Dimensionality Reduction-Based Diagnosis of Bearing Defects in Induction Motors

EECOMOBILITY (ORF) & HEVPD&D CREATE

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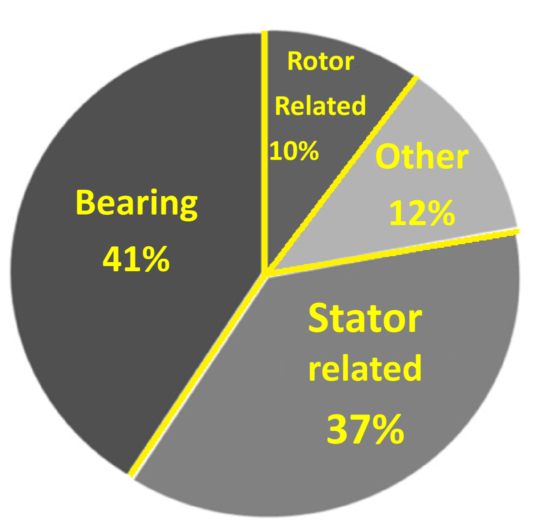
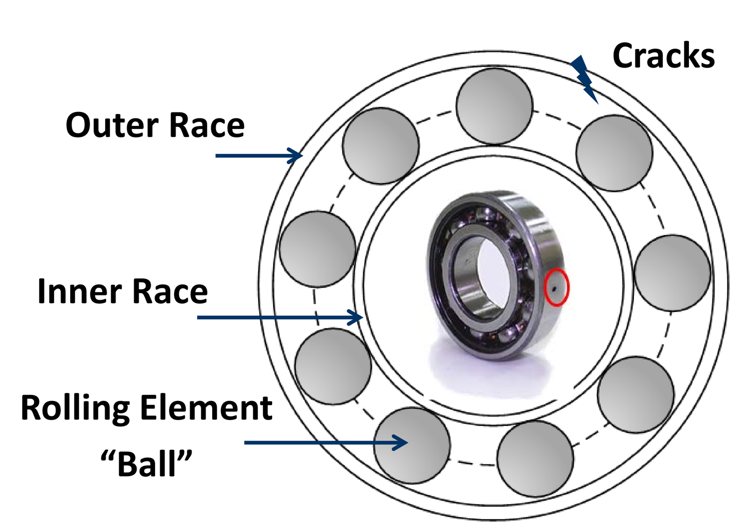
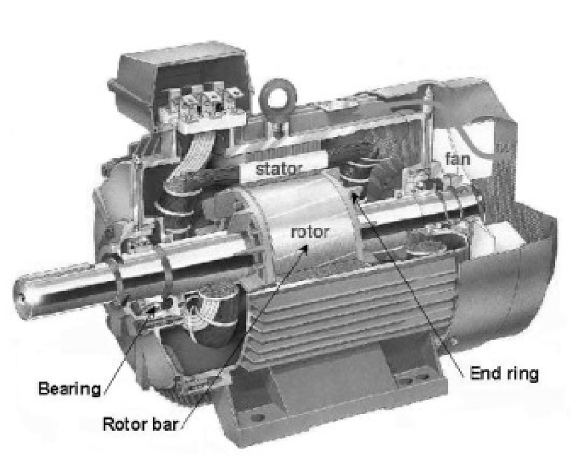
ABSTRACT

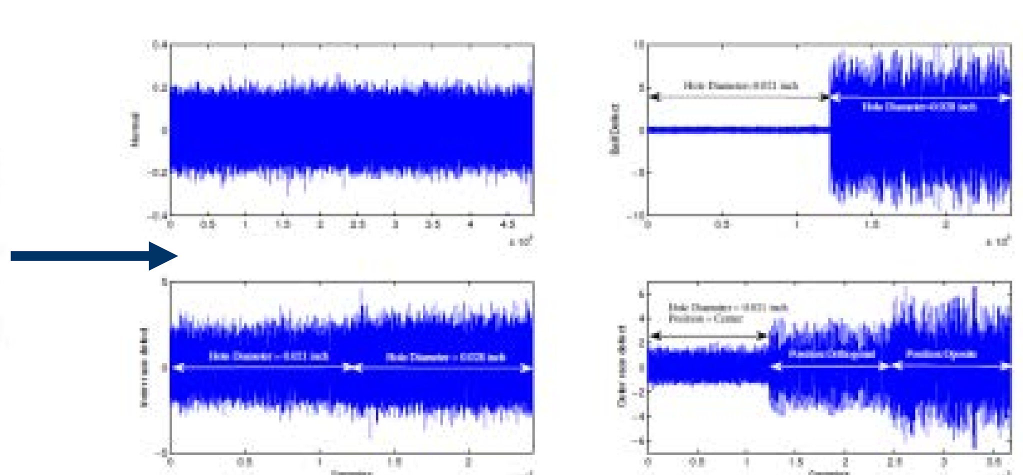
- Efficient diagnosis of bearing defects in induction motors can help to guarantee the reliable operation of industrial systems such as electric vehicles. It usually requires **extracting informative features** from the vibration signal and efficiently **reducing the dimensionality** of the features.
- In this paper, the vibration signal is primarily analyzed by the **empirical mode decomposition** technique to extract informative intrinsic mode functions as a set of features. The dimensionality of the extracted feature set is reduced by means of **maximally collapsing metric learning (MCML)** to create an informative set of small-sized features for fault classification. MCML is an **efficient supervised dimensionality reduction technique** which aims to collapse patterns of the similar class to a point in the feature space while separates patterns of other classes to the maximum extent possible.
- To compare the performance of MCML, other state-of-the-art unsupervised and supervised techniques are used for the dimension reduction of the features. The fault diagnosis unit includes various classifiers which aim to diagnose multiple bearing defects that are ball, inner race and outer race defects of different diameters.

