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Application of Vocal Fold Vibration Analysis Parameter for Infant Congenital Heart Diseases Diagnosis

Bong-Hyun Kim[1*] and Dong-Uk Cho[2]

[1]**Dept. of Computer Engineering, Hanbat National University**

[2]**Dept. of Information & Communications Engineering, Chungbuk Provincial University**

소아 선천성 심질환 진단을 위한 성대 진동 분석 요소의 적용

김봉현[1*], 조동욱[2]

[1]한밭대학교 컴퓨터공학과

[2]충북도립대학교 정보통신과학과

Abstract Due to poor linguistic communication skills of sucklings and infants, crying mostly is only means of communication to express their body conditions and desires. We, therefore, developed an infant auscultation system which detects which part of the body has a pathological problem, by analysing infant's crying sound patterns. Specifically, in this paper, we accomplished an auscultation system for congenital heart diseases detection by performing pitch, intensity and spectrum analysis of the crying sounds between the normal infants group and the congenital heart diseases group. With this system, we can diagnose congenital heart diseases of infants with poor communication capacity, and, in the near future, can build a home care diagnosis system based on crying sound analysis technologies through additional experiments on medical data.

요 약 언어를 통한 의사 전달 능력이 부족한 영아나 소아들은 울음으로서 자신의 몸의 상태나 요구하는 것에 대한 의사 표시를 행한다. 이 중 중요한 것이 소아 상태를 나타내는 것인데 언어 전달 능력이 없는 소아들의 질병은 진단 시기를 놓치거나 정확한 진단 결과를 내리기 어려운 문제가 존재한다. 이를 위해 본 연구에서는 소아의 울음소리를 분석하여 몸의 어느 부위가 문제가 있는지를 판단해 내는 소아 청진 시스템을 개발하였다. 특히 본 논문에서는 울음소리의 피치, 강도 및 스펙트럼 분석을 통해 소아 선천성 심질환자에 대한 질병 진단을 수행하였다. 이를 위해 각각의 분석 요소를 통해 정상적인 아이와 소아 선천성 심질환을 앓고 있는 아이에 대한 울음소리의 비교, 분석을 수행하였다. 이와 같은 방법을 통해 의사표현 능력이 부족한 소아를 대상으로 편리하게 소아 선천성 심질환을 진단할 수 있으며 임상 자료의 추가 실험을 통해 울음소리 기반의 재택형 진단 시스템을 구축할 수 있다.

Key Words : Congenital Heart Diseases, Crying Analysis, Infant Auscultation, Vocal Fold Vibration.

1. Introduction

The efforts for our healthy life is the very right to pursue our happiness and we ought to secure a life worthy of man for everyone. All that our health are the key element for our lives and our governments are doing their best for our healthy lives. Especially, the researches to keep and manage our health from the cradle are expanding gradually along the progress of medical science. Modern medicine does not remain in the protection and medical treatment against disease, but also is expanding its role into the preservation of our good-conditioned body as well as the enhancements of physiological, psychological and social adaptability, and Oriental medicine can not be free from these points. But lots of diseases that can't be treated with the Modern

*Corresponding Author : Kim, Bong-Hyun (bhkim@hanbat.ac.kr)
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Medicine are still remained. The early diagnosis of that diseases seem to be the most important thing above all[1,2]. Even a grown-up person might have some difficulties to be aware of his disease and to descript exactly what they are suffering.

Specially, furthermore children who are insufficient of mental capacity or even are devoid of mental capacity might have much more difficulties to get the early diagnosis. Any infant's crying has the reason and the purpose at all times. Of course, infant's crying is of much help to rapid expansion of the infant's lung[3]. Infant can express several situations such as hunger, sickness and leaving alone by crying. If infant can't cry, there is no way that infant suffering in silence can express what situation it undergoes and what it wants.

