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Issues and research on foetal electrocardiogram signal elicitation

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ABSTRACT

The existence of Electrocardiography (ECG) came to light over a century ago, yet the acquisition and elicitation of non-invasive foetal electrocardiogram (fECG) is still in infancy despite mammoth advances in clinical electrocardiography, advanced Biomedical signal processing techniques and fast growing engineering technology. The acquisition of foetal ECG becomes a challenging task since it is perilous for a direct contact over the foetus. Moreover, the non-invasive abdominal ECG (aECG) measurements obtained over the surface of a maternal abdomen contains several bioelectric potentials like maternal heart activity, foetal heart activity, maternal muscle activity, foetal movement activity, generated potentials by respiration and stomach activity, and noise (thermal noise, noise generated from electrode-skin contact). The strong Maternal Electrocardiogram (mECG) along with the weak fECG in the recordings obtained from a mother is overlapping in time as well as in frequency. Hence separation of these signals cannot be accomplished by simple windowing or filtering. Over the years numerous researchers have put enormous efforts in signal processing and biomedical engineering for humanizing the foetal ECG acquisition techniques used by the physiologists. The fECG signal is a vital information source to assist physicians for precise timely decisions during labor. Some of the recently developed algorithms by researchers have given remarkable results for fECG acquisition. The focus of this paper is to review these existing algorithms for non-invasive detection and elicitation of fECG in terms of their performance and capabilities with respect to standard databases available worldwide.

Contents

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1. Introduction

Though the first observations were made by Cremer in 1906 [1], foetal electrocardiogram (fECG) signal acquisition has always been a challenging task for physiologists and engineers in the cutting-edge field of biomedical signal processing. fECG signal emphasizes the foetal heart activity, which is very vital to determine the foetal heart rate (fHR), foetal development, foetal maturity, and existence of foetal distress or, analyze multiple births, to prevent the neonatal disease and to perform parametric analysis of the foetal heart [2,3].

At present, monitoring the foetus is completely focused on the heart rate. Currently fECG analysis is used in the clinical domain to analyze heart rate and the allied variations. Analysis using the morphology of the fECG is generally not undertaken for cardiac-anomaly populations for several reasons. The ultimate reason for this scenario is due to unavailability in technology for trustworthy fECG measurement. In the clinical perspective, foetal signals recorded by electrocardiogram (ECG) convey more information compared to conventional sonography, auscultation and other techniques.

The fECG acquisition can be achieved by two methodologies, the foetal scalp electrode (invasive) as shown in Fig. 1 and maternal abdomen skin electrode (non-invasive) as shown in Fig. 2. Foetal scalp electrode method is perilous to the foetal. The scalp electrodes to be placed on foetus's head after passing through the mother's womb, is a harmful procedure. This method is harmful for mother that it may rip the womb, cause infection in womb's interior or bloodshed and it is hazardous to foetus as well; impart pressure on foetus head, infection, and risk over foetus safety and so on. In contrast, maternal abdomen skin electrode is convenient, non-invasive and can also be used during labour.

The acquisition of fECG becomes a demanding task since it is death-defying for a direct contact over the foetus. Moreover, the abdominal electrocardiogram (aECG) measurements obtained over the surface of a maternal abdomen contains several bioelectric potentials like maternal heart activity, foetal heart activity, maternal muscle activity, foetal movement activity, generated potentials by respiration and stomach activity, and noise (thermal noise, noise generated from electrode-skin contact and various other noises). The strong maternal electrocardiogram (mECG) along with the weak fECG in the recordings obtained from a mother is overlapping in time as well as in frequency. Hence separation of these signals remains a tricky task. Over the years numerous researchers have put enormous efforts in signal processing and biomedical engineering for humanizing an efficient fECG elicitation technique that can be used by the physiologists. Many emerging techniques and algorithms have been proposed for non-invasive fECG elicitation as portrayed in the taxonomy tree of Fig. 3. Though these methodologies prove to have given significant results for fECG elicitation,

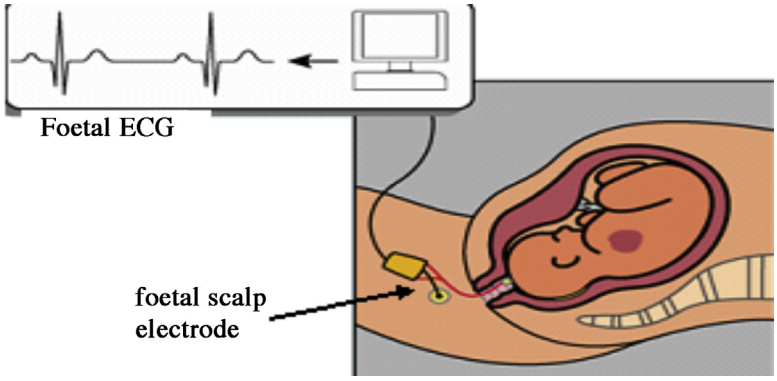

Fig. 1. Invasive foetal ECG acquisition system.

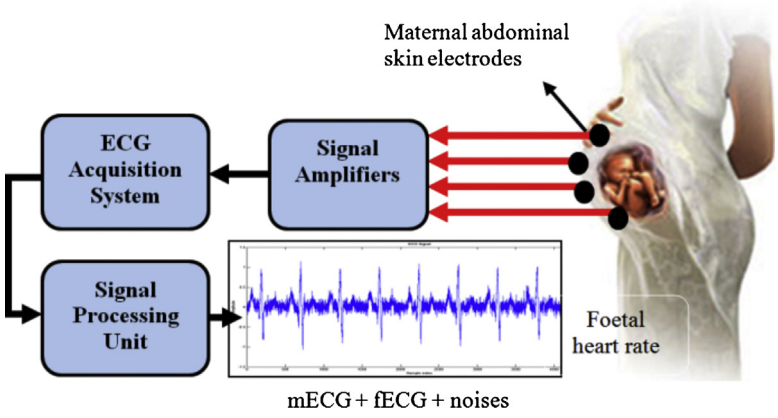

Fig. 2. Noninvasive foetal ECG acquisition system.