Applications of Machine Learning
(Part 2)

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AI, fuelled by machine learning from data, will undoubtedly accelerate engineering progress for the foreseeable future. At DSD, we continually look for opportunities to leverage new technologies, so have been exploring ways in which machine learning could shorten development cycles, reduce costs and improve product performance.

Machine learning offers us another step along the road towards replacing costly traditional development testing by simulation, but effective simulation depends upon verified data. By using data we may already have in new ways, we can accelerate the application of machine learning for real world solutions. In this, the second of a 3-part series, we describe how this approach was successfully used with gearbox vibration data.

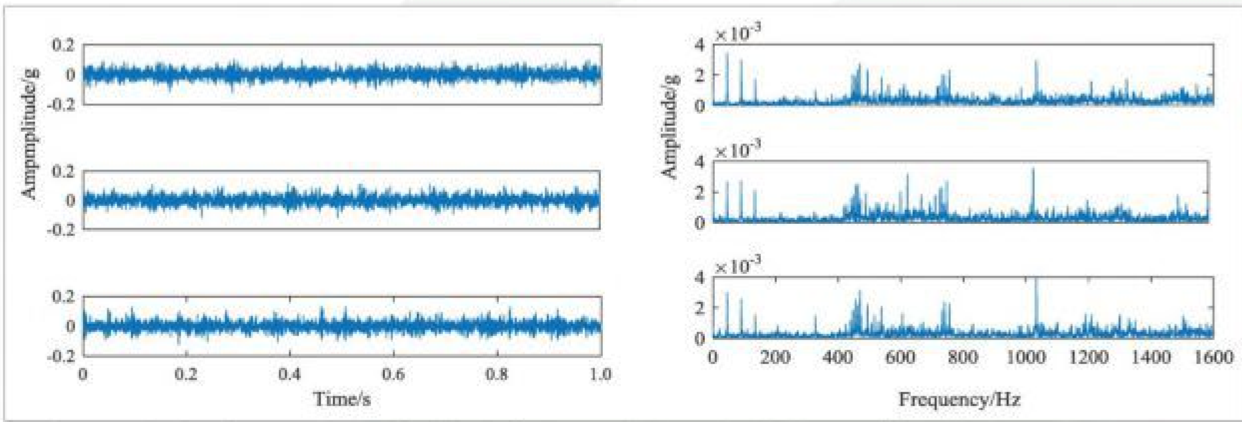
THE BENEFITS OF MACHINE LEARNING TECHNIQUES IN THE FIELD OF PROGNOSTICS AND HEALTH MANAGEMENT (PHM)

Vibration data collected from a gearbox contains extensive information about the interactions inside. The excitations at each rotating interface, every bearing and gear mesh, can be detected by a properly mounted accelerometer. The characteristics of these vibrations are themselves dependent on several factors, including the magnitude of the transferred load, lubrication coverage and wear.

The monitoring of wear and the health of components in rotating machinery is of particular interest to industries where unscheduled maintenance or down-time due to non-operational plant leads to disproportionately high costs. The field of Prognostics and Health Management (PHM) is specifically aimed at improving diagnostic capabilities and creating accurate models for remaining useful life (RUL), permitting scheduled, pre-emptive replacement of a part before it actually fails.

At DSD, we have extensive expertise in applying many of the physical and engineering principles underlying PHM and have explored the addition of machine learning techniques to this field through a recent project. Our goal was to determine how machine learning techniques could be utilized in the PHM field by inferring torque levels in a gearbox from vibration measurements at any given point in time. It is not in itself a demonstration that using vibrational data is the best means of measuring torque, but more to show the potential for machine learning in the key field of rotating machinery prognostics.

