Separating preterm and term delivery uterine EMG records using sample entropy (Assignment 2.b)

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I. Abstract

This report analyzes the uterine electromyogram (EMG) records using sample entropy in an attempt to classify term and preterm deliveries. Using the Term-Preterm EHG Database (TPEHG DB) [1], we calculate sample entropy [2], a measure of signal complexity, for four clinical groups (divided based on time of labor and time of EMG recording). Visualization of calculated sample entropy for all records on whole signals and on cut signals (deleted first and last 3 minutes of each signal) is done. P-values from Student's t-tests for classification of groups are reported on whole and cut signals using results from sample entropy calculation.

II. Introduction

Uterine electromyogram (EMG) is a non-invasive method, which asseses electrical activity of the uterus during pregnancy or labor. The dataset [1] used in this report comprises 300 records acquired using 4 electrodes, placed on the abdomen, above the uterine surface. Each record is then composed of three channels, recorded from these electrodes and each signal was digitally filtered using 3 different digital Butterworth filters. Therefore, for each record, 12 signals are available in the database. For purposes of this report, channel number 10 (filtered with a band-pass filter 0.08–4Hz) was used. Records are 30 minutes long and were sampled with a sampling frequency of 20 $\frac{smp}{sec}$.

III. Methods

The dataset is grouped into four subgroups according to the time of the EMG recording and according to the information about the time of birth. Term deliveries (denoted T) are considered pregnancies of duration ≥ 37 weeks, while preterm deliveries (denoted P) are considered the ones with duration <37 weeks. Then, the groups can be further divided into TE or TL and PE and PL groups depending on the time when the recording was done: E stands for early recording, made during the week of pregnancy <26 weeks and L-stands for recordings done from week 26.

Term deliveries (T): 262 records

- TE - term recorded early group: 143 records
- TL - term recorded late group: 119 records

Pre-term deliveries (P): 38 records

- PE - preterm recorded early group: 19 records
- PL - preterm recorded early group: 19 records

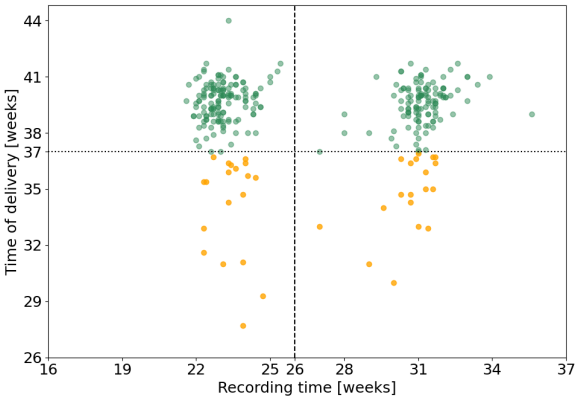

Fig. 1. Time of delivery vs. time of recording of the EMG. Green are term and orange preterm records.

A. Sample entropy calculation

The sample entropy calculation: having a time-series dataset of length N $X = \{x_1, x_2, x_3, \ldots, x_N\}$, we define a vector of length m: $X_m(i) = \{x_i, x_{i+1}, x_{i+2}, \ldots, x_{i+m-1}\}$.

For each record, where:

$$A = d[X_{m+1}(i), X_{m+1}(j)] < r$$
$$B = d[X_m(i), X_m(j)] < r$$

and *SampEn(m, r, N)*, where m is embedding dimension, r is tolerance, calculated as r = r×std(signal), was calculated using:

$$\text{SampEn} = -\ln \frac{A}{B}$$

In cases where A=0 or B=0, the sample entropy was calculated as:

$$\text{SampEn} = -\ln \frac{N-m}{N-m-1}$$

In this report, sample entropy was calculated for m=3 and r=0.15.

B. Calculation of Student's t-test

T-tests were performed on whole signals and on cut signals (deleted first and last 3 minutes of each signal) for term (T) and preterm (P) groups, groups TE and PE and on groups TL and TE groups, to obtain p1, p1_cut, p2, p2_cut, p6 and p6_cut. The `equal_var` parameter was set to `False`. Example of t-test: `t1, p1 = stats.ttest_ind(TE, PE, equal_var=False)`.

