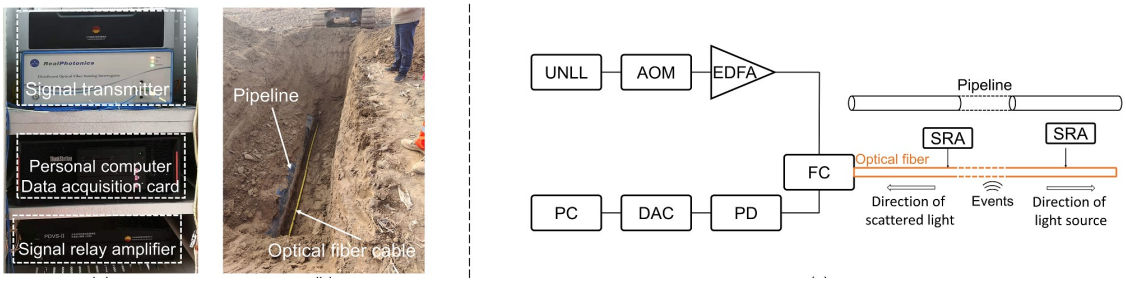
Long-Distance Pipeline Safety Early Warning: A Distributed Optical Fiber Sensor Deep Learning Approach

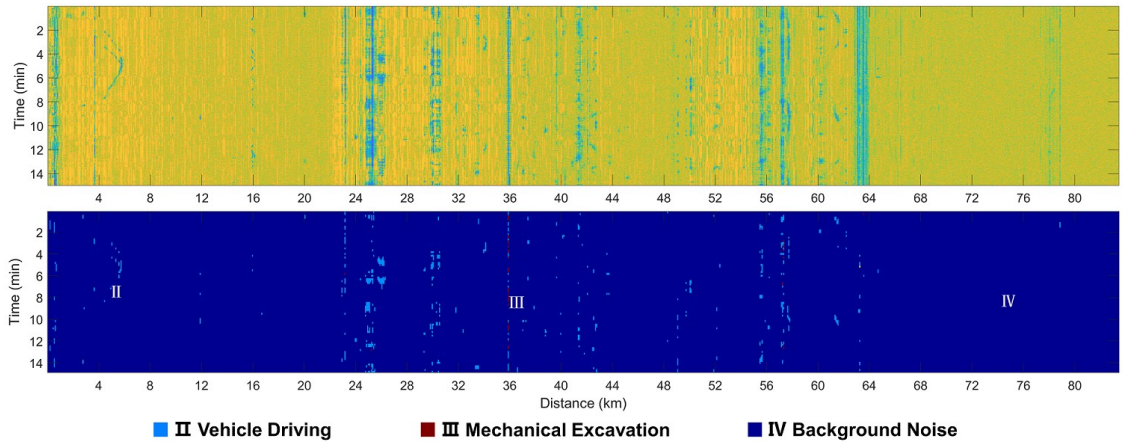
Yiyuan Yang[1], Yi Li[1], Haifeng Zhang[2*]
[1]International Graduate School at Shenzhen, Tsinghua University, Shenzhen, China
[2] Research Institute of Tsinghua, Pearl River Delta, Guangzhou, China
[*]E-mail: zhanghf@tsinghua-gd.org

Abstract

Distributed optical fiber sensors (DOFS) have the advantages of high sensitivity, antielectron magnetic interference, and long-distance distributed detection. And pipeline safety early warning (PSEW) systems based on DOFS are used to recognize and locate the events that may damage long-distance transportation pipes. In this study, we proposed a novel real-time method, combining with a pioneering industrial signal processing approach and a deep learning model, based on coherent Rayleigh scattering DOFS to monitor the safety of pipelines. Specifically, we put forward two complementary features to describe signals of DOFS and built a new action recognition deep learning network based on those features. Besides, experiments were carried out at two different real PipeChina pipelines with different deployments, environmental conditions, signal frequencies, and pipeline lengths (48 km and 85 km). The total dataset was 2.17 TB and took us nearly five months to collect them with over $100,000. The figure below shows the experimental facilities of our PSEW system.



Encouraging empirical results from the above tests indicate that the proposed scheme can identify and locate damage events with good robustness. It demonstrates a high average accuracy of 95.86% for 100 Hz signal and 97.53% for 500 Hz data. Besides, the proposed feature generator can effectively extract features in a short period and has a good visualization effect. More importantly, our system fully meets the industry standards of model size, real-time performance, and adaptability to different deployment conditions and environments, and has already been deployed in a real long-distance energy transportation pipeline for half a year. The figure below shows the features (upper) and identification results (lower) from an operational PipeChina pipe. Our scheme provides a reference for third-party damage event recognition based on DOFS in an open environment. In future, we are interested in exploring higher spatial-temporal resolution by optimizing sampling frequency and sensing mechanism of DOFS and exploring the applications of DOFS early warning system in other areas, such as early warning of undersea and land earthquakes and traffic flow statistic for urban road networks.



Keywords: Distributed optical fiber technology and application; Industrial optical fiber signal processing; Deep Learning; Pipeline safety early warning; Pattern recognition