Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–10, 2015
Copyright © 2015 World Federation for Ultrasound in Medicine & Biology
Printed in the USA. All rights reserved
0301-5629/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.ultrasmedbio.2015.07.026

● *Original Contribution*

MULTIDIMENSIONAL ULTRASOUND DOPPLER SIGNAL ANALYSIS FOR FETAL ACTIVITY MONITORING

SOPHIE RIBES,* JEAN-MARC GIRAULT,† FRANCK PERROTIN,‡ and DENIS KOUAMÉ*

*University of Toulouse III, IRIT UMR CNRS 5505, Toulouse, France; †University of Tours, INSERM U930 Tours, France; and ‡CHU Bretonneau, Tours, service de Gynecologie Obstétrique, INSERM U930, Tours, France

(*Received* 29 *July* 2014; *revised* 22 *July* 2015; *in final form* 27 *July* 2015)

Abstract—Fetal activity parameters such as movements, heart rate and the related parameters are essential indicators of fetal wellbeing, and no device provides simultaneous access to and sufficient estimation of all of these parameters to evaluate fetal health. This work was aimed at collecting these parameters to automatically separate healthy from compromised fetuses. To achieve this goal, we first developed a multi-sensor–multi-gate Doppler system. Then we recorded multidimensional Doppler signals and estimated the fetal activity parameters via dedicated signal processing techniques. Finally, we combined these parameters into four sets of parameters (or four hyperparameters) to determine the set of parameters that is able to separate healthy from other fetuses. To validate our system, a data set consisting of two groups of fetal signals (normal and compromised) was established and provided by physicians. From the estimated parameters, an instantaneous Manning-like score, referred to as the ultrasonic score, was calculated and was used together with movements, heart rate and the associated parameters in a classification process employing the support vector machine method. We investigated the influence of the sets of parameters and evaluated the performance of the support vector machine using the computation of sensibility, specificity, percentage of support vectors and total classification error. The sensitivity of the four sets ranged from 79% to 100%. Specificity was 100% for all sets. The total classification error ranged from 0% to 20%. The percentage of support vectors ranged from 33% to 49%. Overall, the best results were obtained with the set of parameters consisting of fetal movement, short-term variability, long-term variability, deceleration and ultrasound score. The sensitivity, specificity, percentage of support vectors and total classification error of this set were respectively 100%, 100%, 35% and 0%. This indicated our ability to separate the data into two sets (normal fetuses and pathologic fetuses), and the results highlight the excellent match with the clinical classification performed by the physicians. This work indicates the feasibility of detecting compromised fetuses and also represents an interesting method of close fetal monitoring during the entire pregnancy. (E-mail: kouame@irit.fr) **© 2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Fetal monitoring, Fetal heart rhythm, Fetal movement, Multidimensional signals, Support vector machine.**

INTRODUCTION

Fetal monitoring may be required at different times during pregnancy to closely monitor certain fetal and maternal disorders (Manning et al. 1980). Existing methods, which consist of asking women to count the number of fetal movements, performing a biophysical profile or Manning's test (Manning et al. 1980) or analyzing general movements, may be either subjective or time consuming. To automatically monitor fetal activity, the most commonly used system is the cardiotocogram. This device measures fetal heart rate (FHR) and uterine contractions (Royal College of Obstetricians and Gynecologists [RCOG] 2001) but does not provide any information regarding fetal movements. This may explain why the performances of major classifiers, which are based on FHR variability analysis alone (through different kind of entropies), are on the order of 80% for specificity and 80% for sensitivity (Ferrario et al. 2006). We believe that additional information may improve classification performance. There are many dedicated ultrasound systems that collect additional information such as fetal movement and pseudo-breathing. Unfortunately, these systems provide only partially automated detection of fetal movement (Karlsonn et al. 2000a) or breathing (Karlsonn et al. 2000b; Yamakoshi et al. 1996).

