Database and system design for data collection of crying related to infant's needs and diseases

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***Abstract*— In this paper we have focused on designing and collecting an infant crying database. The data have been collected using an in-house developed acquisition system. The study has involved 136 infants aged between 0 and 3 months. Seven types of cries have been collected: hunger, pain, eructation, tiredness, discomfort, colic and pathology. Some of the data (about 750 audio/video recordings meaning about 13000 cries) have been collected from the maternity of the "Sf. Pantelimon" Emergency Hospital and the other part (over 340 audio/video recordings meaning about 5100 cries) have been collected at newborns' home. All the data have been labeled by neonatal experts. This infant crying database will be used to develop new methods for infant cry recognition.**

Keywords*— *database; infant crying; data collection; cry types

I. INTRODUCTION

For an infant, crying is the main form of communication with the external environment. By crying, he/she sends many physical and mental sensations, most often misunderstood at the beginning by his/her mother or entourage.

The intensive research in the area of neonatology highlights the importance of parents distinguishing their newborns' needs and moods. The consistent recognition of the newborn's needs ensures proper care, adequate nutrition, increased quality of sleep and improved interaction between parents and infants. Another important issue is the promptness of the parents' response, which leads to an optimal physical and mental development. The prolonged crying is also stressful for parents, especially in the first few months of the infants' life, when they get accustomed. The automatic interpretation thus benefits the whole family.

Since the early 1960s, computer scientists have been interested in the connection between the infant's cry characteristics and various diseases or needs [1]. The first studies have involved the recording of infant cry for human analysis in time and/or frequency, mostly by means of spectroscopy or sonogram. Many researchers have established evaluation methods by matching certain visual or frequency patterns of the cry to different diseases and/or needs. None of these evaluations has been accepted as standard.

The need for an objective evaluation has generated the interest in developing automatic classification methods of the infant's cry.

The development of automated methods for classifying infant crying demands a more accurate labeled cry database.

In [2] researchers have used tape-recorders for cries acquisition (SONY CFS 210) with a microphone (Philips SBC-3040) held about 17 cm far from the newborn's mouth. 12 seconds long recordings have been acquired from a group of healthy newborns (normal births / cesarean section) and from a group of newborns with pathologies (Hypoxia, Hypoxia with aggravating factors, CIUR (Intra-uterine Growth Delay), Hyperbilirubinemia). In [3] cries have been acquired from 200 healthy newborns (control subjects) and 20 newborns at high risk of autism. The acquisition system has been designed for being used in the subject's home. The system includes a high speed USB video camera connected to a laptop, an external audio acquisition device and a professional microphone (Shure SM58). In [4], cries have been acquired from 69 babies to term (of which 38 healthy, the rest with various diseases) and 67 preterm (of which 25 healthy, the rest with various diseases) using a 2-channel recorder with 44.1 kHz sampling rate.

In [5] there have been recorded a total of 87 infant cries classified as normal infant cries, pathological infant cries, preterm infant cries and high risk babies (infants with a history of siblings' death, thalassemia, neurosis and Down Syndrome. A portable recorder (Zoom H4n) was used for data collection. The recorder was kept at a distance of 5-6 cm. The infant was sitting in his/her mothers' lap. In [6] study data have been collected from 316 infants (293 with normal hearing and 23 with hearing impaired). Most of the recordings have been made in hospitals (in Hungary) and the rest of them at home. The duration of the recordings was 25 – 30 seconds in the hospitals and 60 – 80 seconds at home. The cries have been collected during examination of the eardrum using devices like: minidisk recorder (SONY MZ-R55), digital video camera (SONY DCRTRV25), digital dictaphone (SONY ICD-P28) and a PC sound card with several microphones (SONY ECMMS907, AKG D55S) attached.

In [7] emissions of 111 health term newborns have been recorded using a Sony minidisk (MZ HN7000) and an external microphone AIWA (DM H15). Barry M. Lester et al. in [8] have recorded cries from 1388 infants (658 exposed to different drugs and 730 in the comparison group) using A Marantz PMD201 cassette recorder and Radio Shack Dynamic Unidirectional Microphone. The infant was placed in the

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isolette and maintained in a non-crying state for 30 seconds before the cry was elicited.

This research aims to design a database and a system for data collection of crying related to infant's needs and diseases and its purpose, in the long term, is the development of new methods of newborn language recognition.

This paper will describe the crying acquisition process, the data labeling process, the acquisition system overall architecture, the corpus design and statistics and some aspects of how the data have been prepared for further analysis.

