Cause Estimation of Younger Babies' Cries from the Frequency Analyses of the Voice

- Classification of Hunger, Sleepiness, and Discomfort -

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Abstract— **A method for estimating why a baby is crying is proposed using frequency analyses of the voice. Here, especially three causes, hunger, sleepiness and discomfort, are considered for classification. Moreover, the method intends for younger babies aged form 2 to 4 months old. Some typical characteristics are obtained for hunger, sleepiness, and discomfort, respectively, in the shape of the power spectra of the crying. Using the difference of these characteristics, a rule-based system is proposed, which can classify cries of babies from 2 to 4 months old in a hungry state, a sleepy state, and a discomfort one. Computer simulations show that about 85% of the babies' cries are correctly classified.**

I. Introduction

Babies cry from various causes, such as hunger, sleepiness, pain and so on. Mothers try to understand why they are crying, but it is often difficult to know the truth since baby cannot express their mind definitely by words. Mothers get exhausted if they cannot understand how the babies are feeling. Thus a system to estimate the cause of babies' cries is quite helpful to childcare.

The study on quantitative analyses of babies' cries were first established by Truby et al and some fundamental frequency characteristics were clarified for babies' cries from pain[1]. Next Wolff categorized babies' cries into two groups such as hungry cries (basic cries) and angry cries (mad cries). Recently, according with the development of high-speed processor of sound signal, various works have been done on classification of babies' cries depending on their various physical or mental states not limited to angry and hungry[3]-[5]. However, most of them clarified the difference between angry cries and cooing from hungry ones, which are easy to be recognized by human auditory test. Moreover, these works aim at just showing some statistical difference between the categorized cries, not estimating the cause of each cry. Xie et al proposed a practical system to estimate the babies' emotion from their cries, but it just estimate the level of distress, not for concrete states, such as a hungry state, a sleepy state, and so on[6].

In this paper, a method for estimating the cause of the babies' cry is proposed using the frequency analyses of the baby's voice. Here, especially three causes, hunger, sleepiness and discomfort, are considered, because they often occur in usual childcare and the cries from these causes are usually difficult to be classified by just listening. Cries of 21 babies, both male and female, aged from 2 months old to 4 months old are collected to make the rule to classify the cries. Authors proposed before a rule-based system for classifying hungry cries and sleepy ones for 3-4 month-old babies from the shape of the power spectrum of the cry. For 2 month-old babies, the characteristics of the shape of the power spectrum are not exactly the same, but a similar tendency is obtained for 2 month-old babies for hungry and sleepy states. Moreover another tendency is obtained for the power spectra of cries from discomfort for 2-4 month-old babies. Here, discomfort means the state when a baby seems to be discomfort because of the wet diapers or when he (or she) wants to change his (or her) posture. Finally, a rule-based system, which can classify babies' cries in a hungry case, in a sleepy case, and in a discomfort one, is proposed. Moreover, the correct answer rate of the system can be increased by taking the majority in a series of cries to make the final judgment, since the cause is the same in the whole series. Computer simulations show that about 85% of the babies' cries are correctly classified.

II. Frequency Analyses of Babies' Cries

A. Data acquisition

Cries of 21 babies, both male and female, aged from 2

Fig.1 Extraction of isolated cries from the babies' sequential cries.

