ACOUSTIC RESPONSE ANALYSIS OF MEDICAL PERCUSSION USING WAVELET TRANSFORM AND NEURAL NETWORKS

Imperial College London

EPSRC
Pioneering research and skills

Dyson School of Design Engineering

Pilar Zhang Qiu[1], Oliver Thompson[1], Yongxuan Tan[1], Bennet Cobley[1]
[1]Dyson School of Design Engineering, Imperial College London

ABSTRACT

Medical percussion is a diagnostic procedure used to detect tissue anomalies by acoustic response. Although it is common in medical practice, there is a limited understanding of its dynamics.

This paper examines the acoustic response of percussion and explores how computational techniques may be used to predict the presence and location of tissue anomalies and develop remote assessment devices.

In the experiment, audio signals were obtained using a mechanically actuated device percussing a silicone phantom with an embedded nodule at varying depths. The waveforms were analysed using 1-D wavelet transform and classified through a convolutional neural network (CNN). Results showed that a nodule presence closer to the surface of the phantom increases the damping factor and attenuates frequencies between 50 Hz - 400 Hz.

EXPERIMENTAL SET-UP

An acrylic nodule with a diameter of 11 mm was buried in a silicone phantom, to a depth on either side of 2mm and 15mm respectivel. A robotic percussion device was programmed to tap the phantom at 1.09Hz and the acoustic response was captured with a contact microphone. The signal was trimmed automatically into individual percussion events using a MATLAB peak detection script.