II. ETHICAL ISSUES

Data acquisition has been carried out by a procedure previously approved by the Ethics Committee of the "Sf. Pantelimon" Emergency Hospital. The following types of cries have been taken into consideration: hunger, pain, eructation, tiredness, discomfort, colic in newborns and infants aged up to 3 months. In addition, it tried the acquisition of cries associated to various pathologies, in order to differentiate a normal cry from one associated to pathology.

All study participants have given their written consent and have been informed about the activity of cries acquisition from the newborns. They have been offered 3 types of acquisition to choose from: in the maternity hospital, at home, or in both places.

The pain cry has been recorded while administrating certain well-established treatments, normally carried out every day and about the same time. In the maternity hospital, there were 3 ways the pain was provoked: during hepatitis and tuberculosis immunizations and while collecting blood by capillary puncture during metabolic testing. There was also a fourth way, through venous puncture during blood drawing.

III. DATA COLLECTION SETUP

A. Data collection

The crying acquisition has been performed in the maternity of the "Sf. Pantelimon" Emergency Hospital and at newborns' home.

In the maternity, seven work stations have been installed, one in each rooming-in, and one in the intensive care unit. Each rooming-in had 3 cribs for the newborns and 3 beds for the mothers.

A workstation was composed of a unidirectional microphone iRig Mic [9] mounted on a tripod at a distance of about 20 cm from the newborn's mouth and it was connected to a Samsung Galaxy S4 Mini smartphone, using a jack. The microphone was in the range frequency response of 100 Hz - 15kHz.

For crying recording at home, a dedicated application (CryingPicker) has been installed on the parent's mobile phone. If the parent did not have an Android phone, we chose to record the crying using the phone's standard software for video recording.

Parents had to make two acquisitions for each state, every two weeks until the age of 3 months of the baby.

Fig. 1. Workstation for crying acquisition in the maternity

A recording is represented by a video shooting with an average duration between 30 seconds (in the case of home data acquisition) and 50 seconds (in the case of data acquisition in the maternity) and it contains several cries.

B. Data labeling

Data labeling has been performed in two ways:

In the hospital, data were labeled immediately after the collection (online) by the following scenario: the doctor records the newborn's crying using the dedicated application (CryingPicker), he comforts the need that he thinks the newborn has (validation of need consists of comforting the newborn), labels the recording, then sends the metadata to the server.

The recordings made by parents at home were labeled afterwards (offline) by a team of doctors, based on the recordings, but also on a daily journal filled in by the mother on each day that they made recordings. The journal contains the following pieces of information necessary for doctors to label offline:

- subject id
- meal time
- sleep time and duration
- diaper change time
- type of meal (formula / breastfeeding)
- recording time / clinical observations / recording name / parent's guess about the newborn's need

C. Data acquisition system

The newborn cry related data acquisition system has multiple acquisition nodes and a central collecting point (server) as shown in Fig. 2.

The main purpose of the nodes is audio-video acquisition related to infant's cries, hand labeling guidance by doctors or parents and data sending to the central collecting point; acquisition nodes (dedicated application CryingPicker) have been installed on Android smartphones.

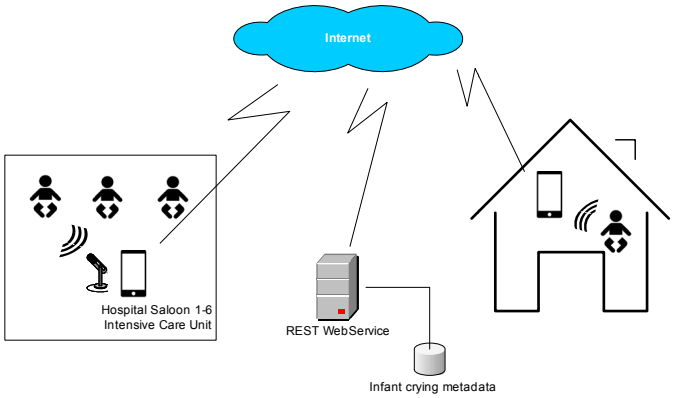

Fig. 2. The crying acquisition system overall architecture

The way of using CryingPicker application is the following (a screenshot is presented in Fig. 3):

- the operator (doctor or parent) launches the application on his/her smartphone and logs in with ID and password (only the first time)
- the operator taps on the Start acquisition button
- after the acquisition process is finished, the operator selects the need related to the crying recorded and sends the recording metadata to the server