INTRODUCTION

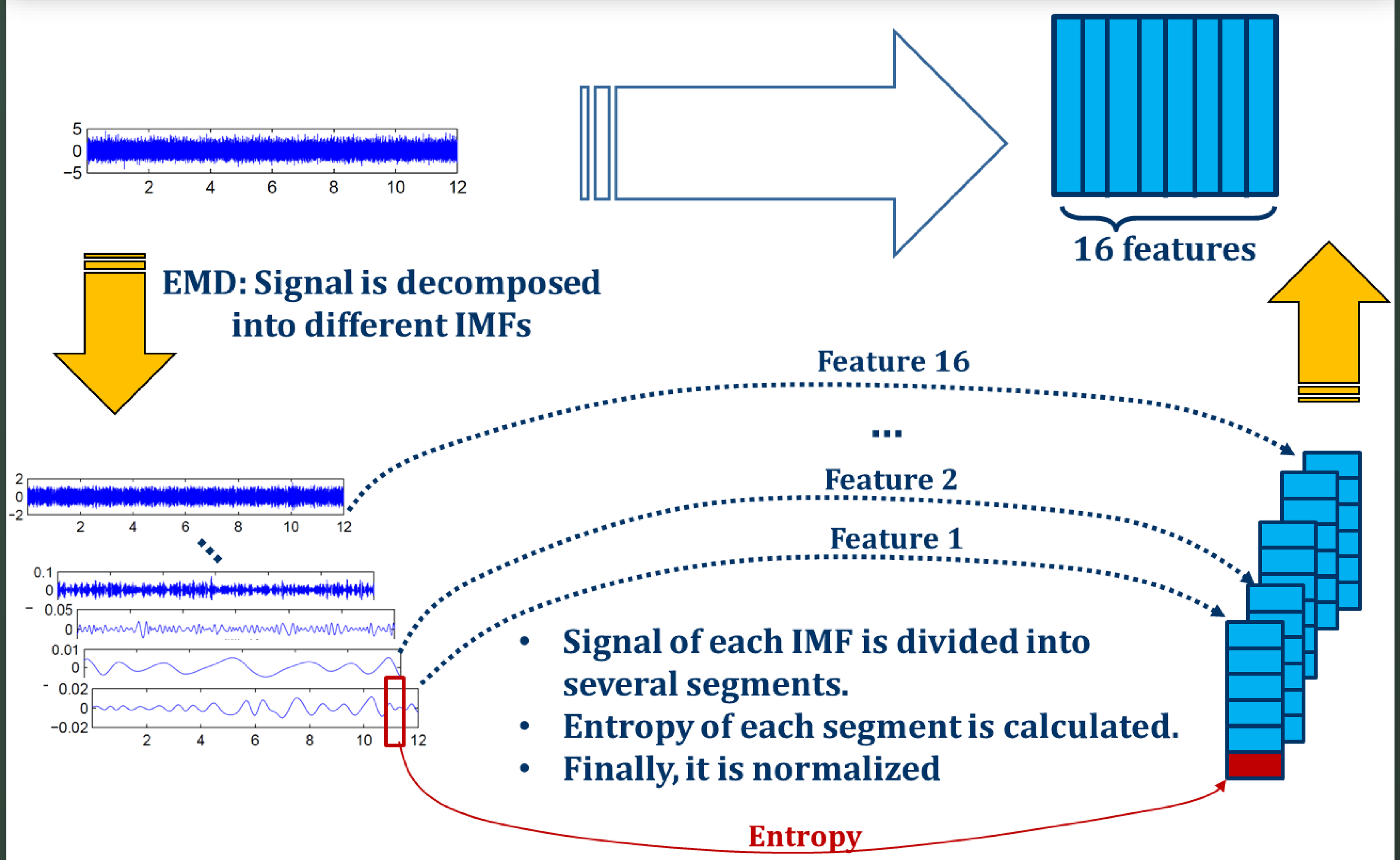




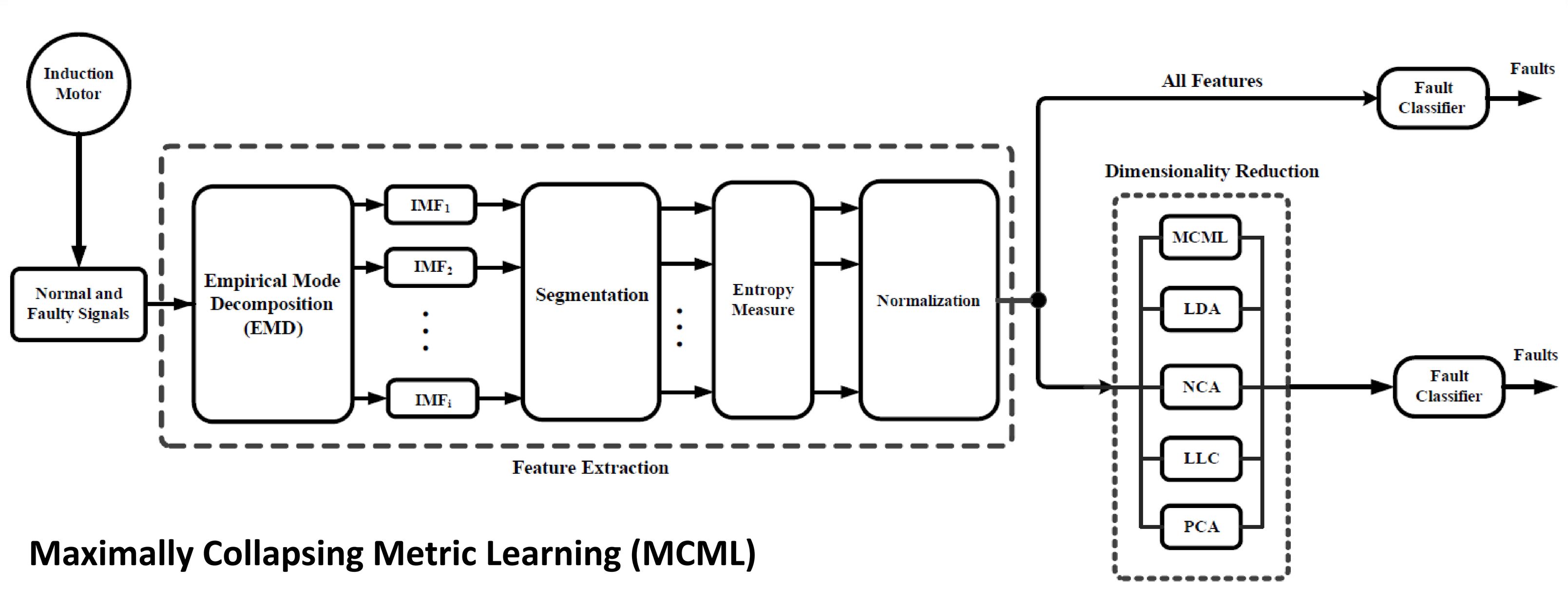




MULTI-STEP PREPROCESSING SCHEME



DIAGNOSTIC SCHEME



Maximally Collapsing Metric Learning (MCML)

aims to collapse all samples of similar class to a single point, and at the same time projects samples of other classes to very far distance point. MCML approximates the local covariance structure of the data and is therefore not based on Gaussian assumption as opposed to LDA which uses global covariance structure.

