**Project – Bearing Fault Diagnosis**

1. **Background**

Rolling element bearing is an indispensable component in rotary machinery systems, and quite usually a critical one that costs significant expense and time when it fails. To monitor bearing health condition, various techniques have been applied including vibration analysis, oil debris and acoustic emission. Among these techniques, vibration analysis is currently the most established with various signal processing methods employed to analyze the fault signatures in high-resolution vibration waveform. An inevitable challenge for bearing monitoring is the multiple possible failure modes and their combinations, which requires advanced analytical methods to extract most relevant information and identify failure modes with high accuracy.

To evaluate analytical methods for bearing fault diagnosis, a test-bed is set up to collect vibration data under different bearing fault conditions. A SKF 32208 tapered roller bearing (TRB) is used and an accelerometer is installed on the orthogonal direction of its housing to measure the axial vibration. A PCM3178-HG-B DAQ card, embedded in Advantech UNO-2160 box, is used to convert analog waveform to digital data.

During the tests, seven (7) bearings with induced defects and a new bearing with no defect are used in turn to generate data under eight different conditions. The bearing models are the same, thus same specification and geometry parameters. The fault conditions are roller defect, inner-race defect, outer-race defect, the three combinations of any two independent faults and the combination of all three.

1. **Problem Statement**

The task for this project is to develop a systematic method to assess bearing health (good or degraded) and diagnose the specific failure modes when bearing is known degraded. Feature extraction is the first module that extracts time domain, frequency domain and other features from raw vibration data. Dimension reduction algorithms can be used to downsize the extracted feature set. With health assessment algorithms, degradation can be assessed with reference to feature set from baseline feature. Eventually classification algorithms are used to learn from labeled training data, and diagnose unknown condition based on testing data.

1. **Bearing Specification and Fault Frequencies**

The bearing is a tapered roller bearing (TRB) manufactured by SKF. Besides the drawings available online, the dimension and parameters needed for calculating fault frequencies are provided:

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| --- | --- |
| Pitch Diameter (D) | 60 mm |
| Roller Diameter (d) | 10 mm |
| Number of Roller (n) | 17 |
| Contact Angle (Φ) | 14.04 |
| Rotating speed of inner race () | 800 rpm |
| Rotating speed of outer race ( | 0 rpm |

Frequencies related with bearing faults can be calculated as:

|  |  |  |
| --- | --- | --- |
| Feature Name | Meaning of the Feature | Equation |
| Ball Passing Frequency Outer Race (BPFO) | Fault on outer race, excited by passing of roller element |  |
| Ball Passing Frequency Inner Race (BPFI) | Fault on inner race, excited by passing of roller element |  |
| Ball Fault Frequency (BFF) | Fault on roller element(s), excited by alternating passing of roller element on inner and outer races |  |
| Fundamental Train Frequency (FTF) | Fault on the cage or mechanical looseness |  |

1. **Provided Data Set**

A training data data\_train.mat is given with 2048 tests, as well as data\_train\_labels.mat as labels for all the 2048 tests. Labels are numbers from 1 to 8, corresponding with normal, roller, inner race, outer race, inner race & roller, inner race & outer race, outer & inner race & roller, and outer race & roller.

Testing data is given as data\_test.mat, with 512 tests.

1. **Some Suggested Algorithms**

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| --- | --- |
| **Feature Extraction** | Amplitudes of fault frequencies, time domain statistics |
| **Dimension Reduction** | Principal Component Analysis |
| **Health Assessment** | Self-organizing Maps Minimum Quantization Error (SOM-MQE) |
| **Diagnosis** | Self-organizing Maps, Support Vector Machine |

1. **Submission of Test Results**

Project team can submit the results for the tests with an Excel spreadsheet. The spreadsheet should contain 512 rows and 1 column, and each cell should be a number from 1 to 8 representing the diagnosis result. The team can email the result to TA ([yangqb@mail.uc.edu](mailto:yangqb@mail.uc.edu)), and multiple submission is allowed.