Therefore, under the hypothesis that any infant crying might have its own meaning and reason, we hope to develop a home network-based remote diagnostic system for infant diseases. Specially, we will give priority to the study of the co-relationship between the waveform of a infant crying and the infant congenital cardiac diseases to develop the home network-based remote diagnostic system for lethal infant congenital cardiac diseases. For this purpose, we've tested the acoustic analysis of infant's crying on the basis of the analytical theory of Oriental medicine between the congenital cardiac diseases and the infant's crying, and we will verify the differences and the similarities between normal newborns and newborn cardiac patients. Especially this article will suggest a method which can diagnose congenital newborn cardiac diseases remotely via internet as its first product. For this, we analyzed and compared crying sound patterns with the normal infant group and congenital heart diseases group, and then designed an objective pattern index about the waveform of crying sound, based on the form of experimental results and abstract of significant patterns.

2. Congenital Heart Diseases & Analysis Parameter

2.1 Congenital Heart Diseases

Congenital heart diseases is diseases having the abnormality of the structure of the heart and the aorta. There is no known cause of the disease except some identified diseases related to the hereditary factor. Up to now, more than one cause among such dubious causes as the natural causes, the environmental factors, infections and hereditary factors are supposed to influence the abnormal heart. However, guess is only guess, so we do not know yet the real causes of the congenital heart diseases[4]. The number of new congenital heart diseases patients per year is estimated to 6~10 infants per 1,000 newborns and that of school age children is about 2 children per 1,000 children. The cause of the congenital heart diseases can be considered to be the co-relationship between the heredity and the environments, but it used to be very difficult to assume the real cause of personal outbreak of the congenital heart diseases[5].

The diagnosis of the congenital heart diseases includes the auscultation and olfaction, the medical testing, the heart murmur check, the Electrocardiography, the cadio-ultrasonography, the chest X-ray, the cardiac catheterization, the cardiovascular photography, the kinetic load test and the Holter test, etc, and the congenital diseases cab be found by the heart murmur during the diagnosis because most congenital diseases would be observed to have some heart murmur during the diagnosis of the heart diseases[6,7]. In the western medicine, there is the therapy to intake a cardiotonic, a diuretic or a vasodilator or their cocktail therapy of intern medicine, but it is only a temporary therapy, so, if it can't take a favourable turn, the surgical operations is inevitable. Although even non-surgical options can be available, but these are limited to only few cases. In the oriental medicine, the methods to elevate the Fire strength and to strengthen the very heart using the herbal medicine[8].

[Table 1] Infant crying connected with diseases

Crying Characteristic	Disease
Sudden and loud crying shrinking with fright	Colic pains
Shrill cry	Meningitis, center nerve neuropathy
Weak and hoarse crying orcat-like crying	Congenital heart diseases
Crying like rams	Konelria Deurangge syndrome
Crying barking	Laryngitis
Groaning	Pneumonia, Dyspnea

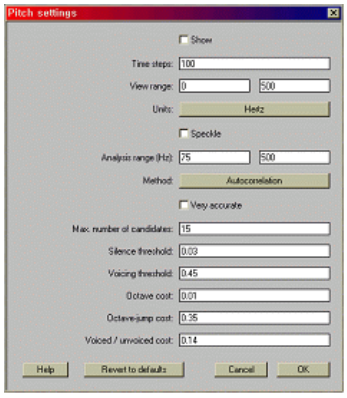
Usually in the oriental medicine, the diagnosis of the congenital heart diseases may be done by listening the newborns' crying and the crying is similar with the cat's mew. From the viewpoint of the oriental medicine, the heart is the Fire strength so has the property of spreading like flame. In this article, we will propose the methodology to analyze the newborns' crying on the basis of this clinical fundamental experiences of the oriental medicine about the congenital heart diseases, and to diagnose newborn infants congenital heart diseases with non-awareness, no-restriction and painless-skills. This article showed the possibility to realize the valuable diagnostic system for the congenital heart diseases of this oriental medicine by the acoustic signal processing technology in the IT technologies.

2.2 Voice Analysis Parameter

If a infant has bad heart, the function of its heart will become weak so that it takes little bit more time to circulate its blood. Especially, the venous blood becomes to mix with the arterial blood so the colors of hands or feet are changed. Like this, the congenital heart diseases can be diagnosed by the ocular inspection. But, in this article, we will propose how to diagnose the congenital heart diseases with the auscultation among the oriental medical diagnostic skills[9]. That is, we will identify the acoustic differences between the normal newborns' heart and the newborn congenital heart disease patients's heart by the close examination of the co-relationship between the sound of the normal newborns' crying and that of the newborn congenital heart disease patients.