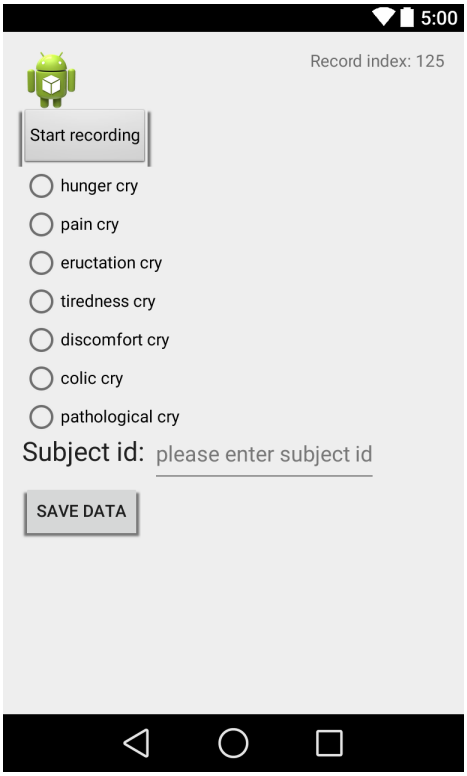

Fig. 3. The main screen of the CryingPicker mobile application

The central collecting point includes a MySQL [12] database and a REST (Representational State Transfer) service which updates the database with information received from the acquisition nodes and allows various other operations on the metadata related to the newborn or infant cries. The MySQL database in shown in Fig. 4.

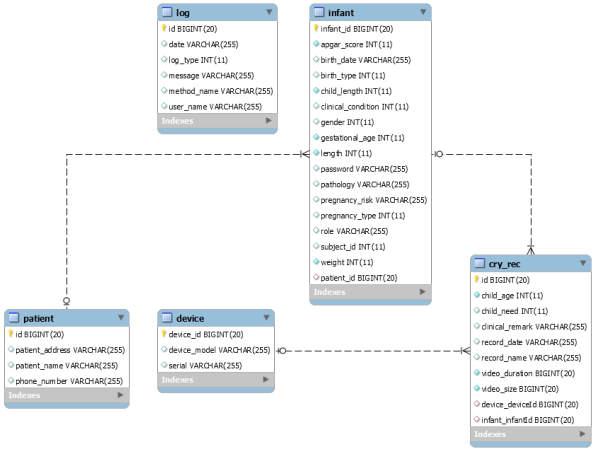

Fig. 4. Database diagram

Full sized videos recorded in the maternity have been periodically transferred from smartphones to an external storage device. This option has been chosen because of the large volume of data.

Two data transfer options have been considered in case of recordings taken at newborn's home: moving to the newborn's domicile or data transfer using a cloud-storage service.

D. Corpus design

The collected cries have been classified as:

- hunger
- pain
- eructation
- tiredness
- discomfort
- colic
- pathological infant cries: cries from all newborns and infants under 3 months, with various pathologies: respiratory, neurological, heart, digestive, infectious, genetic syndromes etc.

The first six categories are considered normal infant cries from the healthy newborns and infants (preterm or term) under the age of 3 months.

Various pieces of information have been stored in the database in order to characterize each subject, in particular on birth parameters. These pieces of data have been entered only once during subject registration:

- subject ID (database unique id)
- gender
- date of birth
- Apgar score [10]

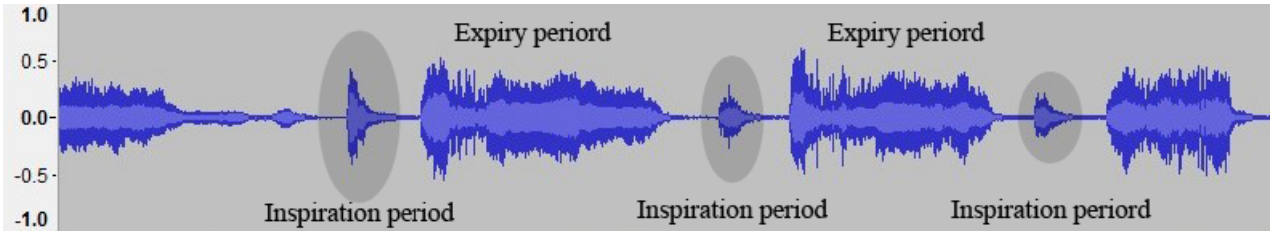

Fig. 5. Time representation of infants cries using the Audacity application [11]

- weight at birth
- length
- gestational age (number of weeks)
- clinical condition (healthy or ill)
- pathology (specified for a newborn with a disease)
- how birth took place (spontaneous or cesarean section)
- newborn's rank (first child, second child, third child etc)
- single or multiple pregnancy
- pregnancy risk

The following pieces of information have been stored for each cry recording:

- newborn's need (hunger, pain, eructation, tiredness, discomfort, colic or pathology) related to his/her cry
- the subject's age (0-3 months)
- the time of cries acquisition
- recording location (maternity or home)
- recording date

E. *Data collection tracking*

Periodical reports have been generated to monitor the acquisition process (to 2-3 days) showing the following:

- the number of recordings per need
- the number of recordings per need per subject id
- the number of recordings per subject id (overall)
- the number of recordings per subject id (in the last week)
- the number of recordings per smartphone (in the last week)

These indicators were regularly sent to the medical team that collected the cries in the maternity. It was also required to optimize the number of maternity visits made by the technical team to transfer the crying recordings.

