Predictive Maintenance on Rotating Machinery Using Artificial Neural Network Methods

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Introduction

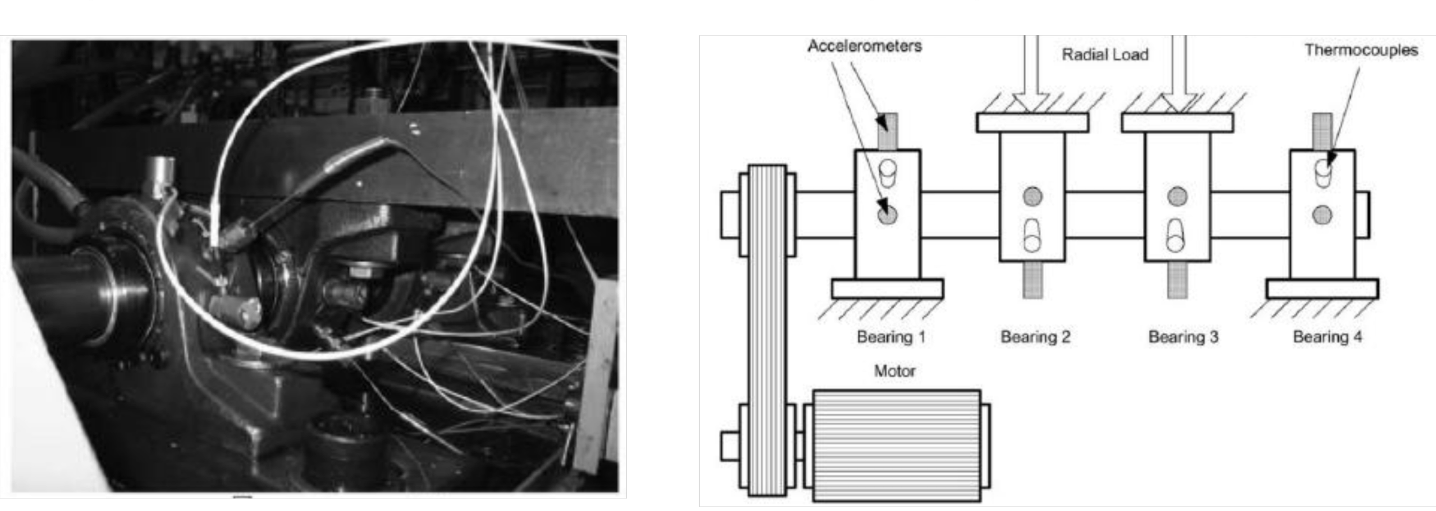
Predictive maintenance (PdM) techniques are designed to help determine the condition of in-service equipment in order to predict when maintenance should be performed. A rotating system is one of the most critical elements in a machine tool system. We want to use artificial neural network (machine learning) methods to monitor the system condition and predict upcoming failures.

Objective

1. Develop artificial neural network models for machine condition monitoring and predictive maintenance.
2. Establish a testbed prototype for failure simulation and data collection on motor.
3. Apply the model to the test dataset, both from on line data set and the one collected from the testbed (on going).

Methodology & Test Dataset

Neural networks are a set of algorithms, modeled loosely after the human brain, that are designed to recognize patterns. Two specific algorithms are being used in this work: Recurrent neural networks (RNN) and convolutional neural networks (CNN).



