

Mobile CTG – Fetal Heart Rate Assessment Using Android Platform

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Abstract

Cardiotocography – measurement of fetal heart rate and uterine contractions is the prominent source of information about the fetal well-being in the late stages of pregnancy and during the delivery. With the stable increase of systematic costs of western medical systems and with the lack of trained personnel especially in the rural areas of BRIIC countries, telemedicine solutions are destined for large range of users.

In the paper we describe our initial approach to proposed solution for mobile fetal heart rate monitoring and evaluation running on Android platform. Additionally the application on the mobile Android device contains viewer of the signal that enables setting of customary thresholds levels for the analysis rules and gives user full control over the settings of the recording device.

1. Introduction

Fetal heart activity is the prominent source of information about fetal well being during delivery. Cardiotocography (CTG) – recording of fetal heart rate (FHR) and uterine contractions enables obstetricians to detect possible ongoing fetal hypoxia which may occur even in a previously uncomplicated pregnancy.

Cardiotocography was introduced in late 1960s and is still the most prevalent method of intrapartum hypoxia detection. To improve the results of cardiotocography, the International Federation of Gynecology and Obstetrics (FIGO) introduced general guidelines [1]. They are based on an evaluation of macroscopic morphological FHR features and their relation to the tocographic measurement. Even though the guidelines have been available for more than twenty years poor interpretation of CTG still persists [2] with large inter-observer as well as intra-observer assessment variations [3]. Nevertheless the FIGO guidelines remain the only generally agreed approach to rule-based evaluation, and therefore features we compute will be based on the guidelines.

During the last weeks of pregnancy the frequency of pe-

riodic controls can increase up to 5 per week creating great burden on both – mother and obstetricians. Based on our previous research [4] dealing with automatic evaluation of the fetal heart rate recordings during the delivery we have developed a tool for monitoring and evaluation of the antepartum fetal heart rate based on the FIGO guidelines.

2. Proposed mobile CTG methodology

Any FHR recording device with bluetooth module and known data format can be prospectively connected to the phone as a data source. After recording of at least 20 minutes the system performs signal preprocessing, including quality assessment and then automatically computes the features such as mean baseline of the FHR, long term variability, and number of acceleration and decelerations. Alarms can be raised at the patient's side if necessary but the data are always sent via internet (using WIFI or GPRS) to the clinician's database for more detailed analysis and confirmation. A clinician can remotely ask for additional measurement, if the first recording was inconclusive. Currently our system works with the FHR recording module developed within the ENIAC-MAS project funded described in the next section. The general methodology of the mobile CTG (mCTG) is depicted in Figure 1.

3. Data acquisition module

Currently our system works with the FHR recording module developed within the ENIAC-MAS project funded by the European Union. The module records fetal phonocardiogram, which is further processed on the chip. The data are then transferred to the mobile phone via the bluetooth module. Prospectively any FHR recording device with bluetooth module and known data format can be connected into the loop via the Android enabled mobile phone as a data source.

