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# MATERIAL CLASSIFICATION BASED ON VIBRATION ANALYSIS

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**Abstract**

In this paper, we investigate the characteristics of an object's vibration in identifying its material of construction. A simple vibration test is performed to classify different types of materials. The test is done by performing small hammer excitation on the object then recording its vibration using one acceleration sensor. Four different materials were tested (steel, hardwood, softwood, and plastic). The vibration signal was analyzed using MATLAB based model. The trained model was able to recognize the testing samples of each material. The advantages of this method are that it is accurate, fast and simple, can be performed on-site and is relatively inexpensive.

**Keywords***: vibration analysis, material identification, real-time recognition, acceleration sensors, impact hammer.*

## 1. Introduction

The material classification has many industrial and commercial applications, as well as real-time recognition for self-autonomous machines and robots. The proposed testing method uses a small hammer which could easily be attached to a robotic arm to provide it with real-time recognition of the surrounding materials.

The field of non-destructive testing (NDT) of materials is wide, including any technique that extracts information about the condition of a material specimen without altering its physical and/or chemical properties (see, e.g., [1] for a survey of different NDT methods).

### 1.1. The experiment setup

An acceleration sensor (Type SCA610) has been attached to a hammer, the sensor output signal is connected to the computer through a data acquisition unit (DAQ) and MATLAB software is used to record the signal, process it and provide recognition as shown in the following Figure 1. (A) and (B).

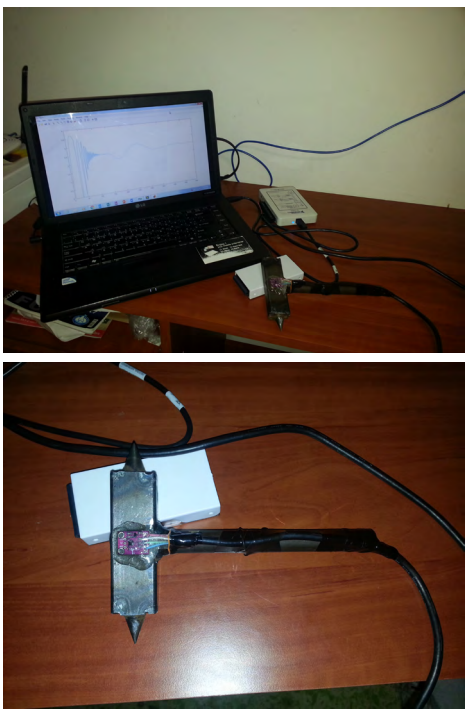


**Figure 1.** *(A) Connection of the Hammer to DAQ unit and to the laptop; (B) Sensor attached to the Hammer*

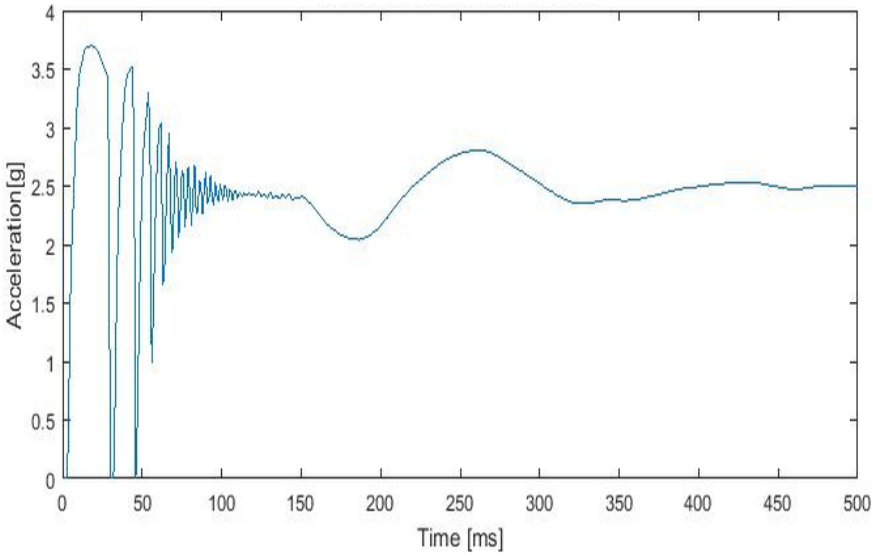


**Figure 2.** *The vibration signal of Hardwood*

### 1.2. Measurement

4 objects of different material were tested, 5 vibrations were recorded for each, the vibration waveform produced by an impact is a transient (short duration) energy transfer event. The spectrum is continuous, with a maximum amplitude at 0 Hz and decaying amplitude with increasing frequency (**Figure 2.**).

### 1.3. Signal Processing

For analysis each vibration signal was sampled, the sampling frequency (Fs) = 1 kHz, and the cut-off frequency of the accelerometer integrated circuit is about 70 Hz.

The signal is an impulse in nature and while Fast Fourier Transform is an industrial standard for processing the signal sequences, we have decided to perform a similar estimation of Welch Power Spectral Density (WPSD) together with a Histogram (**Figure 3.**). Additionally, the mean and the standard deviation values were calculated for each signal.

4 processed signals of each material were used to train the machine learning algorithms on the MATLAB Classification Learner Model. and the fifth record was used to test the recognition after training.

### 1.4. Machine Learning

The MATLAB Classification Learner app was used to train our model to classify the processed vibration data. The automated training models were compared to find the best classification model type, including decision trees, discriminant analysis, support vector machines, logistic regression, nearest neighbours, and Gaussian kernel classification.

