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Seismic Perimeter Surveillance System (Virtual Fence) for Threat Detection and Characterization Using Multiple ML Based Trained Models in Weighted Ensemble Voting

Authors : Vivek Mahadev, Manoj Kumar, Neelu Mathur, Brahm Dutt Pandey

Abstract : Perimeter guarding and protection of critical installations require prompt intrusion detection and assessment to take effective countermeasures. Currently, visual and electronic surveillance are the primary methods used for perimeter guarding. These methods can be costly and complicated, requiring careful planning according to the location and terrain. Moreover, these methods often struggle to detect stealthy and camouflaged insurgents. The object of the present work is to devise a surveillance technique using seismic sensors that overcomes the limitations of existing systems. The aim is to improve intrusion detection, assessment, and characterization by utilizing seismic sensors. Most of the similar systems have only two types of intrusion detection capability viz., human or vehicle. In our work we could even categorize further to identify types of intrusion activity such as walking, running, group walking, fence jumping, tunnel digging and vehicular movements. A virtual fence of 60 meters at GCNEP, Bahadurgarh, Haryana, India, was created by installing four underground geophones at a distance of 15 meters each. The signals received from these geophones are then processed to find unique seismic signatures called features. Various feature optimization and selection methodologies, such as LightGBM, Boruta, Random Forest, Logistics, Recursive Feature Elimination, Chi-2 and Pearson Ratio were used to identify the best features for training the machine learning models. The trained models were developed using algorithms such as supervised support vector machine (SVM) classifier, kNN, Decision Tree, Logistic Regression, Naïve Bayes, and Artificial Neural Networks. These models were then used to predict the category of events, employing weighted ensemble voting to analyze and combine their results. The models were trained with 1940 training events and results were evaluated with 831 test events. It was observed that using the weighted ensemble voting increased the efficiency of predictions. In this study we successfully developed and deployed the virtual fence using geophones. Since these sensors are passive, do not radiate any energy and are installed underground, it is impossible for intruders to locate and nullify them. Their flexibility, quick and easy installation, low costs, hidden deployment and unattended surveillance make such systems especially suitable for critical installations and remote facilities with difficult terrain. This work demonstrates the potential of utilizing seismic sensors for creating better perimeter guarding and protection systems using multiple machine learning models in weighted ensemble voting. In this study the virtual fence achieved an intruder detection efficiency of over 97%.

Keywords : geophone, seismic perimeter surveillance, machine learning, weighted ensemble method
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