Based on sparse optimization, distributed acoustic detection and noise reduction

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Abstract

Every aspect of daily life involves noise, which is a universal truth. Application-specific factors determine whether noise will happen. When the sensor resolution is high, noise in the sensing process will be a major issue. A new technique used in vertical seismic coil (VSP) exploration is called distributed acoustic detection (DAD). It offers a number of benefits, including cheap cost, high accuracy, and excellent tolerance for challenging acquisition environments. But complicated background noise and high energy-coupled noise frequently impair DAD -VSP field data, which negatively impacts the accuracy of seismic data. Therefore, the goal of this research is to develop a scattered representation-based method for noise reduction. The efficiency of the suggested method is first evaluated using fictitious signals, and then it is examined using actual signals obtained from the current supplying the induction motors. The signals are evaluated after the procedure has been applied to demonstrate the accuracy of the information in the article.

1. Introduction

In latest days, there has been a lot of research topic in fiber-optic distributed acoustic detection (DAD) systems. These systems work by using interferometry or coherent interrogation techniques to find the light's Rayleigh backscattering, which occurs in fibre optics and is spread erratically. The geographic distribution of fibre strain or changes in index of refraction can be determined by measuring the variations in this backscattering vs. fibre delay. The (DAD) is typically used for these observations because the strain is frequently brought on by acoustic vibrations (Wang, et al., 2020).

(DAD) is currently widely utilised for applications such as monitoring terrestrial pipelines, border control and security, and oil and gas boreholes. Future uses are anticipated to include observation of railways and highways, cables (telecom and power), and different geophysical and seismic monitoring where long range may be advantageous. At areas more than 50 kilometres from the sensor, the detection of trawler activity close to a subsea telecommunications cable has previously been shown (Rønnekleiv, et al., 2019).

A new generation of in-well monitoring technology is featured under the acoustic energy sensing banner. Some are turbulence or vibration monitoring techniques, but this paper describes distributed acoustic detection (DAD) technology and noise reduction based on scattered enhancement. Distributed acoustic detection (DAD) system allows the user to listen to the acoustic field at each point along several kilometers of fiber-optic cables deployed in the well. With a spatial resolution of 1 meter (Mestayer , et al., 2011).

The device accurately captures the genuine entire audio field (amplitude, frequency, and phase across a large dynamic range) at every point simultaneously using a unique digital optical detection technology. To ascertain the coherent spatially and temporally properties of sound waves, a variety of signal processing tools have been proposed to analyse a wide range of audio signals. Significant advantages are anticipated from in-well monitoring applications, including lower noise based on sparse optimization (Mateeva, et al., 2013).

In order to eliminate the jump edges in the noise level of distributed acoustic detection (DAD), a sparse optimization-based noise reduction method is given in this study. The proposed technique uses well in terms of distributed acoustic detection and noise reduction, according to experimental data. The properties of wave signals are clearer because it guarantees comparatively steady phase sensitivity and boosts the signal-to-noise ratio.

2. Research aim

Fiber optic (FO) cables are the foundation of the distributed acoustic detection (DAD) system. DAD has benefits over geophones but also has particular difficulties, such as transmitter depth uncertainty and low signal-to-noise ratio. Although it seems to be a major source of noise in the raw DAS data, significant loud noise, most probably from the DAD capture equipment, can be eliminated with appropriate processing. The well temperature variations and optical noise are additional sources of noise. sparse optimization of distributed acoustic detection can lower noise, according to experimental field research.

3. Theoretical framework

With coherent Rayleigh backscattering of a low-noise laser in a typical single-mode sensing fibre, distributed acoustic detection (DAD) technology may continuously detect external physical field (vibration, sound, and temperature variation) over large distances. As a fibre sensing technology, DAD offers excellent environmental adaptation, providing resistance to chemicals, superior camouflage, and anti-electromagnetic interference. Additionally, several distinct benefits like high temporal and spatial resolution, a vast sensing distance, dynamic numerical value, and others make DAD popular. Modern DAD systems are capable of monitoring physical fields over distances of tens of kilometres with spatial resolution appropriate to sub-meter scale and sampling rates up to kHz because DAD has been extensively explored up to this point (Juarez, et al., 2007).

