ECG-Based Tracking Stethoscope: Developing an Accurate Real-Time Component

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Introduction

Cardiac auscultation is the auditory detection of heart sounds to diagnose abnormalities, a crucial skill that is both efficient and cost-effective in medical practice.1 However, due to increased prevalence and usage of expensive cardiac technologies, many new physicians and trainees have difficulty performing basic cardiac examinations on their patients.2-4 Trainees should focus on perfecting their cardiac examination skills rather than turning to cost-inefficient technologies that serve similar functions. Simulation technology is a solution that trains students to perform cardiac examinations by listening to abnormal heart sounds in otherwise healthy Standardized Patients (SPs).

This study reports the accuracy of an electrocardiogram (ECG)-based tracking stethoscope that uses an algorithm to classify the location of the stethoscope on each of 4 primary chest sites. The stethoscope was tested on 8 SPs, using an algorithm that was individually trained on signal data from each SP to assess the real-time capabilities of this simulation technology.

Objectives

Primary Goal: To develop an accurate, real-time component to the ECG-based tracking stethoscope.
• The current prototype stethoscope is only able to classify a cardiac auscultation site after approximately 10 beats of signal data.
• We will develop an accurate, real-time component to the stethoscope by completing the following:
  1. Obtaining ECG signal data from SPs.
  2. Training the current algorithm using signal data to increase accuracy and reduce time of site classification.
  3. Testing the trained algorithm on each SP again to record accuracy and speed.

Procedure

Testing of trained algorithm on some 9 SPs to determine accuracy and time of site classification. At each site, 3 runs of data were collected for the 4 angular orientations.

Stethoscope Apparatus

Figure 1: Stethoscope apparatus. A) The four primary cardiac auscultation sites that the algorithm can detect. B) Two direct-contact electrodes fixed on a standard stethoscope head to record ECG signals, with an additional base lead that was placed on the SP’s left leg. C) Setup was attached to a Raspberry Pi computer to run the ECG signal acquisition program. An algorithm developed at Old Dominion University was used to preprocess the incoming ECG signals for noise reduction and site identification, using a series of features of the signals to distinguish the four cardiac examination sites from one another.

Figure 2: Procedures used for assessing the accuracy and time of site classification of the ECG-based tracking stethoscope.

Results

Using the trained algorithm, we improved the real-time auscultation area prediction speed from 10 beats to 2 beats.

Table 1: Mean accuracy, precision, and sensitivity of the classifier for any stethoscope orientation.

<table>
<thead>
<tr>
<th>SP Body Positions</th>
<th>Accuracy* (Mean ± SD)</th>
<th>Precision* (Mean ± SD)</th>
<th>Sensitivity* (Mean ± SD)</th>
<th>F-measure* (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training (10-fold Cross Validation)</td>
<td>92 ± 2.03</td>
<td>88.5 ± 4.0</td>
<td>87.0 ± 4.4</td>
<td>87.00 ± 4.4</td>
</tr>
<tr>
<td>Testing</td>
<td>61.73 ± 9.1</td>
<td>60.1 ± 9.1</td>
<td>62.0 ± 4.4</td>
<td>60.9 ± 9.9</td>
</tr>
</tbody>
</table>

*Average classifier performance and standard deviation for 8 SPs at 95% Confidence level.

Conclusions

• We developed and applied a real-time component to the ECG-based tracking stethoscope, using the SPs own data to train the site classification algorithm.
• Near real-time prediction was achieved at 2 beats.
• Training accuracy ranged from 89% to 95%. Testing accuracy using the real-time component ranged from 47% to 71%. Noise in signal data may be a cause of low classification accuracy in the real-time component, and improvements in the algorithm may be achieved by utilizing the sequential beats of the ECG signal in order to fully take advantage of this stethoscope in medical education.

Future Directions

• Improvement of the accuracy of the real-time component. A new algorithm may need to be developed and trained or new classifiers, such as differences in heart sound amplitudes at each site, may be explored instead of ECG signals.
• Attachment of a playback device to the stethoscope apparatus that produces abnormal heart sounds to the listener in healthy SPs.
• The algorithm may be extended to a generalized scenario so that individualized training will not be required.

References