DISTURBANCE FACTORS IN CONDUCTING ENGINEERING STUDIES ON THE NEWBORNS' CRY, IN A HOSPITAL ENVIRONMENT

Flaviu Feier[1], Claudiu Angelescu[2], Constantin Ilie[2], Ioan Silea[1]

Abstract

Engineering is becoming more and more involved in the medical practice by providing tools, techniques and working protocols that are meant to help in medical decision taking. Conducting a study in a medical environment comes with its challenges. When this study is performed by a non-medical person, outside this system, the challenge becomes even greater and has to be overcome. This paper is focused on presenting the disturbance factors that were encountered during the last 7 years of conducting a study of the newborn cry in a medical unit and the decisions taken to overcome the different obstacles. The topic of studying the cry signal generated by the newborn has been of increasing interest for both the medical and engineering researchers. Latest studies performed mostly in the last 25 years show that through feature extraction from the cry signal, relevant information can be found in order to classify different pathologies such as asphyxia, hypothyroidism, hypoxia, autism or other disorders. The study of pain cries has even a longer history, due to the fact that it clearly states an inner suffering which the newborn is vocalizing in his own language, which must be decoded and given a medical meaning. In order to perform the studies on the newborn cry, besides the cry signal, in some researches medical instruments have been also utilized in order to correlate between physiological parameters and some the cry extracted features.

Key words: disturbance factors in engineering studies, newborns' cry, spectrographic analysis, cerebral oximetry, pain cry, INVOS

Introduction

The medical field has become very interesting for engineers in the last couple of decades, which can be noticed nowdays by the presence of advanced/complex tehnique in hospitals at the hand of medical personelle. Starting with the growth of storable data which can also be processesed and interpreted with the use of computational means, the field of medical engineering has appearead around 1950 when a series of a scientific articles have been written on this topic, culminating in the '70s when this new field becomes officially recognized by the scientific communities. The complex systems that comprise the human organism, as well as the interconnections and their interdependencies, provide multiple research topics for the engineers in collaboration with the medical researchers. The field of medical engineering brings together computer science, information technology, engineering and generic technology in all the medical branches in the areas of education, research and medical practice. The evolution of this new field has been manifesting more prominently in our days when the medical world embraces these computational capabilities and utilizes them in their daily practice as a decision taking support more and more frequently [1]. As it was mentioned before, at the middle of the 20th century the first entries of informatics are reported in the medical field. These first recordings are in the field of stomatology, when despite the lack of computers, doctor Robert Ledley utilizes for the first time the computational power in his research studies, which required numerical processing of his medical data. Ledley is a pioneer of the medical informatics field, his paper dated in 1955, called „Medical progress – medical electronics" being considered a reference and a pleading for the utilization of electronics of those times in advanced medical studies. At the beginning of the '60s the first electronic recordings are reported in veterinary studies, followed at the end of the decade by human medical recordings. Nowadays, each developed country has its national centralized patient data system, which in Europe is intended to be part of a bigger system which would be comprised of the national records from all member countries [2], [3]. Besides the utilization of new techniques for keeping the recordings, the expert system, called Mycin is developed. It uses artificial intelligence in the identification of bacteria that causes severe infections like meningitis. In the context of what was presented before, engineering becomes more present each day in the medical world, especially in the hospital units.

The current study focuses on the engineering aspects that revolve around the newborns' cry. Crying is the first form of communicating by the newborn and could incorporate valuable information to direct the medical diagnosis. The cry is a complex waveform which needs dedicated tools and techniques for in depth analysis. This is where the engineering comes to help such studies, by providing both the tools and technique necessary to carry out research on these complex sound waves. The idea of studying the newborn cry in order to determine possible health problems has been started in the '60s when the first cry spectrograms have been generated.

