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ILLEGAL TREE CUTTING DETECTION USING YOLOv8 AND LoRa NETWORKS

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Abstract: Illegal tree cutting and timber smuggling pose significant threats to forest ecosystems, biodiversity, and environmental sustainability. Continuous monitoring of large and remote forest areas remains a major challenge due to limitations in traditional surveillance methods such as manual patrols and centralized monitoring systems. This paper presents an Illegal Tree Cutting Detection Using YOLOv8 and LoRa Networks, an intelligent and autonomous solution designed to detect unauthorized tree cutting activities in real time. The proposed system utilizes a Raspberry Pi integrated with a USB web camera to continuously capture images of the forest environment. These images are processed locally using the YOLOv8 deep learning model to identify visual changes and unusual disturbances caused by illegal tree cutting. By performing inference at the edge, the system reduces latency, minimizes dependency on cloud connectivity, and enables faster decision-making in remote forest regions. Upon detecting suspicious activity, the system immediately generates alerts through a buzzer and an LCD display to provide local warnings. In addition, LoRa communication modules are employed to transmit alert notifications and event data over long distances to a remote monitoring station, ensuring reliable communication even in dense forest environments with limited network infrastructure. An Arduino microcontroller manages sensor interfacing and peripheral control, while dedicated power supply modules ensure stable and uninterrupted system operation. The proposed edge AI–based framework provides a scalable, low-power, and cost-effective solution for forest protection, enhancing the efficiency of anti-smuggling surveillance and supporting sustainable environmental conservation.

Index Terms: Illegal Tree Cutting Detection, YOLOv8, Edge AI, Raspberry Pi, Deep Learning, Forest Monitoring Systems, Real-Time Surveillance, LoRa Communication

I. INTRODUCTION:

Forests are among the most valuable natural resources on Earth, providing a wide range of ecological, economic, and social benefits. They play a crucial role in maintaining ecological balance and supporting life on the planet. Forest ecosystems are rich in biodiversity, serving as habitats for numerous plant and animal species. They also help regulate the global climate by absorbing carbon dioxide and releasing oxygen through photosynthesis. In addition, forests contribute to maintaining the water cycle, preventing soil erosion, and protecting watersheds. Many communities around the world depend on forests for their livelihoods, as they provide timber, food resources, medicinal plants, and raw materials for various industries..

Despite their importance, forests are increasingly threatened by human activities such as illegal logging, deforestation, and tree smuggling.

Illegal logging refers to the unauthorized cutting, transportation, and sale of timber without proper permission. These activities often take place in protected forest areas and wildlife reserves, causing severe environmental damage. Illegal logging not only destroys forest ecosystems but also results in economic losses for governments and local communities. Furthermore, it contributes significantly to climate change by reducing the number of trees that absorb carbon dioxide, thereby increasing greenhouse gas concentrations in the atmosphere. The effects of illegal logging extend beyond environmental damage. It disrupts ecosystems and destroys wildlife habitats, leading to a decline in biodiversity. Many endangered species face the risk of extinction due to habitat loss caused by deforestation. In most countries, forest protection is managed by government agencies and forest departments, which traditionally rely on manual patrols to monitor forest areas. However, this method has several limitations. Forests often cover vast and remote regions with dense vegetation and difficult terrain, making continuous monitoring challenging.

Illegal activities are usually carried out in isolated areas, making timely detection difficult. With the advancement of modern technologies, new solutions have emerged to address these challenges. Technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and computer vision are increasingly being used to develop intelligent forest monitoring systems. AI, particularly deep learning, is highly effective in image recognition and object detection. It can analyze images captured by cameras to identify suspicious activities such as human intrusion or tree cutting. IoT enables various devices like cameras and sensors to work together in a connected network, allowing automated data collection and transmission.

