CLASSIFICATION OF HEART SOUNDS USING TIME-FREQUENCY ANALYSIS AND IMAGE PROCESSING METHODS

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Abstract: This paper describes the algorithm for detection of heart sounds from phonocardiogram record (PCG) using time-frequency analysis and image processing technique. Presented algorithm extracts time-frequency features using continuous wavelet transform (CWT) and subsequently applies image processing methods such as morphological operations and connected components labeling on hearth sounds segment S1-S2. Furthermore, the segmented PCG signal undergoes correction procedure, which uses the Smith-Waterman local alignment algorithm to correctly predict heart sound sequence.

Keywords: PCG, Hearth sounds, time-frequency analysis, continuous wavelet transform, Smith-Waterman alignment

1 INTRODUCTION

Heart sounds are acoustic waves in the frequency range from 30 to 500 Hz originating from striking of blood flow to the wall of the heart or by opening and closing of heart valves. Resulting vibrations are transferred to the surface of the thorax, where are captured by phonocardiograph. The first heart sound (S1) occurs at the beginning of systole due to the closure of atrioventricular valves. The second heart sound (S2) originates from the end of systolic phase while the semilunar valves are closing [2].

Classification of S1-S2 heart sounds might be tough task while processing noisy or pathologic PCG records (Fig 1a). In general, PCG might be contaminated by several types of distortion. For example, movement of phonocardiograph on the surface of the patient body causes high amplitude friction spikes, which distort detection algorithms. Moreover, a morphological variety of signals depends on patient body structure and health condition.

The aim of this work is the development of an algorithm for detection and classification of S1-S2 heart sounds from PCG signals. All PCG records for this work were taken from the PhysioNet/Computing in Cardiology Challenge 2016 [1].

2 DETECTION ALGORITHM

Presented method involves time-frequency analysis for localization of heart sounds. For the purpose of heart sounds localization is used continuous wavelet transform (decomposition on 32 scales with empirically chosen wavelet bior3.9) resulting in a scalogram (Fig 1b). Furthermore, the envelope is extracted by taking absolute value from the scales after Hilbert transform, which improves localization of heart sounds. Subsequently, scalogram is converted to the binary image, by empirically chosen threshold, and binary image morphological operations like line dilatation (in both time and scale domain) are used to highlight segments with line shape. Furthermore, connected components are found and each connected component which has certain area is marked as a potential heart sound and processed for further analysis. Filtering of the small connected components is a necessary step for suppression of negligible segments which have high amplitude (e.g. spike distortion) in an original image.

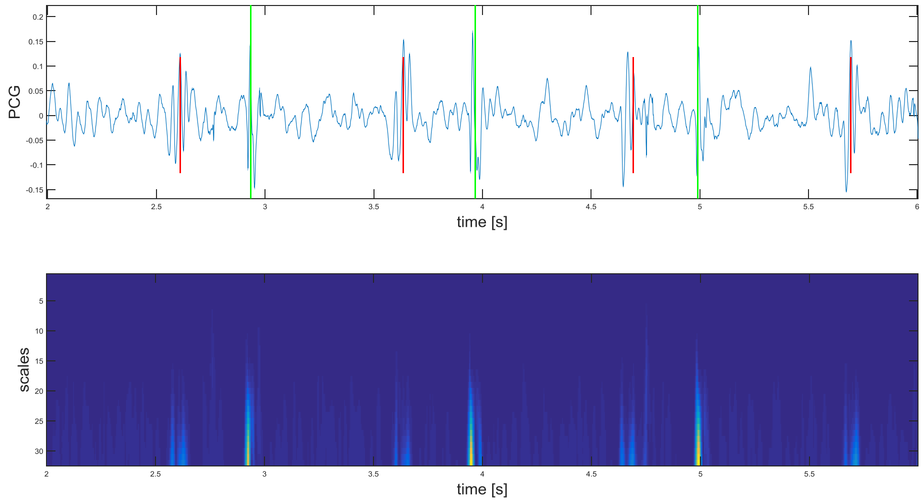


Figure 1: (a) Example of original PCG signal, (b) Wavelet decomposition on 32 scales with empirically chosen wavelet bior3.9, small red lines labels S1 and higher green lines labels S2