[1]University Politehnica Timisoara, Department of Automation and Applied Informatics
[2] "Victor Babes" University of Medicine and Pharmacy Timisoara, Department of Neonatology
E-mail: flaviu.feier@aut.upt.ro, angelescu.claudiu@ymail.com, constantinilie@umft.ro; ioan.silea@aut.upt.ro

Current technical developments provide professional sound acquisition and feature extraction capabilities together with analysis, studies on this topic having evolved gradually, showing remarkable progress [4]-[18]. The studies performed on the newborn cry intend to find a correlation between features extracted from the recorded cry signal and certain pathologies such as: hypoxia, hearing disorder, asphyxia, autism, hypothyroidism or others.

In current medical practice, pregnancies are closely monitored and facts about the newborns health are known even before their birth, but there is the possibility of several affections which unfortunately are found only long time after birth when parents notice issues regarding the development of certain motor or mental functions or their baby's delay or inability to start expressing basic words. Suspecting a medical condition is essential in order to direct an early diagnosis and thus, being able to heal or at least stop the illnesses progression before it is too late. Most of the medical tests that can be done after birth are invasive ones and the most common consist in blood draws from the newborn. Hence, the usage of an indicator such as features from the cry can be a non-invasive method to indicate the presence of pathologies or physical state. Therefore, conducting a thorough engineering study in the Neonatology department would be more than beneficial for both the medical personnel and most important, for the newborn patient. The following paragraphs will focus on the challenges that were encountered in order to conduct such a study, named suggestively, disturbance factors and the solutions taken to overcome these.

This study of the newborn cry in order to determine patterns linking to different pathologies has been started in collaboration between engineers and the medical staff in 2008 at the Obstetrics and Gynecology Clinique "BEGA" from the Emergency County Hospital from Timisoara in the Neonatology department.

Material and Methods

In order to perform a sound analysis investigation, the equipment and protocols for performing the investigation are one of the most important elements. First tentative for recording the newborn cry implied the usage of a video recorder with an external microphone attached in order to capture the audio signal from the newborn (Figure 1). Spontaneous cries were recorder in this manner with the intent of having both facial expressions and the cry sound. The recordings were made in the hospital in different areas on random newborns. The results of this first study were not very encouraging due to a lot of noise in the audio signal. The noise over the utilizable signal was due to the presence of other audio signals over the cry, a poor recording capability and quality from the video recorder and a very difficult possibility to extract sound features like amplitude, fundamental frequency or formants from the recordings.

Figure 1. Video recording of a newborns cry.

In order to perform a more accurate and meaningful study of the cry, requirements were defined in order to have a system capable to overcome the difficulties resulted for the first tentative. The system needs to be comprised of a professional recording instrument that can be utilized by the medical staff which provides online and offline cry signal visualization and the most important cry features need to be extracted and visualized as well.

Having these requirements defined very clearly, the Neonat application was developed in order to be used in the Neonatology department by both medical staff and the engineers involved in the study. The Neonat application has already been presented extensively in [7]. The whole analysis system consists of a professional microphone that is connected to a laptop which has the Neonat application running on it. The cry signal captured by the microphone is analyzed in real time by the application showing a graphical representation of the sound waveform. Features from the cry signal represented by sound intensity measured in two different ways (using an emulated Volume Unit Meter and

Peak Program Meter) and sound spectrum (2D and 3D spectrograms) are both stored locally and represented visually in the application. The cry features are coupled with patient data, so that each relevant information can be accessed in a fast way by everyone using the application. Figure 2 shows a capture from the Neonat application during cry signal acquisition.

