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# Automated detection of uterine contractions in tocography signals – Comparison of algorithms

Krzysztof Horoba [a,*], Janusz Wrobel [a], Janusz Jezewski [a], Tomasz Kupka [a], Dawid Roj [a], Michal Jezewski [b]

[a] Institute of Medical Technology and Equipment ITAM, Roosevelta 118, 41-800 Zabrze, Poland
[b] Institute of Electronics, Silesian University of Technology, Akademicka 16, 44-100 Gliwice, Poland

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ABSTRACT

Monitoring of uterine contractile activity enables to control the progress of labor. Automated detection of contractions is an integral part of the signal analysis implemented in computer-aided fetal surveillance system. Comparison of four algorithms for automated detection of uterine contractions in the signal of uterine mechanical activity is presented. Three algorithms are based generally on analysis of the frequency distribution of signal values. The fourth method relies on analyzing the rate of changes of the uterine activity signal. The reference data in form of beginning and end of contraction episodes were provided by human experts. Obtained results show that all algorithms were capable to detect above 91% reference contractions, and less than 7% of recognized patterns were false. Two algorithms can be distinguished as providing a higher performance expressed by the sensitivity of 95% and the positive predictive value of 97%. Such results could be obtained by optimization of contraction validation criteria.





## 1. Introduction

During the last decade the computer-aided systems have become a standard approach to accomplish the cardiotocographic (CTG) monitoring both during pregnancy and labor [1–3]. The main task of the fetal monitoring system is quantitative analysis of the signals acquired from bedside monitors in order to help clinician in a fetal state assessment [4–7]. Fetal monitor measures the mechanical uterine contractile (UC) activity by means of strain-gauge transducer attached to maternal abdomen with elastic strap [8]. This external activity reflects the intrauterine pressure changes [9,10]. Signal of uterine activity may be printed by bedside monitor or presented in computer-aided system in a graphical form as a tocogram, where the contractile episodes are reflected by temporary amplitude increase (Fig. 1) [11,12]. Although the essential information on the fetus condition is obtained from monitoring and analysis of the changes of the fetal heart rate variability [13–16], such situation when the fetus responds to contraction with decrease of its heart rate is considered as a valid sign of fetal distress [17–19]. Additionally, monitoring of

* *Corresponding author at:* Institute of Medical Technology and Equipment ITAM, Roosevelta 118, 41-800 Zabrze, Poland.
E-mail addresses: krzysztof.horoba@itam.zabrze.pl (K. Horoba), januszw@itam.zabrze.pl (J. Wrobel), jezewski@itam.zabrze.pl (J. Jezewski), tomekk@itam.zabrze.pl (T. Kupka), dawid.roj@itam.zabrze.pl (D. Roj), michal.jezewski@polsl.pl (M. Jezewski).
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**Fig. 1 – Computer screen from a fetal monitoring system with cardiotocographic trace comprising two signals: Fetal Heart Rate – FHR (upper) and Uterine Contractions – UC (lower). Graphical marker of detected uterine contraction is formed by horizontal line corresponding to contraction duration, and vertical one indicating its peak.**

uterine contraction activity enables to control the progress of labor [20,21]. Thus automated detection of contractions is to be an integral part of the signal analysis implemented in computer-aided fetal surveillance system [22,23]. What is more, automated method is able to provide detailed description of contractions which comprises: the onset time, duration, amplitude and area under tocogram waveform [24]. In this paper we compared four automated methods for UC analysis in relation to the reference information provided by the human experts. Three of the algorithms we were developed in different stages of our studies on automated analysis of fetal and maternal biophysical signals. The fourth method for detection of contractions in UC signal was proposed in [25]. It was chosen for this study mainly due to a different approach which relies on analysis of derivative of UC signal. In turn, our methods are based on analysis of the frequency distribution of the UC values within the window of established width to obtain the signal level estimating the resting strength of uterine muscle.

## 2. Material and methods

Research material comprised 180 intrapartum cardiotocographic recordings from 180 patients obtained from the archives of fetal monitoring system within the 50 days period of using the system in Obstetrics Hospital of Silesian Medical University in Katowice, Poland. There were no personal data in the signals files, only the samples of the acquired signals: fetal heart rate and uterine contraction activity (UC), which constitute the cardiotocographic recording (Fig. 1). Minimum duration was 22 min, whereas the maximum one was limited to 40 min. That limit was established on the one hand by the time the experts have to spend on analysis of a certain trace, and on the other hand by our assumption that the material should comprise rather shorter signals but of different characteristics. Total duration of all recordings was 6110 min, whereas the average duration of recording was $33.9 \pm 6.7$ min. In the fetal monitoring system the signals of both the fetal heart rate and the mechanical uterine activity are stored just as they are provided to the system by a bedside monitor via its digital output. The sampling frequency is 4 Hz, and the UC sample values are expressed in arbitrary units in the range of 0–100 with resolution of 0.5.

### 2.1. *Algorithms based on frequency distribution of UC values*

The contractile activity is represented by an increase of the contraction wave above the so-called the basal tone (BT), which refers to resting strength exerted on strain-gauge transducer by uterine muscle when the contractile activity does not occur. During monitoring the basal tone varies, usually from 0 to 20 units [26]. When patient's monitoring starts, it is important to set the zero level of the basal tone when the fetal monitor is measuring none contractile activity episode [27].

In all three methods developed by us an estimation of the basal tone is essential step for automated detection of contractile patterns in UC signal (Fig. 2). In general, these algorithms are based on analysis of the frequency distribution of the UC values within the window of established width to obtain the basal tone values. After estimating the BT the next step is to set the detection level (DL) at constant value of 10 units above BT that enables to recognize candidate patterns every time the UC signal crosses this level. Finally, the candidate pattern is validated as contraction when both its amplitude $A$ and duration $T$ exceed the established minimum values: $A_{min}$ and $T_{min}$. All detected contractions are described by the onset time, duration, amplitude and the time when the maximum amplitude occurs – peak time. In the fetal monitoring system these contraction parameters are listed on request of clinician who evaluates the CTG recording.



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