A NEW TOOL FOR AUDIO AND VIDEO ANALYSIS: AN AID TO CONTACT-LESS CLINICAL DIAGNOSIS IN NEWBORNS

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Abstract: **Recently, and especially in newborn infants, traditional techniques for diagnosis and assessment of neurological disorders are complemented by contactless methods based on the assessment of parameters obtained both from automatic and perceptual analysis of audio and/or video recordings that result in semi-quantitative evaluation of the patient's status. This paper presents a software tool conceived for helping clinicians in the perceptual analysis of neurological impairments in newborn based on audio and video recordings. The system is also provided with devoted software for automatic objective analysis of newborn cry signals.**

Keywords: **Perceptual analysis, newborn cry, general movements, computer aided diagnosis, objective voice analysis.**

I. INTRODUCTION

Recently, and especially in newborn infants, traditional techniques for diagnosis and assessment of neurological disorders are complemented by contact-less methods based on the assessment of parameters obtained both from automatic and perceptual analysis of audio and/or video recordings that result in semi-quantitative evaluation of the patient's status.

Contact-less techniques provide advantages in terms of comfort and safety of the patient with respect to sensor-based/invasive methods, but the amount of recorded data is often prohibitive and highly time consuming for perceptual analysis even for trained and qualified clinicians, as it must be performed in accordance with strict protocols. Moreover, devices and software tools commonly used by clinicians are heterogeneous and not specifically designed for clinical use that is clinicians use different hardware and software tools to manage patient data, record and process audio and video signals to obtain parameters of interest.

To the authors' knowledge, to date there is no software tool that integrates in one system all the components required to successfully perform this kind of analysis.

This paper presents a new tool that addresses this need, particularly critical in neonatal neurology. It allows managing patient data and recordings, processing and analyzing audio and video signals, thus providing an aid to perceptual analysis for contact-less early diagnosis of neurological impairments such as cerebral palsy or autism spectrum disorders in newborns.

In particular, autism spectrum disorders (ASDs) are complex disorders of brain development. In most cases ASDs symptoms appear in the first year of life, when it is not yet possible to carry out a reliable diagnosis. This is because diagnostic tests for ASD are mainly based on the identification of behavioural symptoms that are more evident and recognizable after the 24th month of life. Therefore new approaches are needed and searched for early diagnosis to provide more effective support from caregivers.

Recent studies support the hypothesis of a strict relationship between autism and cry [1] [2], but at present no reliable method for a fully automated analysis is available. Crying is the first and primary method of communication among humans: parents are often able to distinguish a painful cry from a hunger or sleepy one. Thus, acoustic analysis of newborn cry is of relevance to identify parameters that can be indicators of neurological pathologies, such as fundamental frequency (F0), intensity, vocal tract resonance frequencies, length and shape (melody) of cry episodes, and has gained great scientific interest in the last years. [3], [4]. Moreover, motor disorders such as hypotonia, motor apraxia and dyspraxia are main symptoms of neurological disorders and of autism [5], therefore great interest is paid to newborn spontaneous (i.e. not induced or stimulated) movements, named general movements (GMs).

GMs are a set of foetal and newborn spontaneous movements that occur from the 10th week of postmenstrual age to about the 6th month of gestational age. GMs are assessed by expert clinicians that visually analyze and score their variety and complexity. In high risk subjects (i.e. newborns with possible brain dysfunctions or siblings of an already diagnosed autistic child), deficiency in this qualities or almost complete lack of movements is related to a possible neurological
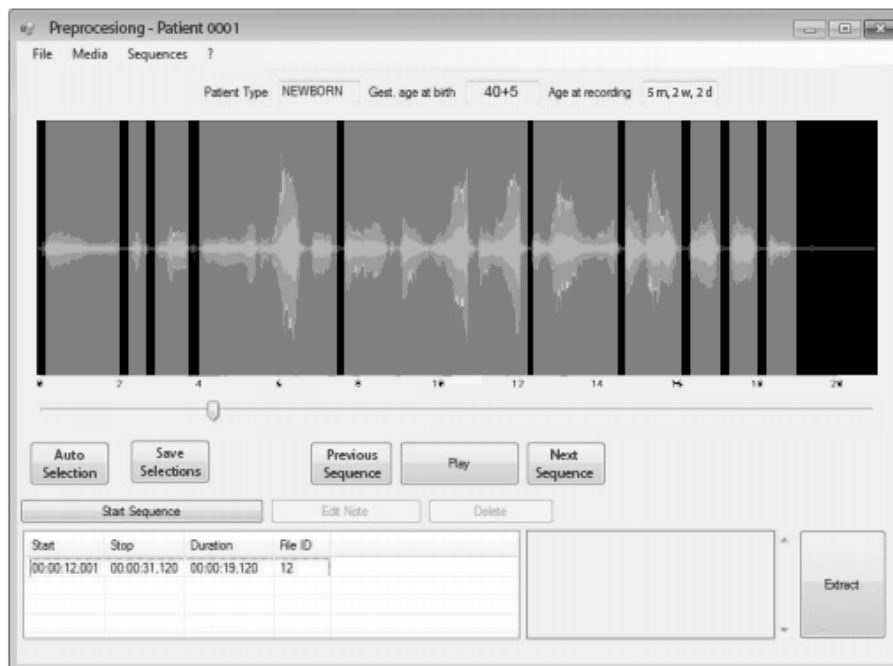
Fig. 1 First window of the tool for audio signal pre-processing. The voiced part of the signal are detected by the implemented algorithm and then merged for further elaboration.