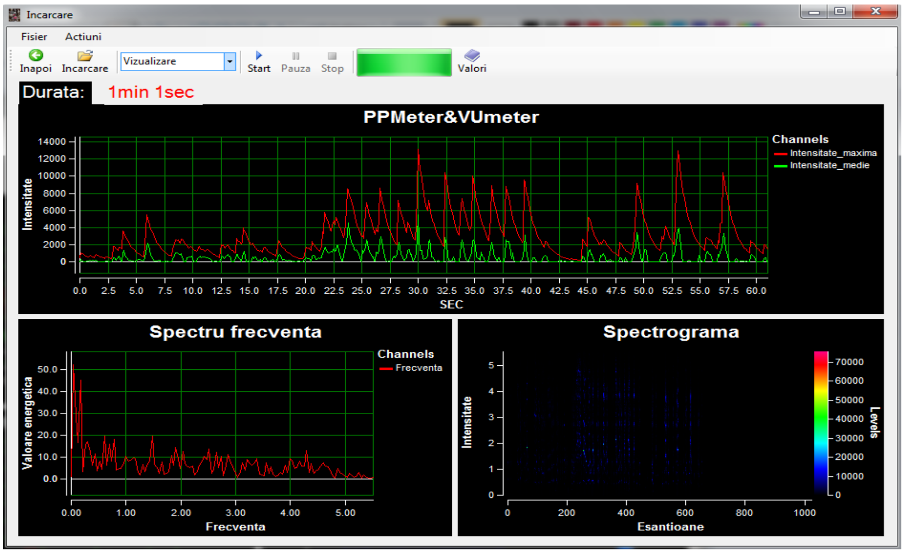


Figure 2. Capture from the Neonat application while recording.

Intensive usage of the Neonat application brought to light a series of other inconveniences when performing the study. Noisy hospital rooms, multiple users of the application and recording sessions at all times, generated the need of a recording protocol. The recording protocol was proposed in order to assure quality and repeatability of the measurements and consisted of a set of rules meant to obtain the data that needed to be gathered for the study (newborn birth data and data from the mother), equipment utilization rules (Neonat application guide and microphone set-up inside incubator) and ethical rules (consent from mother and curing doctor to perform the recording of the newborns cry). Among these rules, the equipment utilization conduit has been emphasized. Tests showed the necessity of through acquisition in terms of having a dedicated room and environment for the recording, similar recording lengths, keeping constant distance between the newborn and the microphone and in case of malfunctions of the microphone it was stated that it should be replaced with one from the same producer and with identical functional characteristics. All the rules have been detailed in one of the article presenting the Neonat application [7].

By following the created protocol, a considerable database with newborns was created in one year (approximately 200 different newborns), without needing to take out too many recordings as a result of noise, faulty handling of equipment or abnormal values of sound extracted features. With such a database a Data Mining study could be performed in order to make a classification between different categories of newborns that were considered. The results of this study have been presented in [19].

The focus of the work was shifted then in determining patterns in the newborn cry that can be linked to physiological measurements such as the cerebral oxygenation. Such correlations have been studied and are still of interest to different interdisciplinary groups where medical personnel works together with sound technicians or engineers to determine the impact brought to the cry signal by heart rate fluctuations, peripheral or cerebral blood oxygenation among others [21], [22].

The study performed by our group consisted in the utilization of several equipment for the cry signal acquisition, real time visualization and post processing together with the measuring of the cerebral blood oxygenation during lab draws. A professional acquisition tool, the Olympus LS-100 PCM Multi Track Recorder was brought into the study in order to have a very good quality recording and to be able to do precise post processing and analysis of the cry signal. In order to determine the cerebral blood oxygenation the oximeter INVOS 5100C has been used. This medical equipment helps to determine in a non-invasive way the ischemic risk (the local deficit of blood) at the brain level or vital organs by measuring the hemoglobin level right under its sensors on the monitored area of the scalp (in this study). The measured parameter is represented by the regional hemoglobin oxygen saturation (rSO2) which is the value at tissue level of the oxygen from the hemoglobin which is left after tissue irrigation [20]. The main goal of the study that was performed was to follow the modification of the blood saturation at cerebral level when pain is present, in this case when the medical personnel performs blood draws from the newborn and correlating this information with features extracted from the pain cry using the Neonat application. The cry signal was visualized in real time with the Neonat application and acquired for post processing with the Olympus PCM recording device.

