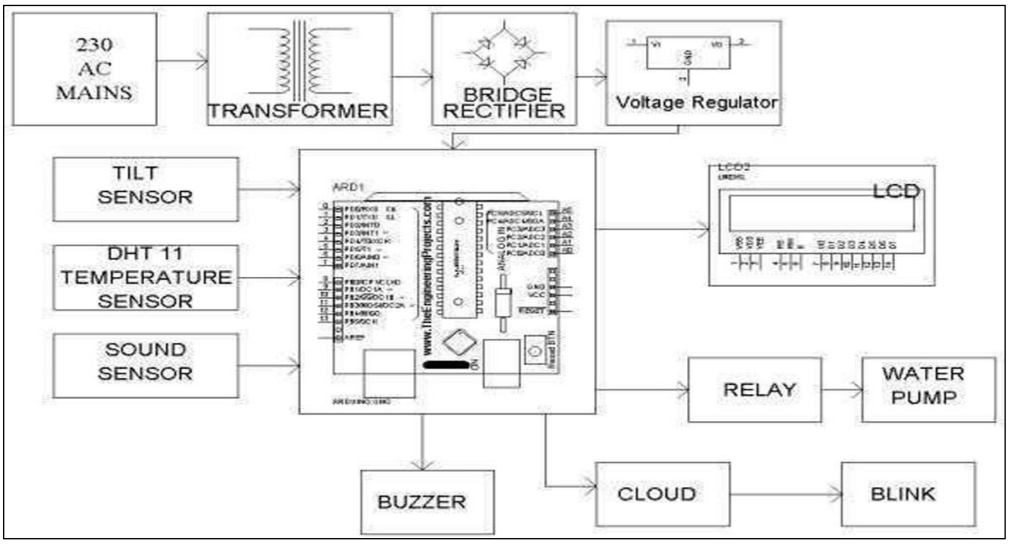

Figure 1 - Block diagram of the anti-poaching alarm system

3.1 Hardware Design and Component Selection

The hardware of the system is designed for reliability, low power consumption, and suitability for outdoor deployment. The power supply unit utilizes a 230V AC mains source, stepped down to 12V AC through a transformer. This is rectified into pulsating DC using a bridge rectifier with IN4007 diodes, filtered by a capacitor, and regulated to a stable 5V DC via an LM7805 voltage regulator for powering the Arduino and sensors, while maintaining a 12V DC line for the submersible water pump. At the core of the system, the Arduino Mega 2560 microcontroller serves as the processing and control unit, chosen for its large number of input and output pins (54 digital and 16 analog) that support multiple sensors and actuators simultaneously, eliminating the need for multiplexers and enabling continuous monitoring algorithms. The sensing unit integrates three types of sensors: the ADXL335 accelerometer, which detects inclination and vibration to identify tree cutting through deviations in calibrated X and Y axis values; a sound sensor module calibrated to capture sharp, sustained noises typical of chainsaws or axes above a 50 dB threshold; and the DHT11 temperature and humidity sensor, which provides digital readings for early fire detection, with alerts triggered when temperatures exceed 35°C. For actuation, a 5V piezoelectric buzzer generates immediate audible alarms to deter illegal logging, while a 5V relay module controls a 12V submersible water pump that activates automatically for fire suppression when triggered by the temperature sensor. Finally, the communication unit employs an ESP-01 ESP8266 Wi-

Fi module, interfaced with the Arduino via software serial, to connect to local networks and transmit sensor data and alert notifications to the cloud server for remote monitoring and intervention.

3.2 Software Algorithm and IoT Integration

The system firmware, developed in the Arduino IDE using C++, operates in a continuous loop that reads sensor data, processes it against thresholds, controls actuators, and transmits information to the cloud. At startup, the system initializes all pins, establishes serial communication, and connects the ESP8266 Wi-Fi module to a predefined network. During operation, the Arduino continuously reads analog inputs from the accelerometer and sound sensor, while periodically acquiring digital temperature values from the DHT11 sensor. These readings are compared against thresholds to detect abnormal events. If the temperature exceeds 35°C, the relay activates the water pump and the buzzer sounds to indicate fire. If sound levels surpass 50 dB, logging activity is suspected and the buzzer is triggered. Abnormal accelerometer readings outside 280–360 on X or Y axes also activate the buzzer. A 16x2 LCD displays real-time data locally, while the ESP8266 transmits structured sensor data to the ThingSpeak platform every 16 seconds, creating a remote monitoring dashboard.