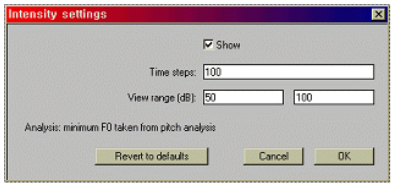
In this article, we will propose a methodology how to analyze newborn infants crying easily in the daily life as a method to diagnose the congenital heart diseases of newborn infants to the exclusion of any direct influence on the heart, based on the theory of the oriental medicine's diagnostic skills. We conducted to study the co-relationship between the newborn congenital heart disease patients crying and the normal newborn infants crying with the proposed method.

On the basis of the predictability of this prepositions, we preceeded this research with the analysis of the pitch, the intensity and the spectrogram of the acoustic sources(crying). The pitch means one cycle of the voice waveform which is translated in our ears into the high or low crying of a infant. The settings for the pitch analysis were shown in Figure 1, and the higher value is set in 'Time Steps', the more pitch will be analyzed in a unit time. Since the average vibration of the vocal cords can't change rapidly, but only smoothly, we set it to 100, the baseline value, and set the view range to 0(min.)~500(max.).



[Fig. 1] The settings for the Pitch Analysis

Also, the intensity is the important measure that expresses the strength of sound in the voice waveform. That is, the intensity means the strength of the crying, so the louder, the more rotund and the more intense is the voice under the same conditions, the bigger is the intensity. The settings for the intensity analysis were shown in Figure 2, and the higher value of the time steps, the more densely are the intensity data displayed in the time-axis and vise versa. In the article, we set the time steps to 100, the basic setting value. And, after setting the view range to 50 as minimum value and 100 as the maximum value, we grasped the changes of the intensity values.



[Fig. 2] The settings for the Intensity Analysis

We assumed that it would be possible to apply the theory of the oriental medicine's auscultation skill using

these analytic factors to the diagnosis of the congenital heart diseases, and it could be applied to the web-based medical service systems. We also assumed that after analyzing a infant's crying in the waiting room and then tossing the result to doctors, doctors in the clinic center could utilize it as the clinical diagnostic materials when they were conducting the diagnosis. Furthermore, the doctor's intuitive diagnosis can be objectified and visualized so that the enhancement of the clients' reliability and preference can be gained additionally by the visualization of the diagnostic result through the analysis of the newborns' crying.

3. Simulation Results & Analysis

3.1 Clinical Data Compilation & Classification

We have conducted all these experiments under the environments of Microsoft Windows XP professional. We used the Samsung Voice Yepp as the voice data collector, and Praat 4.2.07[10] as the acoustic analysis tool. And, we have taken the voice input characteristics of the used microphones into consideration as the experimental environments. Since it may be afraid for the contact noise by hands to be delivered into the microphone, we fastened the microphone with a pin or fixed it at a support as possible. We leaved space of about 15 cm between the microphone and newborns' mouths the plosive sound not to be input strongly in the microphone and we adjusted the input sensitivity properly to keep any surrounding noise from being mixed with the voice input.

And then, after confirming the surrounding noise state for the waiting time without any voice input, the crying inputs of newborn infants were recorded. After the normal newborn infants and the newborn congenital heart diseases patients were divided respectively into the pertinent experimental groups, the groups were analyzed closely based on the factors of the acoustic analysis. As shown in Table 2 and Table 3, the experiments were practiced on five infants respectively in each experimental group, and we could find some similarities as follows from all the infant participants.