F. *Data preparation for analysis*

The data have been collected as video recordings (MP4 files) with an average duration of 50 seconds in maternity and 30 seconds at infant's home. An audio component has been extracted from each video recording and has been segmented to extract more cry units. A cry unit has been defined as the vocal output occurring on a single expiration (between two inspirations). The sounds on inspiration periods has been marked in gray as shown in Fig. 5.

The segmentation has been performed in two stages: first, the Sound Finder option was used from the Audacity [11] application for a coarse segmentation; in the second stage each segment previously identified was visually inspected and listened to by a human operator in order to apply any corrections.

The data segmentation is in progress.

IV. CORPUS STATISTICS AND DISCUSSIONS

A. *Group Statistics*

In the acquisition process 136 newborns and infants up to 3 months have attended. Of these, 72 are boys and 64 girls. In Fig. 6, Fig. 7 and Fig. 8 statistics on the group of newborns involved in the study are shown.

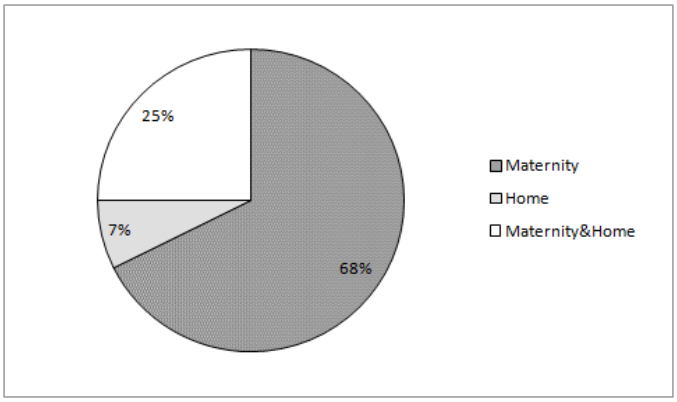

Fig. 6. Distribution of parents who agreed to participate in the study in maternity, at home or in both places

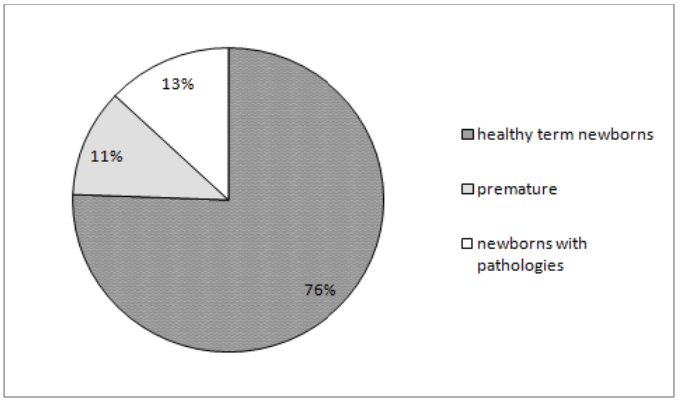

Fig. 7. Distribution of healthy term newborns, premature and those with pathologies

The group of healthy term newborns has the following characteristics:

- the gestational age is over 37 weeks
- the newborn has no clinical signs of disease
- the Apgar score [10] is greater of equal to 8

The premature group consists of newborns with gestational age between 34 and 37 weeks and with no clinical signs of disease, while the group of newborns with diseases covers all the pathologies regardless the gestational age or weight.

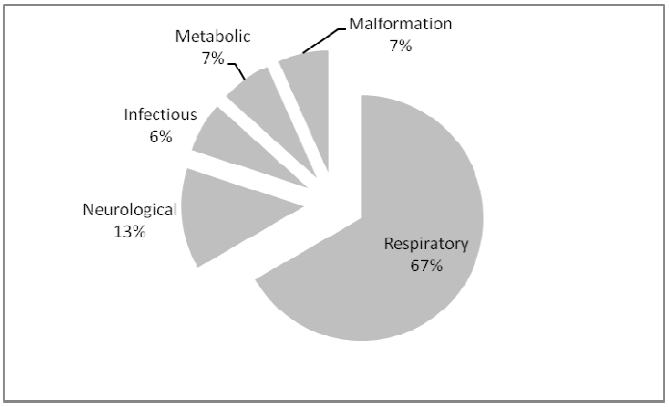

Fig. 8. Distribution of the newborns with pathologies by type of disease

B. Recording statistics

The statistics below refer to the maternity recordings.

