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VANRAKSHAK – A MACHINE LEARNING BASED REAL-TIME AUDIO ANALYSIS AND ALERT SYSTEM

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Abstract : Wildlife reserves and protected forests face serious threats from illegal poaching and unauthorized logging. Monitoring large forest areas is difficult due to lack of manpower, power supply and connectivity. The proposed system 'Vanrakshak' is a machine learning based real-time audio analysis and alert system designed to detect suspicious sounds such as gunshots in forest environments. Continuous audio monitoring is performed and when the sound amplitude crosses a threshold the audio segment is captured. MFCC features are extracted and classified using a trained CNN model. When a gunshot is detected the GPS coordinates are attached and alerts are sent to the cloud dashboard for monitoring. The system enables continuous monitoring and helps protect wildlife in remote forest areas.

***IndexTerms* - Gunshot Detection, Machine Learning, Audio Analysis, Forest Monitoring, Raspberry Pi**

I. INTRODUCTION

Wildlife reserves and protected forests play a very important role in preserving biodiversity and maintaining ecological balance. These areas provide natural habitats for many species of animals and plants. However, forests around the world are increasingly threatened by illegal activities such as poaching and unauthorized logging. Poachers use firearms to hunt wild animals while illegal logging operations use mechanical equipment such as chainsaws to cut trees. These activities cause severe damage to forest ecosystems and reduce wildlife populations.

Monitoring and protecting large forest areas is a challenging task. Forest rangers are responsible for patrolling forest regions and identifying illegal activities. However, forests usually cover very large geographical areas and it is practically impossible for rangers to monitor every location continuously. In addition, many forest regions are located in remote areas where electricity and internet connectivity are not available. Because of these limitations, illegal activities may occur without being detected in time.

Real-time monitoring technologies can help overcome these challenges. One effective approach is acoustic monitoring, which involves continuously analyzing environmental sounds in the forest. Certain activities such as gunshots or chainsaw operations produce distinct sound patterns that can be detected using audio analysis techniques. By monitoring these sounds, it becomes possible to detect suspicious events and alert forest authorities immediately.

However, forests contain many natural sounds such as animal calls, wind, rainfall, and moving branches. These environmental sounds can make sound detection difficult and may produce false alarms in simple sound detection systems. Therefore, intelligent sound classification techniques using machine learning are required to accurately distinguish between normal forest sounds and suspicious sounds.

The **Vanrakshak system** is designed to address these challenges by implementing a machine learning based acoustic monitoring system. The system continuously monitors forest sounds, analyzes audio signals using machine learning algorithms, and sends alerts when suspicious sounds such as gunshots are detected.

NEED OF THE STUDY

The protection of wildlife and forest ecosystems has become a major concern due to the increasing number of illegal poaching activities and unauthorized logging operations. Forest areas are generally very large and difficult to monitor continuously. In many cases, forest guards and rangers cannot patrol every region effectively due to limited manpower and challenging geographical conditions. As a result, illegal activities often occur in remote forest regions without immediate detection.

Traditional monitoring methods mainly rely on manual patrolling or basic surveillance systems. However, these approaches are not sufficient for large forest areas where electricity supply and communication infrastructure are limited or completely unavailable. Many remote forest locations lack reliable mobile network connectivity, which makes it difficult to install real-time monitoring systems that depend on constant internet access. Because of these limitations, authorities are often unable to detect suspicious activities such as gunshots or illegal tree cutting in time.

Another important challenge is the presence of various environmental sounds in forest environments. Forests contain natural acoustic signals produced by animals, wind, rain, and the movement of branches or leaves. These sounds can interfere with simple sound detection systems and may generate false alarms. Therefore, traditional sound detection methods are not reliable enough for identifying suspicious activities such as gunshots.

To overcome these challenges, there is a need for an intelligent monitoring system that can continuously observe environmental sounds and accurately identify suspicious acoustic events. Such a system should be capable of distinguishing between natural forest sounds and harmful human activities. It should also be able to operate efficiently in remote areas where power supply and network connectivity are limited.

The proposed **Vanrakshak system** addresses these requirements by using machine learning based acoustic analysis to monitor forest environments in real time. By continuously analyzing environmental audio signals and detecting gunshot sounds, the system can provide early alerts to forest authorities. This enables quicker response to illegal activities and improves overall wildlife protection.

In addition, the integration of GPS technology allows the system to provide accurate location information for detected events. This helps forest authorities quickly identify the exact area where suspicious activity has occurred. Therefore, the development of an intelligent acoustic monitoring system such as Vanrakshak is necessary to improve forest surveillance, reduce illegal poaching, and support wildlife conservation efforts.

3.1 Theoretical framework

The theoretical framework of this study is based on the concept of acoustic monitoring and machine learning based sound classification for detecting illegal activities in forest environments. Forest areas contain a wide variety of environmental sounds including animal calls, wind movement, rainfall, and natural vegetation noise. These sounds create a complex acoustic environment that makes it difficult to detect suspicious activities using simple monitoring systems.