Edge computing further enhances these systems by enabling data processing on local devices instead of relying on centralized cloud servers. This reduces latency and allows real-time decision-making, which is especially important in remote forest areas with limited internet connectivity. Additionally, communication technologies like LoRa provide long-range, low-power data transmission, making them suitable for remote monitoring applications. By integrating Edge AI with LoRa networks, intelligent systems can detect illegal activities in real time and send immediate alerts to authorities. Overall, these advanced technologies significantly improve the efficiency of forest monitoring systems. They reduce dependence on manual patrols, enable faster response to illegal activities, and help protect forests more effectively. Such systems can also be extended for applications like wildlife monitoring, fire detection, and environmental data collection. Therefore, the use of AI and IoT-based solutions plays a vital role in conserving forests, protecting biodiversity, and promoting environmental sustainability

II. LITERATURE SURVEY

Kumar, S. J., Suman, A., Jayashree, M., Ashwin, R., Abhijith, H. V., "IoT Based System to Prevent Illegal Logging of Trees," International Journal of Advanced Research in Computer Science, Vol. 9, 2018, pp. 250–255.

This paper presents an Internet of Things (IoT) based monitoring system designed to prevent illegal tree cutting in forest areas. The authors propose a system where vibration sensors are attached to trees to detect unusual movements caused by cutting or external disturbances. When the sensor detects abnormal vibrations, the system sends alerts to forest authorities through wireless communication modules. The proposed system also includes GPS tracking for identifying the exact location of the affected tree. Experimental results indicate that the system provides real-time monitoring and improves forest protection by enabling faster response to illegal logging activities..

Ayankoso, S., Wang, Z., Shi, D., Yang, W., Vikiru, A., Kamau, S., Muchiri, H., Gu, F., "Development of Long-Range, Low-Powered and Smart IoT Device for Detecting Illegal Logging in Forests," Journal of Dynamics, Monitoring and Diagnostics, Vol. 3, 2024, pp. 190–198.

This research focuses on developing a smart IoT-based device capable of detecting illegal logging activities in remote forest environments. The system uses acoustic sensors to capture sound signals generated by chainsaws and other cutting tools. The experimental results show that the proposed system achieves high detection accuracy and efficient real-time monitoring performance.

Gadda, A., Rao, C. M., "Monitoring the Signs of Illegal Logging and Alerting Using IoT," Solid State Technology Journal, Vol. 63, 2020, pp. 421–428.

This study presents an Internet of Things (IoT)-based monitoring system designed to detect illegal logging activities in forest areas. Illegal tree cutting causes serious environmental problems such as deforestation and biodiversity loss. The proposed system uses sensors and wireless communication technologies to continuously monitor forest environments and identify suspicious activities.

The system integrates vibration sensors and sound sensors with microcontroller units to detect unusual movements and sounds produced during tree cutting. When abnormal signals are detected, the system analyzes the data and identifies possible illegal logging events. Once confirmed, alert messages are automatically sent to forest authorities through wireless networks. The study shows that IoT-based monitoring systems can improve forest surveillance and enable faster response to illegal logging incidents.

Mporas, I., Perikos, I., Kelefouras, V., Paraskevas, M., "Illegal Logging Detection Based on Acoustic Surveillance of Forest," Applied Sciences, Vol. 10, 2020, pp. 7379–7388.

This paper introduces an acoustic surveillance system designed to detect illegal logging activities in forests using machine learning techniques. The system captures audio signals from forest environments using specialized microphones. These audio signals are processed using feature extraction techniques such as Mel-frequency cepstral coefficients (MFCC). Machine learning classifiers are then used to distinguish between natural forest sounds and chainsaw sounds. The proposed approach demonstrates high accuracy in detecting logging activities in real time. The authors highlight that acoustic monitoring systems provide an effective solution for monitoring large forest areas without requiring continuous human supervision.

III. PROPOSED METHOD

To overcome the limitations of existing forest monitoring systems, this project proposes an Edge AI–Based Tree Smuggling Detection System using image processing and LoRa communication. The system provides an intelligent, cost-effective, and automated solution for detecting illegal tree cutting activities in real time. By integrating artificial intelligence, edge computing, computer vision, and long-range communication, it enhances the efficiency and reliability of forest surveillance.

Traditional monitoring methods rely on manual patrols or periodic data analysis, which often result in delayed detection. The proposed system addresses these challenges by continuously monitoring forest areas using cameras that capture images of the environment. These images are processed locally on an edge device using an AI-based object detection model, enabling faster decision-making without dependence on cloud servers.

