LONG-DISTANCE OIL AND GAS TRANSPORTATION PIPELINE SAFETY EARLY WARNING SYSTEM BASED ON DEEP LEARNING APPROACH

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Oil and gas pipelines are known as the backbone of global energy. Their small size and fast construction make them widely used in the field of energy transportation [1]. Currently, the length of long-distance transportation pipelines worldwide exceeds 3.5 million km and is increasing by approximately 30,000 km per year. However, because buried pipes are not easy to supervise, and the environments along those pipelines are complicated, accidents are unfortunately not rare enough. If an accident occurs, it may cause energy leakage or even an explosion, and cause great economic losses, casualties, environmental pollution, and extremely negative publicity [2]. Automated pipeline safety early warning (PSEW) systems are designed to automatically identify and locate third-party damage events on oil-gas pipelines. They are intended to replace traditional, inefficient manual inspections [3]. However, the following problems with PSEW systems remain: (1) The spatiotemporal features of sensor signals consistently change. (2) Strong noise, weak signals, and signal fluctuations at the scene make an algorithm trained on an ideal condition difficult to fit. (3) A low-frequency signal with higher processing speed and cheaper cost has a higher requirement on the algorithm [4]. To address those problems faced by PSEW systems, we present a novel action recognition method based on a distributed fiber optic sensor (DOFS) network that jointly considers temporal and spatial aggregation. Our experiments show that the results of the proposed method markedly outperform those of other baselines and can effectively alert us to events that could damage the oil and gas pipelines in real time.

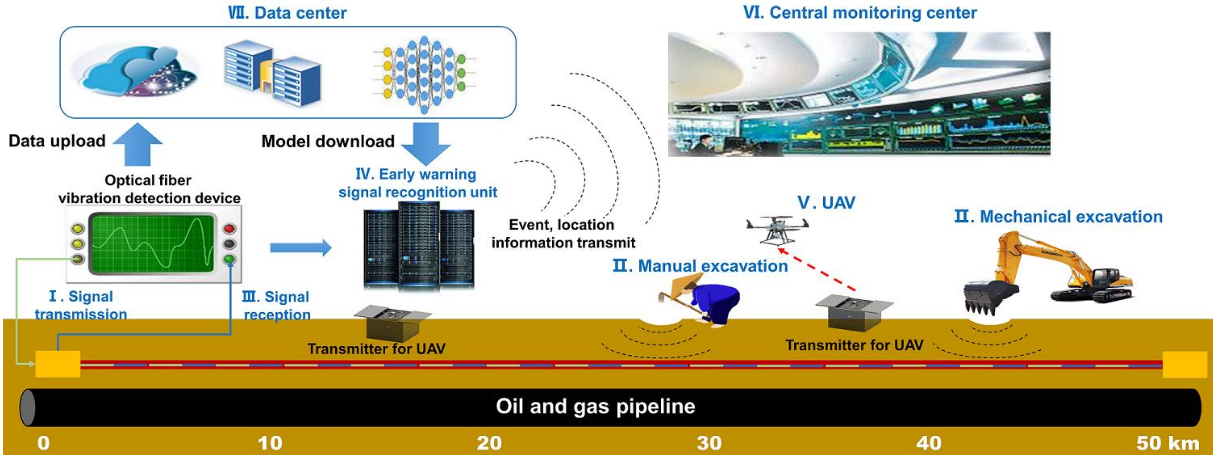

Fig.1 Structure of a novel oil and gas PSEW system.

A novel DOFS-based long-distance oil and gas PSEW system shown in fig.1 is an intelligent system that recognizes and locates dangerous behaviors, issues early warnings, conducts on-site inspections, and records data in real time. Based on that we put forward two complementary features, i.e., peak and energy features, to describe signals of fiber sensors 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 which took us nearly five months to collect with over $100,000. The fig.2 shows the experimental facilities of our PSEW system.