Acoustic monitoring is an important approach for observing environmental activities through sound signals. Certain activities such as gunshots and mechanical tools used in illegal logging produce distinctive sound patterns that can be detected through audio signal analysis. By continuously monitoring environmental sounds, it is possible to identify abnormal acoustic events that may indicate illegal activities occurring in forest regions.

Machine learning techniques provide an effective solution for classifying environmental sounds. In this study, a Convolutional Neural Network (CNN) model is used to classify audio signals captured from the forest environment. The system first converts audio signals into Mel Frequency Cepstral Coefficient (MFCC) features. These features represent the important characteristics of sound signals and help the machine learning model identify different types of sounds.

The theoretical assumption of this system is that gunshot sounds have unique acoustic patterns that can be distinguished from natural environmental sounds. The machine learning model is trained to recognize these patterns and classify the sound events accordingly. When the model detects a gunshot sound, the system generates an alert and records the location of the event.

Location tracking is achieved using the NEO-6M GPS module. The GPS module provides geographical coordinates which help forest authorities identify the exact location where the suspicious activity occurred. This information is essential for quick response and effective forest protection.

The integration of acoustic monitoring, machine learning based sound classification, and GPS based location tracking forms the theoretical foundation of the Vanrakshak system. This framework supports the development of an intelligent monitoring system capable of detecting illegal activities in forest environments and assisting authorities in wildlife protection and forest management.

RESEARCH METHODOLOGY

The methodology section explains the design, development, and operation of the proposed **Vanrakshak system**, which is a machine learning based real-time audio monitoring and alert system designed for forest environments. The purpose of this methodology is to describe the approach used for detecting gunshot sounds and generating alerts along with location information.

The proposed system combines **continuous acoustic monitoring, machine learning classification, GPS-based location detection, and cloud-based alert transmission** to monitor forest areas effectively. The methodology is divided into several subsections including system architecture, data processing methods, feature extraction, sound classification, and alert generation.

3.1 System Architecture

The proposed system architecture consists of multiple hardware and software components that work together to detect suspicious sound events in forest environments.

The system mainly includes the following components:

- Raspberry Pi 3 (processing unit)
- Microphone module (audio input)
- NEO-6M GPS module (location detection)
- Wi-Fi connectivity module (data transmission)
- Cloud dashboard for monitoring

The microphone continuously captures environmental sounds present in the forest environment. These audio signals are sent to the Raspberry Pi, which acts as the central processing unit of the system. The Raspberry Pi processes the incoming audio signals and performs sound analysis using machine learning algorithms.

When the system detects a suspicious sound such as a gunshot, the GPS module provides the geographical location coordinates of the event. These coordinates are attached to the event information and transmitted through Wi-Fi connectivity to a cloud

server. The detected event is then displayed on an administrative dashboard, allowing forest authorities to monitor activities in real time.
This architecture allows the system to perform **edge processing**, which means the main sound analysis is performed locally on the device instead of relying entirely on cloud computing. This reduces latency and allows the system to function even in areas with limited internet connectivity.

3.2 Continuous Audio Monitoring

The Vanrakshak system performs continuous monitoring of environmental sounds using a microphone sensor. Forest environments contain a wide range of sounds including animal calls, wind noise, rainfall, and human-generated sounds. Therefore, the monitoring system must continuously analyze audio signals to identify suspicious acoustic events.
To achieve this, the microphone continuously records environmental sounds and sends the audio data to the Raspberry Pi. The system uses a **ring buffer mechanism** to temporarily store recent audio signals. A ring buffer allows the system to continuously record audio while maintaining only the most recent segment of sound data.
The main advantage of using a ring buffer is that it reduces memory usage while ensuring that important sound events are captured. When the sound amplitude exceeds a predefined threshold value, the system assumes that a significant acoustic event has occurred. At this point, the system captures the relevant audio segment from the buffer for further processing.
This approach allows the system to continuously monitor environmental sounds while efficiently identifying potential suspicious events.

3.3 Feature Extraction Using MFCC

After capturing the audio segment, the next step is to extract important characteristics from the audio signal. Raw audio signals contain large amounts of data, and therefore feature extraction techniques are used to represent the audio in a more meaningful and compact form.
In the Vanrakshak system, **Mel Frequency Cepstral Coefficients (MFCC)** are used as the primary feature extraction method. MFCC features are widely used in speech recognition and sound classification applications because they effectively represent the spectral characteristics of audio signals.
The MFCC extraction process involves several steps:

1. The captured audio signal is first divided into small frames.
2. A Fourier transform is applied to convert the signal from the time domain to the frequency domain.
3. The signal is mapped onto the Mel scale, which represents how humans perceive sound frequencies.
4. Cepstral coefficients are computed to represent the spectral envelope of the sound.

These MFCC features capture the important characteristics of the audio signal while reducing the amount of data required for classification. The extracted features are then used as input for the machine learning model.

