Detection and Classification of the Sounds Produced by Artificial Human Hip Implants

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Total hip replacement has become a common procedure in the treatment of hip disorders. In doing so, the bony components of the hip are replaced with artificial inserts. Regular follow-up is required for all joint replacements to anticipate complications. However, in recent times sounds emanating from the implants have been identified and there is an interest in their causes and implications. It is the latter of these concerns that is the focus of this document.

Sounds were recorded from the hip implants of participants while they performed a number of specified movements. This was achieved using an electronic stethoscope.

Spectrograms were used to identify individual sounds in the complete recordings. In order to filter out the background noise from the recordings, a 5th order Savitzky-Golay filter with a window width of 21 points was implemented. The effectiveness of this filter was confirmed by cross-correlating the original and filtered signals to ensure preservation of low frequencies.

The discrete wavelet transformation was used in order to distinguish between the different sounds. The symlet8 wavelet was used and the signals were decomposed into 10 detail levels. Using this method, 3 different sound classes were identified based on the different wavelet levels. These classes were further characterised by determining the skewness and kurtosis of the Welch power spectra. Upon listening to the sounds, it was found that the three classes also appeared audibly different.

A sound detection and classification procedure, based on the wavelet characteristics and the classes defined, was developed and tested. It allowed individual hip implant sounds to be characterised in previously unseen and unanalysed recordings. These sounds were analysed and classified into one of the 3 main sound classes.

A number of patient and implant factors were also considered in trying to identify whether any condition might predispose an individual implant to produce sounds. These include body mass index (BMI), implant age, implant angle, movement performed and bearing surface combination. The ceramic-on-metal implants, and implants in participants with overweight BMI scores produced the most sounds. Despite this, no consistent links between these factors and the sounds produced could be identified.

The occurrences of the 3 different sounds classes within the different patient factor groups was also investigated. This was done to determine whether or not the pattern of occurrence could be used to determine which of the patient factor groups an unknown recording belonged to. This, by extension, might reveal some information about the implant producing the sounds. However, the occurrence patterns were so similar in many patient factor groups studied that this technique was considered unfeasible. One exception was the different bearing surface combinations, each of which exhibited a different occurrence pattern. Therefore, the occurrence of certain wavelet characteristics may be used to suggest which of the bearing surface combinations a hip implant contains. Another exception was the overweight BMI group, which had a distinct sound class occurrence pattern, and therefore wavelet characteristic pattern, from the underweight and obese BMI groups.

This research supports aspects of previous work done on the topic, and introduces a new methodology to acquire hip implant sound data. In addition, new classes of implant sounds are defined. Discrete wavelet decomposition was shown to be an effective signal analysis tool for this problem. Much work remains to be done on hip implant sounds and these findings add to the growing collection of knowledge on the subject.