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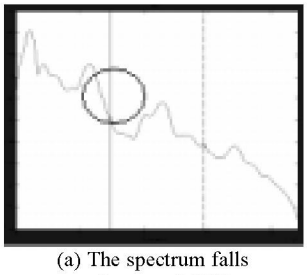
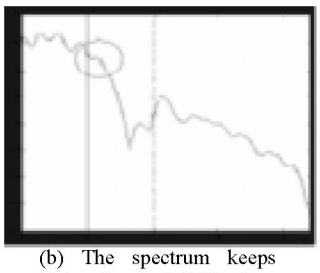
months to 4 months old (8 are from 2 months, 6 are from 3 months and 7 are from 4 months) in a hungry state, in a sleepy one and a discomfort one are collected. The crying voices are acquired with a DAT recorder, digitized in 44.1kHz -16 bits. The microphone is located about 15 cm apart from babies' mouth. The baby is supposed to be in a hungry state if he (or she) has enough amount of milk or meal after the cry. The baby is in a sleepy state, if he falls into sleep soon after the cry (within about 20 minutes). And the baby is in a discomfort state, if he stops crying when his diaper is changed or he looks as if he wants to change his posture. Babies' cries occur sequentially, being connected with unvoiced periods. In order to analyze the series of cries efficiently, only the voiced periods are extracted as shown in Fig.1. Especially, Cries from 2 months old are extracted only where the cries keep much volume so that the difference between every state can be recognized clearly. Consequently, 205 isolated hungry cries, 161 isolated sleepy cries and 78 isolated discomfort cries are obtained. Hereafter, isolated cries are called as 'cries'.

B. Frequency Analyses of cries of babies from 2 to 4 months old

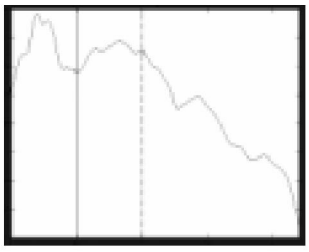
By examining all cries, some typical shapes are obtained for the power spectrum of each cry for hungry, sleepy and discomfort cries respectively. Here Welch's method is applied to obtain the rough shape of the power spectrum. The window size of FFT is 128 and the final spectrum is obtained by averaging the Fourier spectra with 128-point FFT at every 1024 time points using Hanning window.



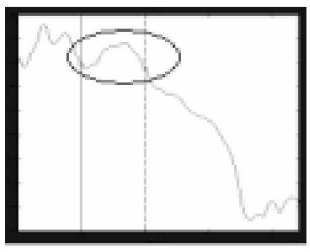
(a) The spectrum falls steeply around 6 kHz



(b) The spectrum keeps high value in 0-5kHz, then falls steeply

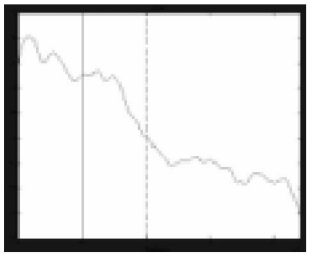


(c) The whole spectrum is the convex form

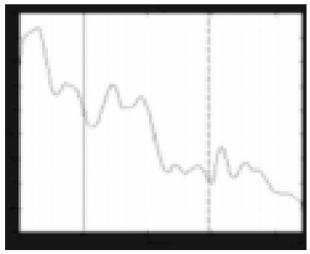


(d) The spectrum keeps high value from 0 to 10 kHz but not up to 10 kHz

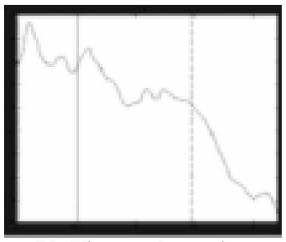
Fig.2 Typical shapes of the amplitude of Fourier spectrum for hungry cries of younger babies.



(a) The spectrum decreases continuously.

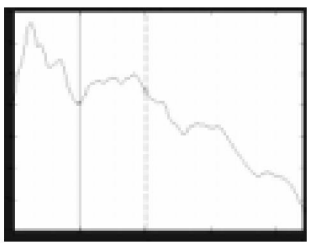


(b) The spectrum suddenly falls around 1-2 kHz but it does not fall steeply after than up to 10 kHz.

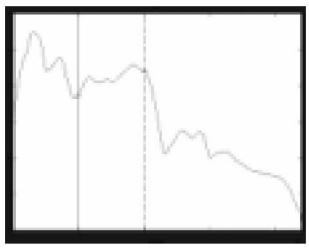


(c) The spectrum decreases almost continuously.

