Yi-xiang HUANG, Xiao LIU, Cheng-liang LIU, Yan-ming LI, 2018. Intrinsic feature extraction using discriminant diffusion mapping analysis for automated tool wear evaluation. *Frontiers of Information Technology & Electronic Engineering*, 19(11):1352-1361. https://doi.org/10.1631/FITEE.1601512

Intrinsic feature extraction using discriminant diffusion mapping analysis for automated tool wear evaluation

Key words: Tool condition monitoring; Manifold learning; Dimensionality reduction; Diffusion mapping analysis; Intrinsic feature extraction

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Motivations

1. In the manufacturing process, tool wear caused by abrasion can severely harm the processing precision and productivity. Thus, it is necessary to develop effective tool condition monitoring (TCM) systems to reduce costs and improve productivity.

2. There are two main challenges in TCM development: finding signals that are suitable for describing the tool status and determining a feature set extracted from the signals that can effectively capture the performance degradation of the tools.

Main idea

1. We propose discriminant diffusion map analysis (DDMA) to analyze current signals and fuse the features for tool wear evaluation. The main steps are as follows:

(1) extracting original features from raw signals;

(2) estimating the dimensionality of the original feature space and calculating the discriminant information and the affinity matrix;

(3) calculating the weighted diffusion distances by discriminant kernels;

(4) constructing the low-dimensional feature space, i.e., the diffusion coordinates.