[Table 2] The Normal Infants Experimental Group

Order	Sex.	Age	Status
1	Male	3	Normal
2	Male	2	Normal
3	Female	2	Normal
4	Male	5	Normal
5	Female	4	Normal
6	Female	2	Normal
7	Male	3	Normal

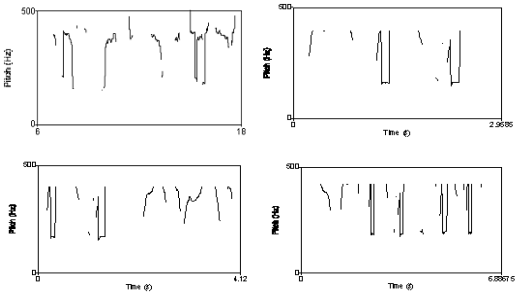
[Table 3] The Infant Congenital Heart Diseases Patients Experimental Group

Order	Sex	Age	Status
1	Male	2	Severe case
2	Male	4	Severe case
3	Female	2	Mild case
4	Male	2	Severe case
5	Female	3	Severe case
6	Female	2	Severe case
7	Male	4	Mild case

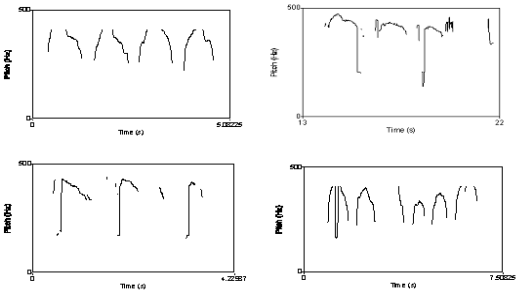
3.2 Simulation Results & Analysis

First, the pitch analysis results of the normal infants group were shown in Figure 3, the result waveforms of them had spreading-out-upward form. These showed that the crying of the normal infants were rotund, and they were taking breath normally and were bursting out very comfort crying fitting for their heartbeat. On the other hand, as shown in Figure 4 representing the pitch analysis results of the infant congenital heart diseases patients group, their result waveforms couldn't spread out, but only sink down. That is, in the case of the infant congenital heart diseases patients, the waveforms of their cryings seems to change rapidly. This represents that they have irregular heartbeats so that the irregular heartbeats would be reflected by somewhere to change the waveform rapidly. We could confirm the consistency between this phenomenon and the diagnostic theory of the oriental medicine about the congenital heart diseases.

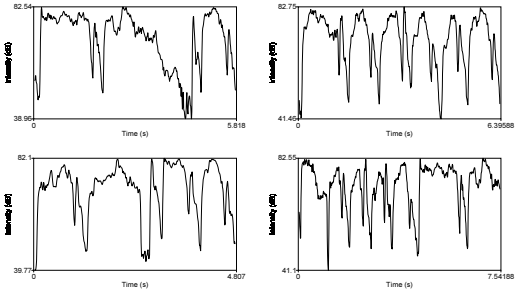
Also, we conducted the intensity analysis to analyze infants cryings. As shown in Figure 5 and Figure 6, the average maximum intensity value of the normal infants group was higher than that of the infant congenital heart diseases patients group so that we could confirm that the results of the intensity analysis were matched with the auscultation theory of the oriental medicine.



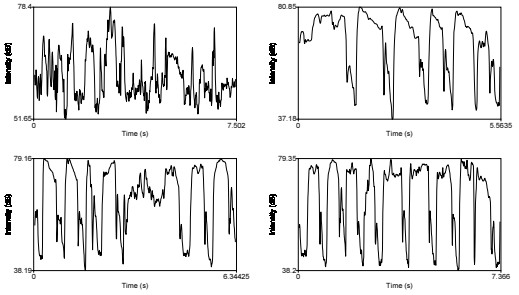
[Fig. 3] The result waveforms of pitch analysis of the normal infants group.



[Fig. 4] The result waveforms of the pitch analysis of the infant congenital heart diseases patients group.



[Fig. 5] The result waveforms of the intensity analysis for the normal infants group.



[Fig. 6] The result waveforms of the intensity analysis for the infant congenital heart diseases patients group.