Key Features of the Proposed System:

1. Real-Time Image Acquisition: Cameras continuously capture images to monitor forest activities
2. AI-Based Object Detection (YOLO): Detects humans, tools, and suspicious activities with high

accuracy

3. Edge Computing (Raspberry Pi): Processes data locally for low latency and quick response
4. LoRa Communication: Enables long-range, low-power transmission of alert messages
5. Automatic Alert System: Sends instant notifications to authorities when illegal activities are detected

Advantages of the System:

1. Real-time detection and faster response
2. Low operational and deployment cost
3. Reduced dependency on internet connectivity
4. Energy-efficient communication
5. Scalable for large forest areas

The system is divided into two main sections:.

1. Forest Edge Node (Detection and Transmission Unit)
2. Remote Monitoring Station (Reception and Alert Unit)

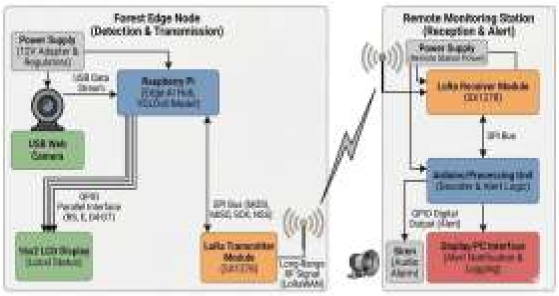

Figure.3.1. Block Diagram of Illegal Tree Cutting Detection System

A. Forest Edge Node (Detection and Transmission)

This unit is installed in the forest and acts as the main sensing and processing system.

1) Power Supply

A 12V power adapter supplies power to the system.
Voltage regulators convert 12V into 5V and 3.3V for components like Raspberry Pi, LoRa module, camera, and LCD.Provides stable power for reliable operation in remote forest environments.

2) USB Web Camera

Continuously captures images and video from the forest area. ends visual data to the Raspberry Pi through a USB interface. Provides real-time input for object detection.

3) Raspberry Pi (Edge AI Processing Unit)

Works as the central processing unit.Runs the YOLOv8 object detection model to analyze camera frames.
Detects objects such as:

a. Humans
b. Chainsaws or cutting tools
c. Suspicious movement near trees

4) 16×2 LCD Display

Displays system status messages such as system start, monitoring mode, and alerts.

5) LoRa Transmitter (SX1278)

Sends alert messages to the remote station.Uses SPI communication (MOSI, MISO, SCK, NSS).
Supports long-range, low-power communication.

B. Remote Monitoring Station (Reception and Alert)

The remote monitoring station is located at a forest control center where alerts from the detection system are received and monitored.

1) LoRa Receiver Module

The LoRa receiver captures RF signals transmitted from the forest edge node.

2) Processing Unit

A processing unit such as an Arduino or computer system decodes the received data and verifies the alert message.

3) Buzzer (Alert System)

The buzzer acts as a local audible alarm. When illegal activity is detected, the Raspberry Pi activates the buzzer to warn nearby forest personnel.

4) PC / Display Interface

The decoded information is displayed on a PC monitoring interface, allowing forest authorities to view alerts, monitor system activity, and maintain event logs for further investigation.

IV. PROPOSED FLOW CHART

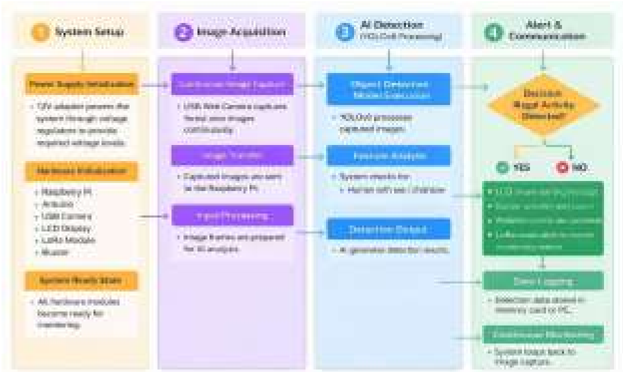

Figure:4.1. Flow chart Of Illegal Tree Cutting Detection System

Step 1: System Initialization

The system begins with the initialization of the power supply using a 12V adapter and voltage regulators. These regulators provide the required 5V and 3.3V power to different hardware components. After power initialization, all modules such as Raspberry Pi, Arduino Uno, USB web camera, 16×2 LCD, LoRa module, and buzzer are activated. Once initialization is completed, the system enters monitoring mode.