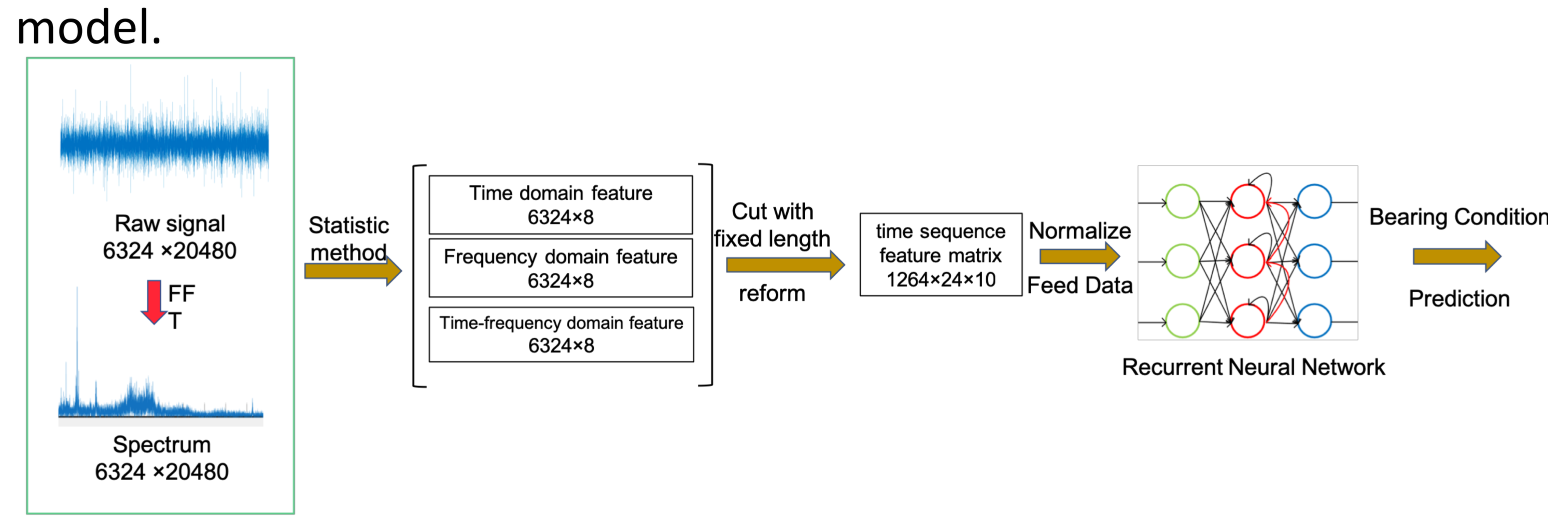
Experiment Setup for the test dataset

To train and test the algorithms, we used bearing data set from NASA prognostics Data Repository[1].

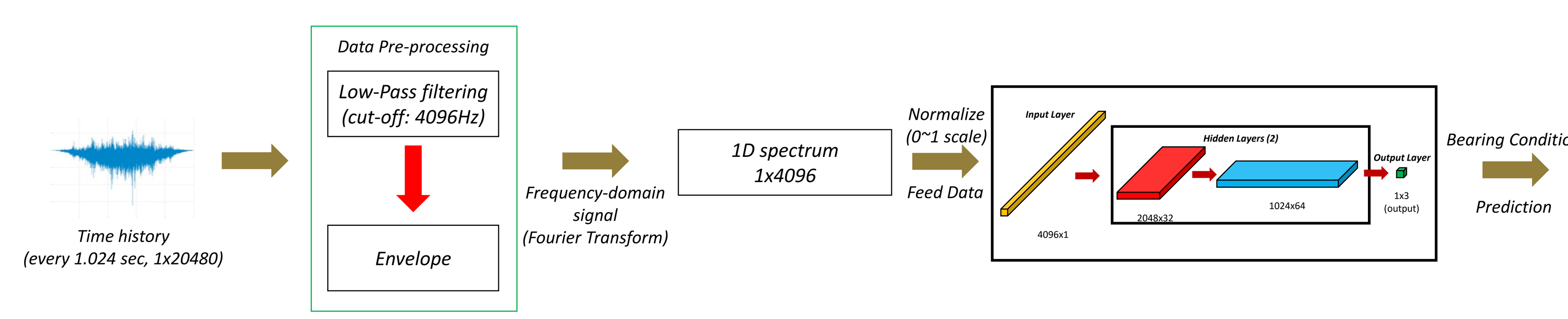
1. J. Lee, H. Qiu, G. Yu, J. Lin, and Rexnord Technical Services (2007). IMS, University of Cincinnati. "Bearing Data Set", NASA Ames Prognostics Data Repository (http://ti.arc.nasa.gov/project/prognostic-data-repository), NASA Ames Research Center, Moffett Field, CA

Data Analysis and Processing

For RNN, feature datasets are extracted from the raw accelerometer signals in time domain, frequency domain, time-frequency domain, and then those features are cut in fixed-width windows with 50% overlap to form time sequential samples, which will be the inputs of the RNN model.



For CNN, short-term Fourier Transform (STFT) is performed over each time series of length 20480 with 20kHz of sampling frequency. Then every single spectrum is low-pass filtered up to 4096Hz, to track harmonics of bearing characteristic frequencies. After normalizing, each spectrum is handled as one feature vector, which is used for training and testing CNN model.