In conclusion, we could get the corresponding results with the diagnostic skill theory of the oriental medicine after we had realized the auscultation theory of the oriental medicine with the IT technology and then had conducted the acoustic analysis of the cryings of the normal infants and the infant congenital heart diseases patients with the realized system. Through it, we could conclude that the intuition of doctors which had been the weak point of the oriental medicine could be visualized and objectified with the IT technology. Also, since all the diagnostic skills of the oriental medicine have the features of the apathy, the unrestrained and the indolence, this system can help diagnosing congenital heart diseases of infants with poor communication capacity. We can build a home care diagnosis system based on crying analysis technologies through additional experiments of medical data.

3.3 Mathematical Modeling of Pitch Analysis

It is possible that pitch of a waveform of normal infant in the experimental group is modeling from linear function y = mx + c with the slope formula of the $\tan 90^\circ$, pitch of a waveform of pediatric congenital heart disease in the experimental group is possible a modeling from straight line having acute angle. When is modeling in linear function, a small linear elements to represent the typical type should be removed, so it should be used as the accumulator array.

First, the linear function can be expressed as y = mx + c. Where m = slope, C is the x-intercept. Waveform of pitch is possible an expression as formula(2) in (m, c)space, if is possible that elements of plotted result expresses X, Y coordinates of point p as formula(1).

$$P_i : (X_i,\ Y_i)\,(i = 1, 2, \cdots, n) \tag{1}$$

$$S_i : C = -X_i m + Y_i \tag{2}$$

In other words, the pitch waveform in the above formula, the plotted points (m, c) parameter mapping is possible on the plane top. If elements of straight line is on the (X, Y) plane, is possible a creation of accumulator array on the (m, c) parameter plane. Thus, we can extracted straight line over length to come under threshold

value on the (X, Y) plane to exist by using formula(3) to decide accumulator value and the threshold value.

$$Y = Xm_i + C_i \ (i = 1, 2, \cdots, m) \tag{3}$$

To improve degree of detection is used (m, c) plane and (θ, ρ) parameter plane. At this time, (θ, ρ) parameter plane is same under formula(4)~formula(6).

$$C: \rho = X_i \cos\theta + Y_i \sin\theta \ (i = 1, 2, \cdots, m) \tag{4}$$

$$Y = -(\cos\theta_i / \sin\theta_i)X + (\overline{\rho_i} / \sin\theta_i) \ (\theta \neq 0) \tag{5}$$

$$X = \rho_i \quad (\theta = 0) \tag{6}$$

4. Conclusion

Since newborn infants and the infant have no ways to notify their inconveniences but crying, they can communicate their situations through only their cryings. Therefore, it can be supposed that any crying of infants have its own meaning and the waveform of its crying differ from the cause and the motive of its crying. In this article, we hoped to analyze the infants cryings on the ground of the oriental medicine based on this suppositions. Especially we analyzed the acoustic features of the infant congenital heart diseases patients group and the normal infants group and compared each other. With our own ears, we couldn't discriminate the crying of the infant patients and that of the normal infants. But, with the acoustic analysis, we could know that while the normal infants could make the pitch of the crying sound clearly, the infant congenital heart diseases patients also could make the pitch, but their sound couldn't spread out. With this system, we can also develop a home care infant diagnosis system of u-Health environment based on crying sound analysis technologies.

We will improve accuracy and reliability of the study results by applying more clinical data, and the studies will be further performed on other infant diseases in future.

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Bong-Hyun Kim [Regular member]

- Feb. 2002 : Hanbat National Univ., Electronic Computer, MS
- Feb. 2009 : Hanbat National Univ., Computer Engineering, PhD
- Mar. 2002 ~ Current : Hanbat National University, Lecturer in Computer & Communications
- Sep. 2005 ~ Current : Chungbuk Provincial University Lecturer in Information Communications & Computer Engineering

<Research Interests>
BIT Technology, Speech Signal Processing, e-Business

Dong-Uk Cho [Regular member]

- Aug. 1985 : Hanyang Univ., Electronic Engineering, MS
- Feb. 1989 : Hanyang Univ., Electro - Communications Engineering, PhD
- Mar. 2000 ~ Current : Chungbuk Provincial University, Professor in Information & Communications Engineering
- Mar. 1991 ~ Feb. 2000 : Seowon University, Associate Professor in Information & Communications Engineering

<Research Interests>
BIT Technology, Image & Speech Signal Processing