Address correspondence to: Denis Kouamé, 118 rte de Narbonne, F31062 Toulouse, France. E-mail: kouame@irit.fr

ARTICLE IN PRESS

Some preliminary attempts to overcome these limitations were made by Kribèche et al. (2007). The main characteristic of their system is that, because of the large number of sensors needed to cover an explored area as large as possible, a large number of Doppler signals have to be processed. The aim of our work was not to develop new signal processing methods and evaluate their performance. Instead, we sought to efficiently combine some relevant existing signal processing techniques to achieve the following goals: extract fetal activity features, such as FHR and movements (and related features), and efficiently collect these features to differentiate between normal and potentially compromised fetuses. To achieve these goals, we needed first to reduce the inherent redundancy related to the large number of acquired Doppler signals and then to separate fetal from maternal signals through a blind source separation. The detailed signal processing algorithms used to extract the fetal activity parameters are not detailed here. The reader is referred to, for example, Rouvre et al. (2005), Voicu (2011) and Voicu et al. (2010, 2014). However, even if the number of relevant data can be reduced, a fusion step is required to provide the physical with global information, for example, an "ultrasound score," on which a decision can be based.

Thus, the main challenge of this study, and its incremental value with respect to the previously published article (Kribèche et al. 2007), was to develop a method that enables extraction of the relevant information necessary to construct a global indicator sufficiently pertinent to classify fetuses into normal and potentially compromised groups. To validate the feasibility, this method was successfully tested on a heterogeneous data set obtained from pregnant women and composed of FHR, movement and pseudo-breathing signals. To our knowledge, this automated classification is a new and important contribution to the search for an objective method for monitoring fetal activity, which remains an open issue (Grivell et al. 2010; Kaluzynskia et al. 2011).

This article is arranged as follows: We first described the device produced by an industrial collaboration and used for this study, and then briefly introduce the signal processing techniques used. The ultrasound score is then introduced and investigated using fetal activity parameters obtained from real fetal Doppler signals. Finally, results from classification of sets of fetuses are discussed.

MATERIALS AND METHODS

Materials

We constructed, in collaboration with Althais Technologies (Tours, France), a multi-sensor Doppler system (Surfoetus) that was able to monitor most parts of the fetal body. Although a complete description of the development of this device is beyond the scope of this article, we briefly provide here a brief description. The system consists of 12 ultrasound (US) sensors, each with five gates, working at a frequency of $f_0 = 2$ MHz and an electronic US device (three electronic pulsed Doppler boards and one data acquisition board). A low-noise amplifier amplifies the received signal; a deep compensated amplifier then balances the strong attenuation of the deepest gates. After complex demodulation and filtering, the Doppler components are sampled sequentially and converted. Sampling frequency, denoted F_e, is 1 kHz. Five adjustable gates ranging from 2 to 14 cm are used to explore the depths. These 12 sensors are divided into three groups of four sensors, as illustrated in Figure 1. Group A (US sensors 1–4) is used to explore the fetal thorax, investigating FHR and breathing movements; group B (sensors 5–8) the upper limbs; and group C (sensors 9–12) the lower limbs. Each sensor is a circular piezoelectric element 12 mm in diameter. The ultrasound beam was not focused. A belt was used during recording to maintain all three groups.

Protocol

In this study, 44 pregnant women at a gestational age >24 weeks were prospectively enrolled. Inclusion criteria were singleton pregnancy, absence of significant maternal complications requiring premature delivery (hypertensive disorders; renal, heart or immunologic pathology; pre-existing diabetes), willingness to have pregnancy followed or delivered locally, maternal age >18 years and health insurance affiliation. Exclusion criteria were fetal malformation, maternal significant complications, pregnancy care in another center and concomitant participation in another research protocol. This study was approved by the University's ethics committee (Clinical Investigation Centre, Innovation

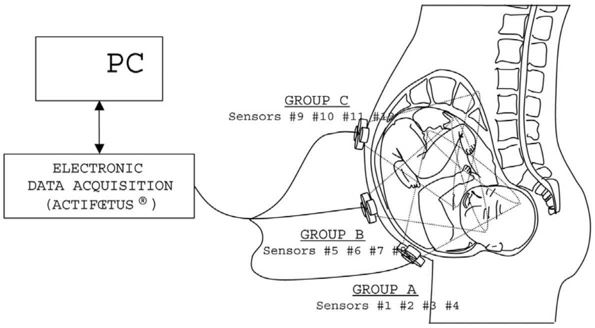

Fig. 1. Sensor group arrangement. Group A (sensors 1–4) explores the fetal thorax, investigating fetal heart rate and breathing movements. Group B (sensors 5–8) explores the upper limbs, and group C (sensors 9–12), the lower limbs. A belt is used during recording to prevent sensor movement.

Download English Version:

https://daneshyari.com/en/article/10691307

Download Persian Version:

https://daneshyari.com/article/10691307

Daneshyari.com