OBSS - seminar 2

Estimating time course of peak frequency and median frequency along the spectrograms of uterine EMG records (2.c)

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Abstract

This report introduces a program for analyzing uterine electromyographic (EHG) signals during pregnancy and labor, utilizing the short-time Fourier transform (STFT) to compute spectrograms and focusing on median and peak frequency estimators. The study explores four groups of records, distinguishing pre-term and term labor before/after the 26th week of gestation, emphasizing changes in frequency estimators, especially in higher frequency bands. The methodology covers preprocessing, record selection, and estimator computation. Results include optimal parameter combinations and insights into estimators for each record. The report concludes with a concise discussion of observed signal characteristics, contributing to a nuanced understanding of uterine electrical activity during various gestational stages.

1 Introduction

This report presents a program developed for analyzing uterine electromyographic (EHG) signals during pregnancy and labor. The program calculates spectrograms using short-time Fourier transform (STFT), focusing on two frequency estimators – median frequency and peak frequency. Four distinct groups of records (pre-term and term labor before/after 26th week) are studied, emphasizing changes in frequency estimators, particularly in higher frequency bands. The selected records include intervals with heightened uterine electrical activity.

2 Methodology

The program itself is implemented in Matlab with the help of some functions from the WFDB software package. As part of the project, a script was written to select 4 random records, each of from one of the distinct groups on which the program is executed. All data used for the implementation and evaluation is taken from the Term-Preterm EHG Database.

2.1 Preprocessing

No data preprocessing is included in the algorithm implementation. The reason for that is that the records from the Term-Preterm EHG Database already include signals, preprocessed by various Butterworth filters. For this project, the signals filtered using a 4-pole band-pass Butterworth filter from 0.3Hz to 4Hz were selected.

2.2 Selecting the records

For testing, the records were selected at random, for evaluation, certain records that showcase heightened uterine activity have been selected by hand. The criteria for such records is that the frequencies in the signals deviate wildly from the baseline, which we defined as the frequencies being stable (represented by a relatively straight line). The chosen records for the evaluation were *tpehg949* (term, before 26 weeks)[1], *tpehg1526* (pre-term, before 26 weeks)[1], *tpehg725* (term, after 26 weeks), *tpehg1720* (pre-term, after 26 weeks).

2.3 Computing the spectrograms

For each record, three distinct spectrograms have been generated, each corresponding to a specific preprocessed signal derived from the record.

The computation of these spectrograms involved the application of various parameter combinations, carefully selected for specific reasons. The details of these parameter combinations are summarized in Table 1.

Seg. len.	**overlap**	**window**	**reason**
256	128	`hamming(seg. len.)`	Balanced resolution
256	255	`hamming(seg. len.)`	Increased time resolution
512	256	`hamming(seg. len.)`	Increased frequency resolution
256	128	`hann(seg.len.)`	Potential increase in frequency resolution
256	128	`blackman(seg. len.)`	Potential reduction in spectral leakage

Table 1: Combinations of spectrogram parameters

2.4 Computing the estimators

As part of our task, we implemented two crucial estimators: the median frequency estimator and the peak frequency estimator. These estimators play a pivotal role in our analysis, providing insights into the frequency characteristics of the spectrogram.

The formulae employed for computing these estimators, as elucidated in the course lessons, are as follows:

1. **Median frequency estimator**:

$$f_{med} = i_m \frac{F_s}{N}, \Sigma_{i=i_{low}}^{i=i_m} P[i] \approx \Sigma_{i=i_m}^{i=i_{high}} P[i]$$

The median frequency estimator involves determining the median index i_m within the frequency range $[i_{low}, i_{high}]$. The corresponding frequency f_{med} is then calculated using the given formula. The approximation symbolizes that the cumulative sum of the power spectrum is approximately equal on either side of the median index.

2. **Peak frequency estimator**:

$$f_{max} = \frac{F_s}{N} arg(max_{i=i_{low}}^{i=i_{high}} P[i])$$

The peak frequency estimator is determined by identifying the index ii within the specified frequency range $[i_{low}, i_{high}]$ where the power spectrum $P[i]$ is maximized. This index is then used to compute the corresponding frequency f_{max} using the provided formula.

These estimators provide valuable quantitative measures, allowing us to characterize and interpret the frequency content of the spectrogram in our analysis. The peak frequency highlights the dominant frequency, while the median frequency offers insights into the central tendency of the frequency distribution within the specified range.