This new direction of the study required more people to be present during a recording: a nurse for performing the blood draw, an operator for the Neonat application, someone to start/stop the Olympus recording device and give the signal for the blood draw sting and an operator for the NIRS equipment. Having this number of people involved at the same time requires precise timing and coordination between all the team members, otherwise the results would be impossible to interpret. The information collected by the INVOS tool about the rSO2 parameter is localized, in real time and continuous. Therefore it allows the possibility to correlate its values with features from the cry signal which are as well in real time and continuous. The problem of the data coming from the cerebral oximeter is represented by the frequency of the measurement, which is fixed at 5 seconds. Therefore the need for one of the team members to give signals at each of the important events during the procedure (starting the recording, setting the cerebral oxygenation parameter baseline, start of the procedure, end of the procedure, stopping the recording) which need to be known and given a time stamp.

Given all the equipment and techniques tried so far in the study of the newborn cry, it can be concluded that in terms of material and methods it is very important to have a protocol to follow during procedures, which in most of the cases was the result of several faulty tentative. The following paragraphs which contain the results will highlight these aspects concerning wrongful procedures and the correction of these.

Results

The first cry acquisition system that was tried out, comprised of the video recorder and the external microphone connect to it, was analyzed in terms of the recorded cry signal is shown in the form of a waveform for one of the newborns is Figure 3. This waveform which was generated was the result of using external sound analysis software and is very affected by noise coming from the ambient and internal equipment noise as well. In order to be able to get useful information from this, filters can be applied. The only problem with applying a low pass filter for instance is represented by a minimal threshold value that needs to be set for the filter, in order to allow values only above that value to pass the filter. Without having a past experience with the newborn cry, setting this lower threshold presented the risk of leaving out values that are not part of the noise, but information from the cry itself. Similar thoughts are available when applying a high pass filter or a band pass filter, namely the possibility of losing features from the cry itself in the tentative of cleaning the noise that is over it. Each of the recordings made in this manner have similar waveforms, and the need of filtering is available there as well.

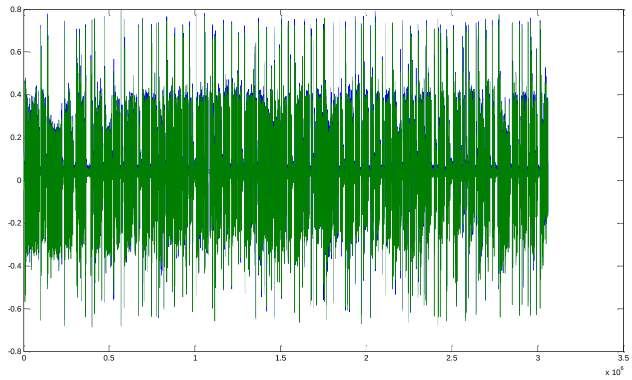


Figure 3. Waveform of a cry recorded with the video camera.

The Neonat software was created for the purpose of having a dedicated tool that can allow both the acquisition and analysis of the cry signal. The software allows a fast configuration for the acquired sound (selecting amplitude representation interval, filters and their parameters, sampling rate, Fast Fourier Transform detailed configuration and other parameters considered useful for the study) and visualization possibilities (2D and 3D spectrogram for data chunks or for the whole cry signal, sound intensity, Volume Unit Meter or Peak Program Meter measurements). This way, many of the disturbance factors can be eliminated and the acquired information becomes more reliable. The screen capture of the on line sound acquisition was presented in Figure 2.