impairment such as cerebral palsy [6], [7] and autism spectrum disorder [8]. As both cry and the GMs are influenced by neurological impairments, they have become the subject of growing clinical interest as early, non-invasive and low cost diagnostic methods.

II. METHODS

Besides becoming a computer-aided diagnosis tool, the software here proposed was developed with the aim of guiding the clinician throughout the process of contactless assessment and diagnosis with the aid of a user-friendly environment.

The software is organized into two main interfaces: the first one, where the signal is pre-processed for the extraction of frames of clinical interest and the second one where the signal is processed to obtain the parameters. This module allows handling both audio and video signals.

The first interface is designed for managing both kinds of signal such as playing the signal, inserting text notes in relation to a particular event and adding reference markers (e.g. point out a relevant event). The selection and extraction of relevant signal segments is simply made by selecting their starting and ending points: the software automatically merges into a single file all the selected segments one after the other. This option is particularly useful in the assessment of GMs from video recordings as

prescribed in the protocol [7], and it is essential in the elaboration of audio signals. Fig.1 shows the first interface for an audio signal.

As concerns audio recordings, a unique feature of the new tool is the possibility to automatically select the voiced parts only. This is performed by implementing a newly developed robust algorithm [5].

The second window allows for parameter extraction from the signal's frames selected in the first window. For audio signal, the software performs newborn cry analysis by the estimation of acoustic parameters such as fundamental frequency (F0), the first three resonance frequencies of the vocal tract (F1, F2 and F3), the power spectral density (PSD) and the spectrogram [9].

F0 is estimated by means of a two-step procedure that was shown to outperform other methods thanks to the adaptive procedure implemented for the local definition of the length of each signal frame on which the acoustic parameters are estimated: the higher the F0 the shorter the length of the window. In this way the high variability of this kind of signal, that is typically non-stationary, is taken into account. Estimation of vocal tract resonances is carried out by finding maxima in the PSD obtained by means of a parametric approach [9] [10] (Fig. 2).