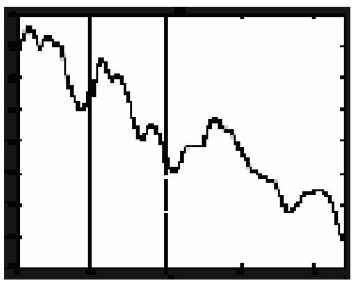
Fig.3 Typical shapes of the amplitude of Fourier spectrum for sleepy cries of younger babies.



(a) The spectrum falls steeply around 3 kHz then is flat in 5-10 kHz.



(b) The spectrum keeps high value up to 10 kHz or increases and decreases steeply around 10kHz



(c) The spectrum falls steeply around 3 kHz then is flat in 5-10 kHz or increases and decreases steeply.

Fig.4 Typical shapes of the amplitude of Fourier spectrum for discomfort cries of younger babies.

Fig. 2 shows typical shapes for hungry cries and Fig. 3 shows those for sleepy cries and Fig. 4 shows those for discomfort cries. One scale on the horizontal axis denotes 5kHz, and that on the vertical axis 10dB. We can see that shape of the hungry cries has tendencies such that the spectrum falls steeply around 6-7kH, the spectrum keeps flat in lower frequency region such as 0-5kHz and then falls steeply, or the spectrum

keeps a high value and does not fall much from 0 to 10kHz. Fig.2(d) is special for 2 month-old babies. As for the sleepy cries, the power spectrum continuously decreases from about 1kHz. This tendency is common for all the age from 2 to 4 months ole. Moreover, the shape of the discomfort cries has tendencies such that the spectrum keeps a high value up to 10 kHz, the spectrum is completely flat from the first peek to 4, 5 kHz, or Spectrum falls steeply around 3kHz then is flat in 5 – 10 kHz or increases and decreases steeply.