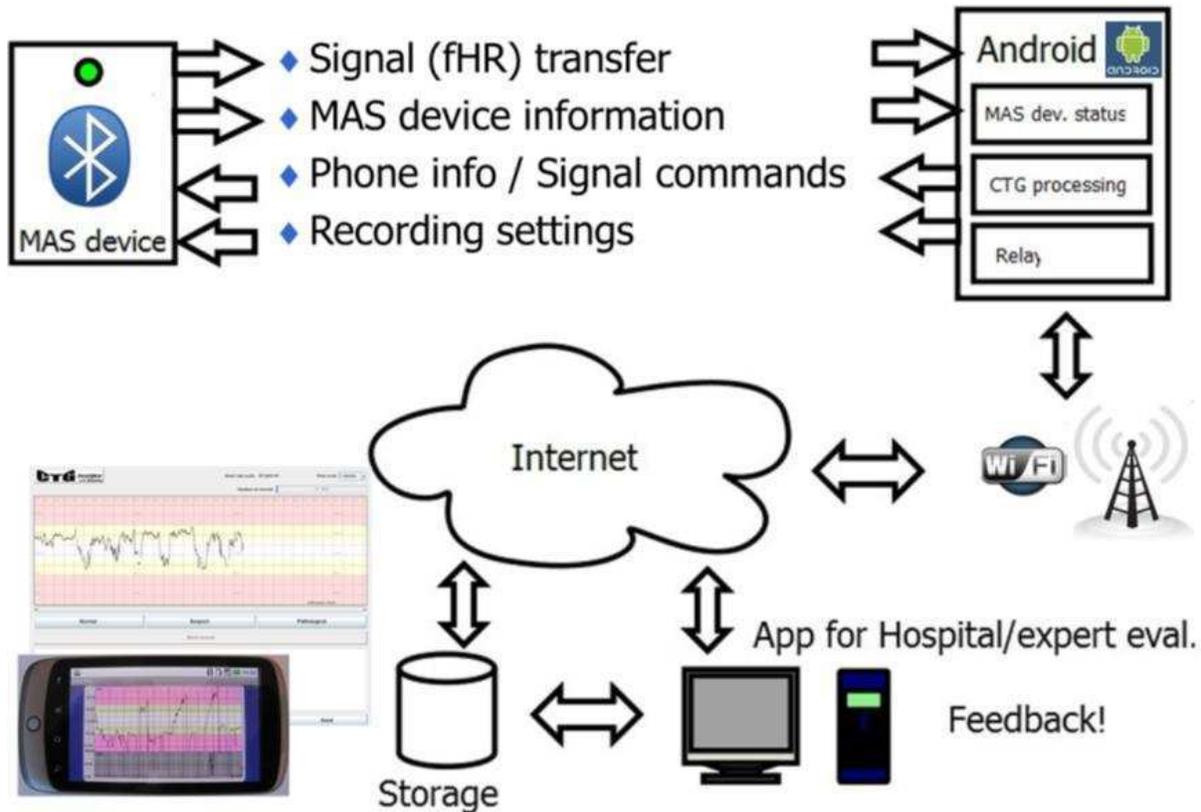


Figure 1. Complete methodology envisioned for the development of the mCTG.

4. Android-based application

The Android-based application which is the focus of this paper, runs on any Android-enabled phone with the Android 2.1 or higher – we currently use the Nexus One by Google. The application scheme is depicted in Figure 2. First the menu is presented to the user, where it is possible to select between the modes of the signal acquisition. The FHR signal can be either opened from the storage (e.g. SD-card) – explorer activity is responsible for that. Or the communication can go via bluetooth module – bluetooth activity – and the interaction with the measuring device can be initialized. In any case the data are downloaded to the mobile phone and loaded into the application. In the following step the data are processed in the CTG-processing activity - which will be described in the following section. The last step from the point of view of the Android application design is the visualization – where either user or the clinician can view the signals with some highlighted features.

5. Signal processing

The processing of the signal can be divided into three separate phases – see Figure 3. In the following subsec-

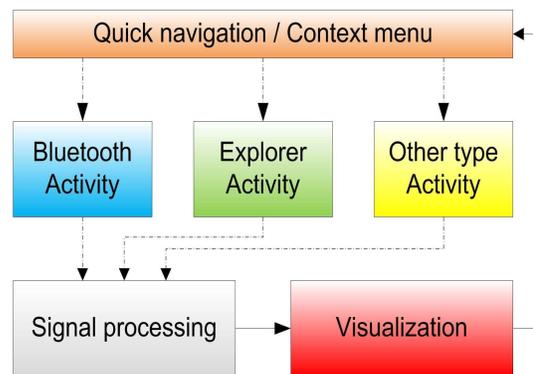


Figure 2. Representation of the processes within the Android application.

tions we describe all the steps of the processing array.

5.1. Interpolation and artefact removal

In general within our application we expect FHR with either 4Hz sampling frequency or signal with timestamps connected to each sample – thus enabling us to resample the possibly unevenly sampled data to the 4Hz sampling

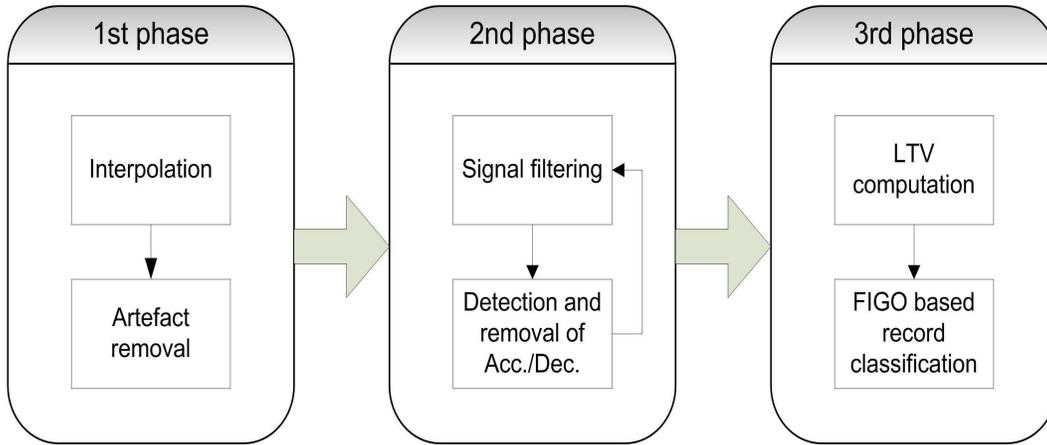


Figure 3. Stages of FHR signal processing.

rate.