For video signal the system offers a movements' analysis tool that allows clinicians to perform a semi-automatic analysis of patient's movements from recorded video clips.
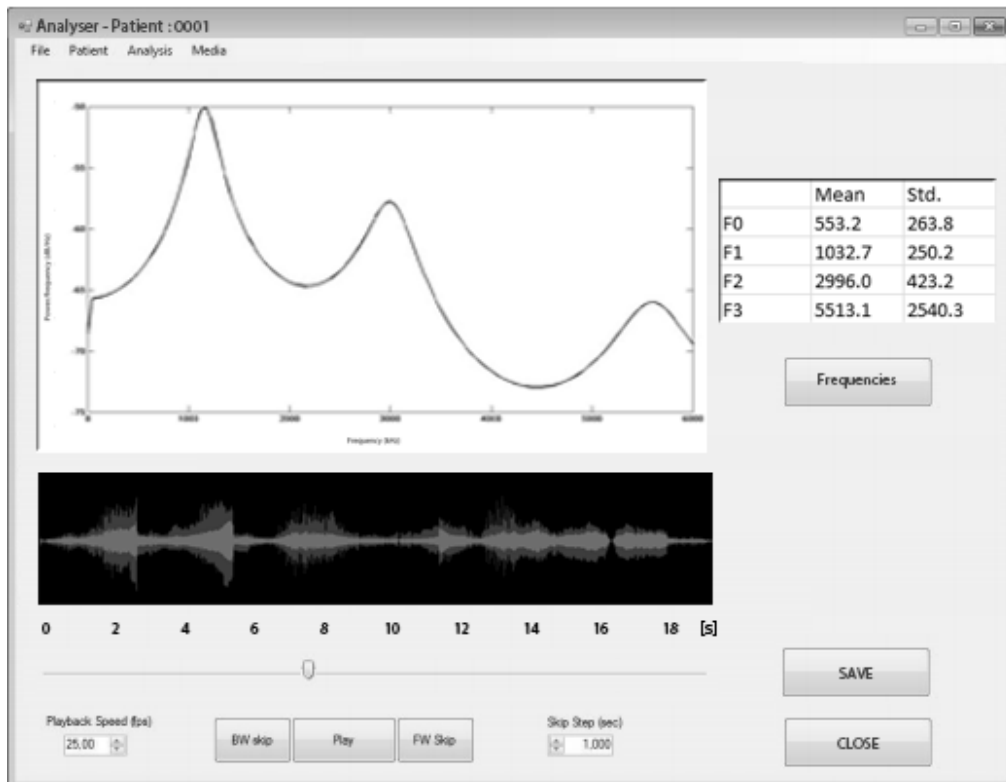
Fig. 2 Second window of the tool for audio signals analysis. The window shows the PSD, F0 and resonance frequencies F1 and F2 (mean and standard deviation) of the cry episode displayed in the lower plot.
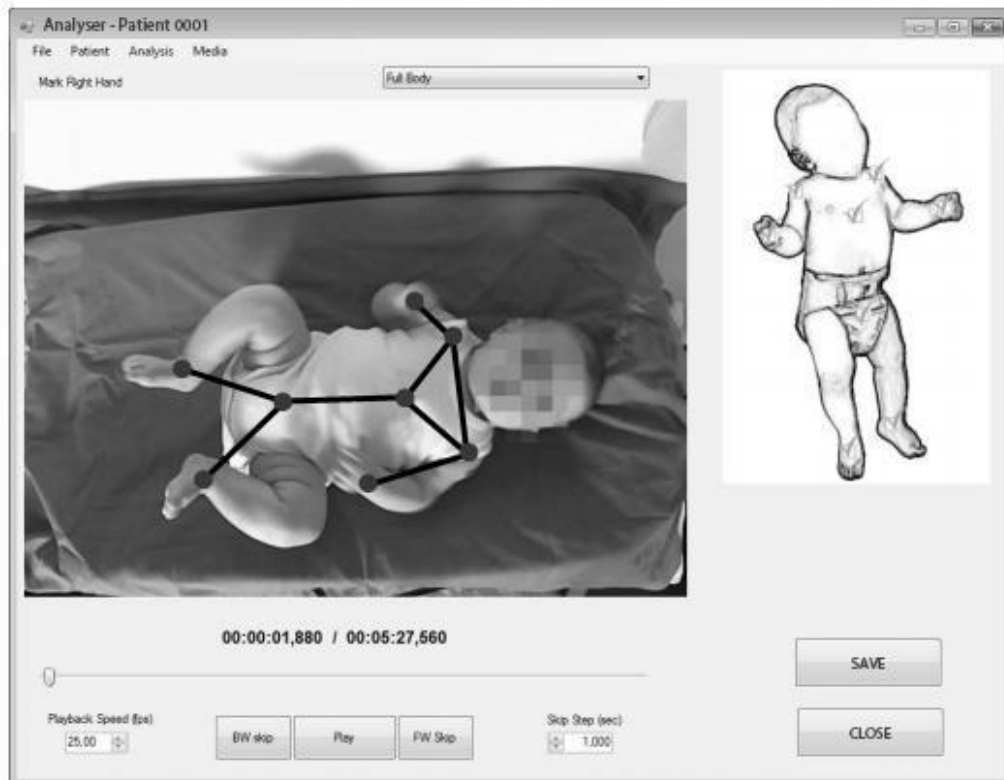

Fig. 3 Second window of the tool for video signals analysis. The body model on the right hand of the window guides the user to the choice of the points of interest to be tracked.

Tracking of movements of a specific section of the body is achieved by manually selecting the points of interest on a video frame with the aid of a body model. The system collects x and y coordinates values of each point on the image plane and saves it on a .csv file that can be handled with any software such as Matlab or Excel to extract and track movements' features, such as speed and acceleration (Fig.3).

III. RESULTS AND CONCLUSIONS

To our knowledge the software here described is the first tool that allows for analyzing both cry and general movements in newborn infants within a single framework.

At present few systems are available for cry recording and analysis, in particular for the study of F0 [11] [12] [13], but no tool exists for the analysis of GMs. As recent studies [14] highlight the possibility of identifying some typical signs of autism in the first year of life from joint audio and video analysis, this tool could give a significant support to early diagnosis of this disorder.

In addition to providing an appreciable decrease in investigation time, costs and manual errors, the tool is a first step towards the growing clinical interest for marker-less monitoring and diagnosis.

The whole system is under further development to include additional options and features. It will undergo testing in the clinical centers as well as a specific assessment according to ISO standards for the design of tools for medical use with human applications.

With few modifications the proposed tool could be used for the screening of a wide range of peri- and post-natal pathologies and could also be adapted for home care monitoring.

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