III. Rule-based system for classifying hungry and sleepy cries

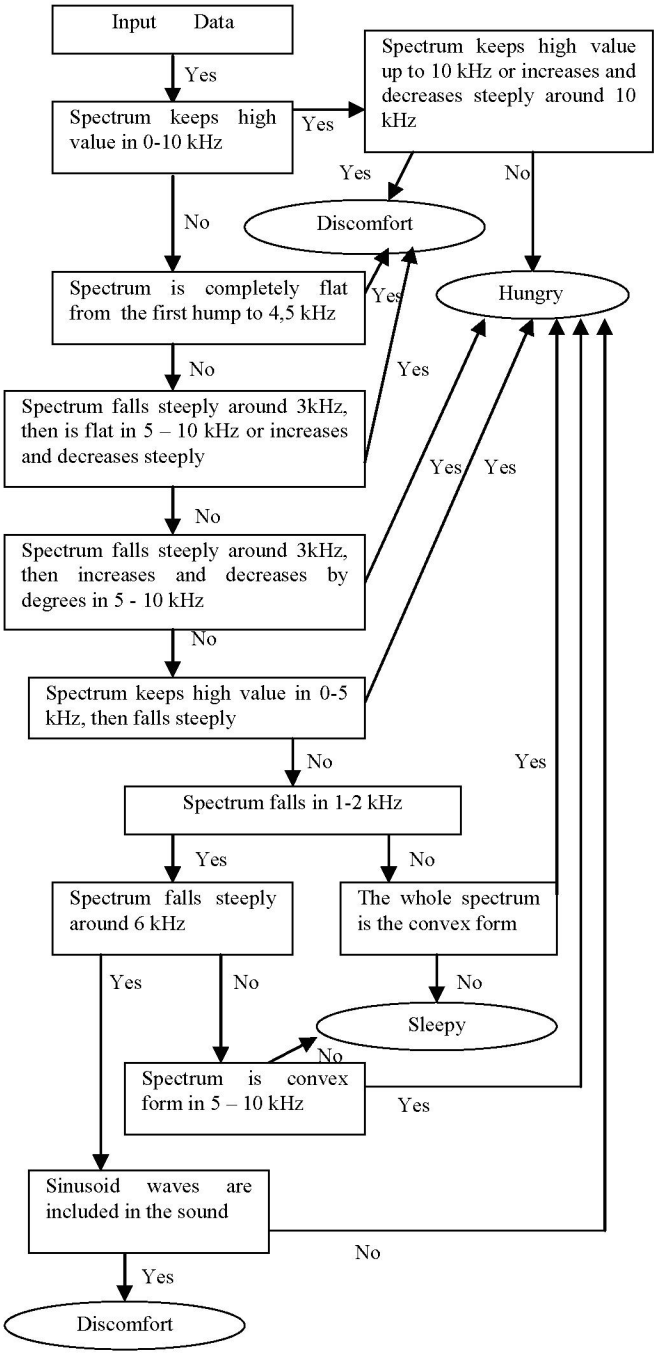


Fig.5 A rule-based system to recognize hungry, sleepy and discomfort states of babies younger than 5 months old.

By examining all the pattern of the shapes of $|X(f)|$ for hungry, sleepy and discomfort cries, a rule-based system which automatically classifies these three states can be considered.
For young babies from 2 to 4 months old, a rule-based system as shown in Fig. 4 can be considered reflecting various features of the amplitude of Fourier spectrum shown in Fig. 2 , 3 and 4.

IV. Results of recognizing hungry, sleepy and discomfort staets

Table 1 shows the results of applying the rule-based system for young babies respectively to all the cry data obtained as mentioned in II *A*. It was almost impossible to recognize whether the baby is hungry, sleepy or discomfort by auditory test. The correct recognition rate, that is the number of cries correctly recognized over the number of all cries in each state, is shown in these tables. We can see that the system can recognize the feeling of hunger and sleepiness with about 75% accuracy in all. And when this recognition is decided by majority vote, about 85% of the babies' cries are correctly classified.

	Total number of cries	Number of correctly recognized cries	Correct recognition rate
hungry cries	205	165	80.4%
sleepy cries	161	123	76.4%
discomfort cries	78	56	71.8%

Table 1 Correct recognition rate for young babies

	Total number of cries	Number of correctly recognized cries	Correct recognition rate
hungry cries	49	42	85.7%
sleepy cries	23	19	82.3%
discomfort cries	20	17	85%

Table 2 Correct recognition rate decided by majority vote.

About 25% of the cries are misjudged. The reason for that is considered that the actual feeling of the babies is not known. We judge the babies' states by how the babies stop crying. For example, we judge that the baby is hungry, if the baby drinks milk (or have meal) after the cry and becomes quiet, but babies may drink milk even if he is not actually hungry.

V. Conclusions

A method to estimate how babies are feeling is proposed. Here, especially three causes of feeling, hunger, sleepiness and discomfort are picked up. By frequency analyses, difference of

the tendencies of the Fourier spectrum is clarified for these three states. In analyzing the cries of young babies aged from 2 to 4 months, it is shown that the hungry cries has tendencies such that the spectrum falls steeply around 6-7kH, the spectrum keeps flat in lower frequency region such as 0-5kHz and then falls steeply, or the spectrum keeps a high value and does not fall much from 0 to 10kHz, while the spectrum of sleepy cries continuously decreases from about 1kHz. And shape of the discomfort cries has tendencies such that the spectrum keeps a high value up to 10 kHz, the spectrum is completely flat from the first peek to 4, 5 kHz, or Spectrum falls steeply around 3kHz then is flat in 5 – 10 kHz or increases and decreases steeply. A rule-based system using these tendencies can by also considered and about 75% of actual cries are correctly classified in experiment

As to the reason of the misjudgment, it is considered that the reason for the cry is not always distinct. In some cases, babies are in both hungry and sleepy. Moreover, it is possible that the baby is in the other state than not hungry, sleepy or discomfort. In this way, since it is difficult to identify the real cause of cry, the correct recognition rate cannot be close enough to 100%. How to deal with the case of the mixed condition and the other reason is for further research.

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