3.3 System Implementation

The circuit was designed using the EAGLE PCB design software and assembled on a general-purpose PCB. All components were housed in a protective casing and mounted on a simulated tree trunk for testing. The complete circuit diagram is shown in Figure 2.

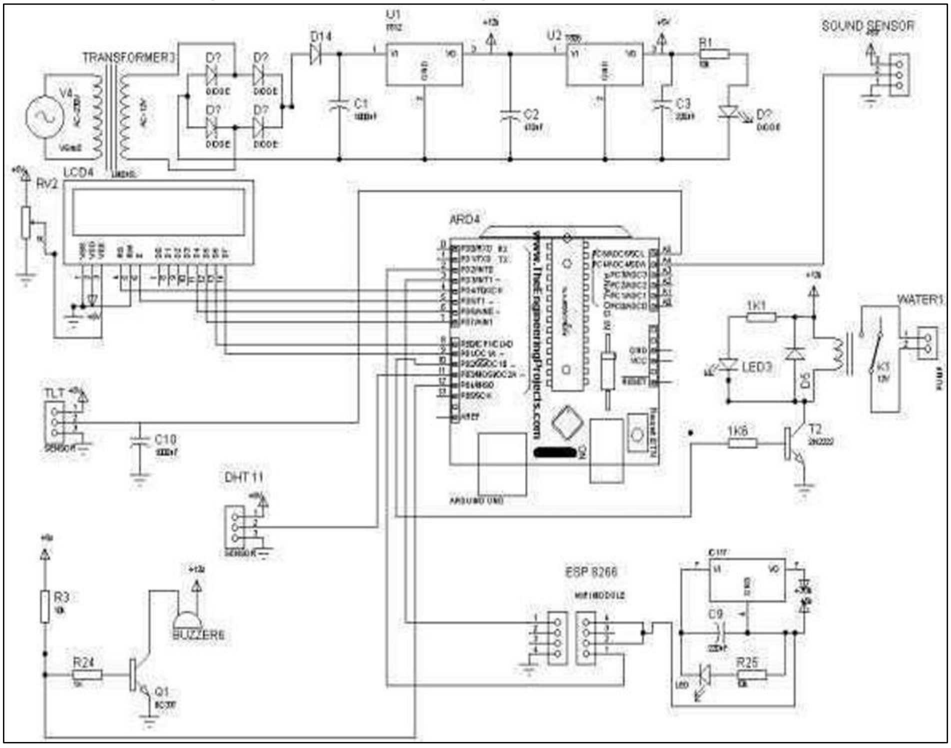

Figure 2 - Circuit diagram of the system

4. Results and Discussion

The proposed system underwent extensive testing to evaluate the functionality of individual components as well as the integrated prototype, with scenarios designed to replicate real-world poaching and fire conditions. Each sensor was first calibrated to ensure accuracy and reliability. The accelerometer was tuned to record baseline values for a stationary tree, while the sound sensor was tested with varied noise sources to establish a threshold that ignored normal forest sounds but responded to sharp mechanical noises. The DHT11 temperature sensor was verified against a standard thermometer and confirmed to operate within its stated accuracy range. Once calibrated, the integrated system was tested under simulated threats. In the tilt and vibration test, applying force to the tree trunk caused accelerometer readings to exceed thresholds, triggering the buzzer and logging the event on the ThingSpeak dashboard as a visible spike in accelerometer data. In the sound test, recordings of chainsaws and axes activated the sound sensor, leading to immediate buzzer activation and cloud logging of increased sound levels. For the fire test, a heat source raised the ambient temperature above 35°C, prompting the DHT11 sensor to activate both the buzzer and water pump relay while updating the dashboard with elevated temperature and pump status changes. Communication reliability was also confirmed, with the ESP8266 consistently transmitting data to the ThingSpeak platform without interruptions. The results demonstrate that the multi-sensor approach significantly enhances system reliability by minimizing false positives, as single-sensor anomalies are filtered by cross-verification. Overall, the system effectively achieves real-time detection, local deterrence, and cloud-based remote monitoring. A photograph of the working prototype during testing is shown in Figure 3.