3 Results

The results of this project are presented in two sections. Firstly, we evaluated various combinations of parameters utilized in computing the spectrograms. This evaluation assists us in identifying the most suitable combination for calculating the estimators.

3.1 Spectrogram Parameters

By examining the parameter combinations detailed in Table 1, we generated spectrograms of the record *tpehg1756*, as illustrated in Figures 1, 2, 3, 4, and 5. Upon closer inspection, we observed that the spectrograms depicted in Figures 2 and 4 best serve as the basis for the estimations. For the purposes of this project, we opted for the second parameter combination (Figure 2) as it yields the highest time resolution of the spectrogram, a crucial factor when estimating frequencies (providing more data).

3.2 Estimators

After identifying the optimal combination of parameters for time resolution, we computed the median and peak estimators for each signal in the records outlined in Section 2.2. The subsections in this chapter discuss the results for each record.

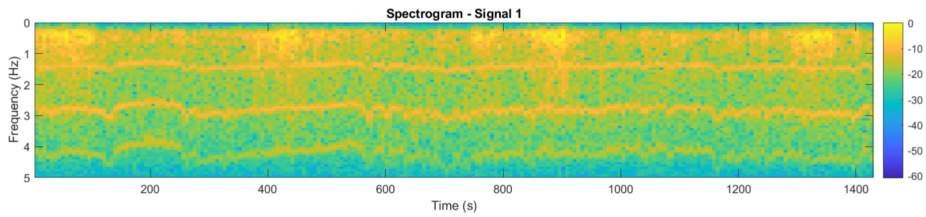

Figure 1: Spectrogram obtained using the 1. combination of parameters

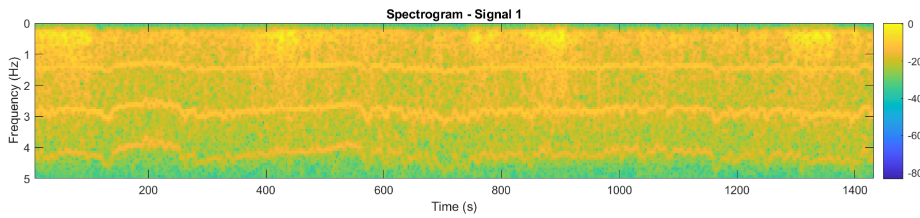

Figure 2: Spectrogram obtained using the 2. combination of parameters

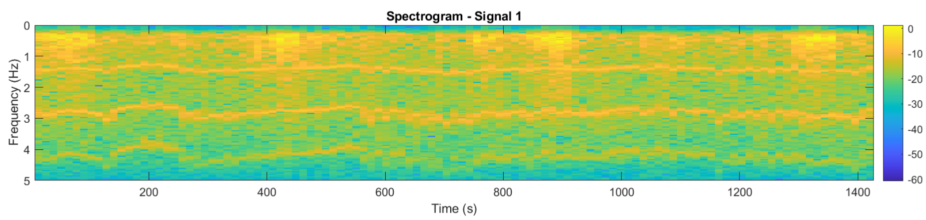

Figure 3: Spectrogram obtained using the 3. combination of parameters

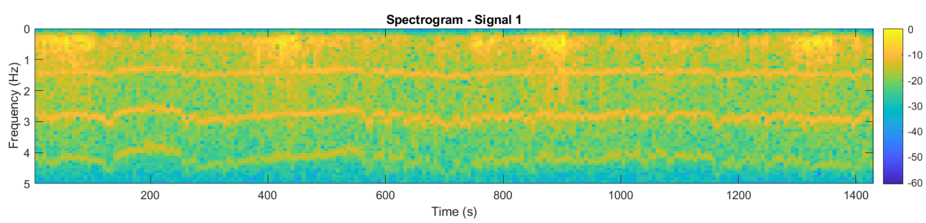

Figure 4: Spectrogram obtained using the 4. combination of parameters

3.2.1 Pre-Term, before 26 weeks - tpehg1526

Upon closer inspection of the spectrograms for the record *tpehg1526* (Figure 6), we observe fluctuations in the peak frequency of the first signal (horizontally positioned electrodes) between low and high frequencies. At approximately 500 seconds, the frequency dips massively for a moment. Additionally, the median frequency is relatively high. Similar fluctuations in the peak and median es-