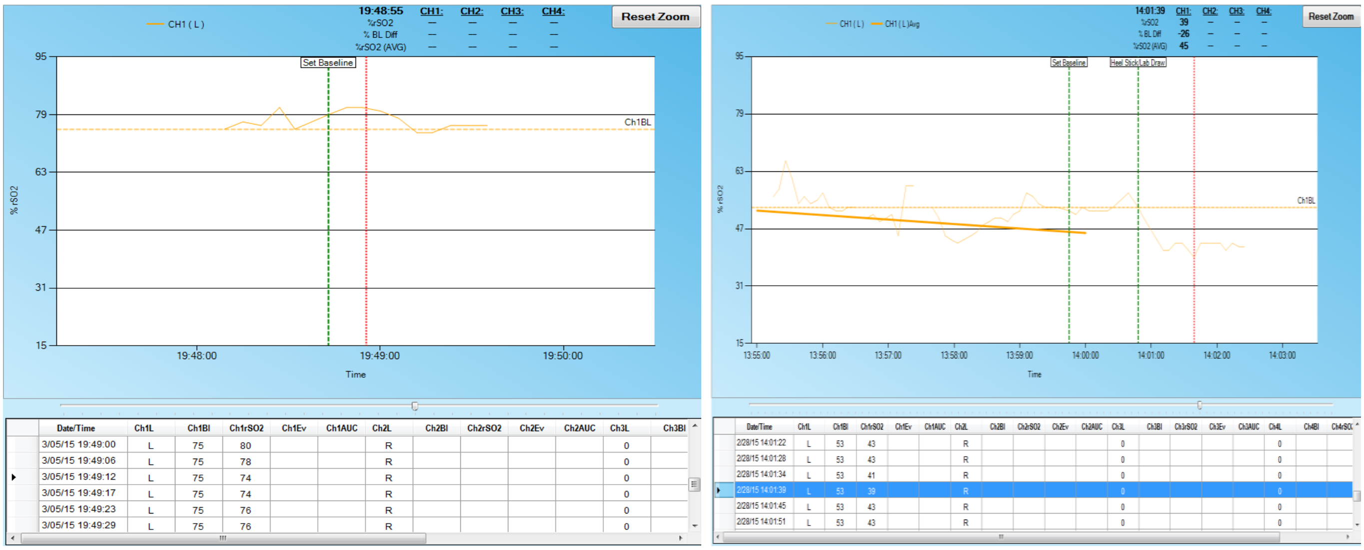
Developments have been obtained and presented in articles of the authors [7], [19] by using this special developed software, Neonat. First studies were conducted in order to determine the protocol (which was mentioned in the previous section) for performing the later on experiments, which consisted in a Data Mining analysis of several new born groups with similar pathologies with the intent of making a classifications between healthy newborns and each of these groups. The results of this study showed a very good classification capability of the tool Weka (which was incorporated in the application) when searching differences between the witness group (healthy newborns) and a group of premature newborns (gestation age < 38 weeks), a group comprised of newborns with respiratory problems and a third cluster of newborns with Apgar score below 7 which were born on time but diagnosed with severe illnesses like neurological suffering.

The results obtained in these first steps, determined the new approach on the cry analysis. As it was mentioned before, the focus was directed towards determining patterns in the cry that could be linked to physical parameters. In the study conducted with the INVOS cerebral oximeter and the auxiliary recording instrument, the Olympus PCM recorder the synchronization between the team members was a big obstacle that needed to be handled. The protocol for this study was created to assure that the information about the rSO2 was mapped correctly on the cry signal in different important moments: baseline setting, nurse starting the blood draw procedure or the blood draw end point. Nevertheless, after having all tasks synchronized and results starting to show there have been noticed several cases when the behavior and evolution of the cerebral oxygenation was not the foreseen one. In these situations, the expected decrease of the oxygenation parameter was not very visible or it presented as an increase (Figure 4 a)). This result was possible when the needle sting or the blood draw did not affect in any way the newborn. There were situations in which all these invasive actions did not generate an expected cry of the newborn and an increase in the saturation could be seen. Two main factors can lead to such a situation:

- the nurse doing the procedure can puncture the vein where the collecting is done, immediately without inducing any pain;
- the newborns pain acceptance level is so high, that it needs a more powerful action to inflict this pain.

Although these situations can be seen very fortunate from the patient caring point of view, in terms of the study these are disturbance factors that make such cases unusable for the study.

In Figure 4 b) is an example from the INVOS software, showing the variation of a newborns' cerebral oxygenation. This example shows a very big decrease in saturation which can be very dangerous for the newborns' state. Such a big decrease can cause brain lesions and is a very unfortunate situation when no monitoring is performed. Since cerebral oxygenation monitoring is not usually performed given the costs that it implies, and without an indication of its necessity, cry analysis can be a very viable alternative if it can give an indication about the cerebral oxygenation level, for instance.



a) b)

Figure 4. Screen captures from the INVOS software.