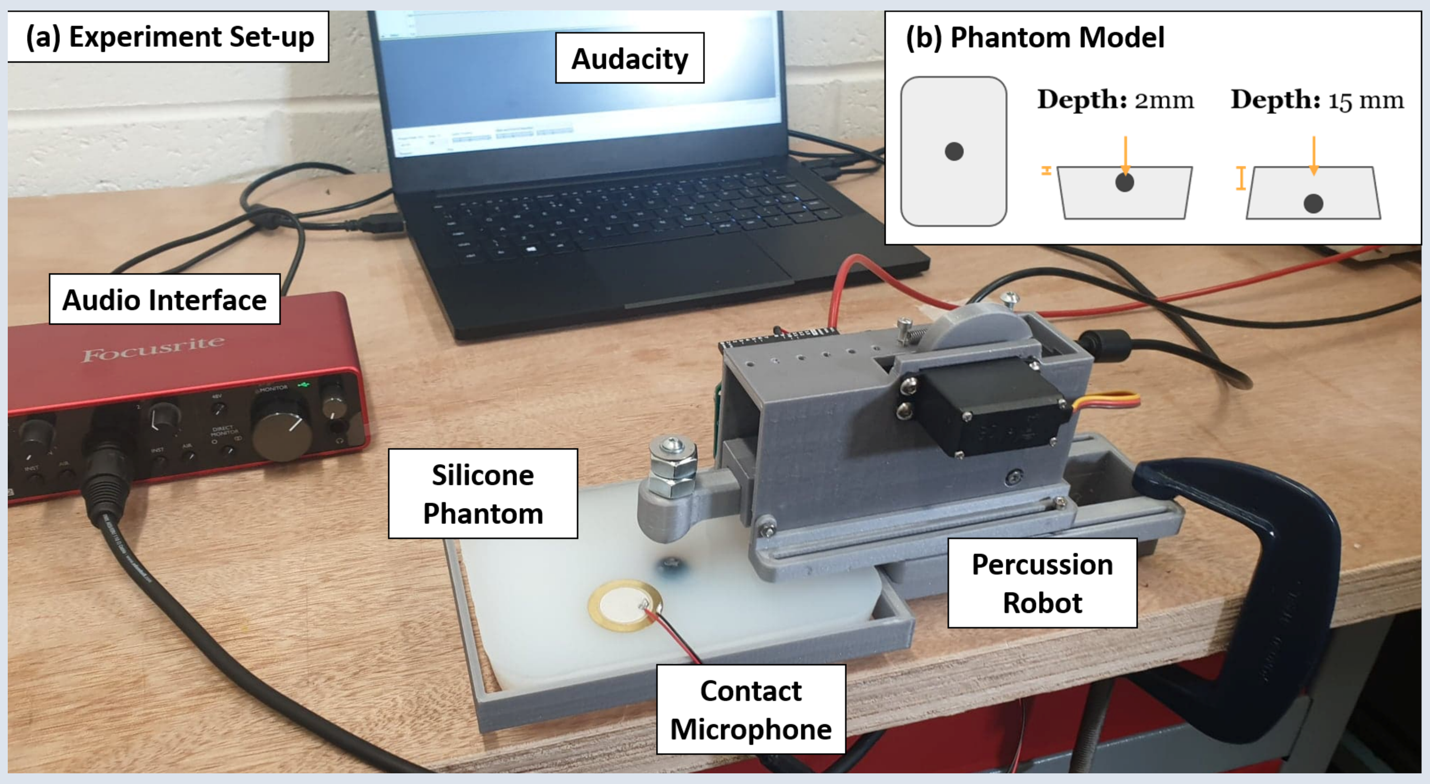

Fig. 1. (a) Robotic percussion device experimental set-up. (b) Visual representation of the silicone phantom

WAVELET TRANSFORM

Savitzky-Golay filtering was employed to de-noise the signals whilst preserving maximum concurrence to the original waveform.

The de-noised signal was analysed through a 1D Continuous Wavelet Transformations (CWT) coefficient scalogram. The chosen mother wavelet family was Symlet (Sym), widely used in audio analysis and signal damping.

Fig. 2 shows a comparison of scalograms for close nodule and far nodule instances. The coefficient C represents how closely correlated the wavelet is with specific sections of the signal as well as the signal intensity. These graphs show the effect of damping on the frequency intensities of close nodules compared to far nodules.

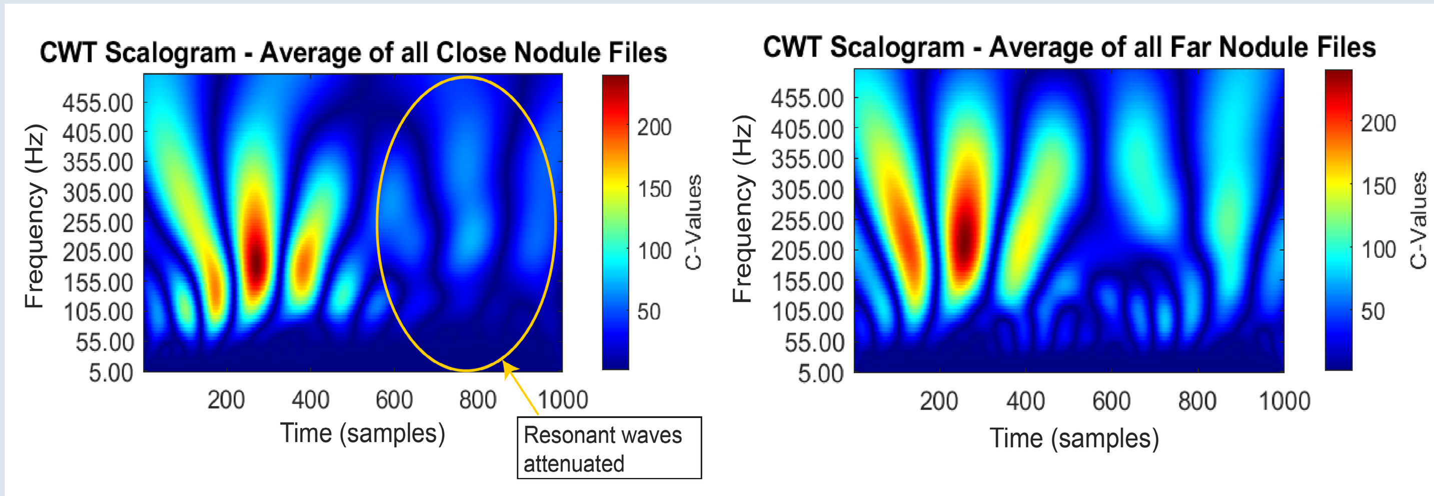

Fig. 2. Coefficient scalograms for the average signal in close nodule (left) and far nodule (right) percussion instances. Graphs fitted to regions of interest(5-500 Hz).