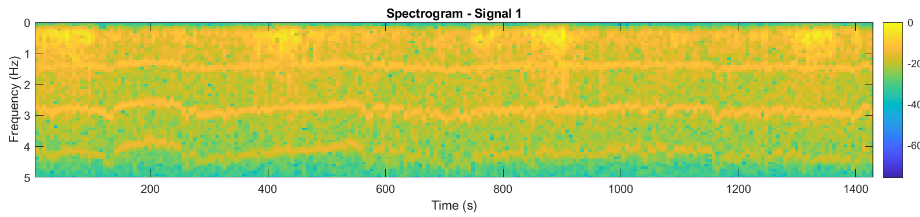

Figure 5: Spectrogram obtained using the 5. combination of parameters

timator, along with higher frequencies can be observed in the second signal (vertically positioned electrodes) and third signal (horizontally positioned electrodes). These patterns align with the premature onset of labor, as indicated by associated contractions.

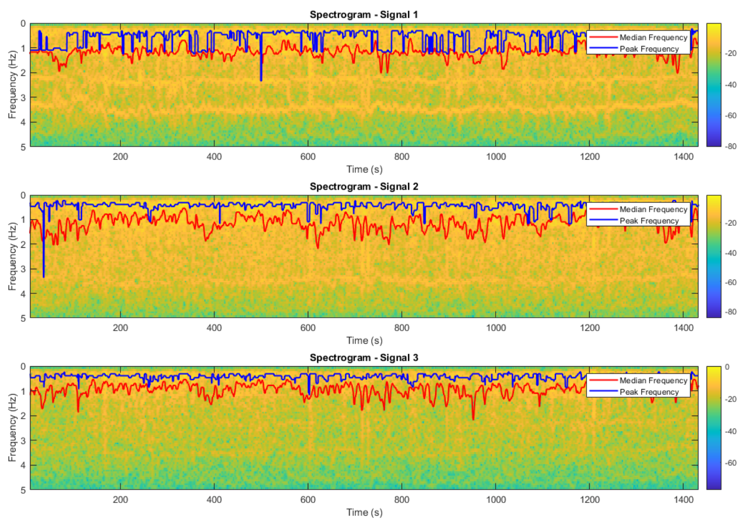

Figure 6: Estimators on the spectrogram of record tpehg1526

3.2.2 Term, before 26 weeks - tpehg949

Upon closer inspection of the spectrograms for the record *tpehg949* (Figure 7), we observe that especially the median estimators is much more consistent throughout the time interval than the corresponding estimators for the record *tpehg1526* (pre-term, before 26 weeks). Additionally, we can observe that the mean frequency is generally lower than in the record *tpehg1526*, consistent with normal uterine activity during early gestation.

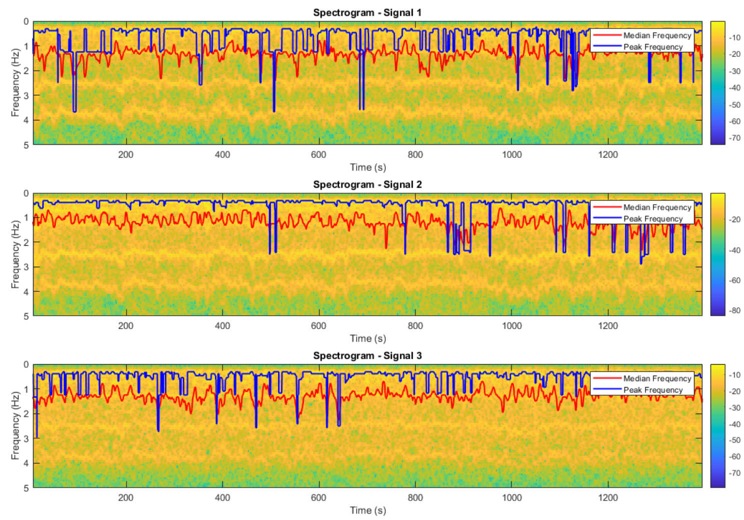

Figure 7: Estimators on the spectrogram of record tpehg949

3.2.3 Pre-Term, after 26 weeks - tpehg1720

Upon closer inspection of the spectrograms for the record *tpehg1720* (Figure 8), we note that the range of frequencies, especially in the second signal (vertically positioned electrodes) covers a wider range than in other records. The third signal, captured on horizontally positioned electrodes closer to the cervix [1], consistently exhibits very high peak frequencies. This aligns with the increased activity of the cervix in the weeks before labor.