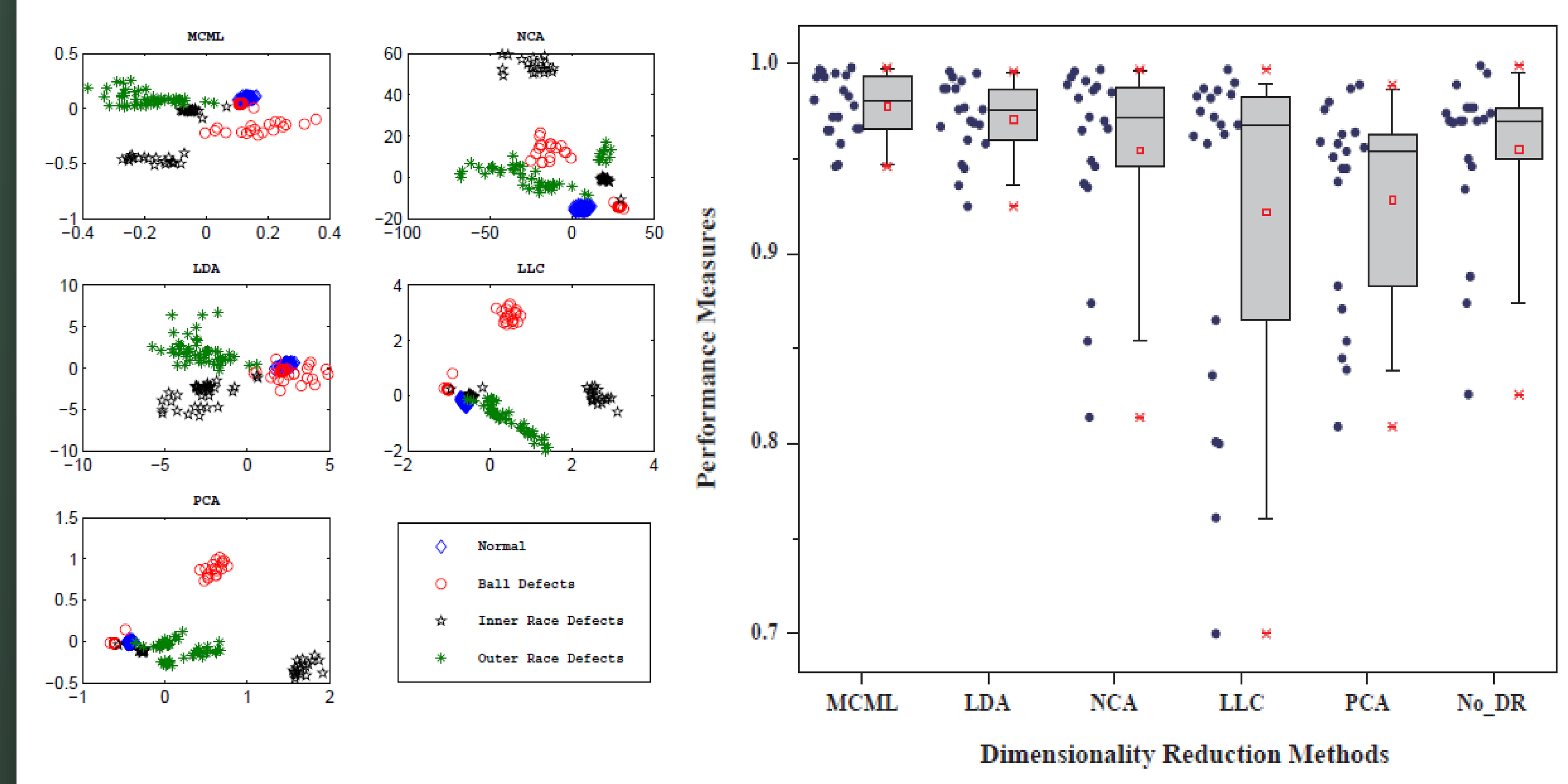
Neighborhood Component Analysis (NCA) vs Linear discriminant Analysis (LDA): it allows two members of the same class to be far apart in the feature space as long as each member of the class is close to k other class members.

Principal Component analysis (PCA) is the most popular unsupervised linear method that focuses on large variance of data points. Linear dimensionality reduction methods such as PCA and factor analysis are easy to train but cannot capture the structure of curved manifolds.

Locally Linear Coordination (LLC) uses mixture of the local dimensionality reduction (DR) methods to create a global coordinate to handle the problem of the curved manifolds.

EXPERIMENTAL RESULTS

Dimensionality reduction methods:



Boxplot illustrates the distribution of the performance measures attained by all classifiers.

CONCLUSION

This work focuses on developing a **multi-step preprocessing scheme** for diagnosing bearing defects in IMs. This scheme has two main sub-modules:

(1) **Extracting informative features**, i.e., intrinsic mode functions, from the vibration signals by means empirical mode decomposition (EMD). The extracted IMFs are segmented to compute the entropy of each segment. The attained features are normalized, and then, fed to the subsequent sub-modules;

(2) **Feature reduction** by means of maximally collapsing metric learning (MCML) to construct an informative set of small-sized features in a supervised manner, that best separate the different classes of bearing defects. To study the efficiency of MCML, other state-of-the-art unsupervised and supervised methods are implemented and compared for reducing the dimension of the features. The reduced features obtained by the DR sub-module are used to train various classifiers to diagnose bearing defects including normal state, ball defects, outer race defects and inner race defects with different diameters.

The experimental results reveal the **effectiveness** of the developed feature extraction and reduction modules in providing discriminant features for diagnosing bearing defects.

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