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Development of Simple Algorithm Cardiotocography for Fetal Heart Rate (FHR) Baseline Using Matlab

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Abstract— Interpretation of Cardiotocography (CTG) performed using a computer can assist the interpretation made by obstetricians. The main objective of this study was to develop a simple algorithm for the development of baseline Fetal Heart Rate feature extraction based on RCOG guidelines. The proposed algorithm was developed using the Matlab application. The results obtained showed that the baseline fetal heart rate feature classification got very good results and was validated by the interpretation obtained from the obstetrician.

Index Terms—Cardiotocography, FHR Baseline Feature, RCOG.

Abstrak — **Interpretasi Kardiotokografi (KTG) yang dilakukan dengan menggunakan komputer dapat membantu interpretasi yang dilakukan oleh dokter kandungan. Tujuan utama dari penelitian ini adalah untuk mengembangkan algoritma sederhana dalam pengembangan ekstraksi fitur Detak Jantung Janin baseline berdasarkan pedoman RCOG. Algoritma yang diusulkan dikembangkan menggunakan aplikasi Matlab. Hasil yang diperoleh menunjukkan bahwa klasifikasi fitur baseline fetal heart rate mendapatkan hasil yang sangat baik dan divalidasi dengan interpretasi yang diperoleh dari dokter kandungan.**

Kata Kunci — Kardiotokografi, Fitur Detak Jantung Janin Baseline, RCOG

I. INTRODUCTION

Every mother's dream is a healthy pregnancy, standard delivery, and a healthy baby. To get these results to need support with prenatal care. For a mother, the examination helps know pregnancy problems, prepare mentally and physically, know the pregnancy condition, and determine the right way of delivery based on examination. Furthermore, examining the baby helps maintain the baby's condition and minimize health risks at birth. Moreover, Cardiotocography (CTG) is one way of prenatal examination[1].

CTG is a practical method for fetal monitoring used for antepartum and intrapartum fetal monitoring [2][3][4]. CTG is, also known as Electronic Fetal Monitoring (EFM), introduced in the late 1960s and the first equipment used phonocardiography to record Fetal Heart Rate (FHR). Phonocardiography has been replaced by Doppler signal with significantly improved signal quality[5].

In more detail, CTG consists of 2 (two) signals that continuously record the Fetal Heart Rate (FHR) and Uterine Contractions (UC) [6]. During the intrapartum period, fetal abnormalities lead to a persistent deficiency of fetal oxygen levels leading to morbidity and perinatal mortality[7].

The current interpretation of clinical GCT is based on visual analysis[8]. The use of GTC relies heavily on reading the FHR pattern, and this pattern reading represents a low standard in clinical practice despite guidelines for reading it [9]. However, there are many guidelines worldwide accessible such as FIGO [10], NICE [11], the NICHD Research Planning Workshop and the Royal College of Obstetricians and Gynecologists (RCOG) for Electronic Fetal Monitoring. However, there is still high variability between observers in interpreting the GTC [12], [13].

In order to minimize interpretation inconsistencies and increase the usefulness and effectiveness of CTG monitoring, various attempts have been made by researchers from various medical and technical backgrounds to develop a computerized system for the analysis and classification of CTG records [14]. They have supported doctors' interpretation to achieve a level of reliability that can be used as a decision support system in obstetrics. Nevertheless, to date, none have been adopted worldwide for everyday practice.

For this reason, this study aims to develop a simple algorithm that can be used to extract Fetal Heart Rate (FHR) based on RCOG guidelines. In this article, we discuss the development of a simple algorithm for baseline fetal heart rate (FHR) using Matlab.

II. RESEARCH METHOD

The steps taken to achieve the research objectives can be seen in Figure 1 below.

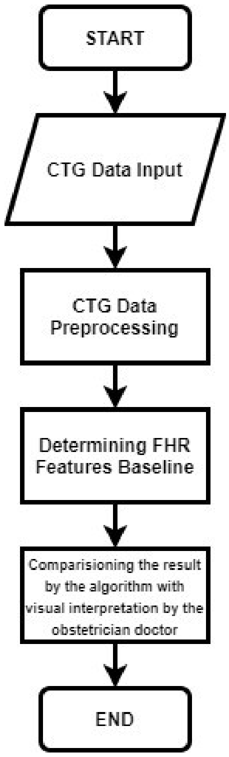

Figure 1. Research Flowchart

Description and Selection Dataset

The proposed algorithm is implemented using a matlab application. In this study using 15 CTG data obtained from previous research conducted by [15]. The data were obtained from Klinikum Rechts Der Isar, Munich Technical University Hospital and other hospitals in Germany.

The signal is given to the obstetrician for visual analysis with the feature baseline CTG signal parameter. The results of the obstetrician's analysis were compared with the results obtained from the proposed algorithm.

Increasing CTG Dataset

During the monitoring and data collection process for the CTG signal, there were fetal movements or errors in the use of the transducer, causing the CTG signal to have spiky artefacts and be noisy. Figure 2 shows the whole procedure for enhancing the CTG data signal.

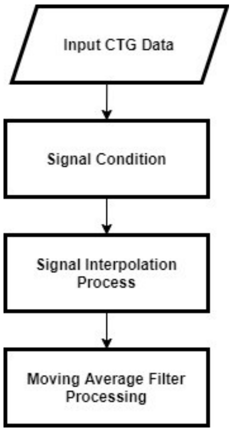

Figure 2. Increasing CTG Dataset Flowchart

In the pre-processing stage, to remove spiky artefacts contained in the CTG signal conditions using the method carried out by (Shahad Nidhal, 2010). The moving average filter was chosen to enhance the CTG signal so that experts can read and provide an excellent visual interpretation.