Results

For each test, we labeled the condition of data samples with three states: normal, warning, failure. The 8 tests were randomly divided into 6 training sets and 2 testing sets. After training the models with the training sets, test sets were used to assess the accuracy of the models. The testing classification results are shown.

True Condition \ Predicted Condition	Failure	Warning	Normal
Failure	98%	2%	0%
Warning	13%	87%	0%
Normal	0%	3%	97%

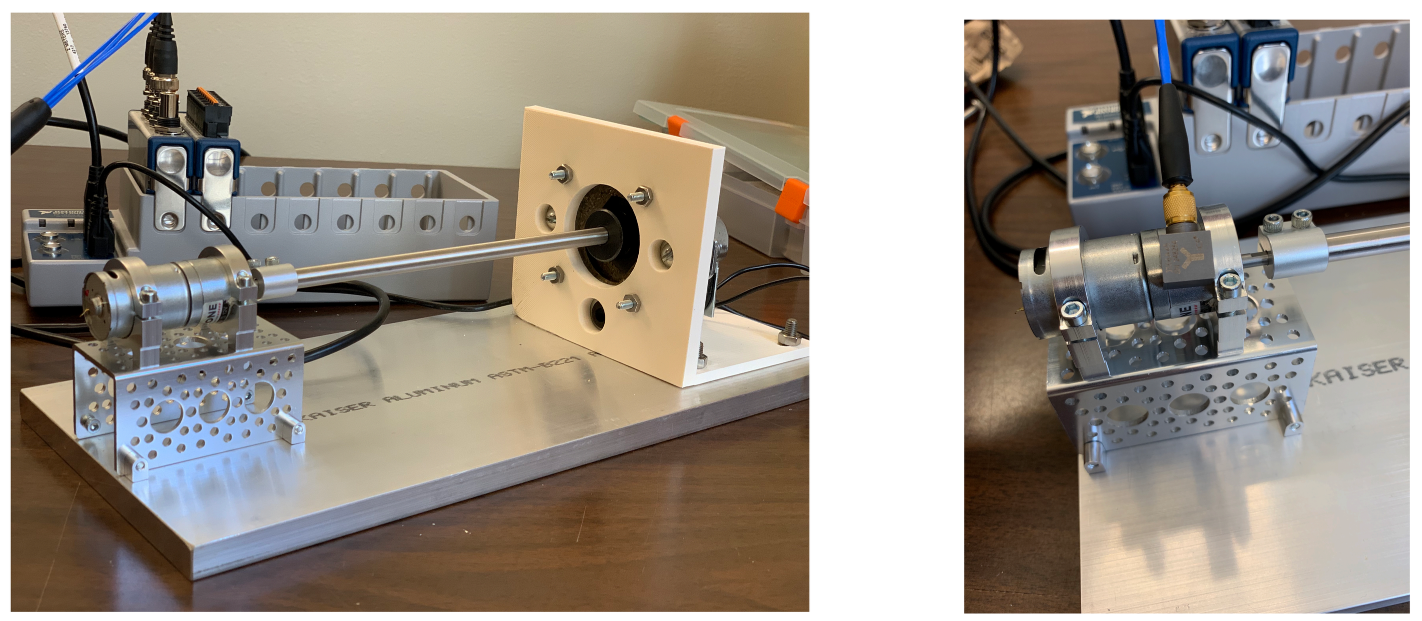
(a) Test result for RNN

True Condition \ Predicted Condition	Failure	Warning	Normal
Failure	99%	1%	0%
Warning	6%	92%	4%
Normal	0%	14%	86%

