Article

A Fuzzy Approach for Term and Preterm Identification

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Abstract: A single paragraph of about 200 words maximum. For research articles, abstracts should give a pertinent overview of the work. We strongly encourage authors to use the following style of structured abstracts, but without headings: 1) Background: Place the question addressed in a broad context and highlight the purpose of the study; 2) Methods: Describe briefly the main methods or treatments applied; 3) Results: Summarize the article's main findings; and 4) Conclusion: Indicate the main conclusions or interpretations. The abstract should be an objective representation of the article, it must not contain results which are not presented and substantiated in the main text and should not exaggerate the main conclusions.

Keywords: Biomedical Instrumentation; Electrohystogram; Uterine Contractions; Fuzzy.)

1. Introduction

Pregnancy is a physiological process that involves anatomic-functional, emotional and psychological changes as result of an increment of hormone that enables compliance with the metabolic demands of the fetus and the mother [1].

Despite being a natural process in women, pregnancy could generate some health complications, constituting a significant proportion of the global burden of maternal mortality and morbidity. That is why to monitor both an adequate adaptation of the women to all the physiological changes as well as the correct development of the fetus are important. According to the World Health Organization (WHO) complications during pregnancy are a leading cause of death among women of reproductive age. In 2015, the maternal mortality (women death during pregnancy and childbirth, or after them) was 216 per 100.000 live births, representing 303.000 deceases. Virtually all of these deaths occurred in low-income countries but most of them could have been avoided [2]. One of the major complications during pregnancy is preterm labor (less than 37 weeks of gestation). Preterm labor and subsequent preterm birth is the primary cause of neonatal mortality and neurological morbidity in the short and long term. Its frequency varies between 5% and 12% in developed regions of the world, but can be up to 40% in the poorest regions [3].

Currently, Tocograph as a part of Cardiotocography (CTG) is used to monitor the strength, duration and frequency of uterine contractions. It is a pressure sensor which picks up the contraction of the uterus and displays it on a graph with the X-axis as time (seconds) and the Y-axis as pressure (mmHg). The sensor is placed at the fundus of the abdomen and is kept in place with the help of a belt. A sample Tocography is shown in Figure 1.

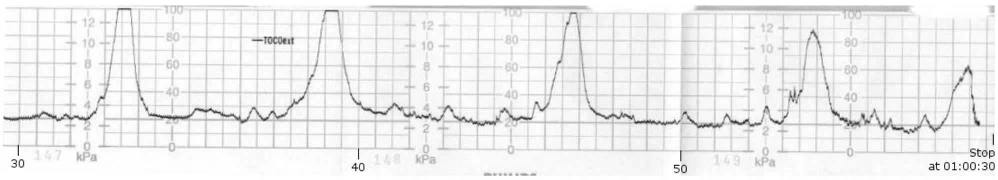

Figure 1. Uterine contractions in Tocography signal.

There are several disadvantages of Tocography. Important among them are:

- Inter and intra-personal variation in interpretation of CTG trace [4].
- Sometimes there is shift (either up or down) in baseline of signal which makes interpretation difficult. This is known as baseline wandering [5].

The purpose of this work is to evaluate the possibility of early detection of preterm delivery (PD), by means of characterization of the contractions, obtained by uterine electromyogram (EMG), on the abdomen of the pregnant woman [electrohysterogram (EHG)], using fuzzy logic. As there is no current published information concerning fuzzy classification of EHG recordings, we propose to investigate, in this study, the potentialities of this method to determine a possible separation between contractions leading to a PD and contractions leading to delivery at term (DT), using fuzzy classification and avoiding CTG disavantages.

2. Materials

2.1. The Icelandic 16-electrode Electrohysterogram Database

The acquisitions of this database were executed between 2008 and 2010 in the Landspitali University Hospital, Akureyri Hospital and Akureyri Primary Health Care Centre in Iceland. Were performed 122 recordings on 45 pregnant woman, where 32 were measured repeatedly during the same pregnancy and participated in two to seven recordings. Sessions ocurred in the third trimester (112 recordings) and during labor (10 recordings). The database includes simultaneously recorded tocographs, annotations of events and obstetric information on participants. Informed consent was obtained from every participant and the protocol was approved by the National Bioethics Committee in Iceland (VSN 02-006-V4) [6].

A 4x4 reusable monopolar eletrode grid (Ag/AgCl) was disposed on the pacients abdomen as can be seen in Figure 2

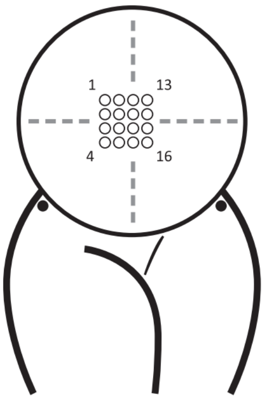

Figure 2. Ideal position of the 16 electrode grid. The black dots represents the patient ground reference.

The measurements were performed using a sixteen channel multi-purpose physiological signal recorder (Embla A10), most commonly used for investigating sleep disorders. An anti-aliasing filter with a high cut-off frequency of 100 Hz was used but no high pass filter was used. The signal sampling rate was 200 Hz and the signal was digitized to 16 bits. [6].

