Signal Quality Dependent Covariance Matrices Modelling for Fetal ECG Extraction by means of Kalman Filtering

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Introduction

The analysis of non-invasive fetal electrocardiograms derived from abdominal leads allows novel diagnostics during ante and intrapartum periods. Despite its benefits, the fetal ECG (FECG) has not yet been established as a standard technique. This is due to the usual low fetal signal amplitude and difficulties in removing the maternal ECG (MECG), which corrupts the abdominal mixture. Since the FECG and MECG overlap in time and frequency domain, elaborated techniques are required to extract the FECG from the abdominal mixture. This study deals with the further development of our own approach to estimate the FECG in long-term abdominal recordings. Specifically, this contribution investigates the impact of varying noise on fetal QRS (FQRS) detection accuracy and the relevance of adapting the observational noise covariance matrix (R - by applying a scalar gain G_R).

Materials and Methods

The Extended Kalman Filter (EKF) has been previsously used for FECG extraction by the Institute of Biomedical Engineering at TU Dresden [1]. The EKF processes abdominal signals based on a dynamical model for the MECG and an estimation for the measurement and modelling noise/error (i.e. observation and process noise covariance matrices). Up to date, the noise covariance matrices in EKF's model are designed using a fixed-length segment of abdominal recordings. However, the abdominal signal may comprise non-stationary mixtures of maternal, fetal and noise signals, e.g. varying noise power and physiological shifts of the maternal heart vector. In order to be able to deliver trustworthy estimates, the filter has to consider the influence of these non-stationary properties.

Tests are performed using an exemplary abdominal recording. The 10-minute recording was selected form a larger collective (recorded at the University Hospital of Leipzig) due to the presence of intermittent muscular noise.

Results

FQRS detection's accuracy varied between 76.5-89.3% (standard deviation 1.5%) when choosing different G_R. Figure 1 demonstrates how varying the gain factor G_R influences the FQRS detections by using the root mean square (RMS) error between each detection and respective reference annotation, i.e. the detection jitter.

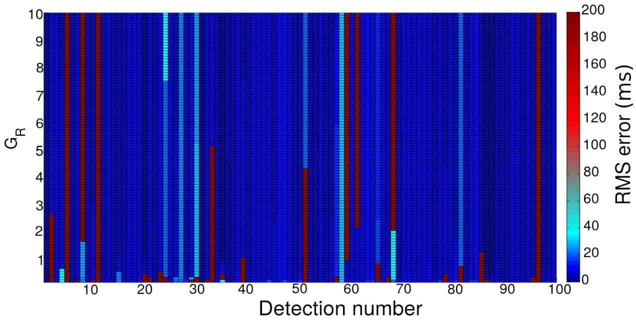

Fig. 1: Effect of varying the multiplying factor G_R on the FQRS RMS value. It can be seen that the optimal value for G_R varies on a beat-to-beat basis.

Discussion and Conclusion

The results suggest that FECG extraction using EKF can benefit from allowing its covariance matrices some adaptation in time, since a single scaling factor does not guarantee optimal performance. The results are in agreement with [2]. Further work must focus on obtaining an auxiliary feature signal for estimating the quality of the measurement for constinuously updating the covariance matrices, therefore improving EKF's model.

References

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