The FHR signal almost always contains artefacts caused by mother and fetal movements as well as artefacts caused by transducer displacements. Based on the amount of missing signal as well as on the amount of artefacts within the signal, the signal quality measure is computed – which is then used for the alarm confidence measures.

For the artefacts removal we have implemented the algorithm proposed by Bernardes et al. [5] – all abrupt changes in FHR were removed and replaced using cubic Hermite spline interpolation.

5.2. Baseline assessment and ACC/DEC detection

The computation of the baseline is based on work of Taylor [6]. The main part of the algorithm is the use of set of three filters, each with slightly different cut-off frequency and order of the filter. For filtering purposes the fast Fourier transform (FFT) was used. The signal length N of 2^{13} ought to be used since our expected length of 20-minute signal was 4800 samples. We have used slightly different cut-off frequencies when compared to the original work of Taylor. The maximum order of the filter was five.

After the first filter is used and the initial baseline is established we search for any significant signal swings on either side of the baseline. Those with sufficient duration and amplitudes are removed from the signal and the filtering of the signal continues with the next filter in an iterative way. After all the filters are used we have the final baseline of the signal and also acceleration/deceleration positions – positions of the significant swings above or below the baseline. Number of accelerations and decelerations and the mean of the baseline computed within this phase are three features used in the FIGO guidelines.

5.3. FIGO features and evaluation

The FIGO guidelines [1] use beside acceleration, deceleration and mean of the baseline one more feature, called long term variability (LTV) that can be computed as the interquartile range $[\frac{1}{4}, \frac{3}{4}]$ of the distribution $x(i)$ where

$$x(i) = \sqrt{FHR^2(i) + FHR^2(i + 1)} \quad (1)$$

With four features already computed the application can continue with assessment of the FIGO sets of rules for antepartum monitoring – which divides signal into three classes Normal, Suspicious, Pathological.

6. Visualization

The final part of our application is the visualization of the results. The main screen captures are depicted in Figure 4, where the FHR signal is presented in the user interface, that tries to mimic recent FHR visualization systems. There is no overall information about the outcome of the FIGO guidelines, instead each rule for each class is shown as either fulfilled or not fulfilled.

7. Conclusions

This paper describes preliminary version of the Android based application for the assisted living telemedicine system. The crucial part of the system is the ability to relay data from sensors to the hospital-based application that enables clinicians to evaluate the signal from distance. Nevertheless our application can also perform simple processing and evaluation task, that could become useful e.g. for the remote monitoring within the hospital.



Figure 4. Graphical user interface and visualization of the signal together with the indication of FIGO rules fulfillment

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References

- [1] FIGO. Guidelines for the Use of Fetal Monitoring. International Journal of Gynecology Obstetrics 1986;25:159–167.
- [2] Steer PJ. Has electronic fetal heart rate monitoring made a difference. Semin Fetal Neonatal Med Feb 2008;13(1):2–7.
- [3] Blix E, Sviggum O, Koss KS, Oian P. Inter-observer variation in assessment of 845 labour admission tests: comparison between midwives and obstetricians in the clinical setting and two experts. BJOG Jan 2003;110(1):1–5.
- [4] Chudáček V, Spilka J, Janků P, Koucký M, Lhotská L, Hup-tych M. Automatic evaluation of intrapartum fetal heart rate recordings: A comprehensive analysis of useful features. Physiological Measurement 2011;32:1347–1360.
- [5] Bernardes J, Moura C, de Sa JP, Leite LP. The Porto system for automated cardiocographic signal analysis. J Perinat Med 1991;19(1-2):61–65.
- [6] Taylor GM, Mires GJ, Abel EW, Tsantis S, Farrell T, Chien PF, Liu Y. The development and validation of an algorithm for real-time computerised fetal heart rate monitoring in labour. BJOG Sep 2000;107(9):1130–1137.

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