A Signal Pre-processing Method for Condition Monitoring based on Vibration Signals from On-Site Manipulators

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ABSTRACT

Handling irregular and noisy field data is challenging in condition monitoring. In contrast to refined lab data, where external influences are kept to a minimum, acquired signal from an accelerometer attached to mechanical devices involves plenty of uncontrollable variables. Especially, irregular operation cycles of the process make it difficult to specify significant vibration signals for monitoring without mechanical expertise and information. In this study, we distinguish motion signals from noisy raw signals using Shannon Energy Envelope (SEE). The extracted individual motion signals are algorithmically clustered by Density-Based Spatial Clustering of Applications with Noise (DBSCAN).

1. INTRODUCTION

In manufacturing sites, where mechanical systems are interconnected, many irregularities occur. Without a proper response, they will ruin the entire production process, shut down the production line, and eventually cause huge losses. Condition-based monitoring (CBM), a key technology of the smart factory, is a suggested approach to decrease downtime and achieve effective maintenance through real-time monitoring of the system (Martin, Jaroslav and Jiří, 2021). However, most of the condition-monitoring methods were created and tested using data collected in the laboratory stage. In actual manufacturing sites, unexpected and uncontrollable noises are generated and detected by the operation of neighboring devices or the external environment. These noisy signals make it difficult to assign analytical signals, and this can lead to incorrect monitoring. In this study, we proposed a method to segment irregular field data into noise and motion data and cluster them by motion.

2. PRE-PROCESSING METHOD FOR IRREGULAR ON-SITE DATA

This study was conducted on a 6-axis articulated robot operating in the body assembly line of a mass production plant of Hyundai Motor Group. Accelerometer sensors were attached to three axes of the robot in a radial direction to collect vibration signals, and the measurement time for each sample is 120 seconds, with a sampling frequency of 12.8 kHz.

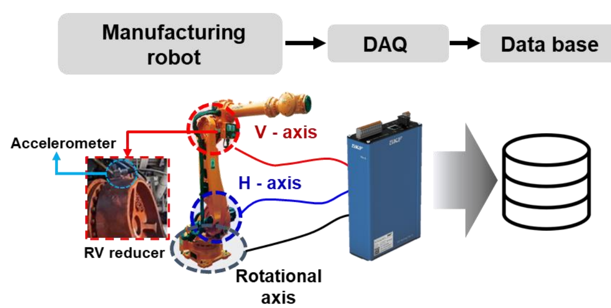

Figure 1. Condition monitoring object and the experimental setup.

Since the robot performs complex motions irregularly, the vibration signals extracted by each sample are also irregular due to the robot's motion. The signals for health monitoring should be analyzed by extracting only the motion signals while the robot is performing a specific motion. In this study, we extract the vibration signal envelope using the shannon energy envelope (SEE) and separate the motion signal from the noise.

Motion-based features were extracted to perform clustering on the extracted motion signals. The motion signals were divided into several windows, and feature values were extracted for each section to better represent the characteristics of the motion signals. We extracted the impulse per section, the slope of the first-order regression line, and the length and amount of energy in each motion signal as features.

The clustering method used density-based spatial clustering of applications with noise (DBSCAN), which can distinguish noise (Dingsheng, 2020). The obvious advantage of this algorithm is that the number of clusters does not need to be specified in advance and outliers can be effectively excluded. The parameters are epsilon (the size of the radius) and minpoints (the size of the smallest cluster), which give a threshold for density. If a data point has no other neighbors closer than this threshold, it is not placed in any cluster and is classified as noise.

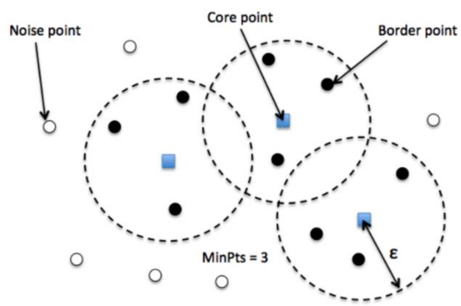

Figure 2. DBSCAN algorithm.

Clustering via motion-based feature values resulted in good segmentation in the three-dimensional reduced space. As a result, the characteristic signals were accurately clustered. Despite the noisy signal, we were able to distinguish between different motions, which is clearly a helpful way to specify the analysis signal.

3. Conclusion

In this study, we proposed a pre-processing method to analyze data collected from robots used in a body assembly line in a real factory. Using vibration data collected from robots with complex movements, we extracted the SEE of the signal. In the lack of motion information or controller signals, SEE was used to separate the true motion signal from the noise. Then, we selected motion-based features and signal energy values as features for clustering by motion. The DBSCAN algorithm was successful in dividing each cluster of motions. In this study, we developed a vibration signal pre-processing algorithm that can distinguish complex motion signals, which has great applicability for condition monitoring in actual industrial sites.

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