A proposal of alarm sound recognition system for the medical instrument

Toshihiro Nishikage, Fumiaki Takeda and Yuhki Shiraishi
Research & Development Center of Intelligent Recognition Systems,
Research Institute of Kochi University of Technology
185, Miyanokuchi, Tosayamada-cho, Kami-gun, Kochi, 782-8502, Japan

ABSTRACT

In this paper, an alarm sound recognition system of medical instruments is proposed. The difference between existing methods and the proposed method is as below: In the proposed method, the static method is used for recognition, but the dynamical method is used for recognition in existing method. Because the specification of artificial sounds such as alarm is very simple. We show abilities of the proposed method by computer simulation. Then, we propose the recognition system of alarm sounds using digital signal processor, in which neural networks are employed as the classifier. We develop the real-time alarm recognition system with the appropriate pre-processing using acoustic pressure waveform, and make some recognition experiments using real alarm sounds. The results of the experiments reveal that the system can effectively resist the interference of noise and correctly recognize the pattern of alarm sounds with low cost.

Keyword: artificial sound recognition, neural network, digital signal processor

1. INTRODUCTION

In daily life, it is important to monitor the operating conditions of various systems automatically, especially for medical instruments. If having these functions, it can be tackled promptly once trouble takes place. However, there is not alarm monitoring functions in some developed systems in market. Generally, if users want to add any function to the developed system, they have to replace it with a new type. It is too expensive.

In this paper, we propose an extension unit having automatic recognition capabilities. The proposed unit, which can recognize alarm sounds automatically, is developed. It can be applied directly on developed systems instead of replacing them.

First, we consider a recognition system that has enough abilities for according to our purpose. In general, dynamical methods such as the hidden markov model (HMM) are used for sound recognition in most of cases such as human voice recognition [1]. However, if the specification of objective pattern is only limited and simple, the static method can be used to resolve this problem. The alarm sounds satisfy these assumptions.

To verify the capability of the proposed method, we implement a recognition system to PC, and we execute computer simulation for verification of the proposed method. After that we develop practical recognition system which can recognize alarm sounds in real time. Finally, we show effectiveness of our system on recognizing alarm sounds of medical instruments.

2. CONCEPT OF ALARM RECOGNITION SYSTEM

We consider a recognition system using appropriate method for artificial sound recognition. There are some differences between artificial sound such as alarm sounds and natural sound such as human voice. The differences between artificial sound and natural sound are shown in Table 1. An alarm sound can represent as a summation of some simple signals. Furthermore, most of artificial sound has simple timing diagram.

Table 1. Differences between alarm and human voice

	Alarm sound	Human voice
Periodicity	High	Nonexistent
Repeatability	High	Extremely rare
Spectral shape	Discrete	Continuous

Through observing some specific frequency elements in the spectrum of the recognition targets tackled by Fast Fourier Transform (FFT), it can be found that the patterns formed by these elements have high periodicity and repeatability. It means that the length fixed frequency elements can be extracted as feature of an alarm sound. In other words, we can solve this problem without using dynamical methods. However, it is essential to decide the starting point of the alarm signals when using statical method. We use a band pass filter to reduce noises and observe a running mean of acoustic pressure of removed noises for finding the start point process to solve this problem.

3. A SOLUTION USING NEURAL NETWORK

For features extracted from some samples, if high recognition capabilities are demanded some samples with linear discrimination method, skilled engineers should draw discrimination rules. However, there are various criteria in the situation of operations. Each situation requires variant rules and we can not disregard human resource for drawing rules consequently. Therefore, we propose to use neural networks (NN), which have noise tolerance and flexibility. Additionally, NN architecture that we proposed have a good track record in currency recognition [2][3][4], discolored rice detection [5], and behavior of arm [6]. The NN structure is a Multi-Layer Perceptron. Numbers of unit in input, hidden and output layer are L, M and N, respectively. We describe NN structure as L-M-N.

3. 1. Feature extraction

We extract some frames from alarm sound signals at even intervals. After frequency analysis, we choose some frequency elements from each frame. The quantity of the frame is F, and the quantity of frequency elements in each frame is C. The flowchart of feature extraction is shown in Fig.1. And combinations of F and C are shown in Table 2. The selected combination is R. There are 7 combinations.

Table 2. Combinations of quantity of frames And quantity of frequency elements

R	*F*	*C*
1	10	5
2	16	3
3	25	2
4	12	4
5	7	7
6	5	9
7	4	11

The fundamental frequency is f_0, and extraction interval of frames is S_f. Extracted element's frequency is integral multiple of $f_0/2$. The features are given by using f_0, S_f, and R. when the target is a single sound source; it is not difficult to decide parameters for feature extraction. In this case, we have to take care of the timing diagram of alarm sound. However, if the target is multi-sound sources, we should refer timing diagrams for each sound source, and decide optimal parameters for feature extraction.