Fetal Heart Rate (FHR) Baseline Feature Extraction

Figure 3 shows the steps performed for baseline feature extraction on the CTG signal according to the RCOG guidelines.

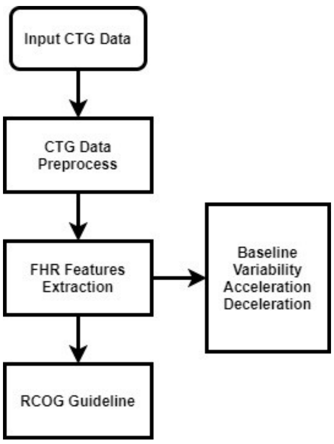

Figure 3. Feature extraction flowchart based on RCOG guidelines

Morphological features were extracted from FHR signals. This stage uses a new method for essential features based on the RCOG guidelines. However, this study focuses on the development of the baseline FHR algorithm.

Baseline Features

The baseline is the essential feature in the FHR feature method because all other FHR features depend on the baseline. Figure 4 below shows the procedure used to calculate the baseline.

The preprocessing stage of CTG data is carried out to increase the dataset. Furthermore, to find out the real baseline value by calculating the virtual imaginary baseline (VBR) value which is assumed to be the same as the average value of the DJJ signal in 30 minutes, using the formula below:

$$VBR = \frac{1}{NS}\sum_{i=1}^{N} S(i) \tag{1}$$

NS is the number of samples, and S is the CTG signal.

This study uses a Matlab application to analyze the imaginary virtual baseline (VBR) of the FHR signal and limit the minimum and maximum values of the FHR input signal taken according to the RCOG guidelines.

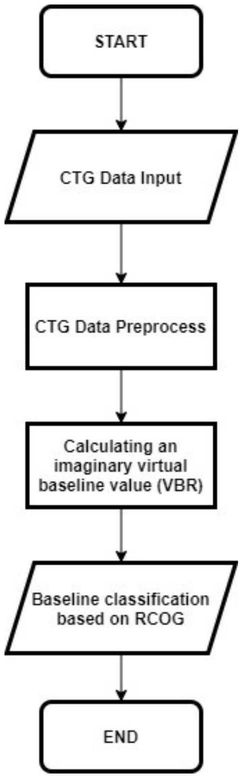

Figure 4. Flowchart for baseline estimation

Next is to find the maximum (MH) and minimum (ML) limits of the DJJ signal using the formula below:

$$MH = VBR + a \tag{2}$$

$$ML = VBR - a \tag{3}$$

After determining the value of an (a is the value in units of b.p.m), ignore any values above MH and below ML. The baseline calculation will process signals not above MH and below ML.

III. RESULT AND DISCUSSION

This section describes the results obtained from the proposed algorithm regarding feature extraction of the fetal heart rate, which focuses on the baseline feature. The results obtained from the proposed algorithm for the cardiotocograph data. Then these results are compared with those obtained from obstetricians (experts). The signal data consists of 15 CTG signals, and the results obtained from the proposed algorithm using Matlab compared with the results from the interpretations of 2 obstetricians (obstetricians 1 and 2). The obstetrician was asked to estimate the baseline for each signal, and table 1 shows the results obtained from the first signal group.

Table 1. Comparison of result between the proposed algorithm and the obstetricians

Signals	Baseline Interpretation		
	Obstetrician 1	**Obstetrician 2**	**Computer Result**
S1	130	130	125
S2	130	130	132
S3	130	130	130
S4	120	120 – 125	133
S5	120	120	132
S6	130	130	134
S7	140	140	125
S8	145	145	129
S9	145	145	135
S10	130	130	137
S11	140	140	137
S12	130	130	148
S13	130	130 – 132	155
S14	130	130	132
S15	140	140	128

The results obtained in table 1 show that there is no significant difference between the results of the obstetrician's interpretation and the interpretation obtained from the proposed algorithm. The results of the baseline feature values obtained in table 1 classify into Reassuring (R), Non-Reassuring (NR), and Abnormal (A) based on the RCOG guidelines, as shown in Table 2.

Table 2. Fetal Heart Rate Baseline Classification Based on RCOG

Classification	Baseline (bpm)
Reassuring	110 – 160
Non-Reassuring	100 – 109 161 - 180
Abnormal	<100 >180 Sinusoidal pattern For >=10 min

The results indicate no significant difference in the classification of baseline features between the proposed algorithm and obstetricians' visual interpretation, as shown in figure 3.

Table 3. Comparison of classification result between the proposed algorithm and the obstetricians

Signals	Baseline Interpretation		
	Obstetrician 1	Obstetrician 2	Computer Result
S1	R	R	R
S2	R	R	R
S3	R	R	R
S4	R	R	R
S5	R	R	R
S6	R	R	R
S7	R	R	R
S8	R	R	R
S9	R	R	R
S10	R	R	R
S11	R	R	R
S12	R	R	R
S13	R	R	R
S14	R	R	R
S15	R	R	R

The results obtained in table 3 above show that all signals from S1 – S15 get the Reassuring category, which means that the baseline FHR is in average condition. The proposed algorithm is by the results obtained from both obstetricians (experts).

IV. CONCLUSION

In this study, we develop a simple algorithm for feature extraction of baseline Fetal Heart Rate (FHR) using Matlab. Guidelines used in developing Fetal Heart Rate (FHR) feature extraction using the RCOG guidelines. The results obtained are a classification of baseline fetal heart rate features with Reassuring (R), Non-Reassuring (NR), and Abnormal (A) categories. The proposed algorithm compares with the interpretation carried out by obstetricians using the same data and gets excellent results because all the data obtained from the proposed algorithm get the same classification as the interpretation made by the obstetrician. Although the results obtained are excellent, they require further validation using more data.

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