

A Quality Index Optimization Method for Non-Invasive Fetal ECG Extraction

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Abstract : Fetal cardiac monitoring by fetal electrocardiogram (fECG) can provide significant clinical information about the healthy condition of the fetus. Despite this potentiality till now the use of fECG in clinical practice has been quite limited due to the difficulties in its measuring. The recovery of fECG from the signals acquired non-invasively by using electrodes placed on the maternal abdomen is a challenging task because abdominal signals are a mixture of several components and the fetal one is very weak. This paper presents an approach for fECG extraction from abdominal maternal recordings, which exploits the characteristics of pseudo-periodicity of fetal ECG. It consists of devising a quality index (fQI) for fECG and of finding the linear combinations of preprocessed abdominal signals, which maximize these fQI (quality index optimization - QIO). It aims at improving the performances of the most commonly adopted methods for fECG extraction, usually based on maternal ECG (mECG) estimating and canceling. The procedure for the fECG extraction and fetal QRS (fQRS) detection is completely unsupervised and based on the following steps: signal pre-processing; maternal ECG (mECG) extraction and maternal QRS detection; mECG component approximation and canceling by weighted principal component analysis; fECG extraction by fQI maximization and fetal QRS detection. The proposed method was compared with our previously developed procedure, which obtained the highest at the Physionet/Computing in Cardiology Challenge 2013. That procedure was based on removing the mECG from abdominal signals estimated by a principal component analysis (PCA) and applying the Independent component Analysis (ICA) on the residual signals. Both methods were developed and tuned using 69, 1 min long, abdominal measurements with fetal QRS annotation of the dataset A provided by PhysioNet/Computing in Cardiology Challenge 2013. The QIO-based and the ICA-based methods were compared in analyzing two databases of abdominal maternal ECG available on the Physionet site. The first is the Abdominal and Direct Fetal Electrocardiogram Database (ADdb) which contains the fetal QRS annotations thus allowing a quantitative performance comparison, the second is the Non-Invasive Fetal Electrocardiogram Database (NIdb), which does not contain the fetal QRS annotations so that the comparison between the two methods can be only qualitative. In particular, the comparison on NIdb was performed defining an index of quality for the fetal RR series. On the annotated database ADdb the QIO method, provided the performance indexes Sens=0.9988, PPA=0.9991, F1=0.9989 overcoming the ICA-based one, which provided Sens=0.9966, PPA=0.9972, F1=0.9969. The comparison on NIdb was performed defining an index of quality for the fetal RR series. The index of quality resulted higher for the QIO-based method compared to the ICA-based one in 35 records out 55 cases of the NIdb. The QIO-based method gave very high performances with both the databases. The results of this study foresees the application of the algorithm in a fully unsupervised way for the implementation in wearable devices for self-monitoring of fetal health.

Keywords : fetal electrocardiography, fetal QRS detection, independent component analysis (ICA), optimization, wearable

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