The choice of this example shown in Figure 4 b) is due to the developments of this newborns' case. Such a big decrease in the saturation, below the value of 40% and a high dominant frequency that was noticed in the cry spectrogram of the word following the puncture, lead to further investigations that discovered a neurological suffering of this newborn. Although this was not the goal of the study, the result was very encouraging for the overall purpose of the newborn cry signal study in order to determine patterns for different pathologies. Although for the other cases such a situation like the one presented was not as clearly highlighted, there were similarities regarding the high decrease in the rSO2 value and dominant frequencies above 1 kHz. Such a high dominant frequency even for a pain cry with no energy components on lover frequencies (400Hz-600Hz) looks to be consistent with the saturation decrease.

Conclusion

The ongoing study of the newborns' cry analysis presents itself with a lot of challenges. In this paper were highlighted a couple of the disturbance factors that have been noticed and overcome in the last 7 years of studies of this topic. The study has gone through different stages, each of them highlighting problems that can occur and which need to be overcome.

Beginning of the study showed the necessity of a sound proof room and the need of a dedicated equipment coupled with a software tool in order to make custom settings to be able to rely on the output results. In this context, the Neonat software was created and the recordings have been taking place in dedicated hospital rooms inside incubators.

When having dedicated software which is easy to use by the medical personal it is necessary to create a procedure protocol in order to offer the same conditions to all the subjects present in the study. A protocol was created as a result of past experience and the results became reliable and first conclusions were drawn by using Data Mining techniques to perform a classification of the newborns present in the study. Such a long term study can have multiple developments in time. The idea of having other equipment to conduct other type of studies is something that is meant to happen. This will generate other types of disturbances in the study, like the problem of having to synchronize work of 4 team members with 4 different tasks on different equipment or the different nurses participating in the study, with different abilities to puncture a vein that can lead to different reactions from the newborns investigated.

Overall, the study has shown so far very promising results that were obtained when dealing with disturbances from the engineering point of view, namely: dedicated tools, well defined work protocols and synchronization between tasks in order to have reproducible and reliable outcomes.

Acknowledgements

This work was partially supported by the strategic grant POSDRU/159/1.5/S/137070 (2014) of the Ministry of National Education Protection, Romania, co-financed by the European Social Fund – Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013.