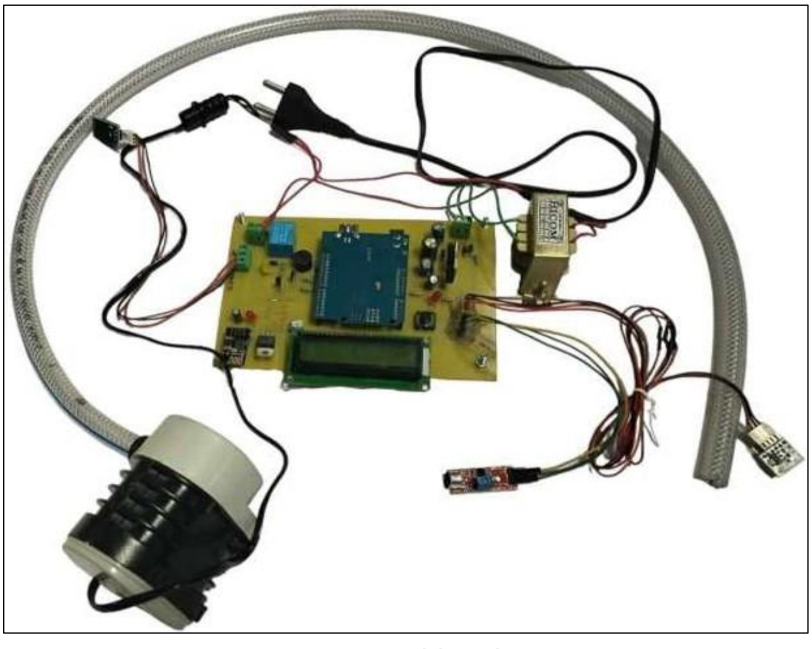

Figure 3 - Implemented hardware prototype

5. Conclusion and Future Work

This research successfully designed, implemented, and validated a cost-effective IoT-based anti-poaching system for forest trees. The system integrates accelerometer, acoustic, and temperature sensors to reliably detect illegal logging and forest fires, triggering local actuation while simultaneously transmitting alerts to a cloud-based dashboard via Wi-Fi for real-time remote response by forest authorities. The prototype demonstrated high reliability in controlled tests, effectively identifying simulated threats and ensuring prompt communication. This marks a significant step toward automating forest conservation by providing a scalable and practical solution deployable across vulnerable areas to deter poaching, safeguard biodiversity, and protect economic resources.

Future enhancements aim to transition the prototype into a robust field-deployable product. Energy autonomy will be achieved by integrating solar panels and high-capacity batteries for sustainable operation in remote, off-grid locations. Communication capabilities will be improved by replacing Wi-Fi with GSM, GPRS, or LoRa modules to ensure long-range connectivity. Machine learning integration, supported by edge computing on more powerful microcontrollers, will enable the system to distinguish between specific patterns such as chainsaw versus thunder or animal versus human-induced vibrations, thereby reducing false positives. Additionally, the development of a mesh network protocol will allow individual units to communicate with each other and a central gateway, expanding coverage efficiently while ensuring redundancy in communication.

References

[1] Forest Survey of India, “The State of India’s Forests Report 2021”, Ministry of Environment, Forest and Climate Change, Government of India, Dehradun, India, 2021.

[2] Ministry of Agriculture and Farmers Welfare, “The Sandalwood (Amendment) Rules, 2021”, The Gazette of India, Government of India, New Delhi, India, 2021.

[3] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “A survey on sensor networks”, IEEE Communications Magazine, vol. 40, no. 8, pp. 102–114, 2002. doi:10.1109/MCOM.2002.1024422

[4] M. Parthiban, M. Dharani, S. Kathiga, and M. Keruthika, “IoT based anti-poaching sensor system for trees in forest”, International Journal of Innovative Technology and Exploring Engineering, vol. 8, no. 6S4, pp. 172–177, 2019.

[5] S. Khan and M. B. Kadri, “DC motor speed control by embedded PI controller with hardware-in-loop simulation”, in Proceedings of the 3rd IEEE International Conference on Computer, Control and Communication (IC4), Allahabad, India, pp. 1–4, 2013. doi:10.1109/IC4.2013.6653719

[6] R. Rajeshkanna, “Modern speed control of separately excited DC motor by boost converter fed field control method”, in Proceedings of the International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, pp. 1–7, 2013. doi:10.1109/ICCCI.2013.6466257

[7] G. P. Asner, D. E. Knapp, A. N. Cooper, M. M. Bustamante, and L. P. Olander, "Ecosystem structure throughout the Brazilian Amazon from Landsat observations and automated spectral unmixing", Earth Interactions, vol. 9, no. 1, pp. 1–31, 2005. doi:10.1175/EI134.1

[8] S. Kumar and R. Singh, "Design of a WSN node for forest trees against poaching", International Journal of Engineering Research and Technology, vol. 7, no. 5, pp. 1–5, 2018.

[9] P. Sharma, A. Verma, and S. Gupta, "Forest monitoring system using wireless sensor network", International Journal of Scientific and Engineering Research, vol. 10, no. 3, pp. 456–462, 2019.