TABLE I. DISTRIBUTION OF MATERNITY CRY RECORDINGS OVER CRY TYPE AND AGE

	Number of recordings				
Need	***<= 3 days***	***3 days - 7 days***	***7 days - 30 days***	***31 days - 60 days***	***61 days - 90 days***
Hunger	220	42	29	12	2
Pain	214	24	7	4	3
Eructation	12	5	1	1	0
Tiredness	0	0	0	0	0
Discomfort	113	15	9	5	0
Colics	1	5	2	0	0
Pathology	27	5	4	0	0

TABLE II. DISTRIBUTION OF MATERNITY CRY RECORDINGS OVER CRY TYPE AND GENDER

	Gender	
Need	***Male***	***Female***
Hunger	157	148
Pain	127	126
Eructation	10	9
Tiredness	0	0
Discomfort	83	60
Colics	4	4
Pathology	23	13

The statistics below refer to recordings at home (still in progress).

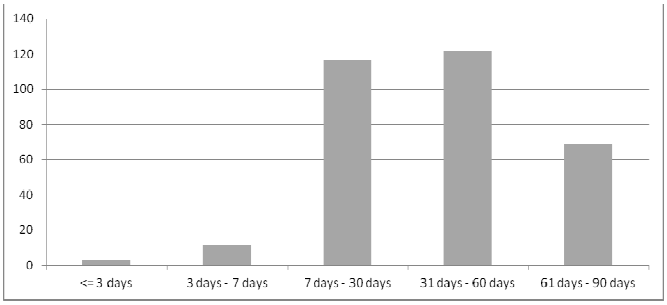

Fig. 9. Distribution of home cry recordings over age

TABLE III. DISTRIBUTION OF HOME CRY RECORDING OVER AGE

	Gender	
	Male	***Female***
Number of recordings	173	167

C. Experiences during data collection

- Cries recording in the maternity hospital generated issues in general when obtaining the consent and in particular when the patient in question had serious pathologies.
- The recording of crying at home, in some cases may be doomed to failure because parents are overwhelmed by activities occurring at the newborns' birth, or because they are having trouble dealing with their prolonged crying. There have been situations where parents have not consented to home recording from the beginning, but also situations in which, with all the consent given, they have not made acquisitions after discharge from hospital.
- During the data acquisition in the maternity (it lasted 3 days on average) we didn't encountered any tiredness or colic cries. The few colic recordings collected and labeled in the maternity are associated with stomach pain. One possible explanation for the lack of tiredness crying is that the newborn sleeps a lot (over 18 hours a day) and the only need occurs when he/she wakes up hungry. We estimate (based on preliminary data) that the number of tiredness, colic and eructation recordings will increase so that the further analysis will not be affected.
- Of the 326 newborns from maternity in the period in which data collection was made (3 months), only 37% of them had parental consent for data acquisition in the maternity, and of these, only 28% had given consent for data acquisition at home.
- The CryingPicker installation on the parents' smartphones and the training for using the application were performed in the maternity, in the rooming-ins, by a mixed team made up of a man and a woman. There were some problems during the face-to-face training caused by the mothers' convalescence.

- Since the video recordings made at newborn's home had a large volume of data, data transfers to a central point was periodically required. Parents had to choose the method of transferring the video recordings: data transfer using a cloud-storage service or moving a mixed team at the parents' home. The second option was less preferred.
- Another issue raised during the acquisition process was keeping a close contact with the parents. Where possible (being conditioned by the parents'skills in using the internet) a contact via email was kept. In other cases, the contact was kept by phone, but several attempts were needed to communicate effectively because of the newborn's sleeping program. A version that worked best was communicating through the maternity medical team.

V. CONCLUSSIONS

In this paper we have proposed a method by which a crying database can be designed and collected from newborns and infants aged between 0-3 months. A newborn crying acquisition system has been proposed.

The collected data can be used to develop automatic recognition methods of assessing the infant's needs (hunger, pain, eructation, tiredness, discomfort, colic) based on his/her cry, but also to differentiate between normal and pathological cry.

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The medical team has played a key role in convincing the parents to get involved voluntarily in the study (in the maternity and / or home).

The authors also thank all the parents participating in the study and guarantee their valuable contribution they bring to the achievement of a scientific crying translation, the only form of nonverbal communication of the newborn and infant.

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