References

1. M. Morris F. Collen, "Origins of Medical Informatics," Medica informatics (Special Issue), vol. West J Med, 1986, Dec.
2. Illaria Passarani, "Patient access to Electronic Health Records - Report of the eHealth Stakeholder Group," 2013.
3. Europeean Comission, " "Digital Agenda for Europe"," [Online]. Available: http://ec.europa.eu/digital-agenda/en/news/ehealth-stakeholder-group-members. [Accessed 31 March 2015 2015].
4. G. György Várallyay, Jr., and Zoltán Benyó, Melody Shape – A Suggested Novel Attribute for the Biomedical Analysis of the Infant Cry, Proceedings of the 29th Annual International Conference of the IEEE EMBS Cité Internationale, Lyon, France August 23-26, 2007, p.4119-4121.
5. Glen Balou, Handbook for Sound Engineers, Fourth Edition, 2008 Elsevier Inc. , p.999-1005
6. C.A García, S.D Cano, "Fundamentos Teóricos y Prácticos del Análisis de Llanto Infantil", 2009
7. Robu, R.; Feier, F.; Stoicu-Tivadar, V.; Ilie, C.; Enatescu, I., "The analysis of the new-borns' cry using NEONAT and data mining techniques,"Intelligent Engineering Systems (INES), 2011 15th IEEE International Conference on" , vol., no., pp.235,238, 23-25 June 2011
8. M. Petronil,A.S. Malowany, C.C. Johnston, B.J. Stevens, A New, Robust Vocal Fundamental Frequency (Fo) Determination Method for the Analysis of Infant Cries, Seventh Annual IEEE Symposium on Computer-Based Medical Systems, 1994
9. A. Ismaelli, G. Rapisardi , GP. Donzelli, M. Moroni, P.Bruscaglioni. A new device for computerized infant cry analysis in the NICU, Engineering in Medicine and Biology Society, 1994. Engineering Advances: New Opportunities for Biomedical Engineers. Proceedings of the 16th Annual International Conference of the IEEE
10. M. Petroni,A.S. Malowany, C.C. Johnston, B.J. Stevens, A Robust and Accurate Crosscorrelation-Based Fundamental Frequency (Fo), Engineering in Medicine and Biology Society, 1995., IEEE 17th Annual Conference
11. K. Michelsson, H. Tood de Barra and O. Michelsson, "Focus Nonverbal Communication Research", vol. 2, chapter Sound Spectrographic Cry Analysis and Mothers Perception of their Infant's Crying.
12. György Várallyay, Jr., and Zoltán Benyó, Melody Shape – A Suggested Novel Attribute for the Biomedical Analysis of the Infant Cry, Proceedings of the 29th Annual International Conference of the IEEE EMBS Cité Internationale, Lyon, France August 23-26, 2007
13. Wermke, Kathleen and Mende, Werner, Variability of the cry melody as an indicator for certain developmental stages, Engineering in Medicine and Biology Society, 1993. Proceedings of the 15th Annual International Conference of the IEEE
14. S. Orlandi, C. Manfredi, L. Bocchi and M.L. Scattoni, Automatic Newborn Cry Analysis: a Non-Invasive Tool

to Help Autism Early Diagnosis, 34th Annual International Conference of the IEEE EMBS, 2012
15. L. Bocchi, L. Spaccaterra, F. Acciai, S. Orlandi, F. Favilli, E. Atrei, C. Manfredi, G.P. Donzelli, Non invasize distress monitoring in children hospital intensive care unit, Advances in Medical, Signal and Information Processing, 2008. MEDSIP 2008. 4th IET International Conference
16. L. Sasvári, P. Gegesi-Kiss, P. Popper, Z. Makói, Z. Szöke. “1st Cry of Newborn After Vaginal and Cesarean Delivery”, Acta Pediatr Hung, vol. 16(2): 155-161, 1975.
17. María A. Ruíz Díaz, Carlos A. Reyes García, Luis C. Altamirano, Robles, Jorge E. Xalteno Altamirano, Antonio Verduzco Mendoza, Automatic infant cry analysis for the identification of qualitative features to help opportune diagnosis, Biomedical Signal Processing and Control Volume 7, Issue 1, January 2012, Pages 43–49 Human Voice and Sounds: From Newborn to Elder
18. T. Szende, J Hirschberg. , 1983, Pathological Cry, Stridor and Cough in Infants, Archives of Disease in Chidhood, vol. 58.
19. Feier, Flaviu, et al. "Newborns' cry analysis classification using signal processing and data mining."Optimization of Electrical and Electronic Equipment (OPTIM), 2014 International Conference on”, IEEE, 2014.
20. Covidien Inc., "Official brochure “Oximetry with INVOS in Neonatology" [Online]. Available: http://www.covidien.com/rms/products/cerebral-somatic-oximetry/invos-5100c-cerebral-somatic-oximeter
21. Manfredi, C., et al. "Non-invasive distress evaluation in preterm newborn infants."Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE”, IEEE, 2008.
22. Bocchi, L., et al. "Non-invasive distress monitoring in children hospital intensive care unit." 4th IET International Conference on Advances in Medical,Signal and Information Processing (MEDSIP 2008), 2008 page 226

Correspondence to:
Flaviu Feier
PhD. Student at Universitatea Politehnica Timisoara, Romania
Bd. Vasile Pârvan, Nr. 2
300223 Timişoara, România
Tel 0356 086849 Romania
E-mail: flaviu.feier@aut.upt.ro