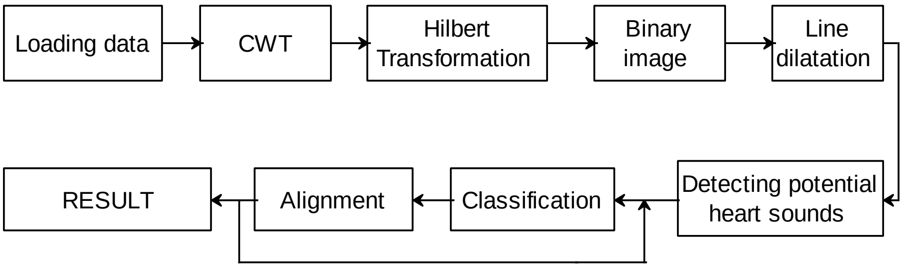
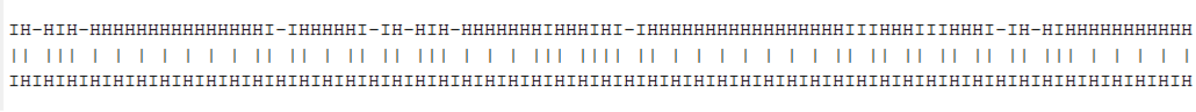


Figure 2: Block diagram of detection and classification process

3 S1-S2 CLASSIFICATION TECHNIQUE

The classification technique is an iterative process, which improves the actual sequence of heart sounds by local alignment scoring. In each iteration alignment is made for different delays between the hearth sounds. Predicted heart sounds are locally aligned to general S1-S2-S1-S2 sequence, which we would like to obtain at the end of the classification process. For example, if the sequence HH is detected (S2-S2), the algorithm automatically scans for a local maximum (S1), which is located between those detections. By localization of new heart sound, local alignment score is improved and algorithm continues until score remains same or increases, which is time to stop the iteration process. Smith-Waterman algorithm is described in [3].



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IH-HIH-HHHHHHHHHHHHHHHI-IHHHHHI-IH-HIH-HHHHHHHIHHHIHI-IHHHHHHHHHHHHHHHHHIIIHHHIIIHHHI-IH-HIHHHHHHHHHHH
|| ||| | | | | | | | || || | || || ||| | | | ||| |||| || | | | | | | | || || || || || || ||| | | | | |
IHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIHIH
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Figure 3: The Graph shows the result of sequences aligned using the Smith-Waterman algorithm before application of correction factors, I tag S1 and H tag S2 heart sounds

4 RESULTS

Detected and classified heart sounds were compared with annotated 449 records (normal and pathologic) from database. Sensitivity and positive predictive value were estimated for each record separately. The overall results are in the table (Tab 1), where average value and standard deviation are given.

Overall results	**Average**		**Standard deviation**	
	S1	**S2**	**S1**	**S2**
Sensitivity	0.81	0.71	0.18	0.22
Positive prediction value	0.78	0.81	0.23	0.22

Table 1: Overall results of heart sounds detection and classification

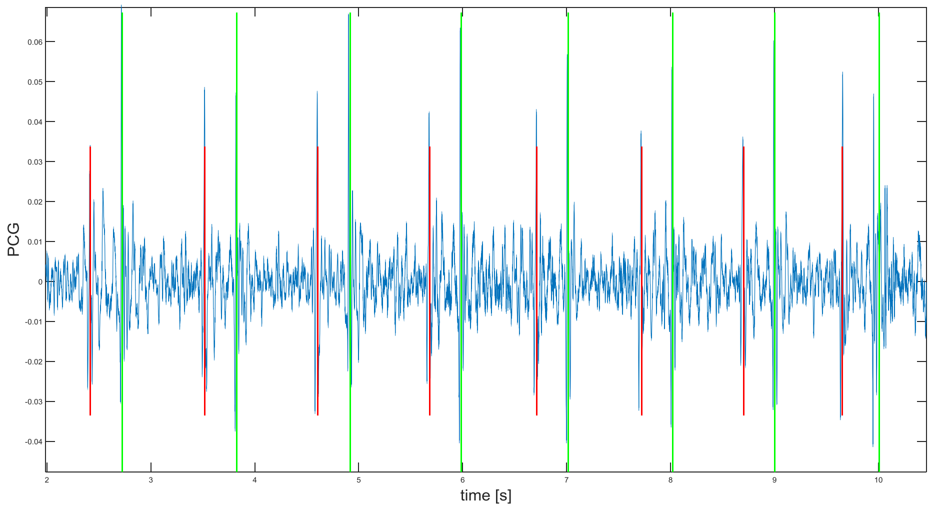

Figure 4: The graph shows heart sounds classification results, small red lines labels S1 and higher green lines labels S2

5 CONCLUSION

We have developed heart sound detection algorithm based on continuous wavelet transform, Hilbert transform and image processing methods. Moreover, S1-S2 classification technique based on Smith-Waterman local alignment and iterative corrections has been proposed. The algorithm achieved promising results with average sensitivity 0.76 and average positive predictive value 0.79. Proposed results are comparable to standard methods, however complex machine learning techniques and hidden Markov models achieve *SE* and *PPV* up to 0.95.

REFERENCES

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