Remote Laser-Speckle Sensing of Heart Sounds for Health Assessment and Biometric Identification

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Introduction

To diagnose patients’ heart condition cardiologists use electrocardiograms, chest X-rays, ultrasound imaging, MRI, Doppler techniques, angiography, and transesophageal echocardiography. These techniques require a cardiologist's visit, are expensive and the waiting lists are long.

Phonocardiography is a cost-effective technique which records heart sounds. This is a viable diagnostic technique since many heart diseases cause changes in heart sounds before other symptoms appear. However, auscultation is not widely used to diagnose because it requires considerable training, it relies on the hearing abilities of the clinician and specificity and sensitivity are low.

Hypothesis

We hypothesized we could build an affordable and miniaturised laser-based device which could be used for constant monitoring of patients' heart sounds. We then hypothesized that a Machine Learning (ML) aided software trained on this data could classify healthy from unhealthy heart sounds and could perform biometric authentication.

Methods

Vibrations produced when the heart pumps blood propagate through the blood vessels until they dissipate, therefore we shined a low-light eye-safe laser onto patients’ neck and with a fast frame rate camera we collected the reflected speckle patterns whose shape change with nanometer-wide skin movements due to the pumping heart.

We then retrieved heart sounds through computational methods.

For heart health assessment we trained a ML model with digital stethoscope data labelled either healthy or unhealthy. Then we tested the model on an unseen subset of that data and on data acquired with our device on a cohort of ten test subjects.
For biometric authentication we trained the ML model on digital stethoscope data labelled from 1 to 10, each numbered class representing a different person. For comparison, we also trained and tested the algorithm on data acquired with the digital stethoscope.

**Results**

Figure 1 shows heart sounds acquired with the digital stethoscope versus heart sounds acquired with our device, which obtains a better SNR. When testing data acquired with this device with our ML algorithm, 9 people were labelled healthy and 1 was labelled unhealthy. A GP confirmed the diagnosis for the unhealthy individual.

Figure 2 shows CM for a biometric authentication algorithm tested with stethoscope data vs data acquired with our device.

**Conclusion**

We have shown our device can acquire heart sounds from peripheral blood vessels from a distance with a better SNR than the stethoscope. We have also shown that we could train ML algorithms with this data to perform biometric authentication and heart health assessment.

**Figures**

![Figure 1](image1.png)

**Figure 1.** A shows the frequencies between 30-250 Hz of the heart valve sounds acquired with the digital stethoscope placed above the chest of a healthy individual. The dataset was made available from Physionet 2016 Challenge. Figure 1 B shows the same dataset shown in Figure 1 A, but with only the frequencies from 375-750 Hz. Figure 1 C shows the heart valve sound signal from 30-250 Hz acquired from one of our subjects. The sound is acquired from the neck of the subject. Figure 1 D shows the same signal set shown in Figure 1 C but with the frequencies from 375-750 Hz.
Figure 2. Shows the confusion matrices (CM) of the biometric identification algorithm. The algorithm was trained on 30 sec of heart valve sounds per person. It was once trained with stethoscope data and once with data acquired with our device. Fig. 2 (a) shows the CM for 10 arbitrary subjects taken from the HSCT-11 open heart-beat sound dataset and tested on 35 3 sec recordings (90.6\% accuracy). Fig. 2 (b) shows the CM for the remote detection method with the test data (86 2.5 sec recordings) taken on the same date as the training (99.1\% accuracy). Fig. 2 (c) was trained on the same data as (b) but tested on data acquired on different days (12 2.5 sec recordings, 91.7\% accuracy).

Keywords
Artificial Intelligence; Clinical Workflow & Productivity; Emerging Technologies; Imaging Research

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