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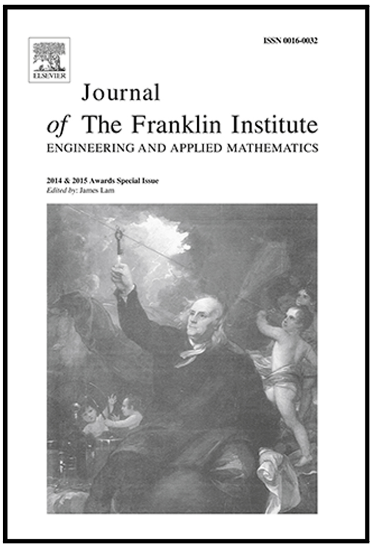

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An Intelligent Propagation Distance Estimation Algorithm based on Fundamental Frequency Energy Distribution for Periodic Vibration Localization

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Abstract

Earth surface vibrations generated by passing vehicles, excavation equipment, footsteps, etc., attract increasing attentions in the research community due to their wide applications. In this paper, we investigate the periodic vibration source localization problem, which has recently shown significance in excavation device detection and localization for urban underground pipeline network protection. An intelligent propagation distance estimation algorithm based on a novel fundamental frequency energy distribution (FBED) feature is developed for periodic vibration signal localization. Contributions of the paper lie in three aspects: 1) a novel frequency band energy distribution (FBED) feature is developed to characterize the property of vibrations at different propagation distances; 2) an intelligent propagation distance estimation model built on the FBED feature with machine learning algorithms is proposed, where for comparisons, the support vector machine (SVM) for regression and regularized extreme learning machine (RELM) are used; 3) a localization algorithm based on the distance-of-arrival (DisOA) estimation using three piezoelectric transducer sensors is given for source position estimation. To testify the effectiveness of the proposed algorithms, case studies on real collected periodic vibration signals generated by two electric hammers with different fundamental frequencies are presented in the paper. The transmission medium is the cement road and experiments on vibration signals recorded at different propagation distances are conducted.

Keywords: Frequency band energy distribution, Periodic vibration source localization, Fundamental frequency estimation, Distance-of-arrival, Machine learning algorithms

1. Introduction

Earth surface vibrations have been extensively investigated in the past years due to their wide applications in many signal detection and estimation fields [1–16]. In the area of human activity detection, Ranta *et al.* [1] developed a mechanical vibration based instrument to detect the presence of a person seated on a vehicle; Gabriel and Anghelescu [2] investigated a low power human activity detection system for critical infrastructure protection and monitoring; Madarshahian *et al.* [3] analyzed the floor vibrations for health care and security. In the area of vehicle and device detection, Tsurushiro and Nagaosa [17] employed a smart phone to observe the vibrations generated by vehicles and performed the localization through comparisons to a prior constructed benchmark vibration map in the database. In the area of security monitoring and fault detection, Qu *et al.* [4] used the fibre vibration as an aid to the optic fibre pre-warning system; Ishigaki *et al.* [14] presented a vibration frequency spectrum classification method using support vector machine (SVM) to detect the faults in gas pressure regulator; Sun *et al.* [15] discussed the wood pellets detection system in pneumatic conveying pipelines using the vibration and acoustic signals generated between the biomass particles and the pipe wall; Sinha and Feroz [16] shown novel results on detecting the rock and timber drops in railway tracks using vibrations captured by accelerometer. In the area of human footstep detection, Venkatraman *et al.* [6–8] and Reddy *et al.* [5] presented a series of achievements on human footstep detection and bearing estimation using a

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