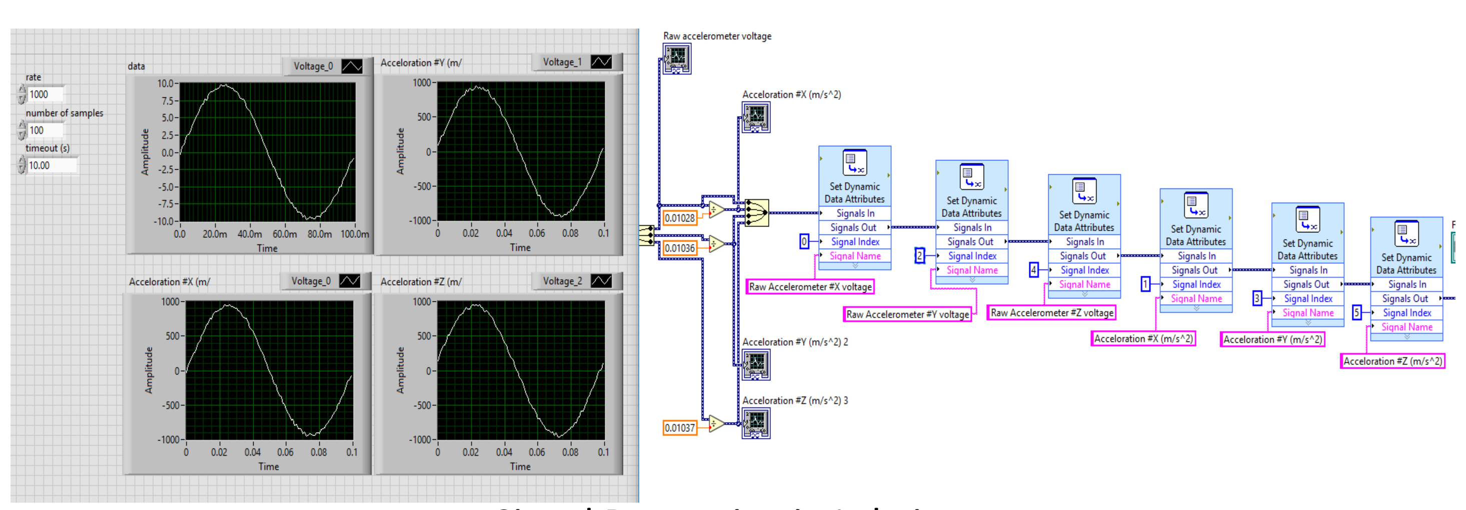
(b) Test result for CNN

Testbed & DAQ System

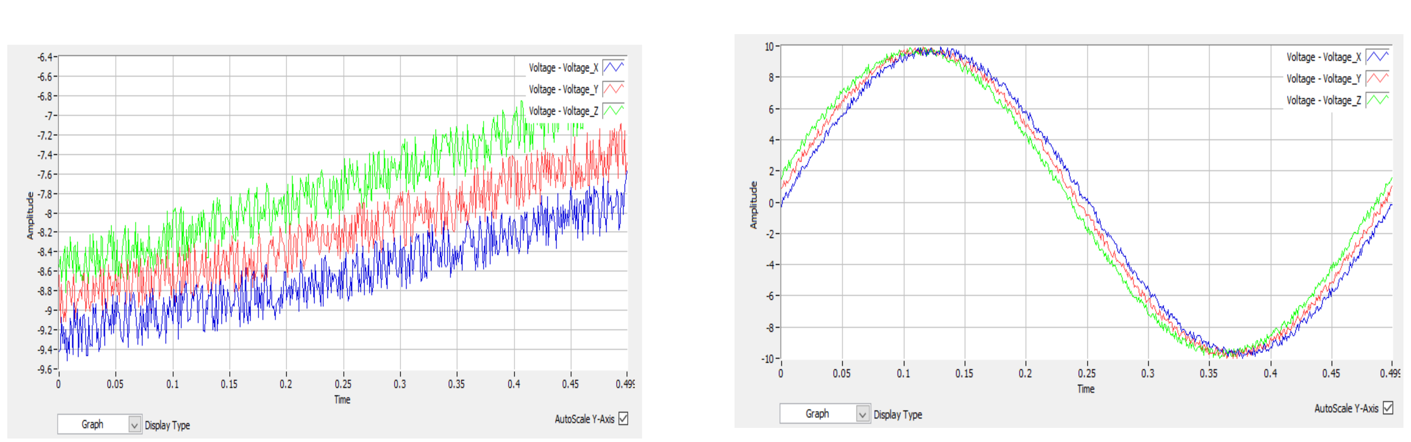
In the test-bed, a 12V DC brush-less motor is being used to evaluate the ability of the methods to identify motor faults, and formulate appropriate responses. The testbed utilizes hardware and software that are similar to what would be employed in an industrial setting (accelerometer, DAQ, FFT signal analyzer, etc.). Many failure scenarios can be evaluated with the low cost small test-bed motor.



Motor Testbed and DAQ System



Signal Processing in Labview



Raw Data Collected from the Sensor

Conclusion

In this work, artificial neural network models are being used to develop PdM techniques for rotating systems. A test-bed has been constructed and is being used to generate motor failure data. Initial results with the RNN and CNN methods indicate that they can distinguish the condition of motors. A real-time monitoring system is planned, which includes a module maintenance recommendation.