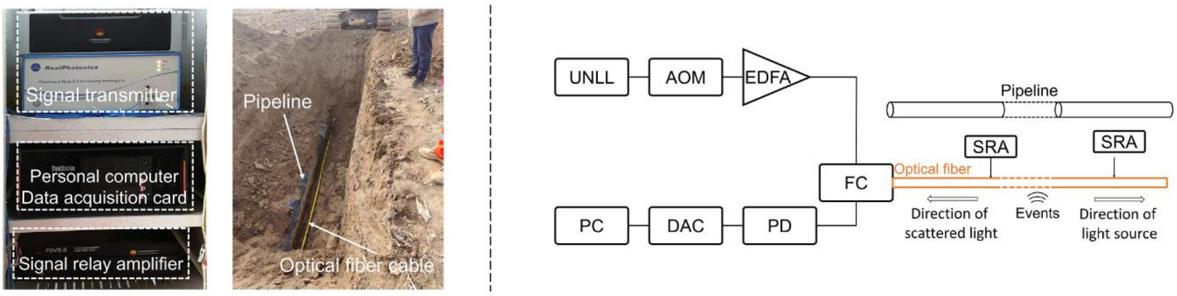

Fig.2 Real experimental facilities of our PSEW system.

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 oil transportation pipeline for half a year. The fig.3 shows the features (upper) and identification results (lower) from this operational PipeChina pipeline.

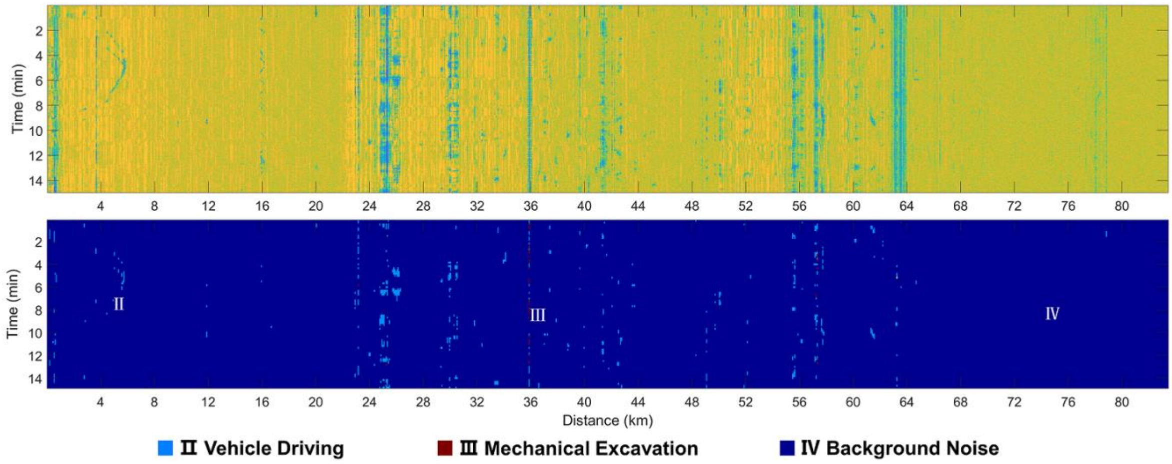

Fig.3 Feature maps and identification results. It can be seen that mechanical excavation occurred for 15 mins at around 36 km, which was usually accompanied with the vehicle driving; i.e., the excavators' engine was running or the position was adjusted to find a better angle for excavation.

Our work provides a new perspective on the practical application of PSEW systems in industrial scenarios and it will be more effective in securing energy pipeline transport. In future, we are interested in exploring higher spatial-temporal resolution and exploring the applications of perimeter security for pipeline stations.

References

[1]. F. Tanimola and D. Hill, "Distributed fibre optic sensors for pipeline protection," Journal of Natural Gas Science and Engineering, vol. 1, no. 4-5, pp. 134–143, 2009.

[2]. J. G. Ramirez-Camacho, F. Carbone, E. Pastor, et al. "Assessing the consequences of pipeline accidents to support land-use planning," Safety science, vol. 97, pp. 34–42, 2017.

[3]. Y. Yang, Y. Li, T. Zhang, et al. "Early safety warnings for long-distance pipelines: A distributed optical fiber sensor machine learning approach," in The Thirty-Fifth AAAI Conference on Artificial Intelligence. AAAI Press, 2021, p. online.

[4]. J. Li, Y. Wang, P. Wang, et al. "Pattern recognition for distributed optical fiber vibration sensing: A review," IEEE Sensors Journal, 2021.