MONITORING UNDERGROUND POWER CABLES IN URBAN AREAS USING DEEP NEURAL NETWORKS AND DISTRIBUTED ACOUSTIC SENSING

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ABSTRACT

Distributed acoustic sensing is well-suited for monitoring underground power cables by measuring vibration signals along the cable. These signals can be used to detect mechanical activities that pose a risk to the infrastructure. We present an approach that performs this detection using deep neural network models. The models are evaluated on data from an installation site in an urban area that contains potentially disturbing signals from streets and construction sites. To assess the generalizability of the models they are evaluated on data from an installation site that is different to the sites used for training. Experimental results show that the models detecting excavator digging and jackhammer activity achieve an accuracy of 97.7% and 98.1%, respectively.

KEYWORDS

Distributed Acoustic Sensing, Deep Neural Networks, Power Cable Monitoring

INTRODUCTION

Distributed acoustic sensing (DAS) systems have a wide range of applications, above all real-time monitoring of power cables or infrastructure in oil and gas industry [1]. DAS uses a fiber optic cable (FOC) that is installed along the asset to capture the signal of vibrations near the cable. Buried infrastructure like power cables and pipelines can be damaged by third party activities. Using DAS, it is possible to detect and classify the third party intrusion (TPI) e.g., mechanical activities around buried assets and alarm on the threat [2].

Detecting TPI is a challenging task because the DAS data of mechanical activities depend on several factors like ground conditions and the tools that are used. Furthermore, signals that look similar to TPI signals caused by other activities should not trigger an alarm. To overcome these challenges an advanced machine learning method, namely deep neural networks (DNN), is used. A DNN can learn to detect signals of TPI activities based on data that were recorded in the past. Unlike threshold based approaches which depend on signal strength, DNNs take advantage of pattern recognition to classify activities.

Detecting TPI activities using DAS data and machine learning techniques has been proposed in previous works. In [3] a speaker is placed near a FOC and used to play back the acoustics of various activities including the sound of jackhammer in action. A convolutional neural network (CNN) is used to classify the signals. The work in [4] compares the performance of different machine learning algorithms to detect and classify excavator activities. To process the data, horizontal and vertical Sobel filters are applied. In [5] the Rayleigh backscattering traces are transformed to a gray scale image and used as the input to a CNN. A small CNN is used to achieve a high training speed. The work in [6] proposes a deep dual path network to classify TPI activities based on the spatial time-frequency spectrum. Data from seven classes are used, including excavator operation. The data are collected at three different railway lines.

In this paper, we present our approach to detect TPI activities using DNNs and DAS. Our system is installed in an urban area, where the power cables along with the fiber cable are buried under diverse active areas, including streets, bridges and construction sites. The DNNs we evaluate in this paper are trained using only data from installation sites that are different to the installation site used for evaluation. This approach is chosen in order to test our method in a scenario in which the detection system is used at a new installation site without adapting the DNNs to that site. We focus on two types of TPI namely: excavator digging and jackhammer activity. Since both are performed by heavy machines they may cause real damage to the power cable.

BASIC CONCEPTS

Distributed Acoustic Sensing

DAS is a technique to measure acoustic and vibration signals along a FOC using a single measurement device. When a laser pulse is sent into the fiber it is partially reflected along the fiber which results in a return signal that is measured. Depending on the application different wavelengths of the return signal are of interest, as can be seen in Fig. 1. For DAS the coherent Rayleigh scattering is used which is stimulated by strain changes in the fiber that are caused by acoustic and vibration activities. Like in a radar system the position of the vibration event is estimated by the traveling time of the laser pulse and the backscattered Rayleigh signal from the fiber.

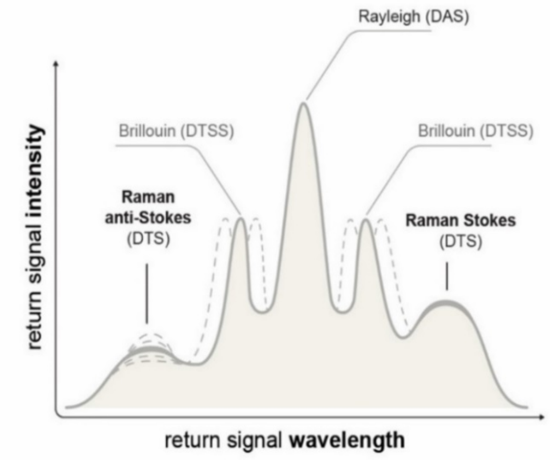

Fig. 1: Distribution of the return signal when a laser pulse is sent into a FOC