### 1.5. Result and Discussion

The classifier identified the different pattern of the processed signals, and a scatter representation was produced as shown in **Figure 4.**

The hardwood and the steel signals were near to overlapping, which suggests that more signal processing is needed.

To reach distinguished results the derivatives of the first peak were suggested, some other signal processing tools (see **[2-8]**) could enhance the result.

## 2. Conclusions

This experiment is a part of an ongoing project and is used to proof the concept. Classifying different materials based on their vibration signal analysis using tools on MATLAB could be useful in many applications.

The vibration test is fast, portable and not expensive.

A larger dataset is needed to determine the accuracy, and an expanded set of materials will be investigated in future work.

MATLAB is a powerful tool and its machine learning algorithms could be used in any data analysis project to classify different patterns.

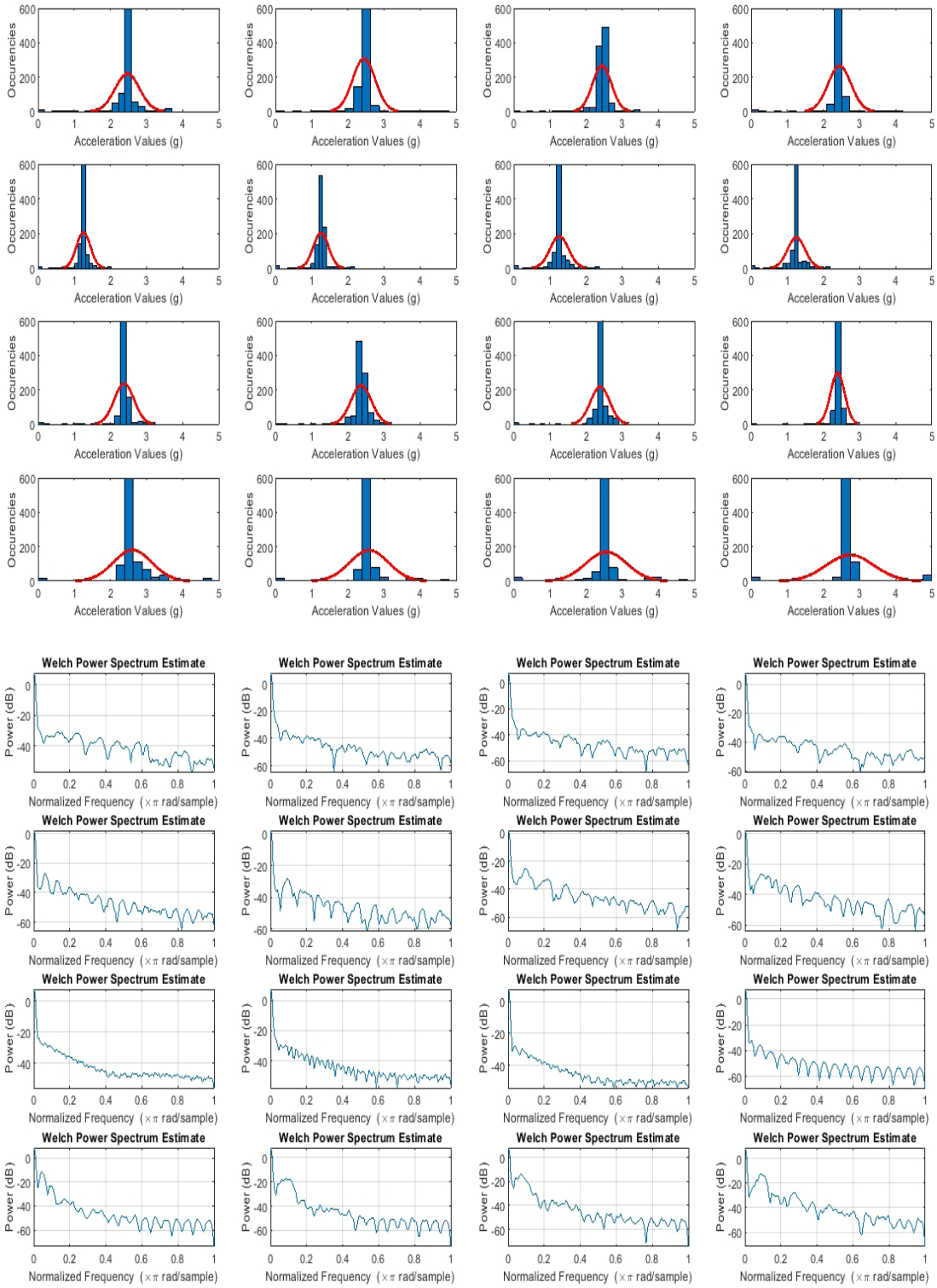


**Figure 3.** *Histogram and (WPSD) graphs for the total 16 signals that were used for training the MATLAB Classifier*

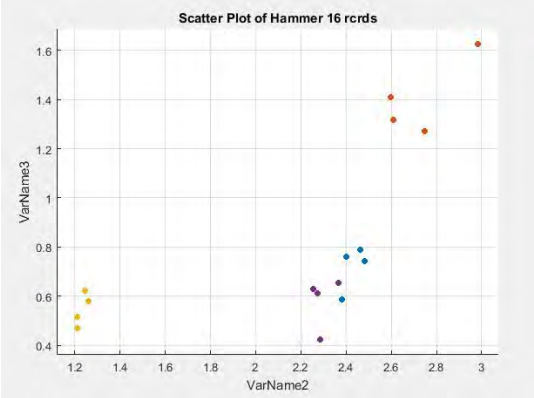


**Figure 4.** *The vibration signal of Hardwood*

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