2.2. The Term-Preterm Electrohysterogram database

The EHG records included in the Term-Preterm Electrohysterogram database (TPEHG DB) were obtained from 1997 to 2005 at the University Medical Centre Ljubljana, Department of Obstetrics and Gynecology. The records were obtained during regular check-ups either around the 22nd week of gestation or around the 32nd week of gestation. In all, almost 1300 records were obtained during these years, and a preliminary database was built and used for studies by Ivan Verdenik, Gorazd Kavšek, Marjan Pajntar and Živa Novak-Antolič [7],[8]

During the selection of records, all records with apparent recording artifacts, all records from pregnancies where labor was induced, and all records where delivery was performed using a Cesarean section, were rejected. The 300 resulted data are:

- 262 records were obtained during pregnancies where delivery was on term (duration of gestation at delivery > 37 weeks):
  - 143 records were obtained before the 26th week of gestation and
  - 119 were obtained later during pregnancy, during or after the 26th week of gestation;
- 38 records were obtained during pregnancies which ended prematurely (pregnancy duration $\leq$ 37 weeks), of which:
  - 19 records were obtained before the 26th week of gestation and
  - 19 records were obtained during or after the 26th week of gestation.

The differences in the electrical potentials of the electrodes were recorded, producing 3 channels:

- S1 = E2–E1 (first channel);
- S2 = E2–E3 (second channel);
- S3 = E4–E3 (third channel).

A $2x2$ reusable monopolar eletrode grid (Ag/AgCl) was disposed on the pacients abdomen as can be seen in Figure 3.

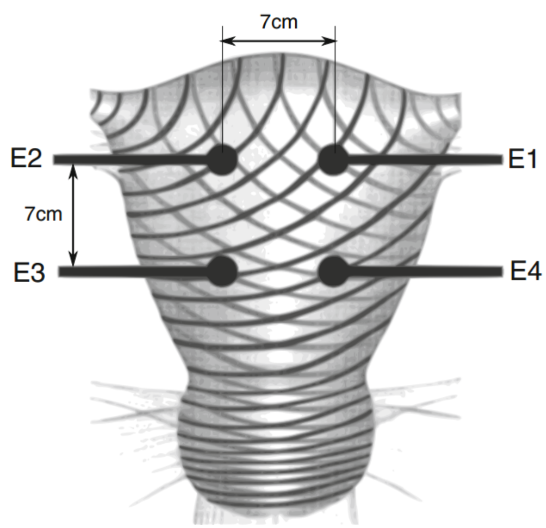

Figure 3. Ideal position of the 4 electrode grid.

The records are of 30-min duration and consist of three channels. The sampling frequency was 20Hz and the signal was digitized to 16 bits. Prior to sampling the signals were filtered using an analog threepole Butterworth filter with the bandwidth from 0 to 5 Hz [9]

2.3. The Fuzzy Logic

Unlike in the boolean logic, in the fuzzy logic the variables can assume more than 2 values (true and false). That is, it can work in the concept where the truth can range between the completely true to completely false [10]

3. Methods

3.1. Pre-Processing

The TPEHG database was chosen for providing more consistent data, information on the type of contraction (preterm and term) and using differential signals. Moreover, because it has been elaborated longer, it has more work based on its measurements, thus allowing the results obtained here to be compared in the future.

The selection of digital filters to remove noise from signals before the processing may greatly influence the results. A band-pass filter is needed. It was recognized that the uterine EMG content ranges from 0 to < 5 Hz [11].

4. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

4.1. Subsection

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Bulleted lists look like this:

- First bullet
- Second bullet
- Third bullet

Numbered lists can be added as follows:

1. First item
2. Second item
3. Third item

The text continues here.

4.2. Figures, Tables and Schemes

All figures and tables should be cited in the main text as Figure 1, Table 1, etc.

Figure 4. This is a figure, Schemes follow the same formatting. If there are multiple panels, they should be listed as: (**a**) Description of what is contained in the first panel. (**b**) Description of what is contained in the second panel. Figures should be placed in the main text near to the first time they are cited. A caption on a single line should be centered.

Table 1. This is a table caption. Tables should be placed in the main text near to the first time they are cited.

Title 1	**Title 2**	**Title 3**
entry 1	data	data
entry 2	data	data

4.3. Formatting of Mathematical Components

This is an example of an equation:

$$\mathbb{S} \tag{1}$$

Please punctuate equations as regular text. Theorem-type environments (including propositions, lemmas, corollaries etc.) can be formatted as follows:

Theorem 1. *Example text of a theorem.*

The text continues here. Proofs must be formatted as follows:

Proof of Theorem 1. Text of the proof. Note that the phrase 'of Theorem 1' is optional if it is clear which theorem is being referred to. □

The text continues here.

5. Discussion

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

6. Conclusions

This section is not mandatory, but can be added to the manuscript if the discussion is unusually long or complex.

Conflicts of Interest: The authors declare no conflict of interest.

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