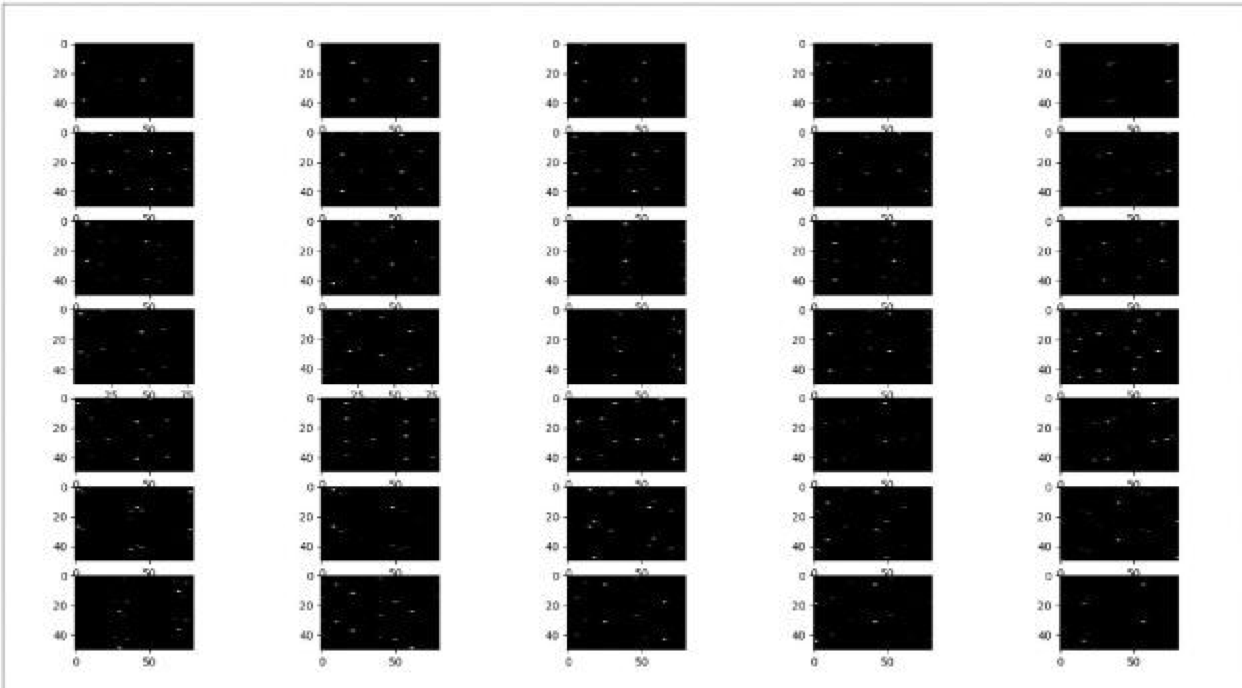
A representative model of a 2-speed integrated electric drive unit (EDU) was created in MASTA, which included a stiffness representation of the EDU housing. The model was simulated at discrete input speeds and torque points, ranging from 1200 -14000rpm and 10-100% of the maximum rated input torque. This generated simulated vibration data for 320 unique speed and torque operational points of the gearbox.



Learning to see the vibration: a neural network for vibration frequency prediction, author Liu, Jiantao and Yang, Xiaoxiang

The vibration data with frequencies up to 10kHz were decomposed using an FFT into different orders, and the first two harmonics of the first two orders of the system were considered.

The magnitude of each observed frequency was then translated into images for the machine learning algorithm.

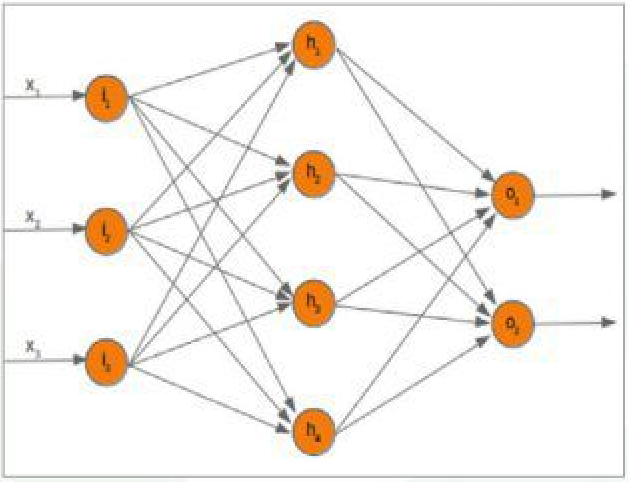


Each image contained 4,000 individual input features (1,000 per order), represented as different colored pixels, that were fed into the algorithm.

A neural network was chosen as the method for classification, and the model was trained with 2 sets of data in which the microgeometry on the gear teeth was varied. The model was trained to classify input images as one of a possible set of 320 output labels. Each label represented a prediction of a unique torque and speed pair that was experienced by the gearbox.

After training, the neural network showed good accuracy and was able to predict torque within +/- 5% for 99% of the test points.

Utilizing machine learning in this way advances the development of a full PHM solution set in two ways.



Firstly, it proves our hypothesis that a machine learning algorithm can glean useful information from a data set collected from a housing-mounted accelerometer, in this case torque. This serves as a proof of concept for the continued creation of more sophisticated machine learning models that can predict other attributes like RUL.

Secondly, the ability to predict torque through vibration measurements offers a much cheaper and more accurate way to collect duty cycle information throughout the life of a gearbox. As the RUL of an individual component is a function of the cumulative duty cycle it has experienced, this provides a useful synergy with physics-based durability models.

Our next steps in this research will be to validate the methodology further, by training and evaluating the neural network using real-world test data instead of simulated data.

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