DAD has been successfully utilised in numerous significant fields with the help of collective efforts, including perimeter security, passenger rail, pipeline safety monitoring, natural danger detection, geophysical prospecting, etc. It is interesting that current studies give DAD optimism that they can illuminate all of the world's black communication lines for unprecedentedly widespread pervasive sensing. DAD is quickly evolving as a crucial sensing technology, and there is a vast market for its potential applications. Researchers focused on enhancing DAD function, covering response bandwidth, spatial resolution, dependability, coverage, signal-to-noise ratio (SNR), and other factors. In the third stage, DAD is used to build various novel detection capabilities, particularly multi-component detection and multi-dimension localization (Franklin, et al., 2019).

In DAD, the coherent Rayleigh backscattering of the probe laser in the optical fibre is used to acquire the surrounding physical field. Physical factors (such as the elastic-optical effect, thermo-optical effect, thermal expansion, etc.) on the properties of optical fibre cause the optical properties (such as amplitude, process, and frequency) of the probe laser to change. The physical field can be produced and sensing is accomplished at each place along the sensor fibre once these features have been recognised and demodulated (Juarez, ET AL., 2005). according to Figure 1.

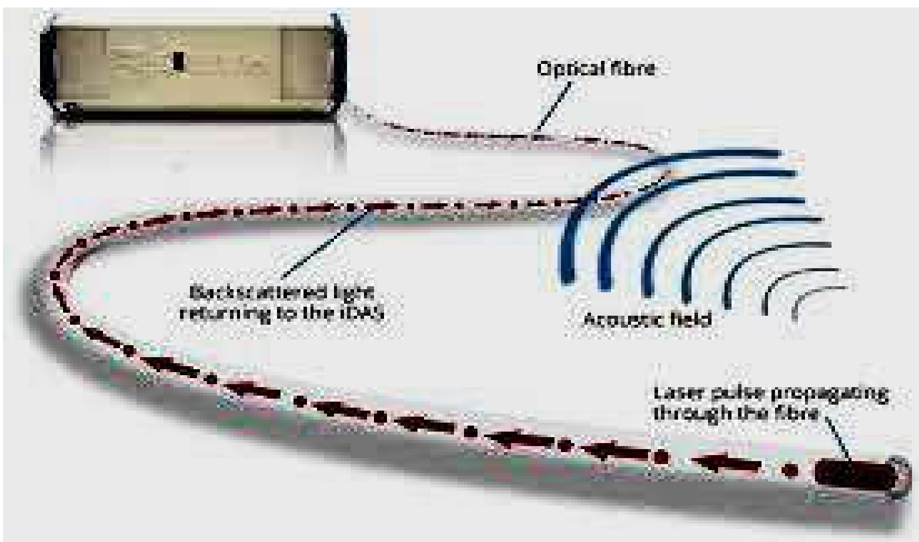

Fig.(1) distributed acoustic detection

Distributed Acoustic Detection (DAD), which obtains the data required for distributed acoustic sensing over a fiber-optic connection, is widely regarded as a new and quickly developing technology. High-resolution photographs and more thorough inspection photos can be acquired using the high-quality dataset the DAD acquisition system produced. The collected data set, however, exhibits significant coherent DAD coupling noise in field data.

Coherent DAD coupling noise may be brought on by a variety of circumstances, including physical position-related cable slamming and ringing, wired cable swinging on a frequent basis, and separation of the fibre cable from the sheath. We lower the DAD coupling noise from the signal-to-noise ratio based on sparse optimization, which has an impact on analysis and processing (Daley, et al., 2015).

The data set obtained from the DAD system can be of higher quality thanks to the sparse optimization technology, which can help reduce DAD coupling noise. Our strategy for removing DAD coupling noise is based on distributed optimization. Effective signal and coupling noise in the DAD-based data set exhibit different morphological traits. The DAD coupling noise only manifests in a few small frequency ranges in the frequency domain, in contrast to the effective sparse optimization signal, which has a large bandwidth. The efficacy of our strategy was proved in field trials using two sets of field data and a synthetic data set (Yang, et al., 2018).

