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# Automated Estimation of Foetal Heart Rate Variability Using Frequency-Based Floatingline Method

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## Abstract

The assessment of foetal heart rate (FHR) variability plays a crucial role in diagnosing foetal well-being. However, the lack of a standardized definition of FHR variability (FHRV) and agreement on evaluation methodologies remains a challenge. Existing approaches often compute FHRV in segments devoid of accelerations and decelerations, making it challenging to evaluate signals with frequent and closely spaced events of this nature. In this study, we propose an automated method for estimating FHRV by defining it as the difference between the FHR signal and the floatingline. The floatingline represents an imaginary line that follows accelerations and decelerations while considering their frequency characteristics. We evaluated the developed software on both simulated and real FHR signals comprising sets of 62 signals. For simulated signals, the mean square error between the estimated and simulated floatinglines was only 0.039 bpm$^2$. In the case of real signals, without a gold standard reference, a team of five expert obstetricians visually assessed the estimated floatinglines, finding them matching the defined criteria in 95.84% of cases. Regarding FHRV evaluation, we compared the estimated values with reference values of short-term variability (STV) and sympathovagal balance (SVB) using simulated FHR signals. The error was below 1.68% for the STV index, while the SVB index was underestimated with an error of approximately 4.32%. Furthermore, we compared our proposed floatingline estimation method with traditional filters such as moving average and FIR with Hamming window. On average, our method outperformed these filters, exhibiting mean square errors up to five times lower.

**Keywords**: Foetal heart rate variability, floatingline method, frequency characteristics, automated estimation, computerised foetal monitoring

## I. Introduction

Foetal surveillance plays a vital role in healthcare, with two primary objectives: excluding foetal abnormalities and evaluating the health of a presumably normal foetus. Monitoring the foetal heart rate (FHR) through various techniques is crucial for assessing the foetal well-being. However, measuring problems arise due to the foetus being in the womb. While cardiotocography (CTG) is the routine test for assessing foetal well-being at the end of pregnancy, alternative techniques like electrocardiography (ECG) and magnetocardiography face limitations and complexity in obtaining accurate signals. These challenges hinder their clinical application [1-3]. Foetal heart rate variability (FHRV) is an important characteristic evaluated by gynaecologists to diagnose foetal well-being. It has a strong connection to the autonomic and central nervous systems, demonstrated through pharmacological experiments. Additionally, FHRV is linked to foetal oxygenation. Extensive studies have analyzed FHRV using various techniques such as time and frequency domain analysis, as well as nonlinear approaches. The aim is to establish diagnostic indexes for early recognition of foetal distress and investigate factors affecting FHRV [4-5]. However, there is significant variability in the interpretation of FHR signals among observers, and standard definitions and evaluation criteria for FHR changes are lacking. Although algorithms have been developed to quantify FHR parameters, standardization for clinical applications is yet to be achieved. The estimation methods and definition of power spectral bands for FHRV are also not standardized, despite their widespread use in electronic foetal monitoring. The boundaries of the spectral bands remain a subject of disagreement [6]. Furthermore, the presence of accelerations and decelerations in the FHR signal complicates the definition and identification of

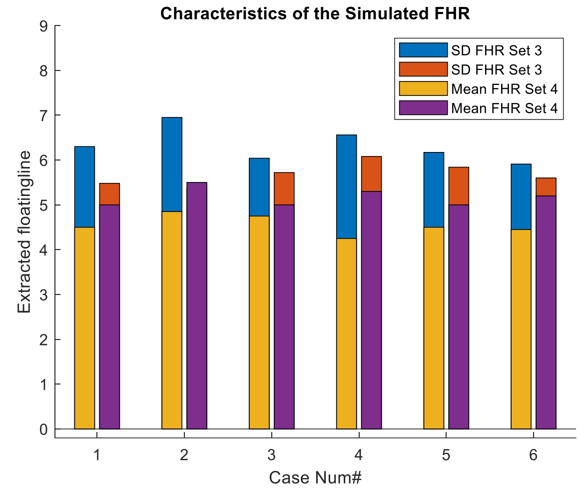


**Fig. 7**: Simulation results of the FHR characteristics

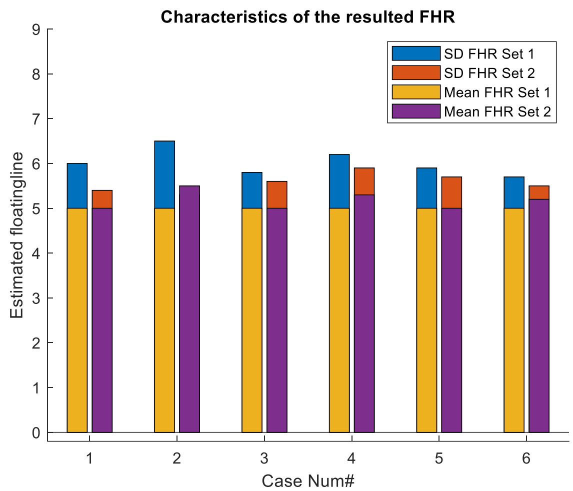


**Fig. 8**: Experimental Human test-study results of the FHR characteristics

## VII. Conclusion

In conclusion, the fetal heart rate variability (FHRV) is a crucial parameter for evaluating the well-being of the fetus. However, there is a lack of standardized definitions and guidelines for assessing FHRV, and existing approaches often overlook important information. To address these issues, a methodology has been proposed that computes FHRV by subtracting the floatingline from the FHR signal. The floatingline, which represents the median line following accelerations and decelerations, is distinct from the baseline used during stable periods. The methodology has been incorporated into an updated software version, which utilizes advanced filtering techniques and automated floatingline assessment. The software can be integrated into computerized cardiotocography (CTG) systems and is applicable during both the antepartum and intrapartum periods. Validation studies have shown satisfactory performance compared to other methods, but there are limitations in estimating low-frequency power. Future research aims to overcome this limitation and make the software more accessible for clinical environments. Overall, the proposed methodology shows promise in improving the assessment of FHRV and has the potential to enhance the diagnostic value of fetal monitoring.

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