CONVOLUTIONAL NEURAL NETWORK

A CNN was used to verify that the changes in the time and frequency domain observed from the wavelet transform could be used to classify the presence of a nodule. Greyscale scalograms were generated using MATLAB for each of the 1688 taps measured in the experiment.The CNN was trained on 75% of this data, with the remaining scalograms used for validation.

The CNN architecture consisted of three 2D convolutional layers, two max pooling layers, one flatten layer and one linear layer. Training was stopped when the CNN was able classify the test scalograms with an accuracy of 100%. Saliency maps were generated to highlight which pixels informed the CNN's successful classification.

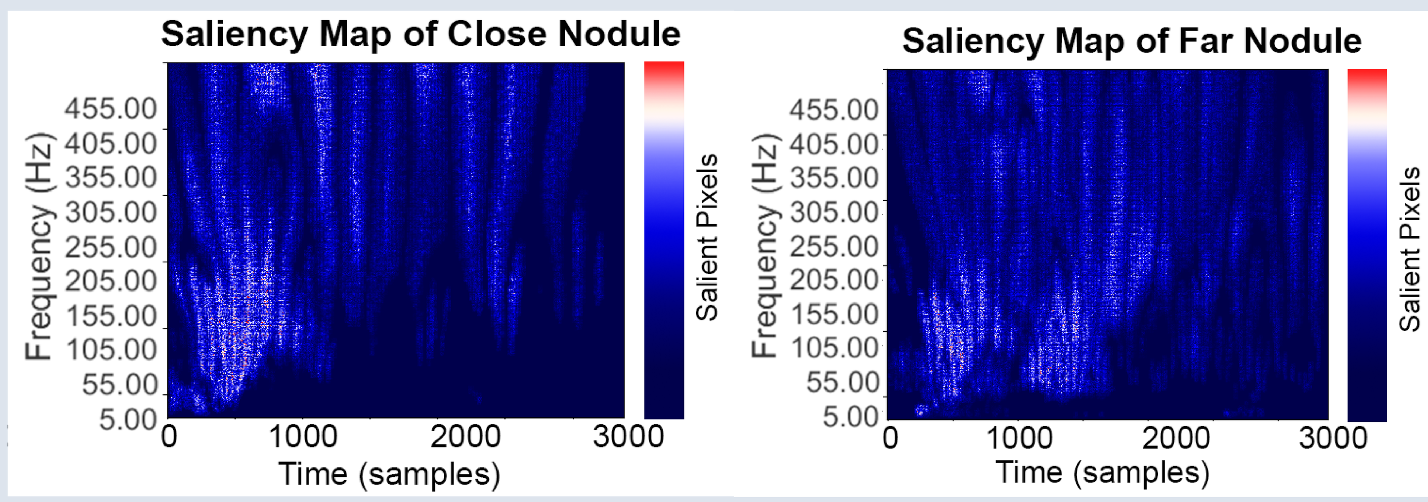

Fig. 3. Saliency maps from the final layer of the CNN for 2 individual percussion data-points (close and far). Saliency maps show which areas of the input image triggered the CNN's neurons and the salient pixels (red) show which time variant frequency amplitudes are used to classify the presence of a nodule.

CONCLUSION AND FUTURE WORK

A robotic percussion device was developed and tested on a silicone phantom containing a hard nodule. Wavelet transform analysis reported clear attenuation of frequency intensities and saliency maps from the CNN confirmed that the observed differences can be used to classify the presence of a nodule accurately. This method provides guidelines to automate percussion examination.

Future studies will explore the results in an abdomen more representative of a human.

LinkedIn IDs:
jacob-tan-ic
pilar-zhang-qiu
oli-thompson
bennetcobley

MATLAB and Python codes available at Github:
github.com/ot316/Percussion-RRP