Automatic fundamental frequency characterization of premature newborns' cries in Neonatal Intensive Care Unit

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Introduction

Newborn cries have been widely studied in the literature and have been proven to be relevant for the detection of pathologies and for the assessment of the neurobehavioral development [1]. However, to date, solutions to automatize this analysis in care routine remain to be proposed. The European project Digi-NewB aims to address this point by developing a new generation of monitoring system in Neonatal Intensive Care Unit (NICU), that will combine signals from different sources, including electro-physiological, video and audio data.

This work deals with sound aspects and has for first objective to automatically extract and characterize newborn cries in long recordings and in a noisy acoustic environment (e.g., adult voices, alarms). A focus is made on the automatic estimation of the fundamental frequency and its evolution along a cry (also called melody), using an image processing method applied to the spectrogram.

Methods

The developed automatic processing chain is schematized in Figure 1 and is divided into six main steps that are described hereafter:

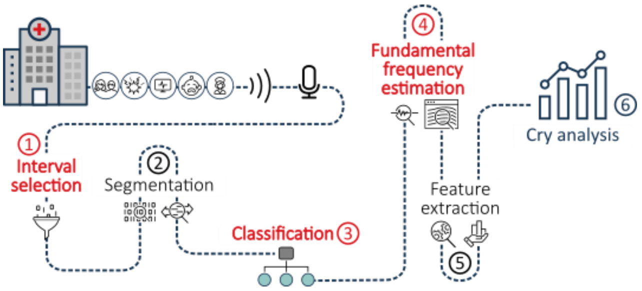

Figure 1: Diagram of the overall processing chain of the study. The steps in red represent the contributions made by our team.

1. Selection of intervals of interest to analyze only recordings where newborns cry. This step is based on the energy level of the soundtracks.
2. Extraction of all sound events from the recordings by a short-term energy thresholding described by [2].
3. Separation of cry segments and noisy ones using a classification model (KNN) [3].
4. Detection and tracking of the fundamental frequency using an image processing method applied to the spectrogram.
5. Extraction of the most suitable temporal and frequential features (e.g., duration, fundamental frequency, melody).
6. Analysis of the cry characteristics.

This contribution focuses on the estimation of the fundamental frequency and its evolution over time. According to the literature, this estimation is usually done in a fixed and manually chosen frequency band, that implies two types of limitations: i) the poor estimation of hyperphonic cries (whose fundamental frequency is higher); ii) the possible jumps in the fundamental frequency estimation when high-energy formants are included in the study frequency band.

The method developed here is based on:

1. Computation of the spectrogram of a cry;
2. Automatic detection of the frequency sub-band containing the fundamental frequency;
3. Detection of all the contours present in this band;
4. Selection of the longest contour as the main component of the melody of the cry.

Results and Discussion

From the first three steps of the processing chain, a total of 5016 segments were automatically extracted from 18 newborns and 240 hours of recordings. Figure 2 shows the results of the frequency estimation method applied on two different types of cries. It can be observed that the melody is well tracked by the algorithm in both cases.

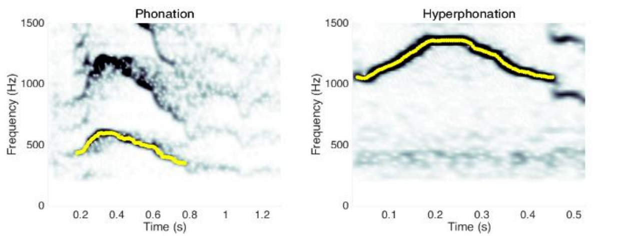

Figure 2: Fundamental frequency estimation for two type of cries: a phonation cry (left) and an hyperphonation cry (right).

This method will now allow an automatic and accurate characterization of the cries. To this end, we will process the thousands of cries that were extracted in order to identify the most relevant features for the evaluation of the neurobehavioral development of premature newborns.

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