IV. Results

A. Sample entropy

Graphs of sample entropy for all the records using whole (uncut) signals and sample entropy for cut signals (the cut signals were obtained by deleting the first and last 3 minutes of recording). The signal were from channel utilizing band-pass filter 0.08-4Hz.

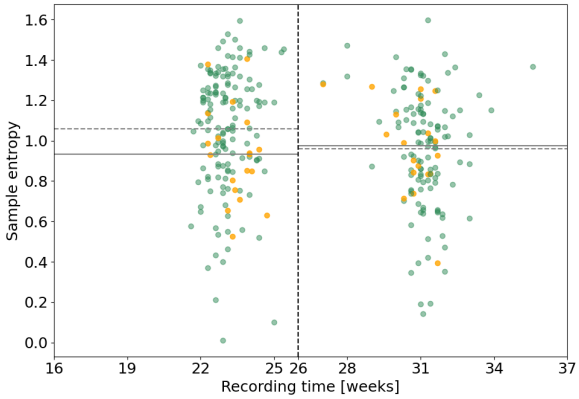

Fig. 2. Sample entropy (m=3, r=0.15) for records using the whole length of signals. Green are term and orange preterm records.

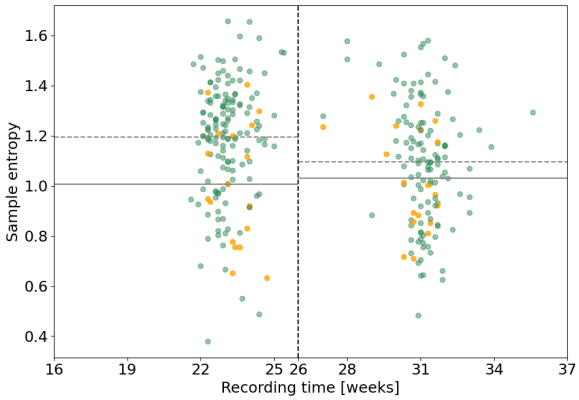

Fig. 3. Sample entropy (m=3, r=0.15) for records using cut signals. Green are term and orange preterm records.

B. Student's t-test

Results from t-tests on: whole signals, where *p1* is result of t-test between groups TE and PE, *p2* the result for TL and PL and *p6* for whole term (T) and preterm (P) groups. P-values for cut signals were obtained from the same groups, just the signals were cut at the start and at the end.

	p1	*p2*	*p6*
whole signal	**0.045**	0.822	0.152
cut signal	**0.004**	0.231	**0.0015**

TABLE I
P-VALUES FROM T-TEST ON WHOLE AND CUT SIGNAL FROM CHANNEL USING BAND-PASS FILTER 0.08-4 Hz

C. Discussion

Difference between whole and cut signals is evident, as p-valuess of t-test on cut signals result in two statistically significant differences between the term and preterm groups in values *p1* and *p6*, where the significant difference in whole signals was shown only with *p1* value. In both instances, *p2* value did not show significant difference with 0.822 and 0.231.

Additionally, the visualization of sample entropy results for whole and cut signals exhibits difference, as on cut signals, the mean sample entropy for term and preterm records has an evident difference for early especially and also for later cases. For sample entropy visualization of whole images, the mean values for later recordings have slightly smaller mean sample entropy, which does not support our hypothesis of term recordings having a signifficantly smaller sample entropy.

References

[1] G. Fele-Žorž, G. Kavšek, Živa Novak-Antolič, and F. Jager, "A comparison of various linear and non-linear signal processing techniques to separate uterine emg records of term and pre-term delivery groups," *Medical & Biological Engineering & Computing*, vol. 46, no. 9, pp. 911–922, 2008.

[2] D. E. Lake, J. S. Richman, M. P. Griffin, and J. R. Moorman, "Sample entropy analysis of neonatal heart rate variability," *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology*, vol. 283, no. 3, pp. 789–797, 2002.