Step 2: Image Acquisition

The USB web camera continuously captures images and video frames from the forest environment. These images represent real-time data used for identifying suspicious activities. The captured frames are transferred to the Raspberry Pi through the USB interface for further processing.

Step 3: Image Preprocessing

Before object detection, the captured images undergo preprocessing. This includes resizing the images, reducing noise, and normalizing the data. Preprocessing improves image quality and ensures accurate detection by the AI model.

Step 4: YOLOv8 Object Detection

The YOLOv8 object detection model is loaded on the Raspberry Pi. The model analyzes each image frame and identifies objects present in the scene. It detects objects such as humans, vehicles, chainsaws, or suspicious movements near trees, which may indicate illegal tree-cutting activities.

Step 5: Alert Generation and Communication

If suspicious activity is detected, the system generates an alert. The Arduino Uno activates the buzzer, producing a warning sound. At the same time, the LCD shows an alert message, and the LoRa module sends a notification to the remote monitoring station.

Step 6: Continuous Monitoring

After sending the alert, the system stores detection information such as timestamps and event logs. The system then returns to the image capture stage and continues monitoring the forest area.

Key Points

- Real-time forest monitoring using a camera module
- AI-based object detection using YOLOv8
- Edge processing with Raspberry Pi
- Local alerts using buzzer and LCD
- Long-range alert transmission using LoRa
- Continuous monitoring for forest protection

ALGORITHM STEPS

The detection system operates using the following algorithm:

- *Step 1*: Initialize system hardware components including the camera and LoRa module.
- *Step 2:* Load the trained YOLOv8 object detection model into memory.
- *Step 3:* Start continuous image capture using the camera module.
- *Step 4:* Preprocess captured image frames to match the model input format.
- *Step 5:* Pass the processed image through the YOLOv8 detection model.
- *Step 6:* Analyze the detected objects and identify suspicious activities.
- Step 7: If suspicious objects are detected:
- Activate buzzer alert
- Generate alert message
- Transmit message using LoRa module
- *Step 8:* Store detection logs for further analysis.
- *Step 9*: Continue monitoring the environment.

V. RESULTS

The experimental results demonstrated that the proposed system successfully detected suspicious activities related to illegal logging.

Detection Examples

Case 1: Human Detection

The system successfully detected human presence in the monitored forest area and generated an alert.

Case 2: Chainsaw Detection

When chainsaw equipment appeared in the camera frame, the YOLOv8 model correctly classified the object and triggered an alert.

Case 3: Combined Detection

In scenarios where both human and tools were present:

a. The model detected multiple objects simultaneously
b. It improved reliability by confirming suspicious activity
c. multi-object detection increases system intelligence and reduces false alarms.

Observations

1.The YOLOv8 model provided real-time detection performance.
2.The system generated alerts within 1–2 seconds of detection.
3.The buzzer produced an instant audible warning
4. LCD displayed clear alert messages.
5.The LoRa communication module successfully transmitted alert messages over long distances.

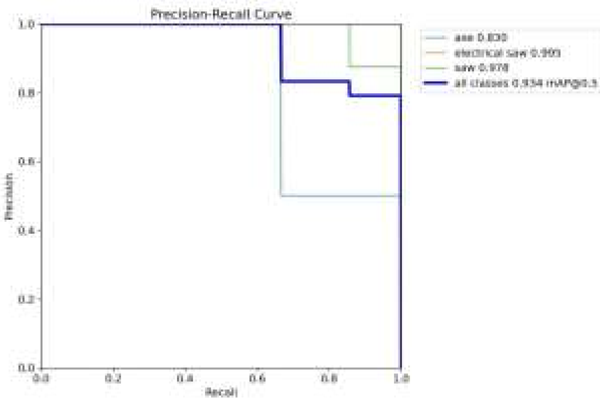

Fig 5.1: Precision-Recall Curve

A curve closer to the top-right corner indicates better performance

High precision → fewer false positives

High recall → fewer missed detections

The Area Under Curve (AUC) represents overall model quality.