3.4 Sound Classification Using CNN

The Vanrakshak system uses a **Convolutional Neural Network (CNN)** model to classify environmental sounds. CNN models are commonly used in machine learning for pattern recognition tasks, including image recognition and audio classification.
The extracted MFCC features are provided as input to the trained CNN model. The CNN analyzes the patterns present in the audio features and determines whether the sound corresponds to a gunshot or a normal environmental sound.
The CNN model is trained to recognize the unique acoustic characteristics of gunshot sounds. Gunshots produce distinct sound signatures that can be distinguished from other environmental sounds such as animal calls or wind noise.
During the classification process, the CNN evaluates the input features and produces an output indicating the predicted sound category. If the sound is classified as a gunshot, the system triggers an alert event.
Using a CNN model improves the accuracy of the detection system and helps reduce false alarms caused by natural environmental sounds.

3.5 Location Detection Using GPS

Once a suspicious sound is detected, the system retrieves the location information of the event using the **NEO-6M GPS module**.
The GPS module communicates with satellites to determine the geographical location of the device. It provides the latitude and longitude coordinates of the detected event.
These coordinates are essential for forest authorities because they allow them to identify the exact location where the suspicious activity occurred. By providing accurate location information, the system enables quick response and investigation.
If the GPS signal becomes temporarily unavailable due to environmental conditions, the system uses the **last valid location data** to maintain reliability.

3.6 Alert Generation and Data Transmission

After detecting a gunshot sound and retrieving the location coordinates, the system generates an alert message. The alert includes the following information:

- Detected event type (gunshot)
- Latitude and longitude coordinates
- Timestamp of the event

This information is transmitted to a cloud platform through Wi-Fi connectivity. The cloud server processes the incoming data and updates the monitoring dashboard.
The administrative dashboard displays alerts in real time, allowing forest authorities to track suspicious events occurring in forest areas. This real-time alert system helps authorities take immediate action against illegal activities.

3.7 System Workflow

The overall workflow of the Vanrakshak system can be summarized as follows:

1. Environmental sounds are continuously captured using the microphone.
2. Audio signals are stored in a ring buffer.
3. When sound amplitude exceeds a threshold, the audio segment is captured.
4. MFCC features are extracted from the captured audio.
5. The CNN model classifies the sound.
6. If a gunshot is detected, the GPS module retrieves location coordinates.
7. An alert message is generated and sent to the cloud server.
8. The alert is displayed on the administrative monitoring dashboard.

This workflow enables continuous monitoring and real-time detection of suspicious acoustic events in forest environments.

SYSTEM ARCHITECTURE DESCRIPTION

The system architecture consists of multiple components working together to detect suspicious sounds and send alerts.
The microphone module captures environmental audio signals and sends them to the Raspberry Pi. The Raspberry Pi processes the audio signals and extracts MFCC features for sound classification.
The machine learning model running on the Raspberry Pi classifies the sound to determine whether it is a gunshot or a normal environmental sound. When a gunshot is detected, the system retrieves location information from the GPS module.
The detected event along with the GPS coordinates is transmitted through Wi-Fi connectivity to a cloud server. The cloud server updates the monitoring dashboard which allows forest authorities to visualize alerts and track suspicious activities.

SAFETY AND RELIABILITY CONSIDERATION

Since the system is designed to operate in forest environments, several safety and reliability measures are implemented.
Moisture control is achieved by placing silica gel inside the device enclosure to prevent moisture buildup. The enclosure is designed with camouflage colors so that the device blends with the natural surroundings and remains hidden.
Noise reduction is achieved using a fur windshield and sound-dampening materials that reduce interference caused by wind and rain. The microphone port is covered with acoustically transparent fabric which allows sound waves to pass while protecting internal components from water.
If the GPS signal becomes unavailable, the system stores and uses the last valid location to maintain reliable location information.

ADVANTAGES AND APPLICATION

The Vanrakshak system offers several advantages.
It enables real-time detection of illegal poaching activities by automatically identifying gunshot sounds. The system can also be adapted to detect chainsaw sounds used in illegal logging operations.
The use of cost-effective commercial hardware components makes the system affordable and practical for large-scale deployment in forests. Since the system relies on audio monitoring, it does not require direct line-of-sight monitoring.
The system can be used in several applications including border monitoring, wildlife sanctuary protection, and smart forest management. By analyzing acoustic data, authorities can identify crime-prone areas and take preventive measures.

CONCLUSION AND FUTURE SCOPE

The Vanrakshak system demonstrates how machine learning and acoustic monitoring technologies can be used to improve forest protection. By detecting gunshot sounds and providing location information, the system enables authorities to respond quickly to illegal activities.
Edge processing performed by the Raspberry Pi allows the system to operate efficiently even in areas with limited connectivity. Continuous monitoring helps forest authorities track suspicious activities and improve wildlife protection.
Future improvements may include detection of chainsaw sounds for illegal logging, integration with long-range low-power communication networks, and the use of drones for visual verification of detected events.