Optical fibre cables can be used in many industries where dispersed acoustic detection is applied. While quicker and less expensive, this has the acknowledged disadvantage of adding more coherent coupling noise to the data due to the slap and resonance of the freely dangling wire connection inside the enclosure. Based on scattered optimization, the current study suggests an explanation of the noise reduction method. With the help of this technique, resonance noise may be lessened, its behaviour can be studied, and the known effects of the length measurement filter can be taken into account. One reason for this fact could be that the temporary cable installation interferes with correct cable coupling, increasing the amount of coherent noise in the data as a result (Bakku, et al., 2014).

In many technical and scientific disciplines, such as signal and image processing, the search for discrete solutions to non-linear systems is necessary. Effective Sparse Optimization becomes fundamental to many large- or high-dimensional data processing tasks, yielding both beneficial theoretical and practical outcomes. For variance finding issues coming from big data processing, compressed sensing, statistical learning, computer vision, etc., Sparse Optimization plays a significant role primarily in creating these results and reduce noising from employing DAD. Numerous researchers working at the intersection of technology, math, and computer science have expressed interest in this (Yun Bin Zhao, 2018).

Modern theory and algorithms for signal recovery under noise coupling are provided by Spare optimization theory and methods. For the linear, subsidence systems, updated singularity terms for the sparse solution are provided. The outcomes of the dispersed signal recovery using convex optimization techniques are shown under the matrix property known as band space property (RSP), which is a deep and moderate case. This framework is expanded to encompass compressed 1-bit sensors, resulting in the development of a new tag recovery theory (Ibid).

4. Discusion

One reason for this fact could be that the temporary cable installation interferes with correct cable coupling, increasing the amount of coherent noise in the data as a result. Consequently, while obtaining DAD data utilizing wired fixation, multiple investigators found the similar noise patterns (Hartog et al., 2014; Dean et al., 2015; Yu et al., 2016a). Sparse optimization during data recording has been suggested by Schelke and others (2016) and Constantinou et al. (2016) to enhance cable coupling and lower noise.

Field testing from Rittershoffen, France, and numerical modelling techniques were used in the research. The labeled dataset example created with sparse optimization of 2 percent, however, demonstrated a drop in the signal-to-noise ratio as well as a reduction in noise in the cable build-up zone.

Using data from a tube-mounted DAD cable, Barbaran et al. (2012), Didraga (2015), and Daley et al. (2016) identified areas of ringed noise. Didraga (2015) claims that the vertical parts that connect the noise-generating mechanism function as a vibratory chain between the connection points of the outer shell. Daly and other people (2016) Reverberation waves entrapped between two depths can be used to explain resonant noise phenomena. The authors mentioned above also point out noisy areas in the data that correlate to wave propagation in a steel shell with weak cementing.

The features of resonance noise were further examined by Willis and colleagues in 2019, who also discussed the varying speeds of the top and bottom windings of the noise. Noise creation is described as a loose cable bouncing back and forth in the deep areas. To lessen this noise and improve the quality of the produced signals, they advised employing sparse optimization.

YU et al (2016a) Examples of distributed acoustic sensor (DAS) data sets received on a wired connection are given by Willis et al. (2019). The well cap, which is visible at specific different depths, and poor sensor-cable coupling, according to the scientists, are the most possible reasons of this resonant noise. The coupling of cables within the well is not well controlled since, while getting a wired cable, the cable is not fastened and floats freely. The connection of the cable to the well wall varies due to well characteristics, such as inclination and termination at certain depth ranges; consequently, it is likely that some parts will be exposed to echoes from various sources, like the vibration signal while data gathering (Yu et al., 2016a; Willis et al., 2019). Eliminating this noise pattern severely complicates data processing since slapping cables creates a distinct noise pattern. The resulting noise was decreased by using the dispersed optimization technique.

Conclusion

In order to improve the signal to noise ratio performance of the DAD system, a DAD-based noise reduction strategy based on sparse optimization is presented in this study. It was shown through theoretical analysis and data assessment of field investigations that dealt with this subject that the suggested strategy performs well in terms of noise reduction. The SNR is increased by around 10 dB, ensuring a comparatively steady phase sensitivity across the whole sensing range, and the wave signal features are more distinct than they were in the original signal. Additionally, the noise-induced hop edges are removed while maintaining the same peaks and valleys as the original signals, which is crucial for figuring out how long the peaks and valleys between various channels take to rise and fall.

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