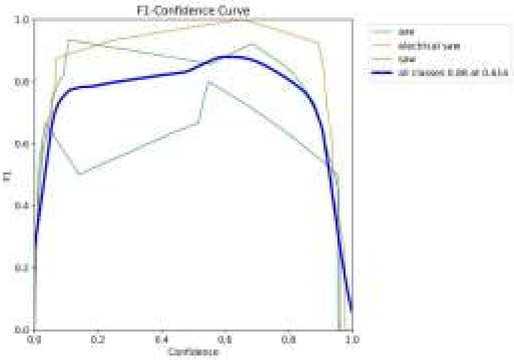

Fig 5.2: *F1-Confidence Curve*

This graph shows how the F1 score changes with different confidence thresholds. It helps in selecting the optimal threshold for detection.

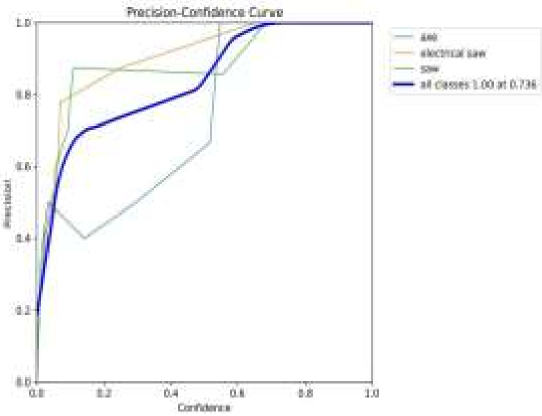

Fig 5.3: *Precision-Confidence Curve*

This graph shows how precision varies with confidence levels. Analysis:

Precision increases as confidence threshold increases. High confidence reduces false detections Helps determine safe detection thresholds for real-world use.

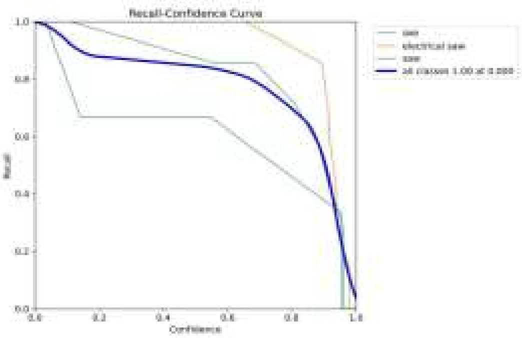

Fig 5.4: Recall-Confidence Curve

Recall–Confidence Curve

This graph shows how recall changes with confidence thresholds.

Recall decreases as confidence increases

Low confidence ensures most objects are detected

Fig 5.4: Output Image

Conclusion of Graph Analysis

The graphs clearly demonstrate that the YOLOv8 model achieves a strong balance between precision and recall. The optimal confidence threshold ensures high accuracy while minimizing false detections. Overall, the graph analysis confirms that the system is reliable for real-time illegal tree cutting detection.

Detection Speed

The system processed image frames at approximately 10–15 frames per second (FPS) on the Raspberry Pi.This speed is sufficient for real-time monitoring application

VI CONCLUSION

Illegal logging and tree smuggling pose serious threats to forest ecosystems and environmental sustainability. Forests play an important role in maintaining biodiversity, regulating climate, and supporting human livelihoods. However, increasing deforestation due to illegal logging has led to habitat destruction, soil erosion, and higher carbon emissions. Traditional monitoring methods such as manual patrols and satellite observation often have limitations including delayed detection, high operational costs, and lack of real-time monitoring.

To address these challenges, this project proposes an Edge AI–Based Tree Smuggling Detection System using YOLOv8 and LoRa Communication.

The system integrates technologies such as computer vision, edge computing, embedded systems, and long-range wireless communication to create an intelligent forest monitoring solution capable of detecting illegal tree cutting activities.

In the proposed system, a Raspberry Pi edge device is connected to a camera module that continuously captures images from the forest environment. These images are processed locally using the YOLOv8 object detection model, which can detect objects such as humans, vehicles, or chainsaws that may indicate illegal logging activities. Processing data locally reduces dependency on cloud infrastructure and enables faster detection. When suspicious activity is detected, the system generates alerts through a buzzer and sends warning messages to monitoring stations using LoRa communication technology. This system provides a cost-effective and scalable solution for real-time forest monitoring

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