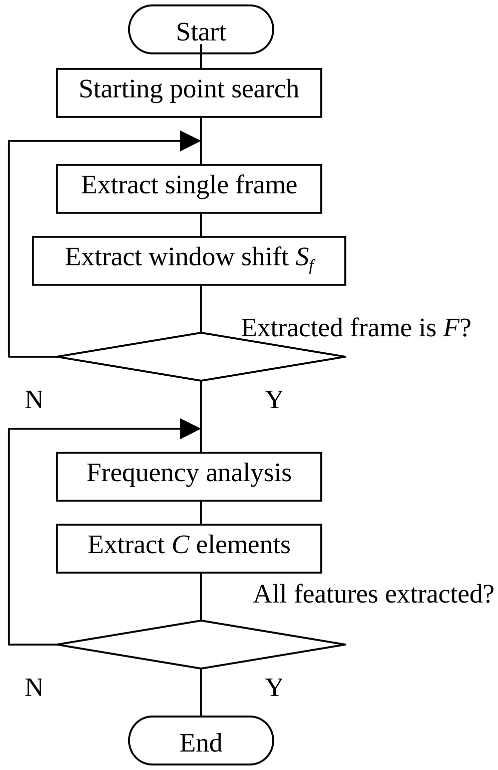

Fig. 1. Flowchart of feature extraction

3.2. Ability of the proposal system

To verify the recognition capability of the proposed system, computer simulation is executed. We use oxgen concentrators as recogniton targets shown as Fig. 2. First, we collected alarm sound samples from two types of oxygen concentrator with no disturbances. Type A has two alarm patterns and another type has three alarm patterns. Each of them has three units. One of them were used as the training data of the NN.

Even if a learning process converged normaly, the recognition ability is unsatisfied when using only data set affiliated with target category to solve this problem, because of lack of negative data. We prepare enough negative samples which is not affiliated with target category, and using these negative samples for constructing "gabage" category. We can expect high ability by the cell corresponding to gabage category (gabage cell). The negative samples are generated by randomize function, through reversing of positive sample and shifting positive sample.

a) type A b) type B

Fig.2. Oxygen concentrator

In the evaluation procedure, the influence of the starting points for recognition accuracy was considered. We determine the starting point by observation in advance, and then we evaluate using the starting point that is shifted in small steps. The result of this experiment reveals that if the misalignment of the starting points is less than 0.1sec, the system can recognize the alarm sound correctly. A band pass filter is applied to counteract the noises: The simulation shows it can resolve the noises effectively.

Because each of recognition targets is single sound source, it is readily to obtain parameters for recognition from spectrum patterns. For example, f0 is given as fundamental frequency of alarm sound and upper bound and lower bound of passing band are given from f0 and variability of machines.

We show capabilities of the proposed system to disturbance in 87dB as in Table 3, in which alarm sound in unit 2 and unit 3 is not used for learning.

Table 3. Ability of the proposal system

Type A(network structure:50-30-3)		
Unit number	Alarm pattern	Recognition rate
1	1,2	100%
2	1,2	100%
3	1,2	100%
Type B(network structure:48-30-4)		
Unit number	Alarm pattern	Recognition rate
1	1,2	100%
	3	100%
2	1,2	100%
	3	80%
3	1,2	100%
	3	90%

There are some unrecognizable alarm sounds. However, we presume if increasing learning samples, the recognition rate will be sufficient. Therefore, Our proposed system can recognize alarm sound accurately even if having strong disturbances.

4. EXPERIMENTS USING DSP

It is impractical to develop the recognition system using PC even if it has enough processing ability considering the cost and size of the system. In addition, we have to consider task scheduling with using built-in OS because of limit functions of our system.

For all of these reasons, we employed digital signal processor (DSP) which has good track record in out previous work. We build a recognition board that applied DSP as shown in Fig. 3 and an additional unit including recognition board as shown in Fig.4. The recognition board includes all functions that we proposed in section 3. Furthermore we have prepare a fundamental frequency searching function since the data variation is not same with that of the ideal situation.

We make experiment using the additional unit. The system specification is as in Table 4.

Table 4. System specification

Processor	Texas instruments TMS320C32(33MHz)
Sampling frequency	24KHz
Frequency Analysis	1024point FFT
Band pass filter	Biquad
Passing band, R, f_0, S_f	Depend on target

Fig.3. DSP board

Fig.4. Additional Unit

In Table 4, "Depend on target" means that these parameters have given a definition in specification information [7]. And we can handle these parameters for feature extraction according to the different demand.

Table 5 and 6 show the calculation time and the recognition ability of disturbance in 85dB, respectively. It reveals our developed system can recognize alarm sounds of the medical instrument quickly and accurately even if there are some noises.

Table 5. Calculation time of principal process

Rising point detection (include band pass filter)	55.03 [msec]
FFT + feature extraction	79.98 [msec]
Calculation of NN (4 pattern identifiable)	0.31 [msec]

Table 6. Recognition ability of proposed system

Type	A	B
Unit number	1,2,3	1,2,3
Alarm pattern	1,2	1,2,3
Recognition ratio (Evaluate Result)	100% (80/80)	100% (80/80)

5. CONCLUTION

In this paper, we show it is possible to realize artificial sound recognition using statical method. We have been constructing real-time alarm recognition system that transacts sound signals of the medical instruments. And it has enough recognition ability with high noise tolerance and flexibility. The proposed system will be efficient on not only alarms recognition of medical instrument but also recognition of other artificial sound recognition.

The future task is how to decide optimal parameters for feature extraction when recognition targets is multi-sound sources.

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