3.2.4 Term, after 26 weeks - tpehg725

Upon closer inspection of the spectrograms for the record *tpehg725* (Figure 9), we observe stronger fluctuations in frequencies, with a higher baseline, compared to the record *tpehg949* (term, before 26 weeks). This consistency aligns with the proximity of labor in this record, indicating increased uterine activity.

4 Discussion

In conclusion, the analysis of median and peak frequency estimators across the selected records sheds light on distinctive patterns associated with different gestational and labor stages. Notably, records from pre-term labor before 26 weeks exhibit fluctuating frequencies and elevated median frequencies, indicative of premature onset with visible contractions. Term labor before 26 weeks shows a more stable median estimator, aligning with normal uterine activity during early

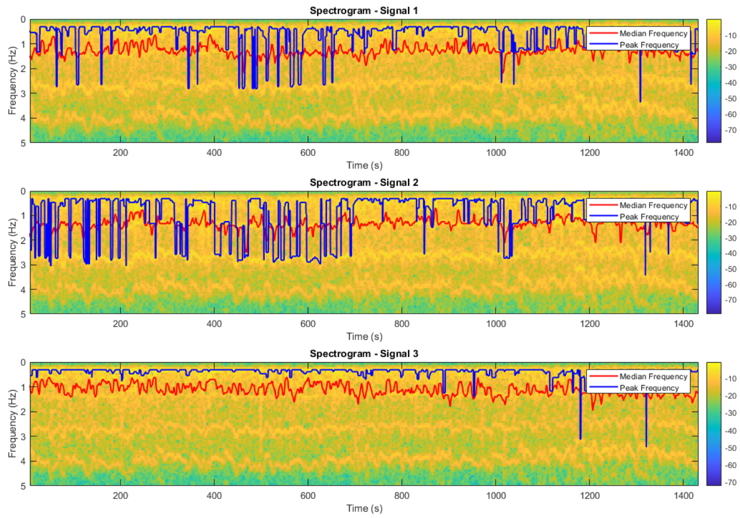

Figure 8: Estimators on the spectrogram of record tpehg1720

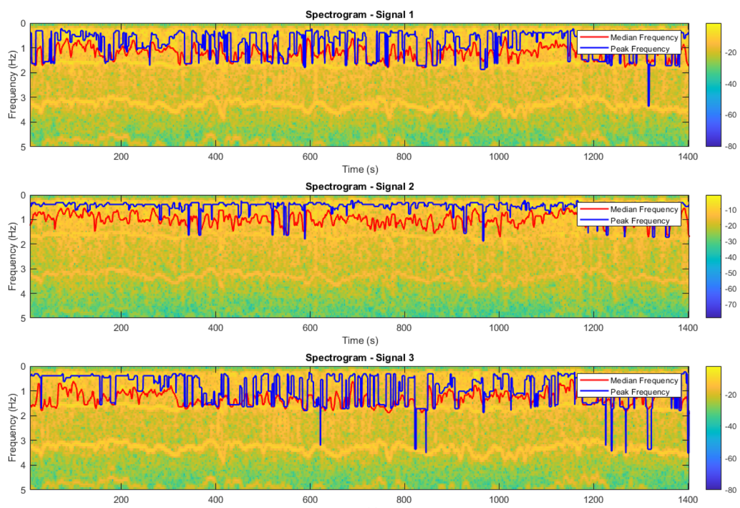

Figure 9: Estimators on the spectrogram of record tpehg725

gestation. In pre-term labor after 26 weeks, a wider frequency range and consistently high peak frequencies in the cervix-related signal highlight increased cervical activity preceding labor. Lastly, term labor after 26 weeks displays heightened frequency fluctuations and an elevated baseline, signifying the imminent arrival of labor. These nuanced insights underscore the potential of frequency estimators in capturing dynamic changes in uterine electrical activity and offer valuable information for understanding gestational and labor-related physiological variations.

References

[1] Žiga Pirnar, Franc Jager, and Ksenija Geršak. "Characterization and separation of preterm and term spontaneous, induced, and cesarean EHG records". In: *Computers in Biology and Medicine* 151 (2022), p. 106238. ISSN: 0010-4825. DOI: `https://doi.org/10.1016/j.compbiomed.2022.106238`. URL: `https://www.sciencedirect.com/science/article/pii/S0010482522009465`.