Method

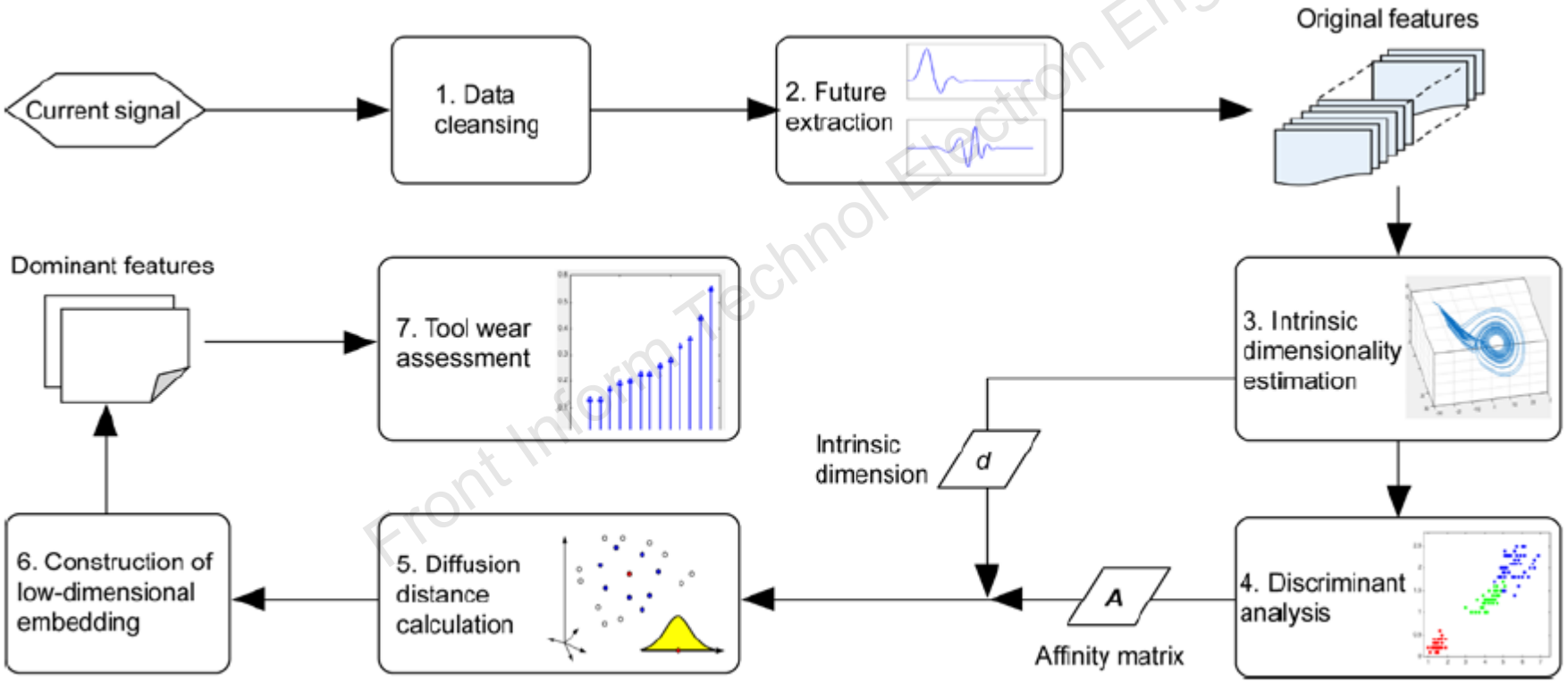

Fig. 3 Flowchart of the discriminant diffusion maps analysis (DDMA) for tool wear evaluation

Major results

Experiment setup and sensor data:

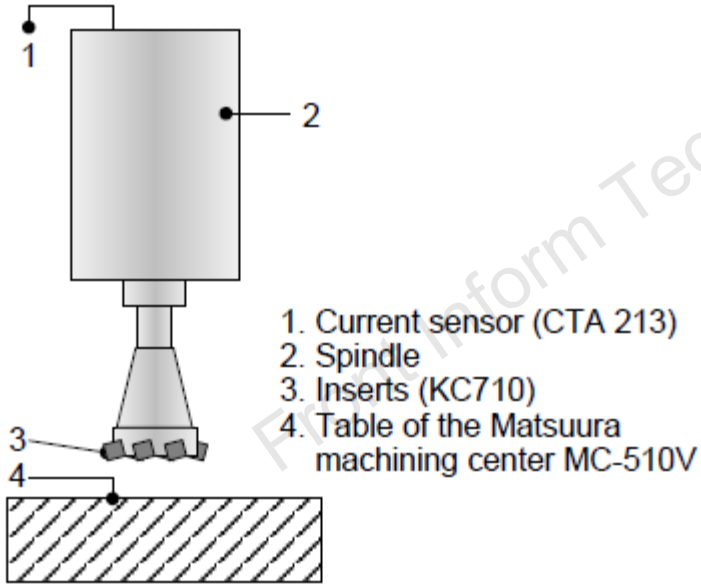

Fig. 1 Test stand for the face milling tool experiment

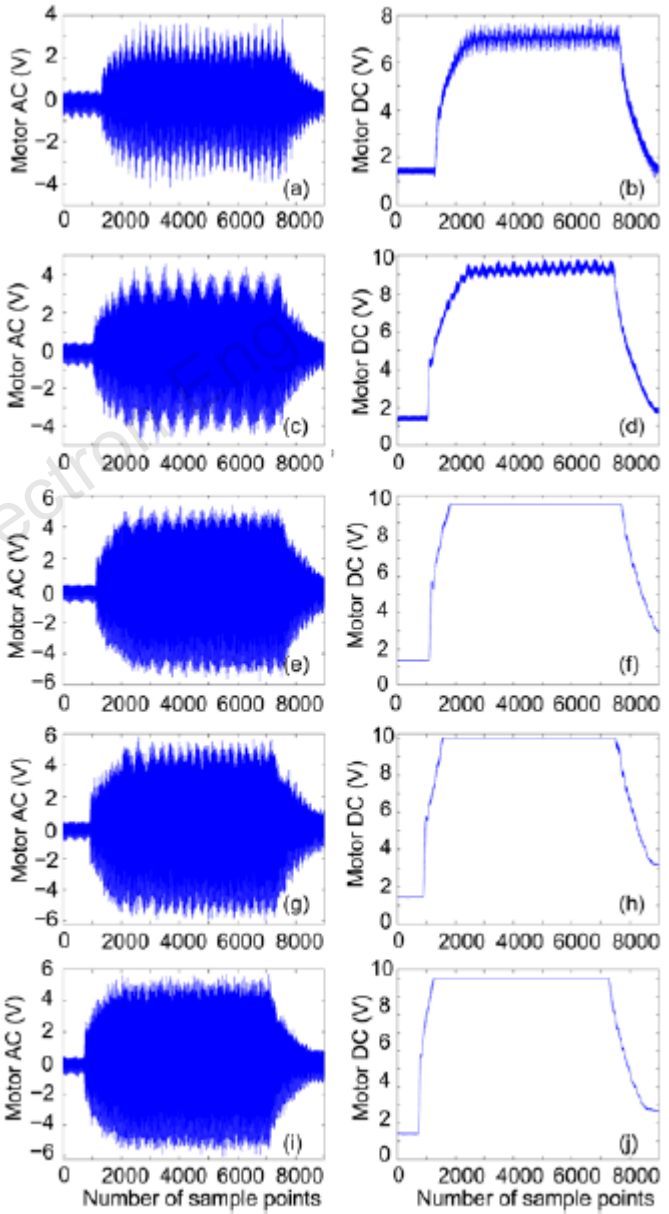

Fig. 5 Typical current signal waveforms for the spindle drive

Major results (Cont'd)

Tool wear level evaluation results:

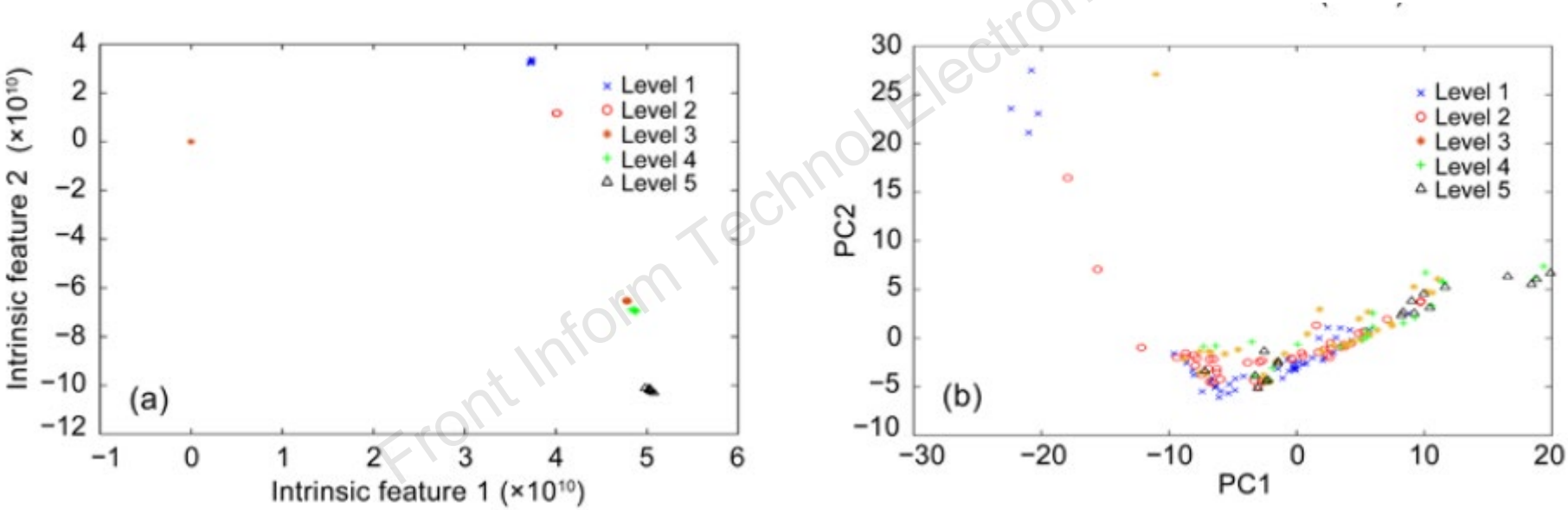

Fig. 7 Two-dimensional intrinsic features marked with true tool wear levels extracted by DDMA (a) and PCA (b)

Conclusions

1. A DDMA technique has been studied for intrinsic feature extraction in evaluating the tool wear. In principle, the method applies the Markov random walk theory to a graph and uses a discriminant kernel scheme to refine the high-dimensional feature space.

2. The performance of DDMA has been evaluated on the current signals collected from a milling experiment, which can be accessed easily in industrial machine centers.

3. The results have shown that DDMA can transform the original high-dimensional features to an intrinsic feature space with a significantly lower dimension for machining processes.