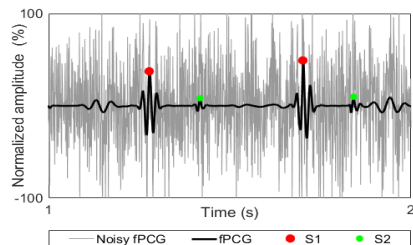# PCG-Delineator: An Efficient Algorithm for Automatic Heart Sounds Detection in Fetal Phonocardiography

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Fetal phonocardiography (FPCG), consisting in the recording of the fetal heart sound, is a clinical test that provides precious information on fetal health during antenatal period. Being noninvasive, simple and economic, FPCG is ideal for long-term monitoring. Unfortunately, its use is limited by the lack of reliable techniques for automatic FPCG analysis. Indeed, FPCG is usually hidden by high-amplitude noise which makes detection of FPCG waveforms challenging (Figure). Aim of the present study is to propose PCG-Delineator as an efficient algorithm for automatic detection of S1 (first heart sound, marking systole onset) and S2 (second heart sound, marking diastole onset) from FPCG. According to PCG-Delineator, FPCG is initially filtered by means of a wavelet-based procedure (4th order Coiflets mother wavelet with 7 decomposition levels) to erase noise. Successively, S1 and S2 are detected. S1 detection procedure is threshold-based (threshold=30% of the filtered FPCG signal maximum amplitude), under the condition that at least 40ms separate two consecutive S1 sounds. S2 detection procedure is also threshold-based, but under the conditions that S2 has to fall at least 100ms after preceding S1 and at most 200ms before successive S1, and that S2 has to have an amplitude lower than 80% that of preceding S1. PCG-Delineator performance was tested on 37 simulated FPCG tracings ("Simulated Fetal PCGs database" by Physionet; length: 8min; sampling frequency: 1kHz). Automatic S1 and S2 detections were compared against manual annotations, provided by experts. Sensitivity (SE) and positive predictive values (PPV) were computed. Results indicate that PCG-Delineator was able to drastically reduce noise (our signal-to-noise ratios: from -1.1÷7.4 dB to 12.9÷17.9 dB; $P<10^{-14}$) and to accurately detect both S1 (SE: 88%; PPV: 91%; Figure) and S2 (SE: 77%; PPV:99%). In conclusion, PCG-Delineator is an efficient algorithm for automatic heart sounds detection in FPCG.

Automatic S1 and S2 detection
by PCG-Delineator