A New Method of Vehicle Initiative Safety: Heart Sound Acquisition and Identification Technology

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***Abstract*-This paper presents a method based on heart sound analysis of the characteristics of the vehicle initiative safety technology, to explore the feasibility and implementation method of monitor the pilot health condition using the heart sound signal. The article analyzes the characteristics of heart sound signal and vehicle background noise firstly, and proposes the model of the heart sound in vehicle internal environment; according to the model, a kind of acquisition device is designed; then, it discusses the heart sound classification and identification method based on independent sub-band function, especially the rules and algorithms of independent sub-band function construction, as well as how to make independent sub-band function as a new statistics characteristic parameter. In order to quickly determine a heart sound signal which separated from the heart sound acquisition apparatus, the paper introduces the new concept, i.e., degree of heart sound signal certainty. Finally, efficiency and feasibility are verified through the heart sound acquisition, classification and identification experiments.**

Keywords-Vehicle initiative safety; Heart sound acquisition and identification; Independent sub-band function; Degree of heart sound signal certainty

I. INTRODUCTIONS

In order to improve the automobile intelligence and security, contemporary cars have already gradually entered into active safety design from the past passive security settings. Now, except for the seat belts, airbags, bumpers and so on, we have to take active safety design into more consideration. The car can take the initiative to take measures to avoid accidents in advance. For example, the driver drowsy warning system, automobile anti-collision radar, GPS (Global Position System) system, tire pressure monitoring warning system, engine fire alarm prediction system, headlight automatic adjustment system, blind area monitoring system, vehicle information transmission system, automatic braking system, SOS parking system and automatic fire extinguishing system. All of these are to actively avoid a variety of accident factors that may be triggered by people or the vehicles. But studies into the various accident factors triggered by drivers is not a very active research topic; for example, traffic accidents caused by driver fatigue and cardiac sudden death is not uncommon, which contribute the appearance of driver on-site health monitoring mode that is based on the driver's physiological state detection. In recent years, the aging population is a growing trend and aging problems are spreading between car drivers who take a certain proportion of the underlying heart disease; when a sudden heart attack occurs when driving a vehicle, current active safety facilities cannot detect it timely, which creates an obvious danger [1-3].

Some fundamental research about heart sound shows that heart sound can reflect the health status of different people [4-5]. When we make a combination of the existing driver fatigue detection system and automotive active safety systems, a more comprehensive unity of car reliability and security will be achieved. Therefore, the article analyzes the characteristics of heart sound signal and vehicle background noise firstly, and proposes the model of the heart sound in vehicle internal environment; according to the model, a kind of acquisition device is designed; then, it discusses the heart sound classification and identification method based on independent sub-band function, especially the rules and algorithms of independent sub-band function construction, as well as how to make independent sub-band function as a new statistics characteristic parameter.

In order to quickly determine a heart sound signal, which is separated from the heart sound acquisition apparatus, the paper introduces the new concept, i.e., the degree of heart sound signal certainty. Finally, efficiency and feasibility are verified through the heart sound acquisition, classification and identification experiments.

II. CHARACTERISTICS OF HEART SOUND SIGNAL AND AUTOMOTIVE BACKGROUND NOISE

The ventricular and the atria’s filling and contraction leads to heart beat, while heart beat information after cardiothoracic body reaches the surface and form the “heart sounds” that we can hear. Heart sound signals have the following main characteristics [5-6]:

In most cases, we only can hear the first heart sounds s1 and the second heart sounds s2; s1 is relatively low and long, lasting about 0.15s, while s2 is relatively high and short, lasting about 0.12s. Heart sound signals are mainly distributed in the first heart sound and second heart sound where a dominating place for us to extract heart sound parameters. However, the third heart sound and forth heart

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sound are inconspicuous, so they are not underlined. Frequency of the heart sound is mainly concentrated on the range of frequency from 0~600Hz. Frequency of the first heart sound is between 50 and 150 Hz, while the second heart sound is concentrated in the range of 50 ~ 200 Hz. They have obvious change on amplitude while the other frequency range tends to zero. Figure 1 shows the heart sound signal spectrum.

The heart sound signal is periodic, so we perform the analysis of the heart sound in one cycle. Although the waveform of each cycle is different and there are various interferences, we can still deal with the heart sound signal by regarding it as a repeated stable signal.

Horn, the sound of a motor, brake sound, voice (audio), the wind, the sound of tire on the road and other noise are the main background noise in the automotive environment; in most cases, this noise can be divided into the interior noise and exterior noise. In this work, we focus on the interior noise. The typical car background noise has the following characteristics [1, 2]:

The sound of a motor, we also mean the sound of engine noise, which is one of the main sources of interior noise, typically including gasoline-combustion noise and mechanical vibration noise. When the car at low speed or go idling gasoline combustion noise is greater than the mechanical vibration noise, on the contrary, the later is greater than the former. Frequency of the engine noise is between 0 and 200 Hz, if the sound of a motor is smooth, there will a peak point in frequency 100HZ. Figure 1 (b) shows the frequency spectrum diagram of the motor sound. The car acceleration sound whose spectrum showed obvious ultra-low frequency and with a typical low-pass band spectrum, that is one special sound of a motor. Figure 1 (c) shows the acceleration sound spectrum.

The voice is the sound of the voices of the passengers in the car or stereo, and it is an active interior noise, which was relevant with the occupant's physiological characteristics, emotional and language content. Voice pitch frequency is a range of 130 Hz to 350Hz, while the harmonics of the frequency range up to 130 Hz to 4000 Hz, but the energy is mainly concentrated in the pitch range. Figure 1 (d) shows the sound spectrum; the music signal has a wider range of the spectrum and contains a richer, higher harmonic.

The brakes sound is that when there is a car braking, brake pads hugging tire, tire and ground cause a dramatic friction, then, the tire will make a harsh braking sound; the faster, heavier quality of the car and the sharper the brakes, the louder the noise; sometimes, the brakes sound will be up to 70-90 dB. Figure 1 (e) shows the acceleration sound spectrum diagram, which is energy-frequency mainly concentrate between 0 Hz and 200Hz, but there are also obvious treble component; the brakes sound is an interior noise with wider spectrum.

Horn, a peculiar language among car, people and vehicles to talk to each other, is indispensable in automotive safety systems. The horn is a steady-state signal with a good point and timbre; in addition, the baseband frequency of horn general around 400Hz and its spectrum showed baseband and several octaves, according to the spectrum. We cannot see significant fluctuation in the sound stage. Figure 1 (f) shows the spectrum of horn. The noise in the range of 0 to 200Hz clearly coincides with the spectrum of the heart sound signal.

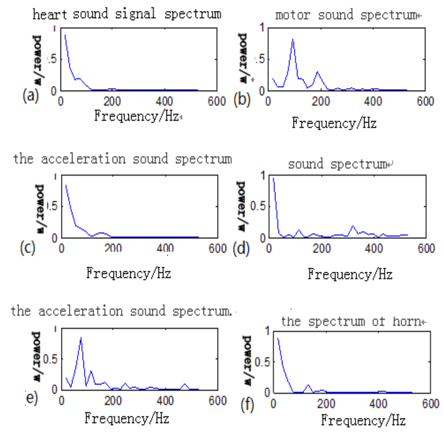


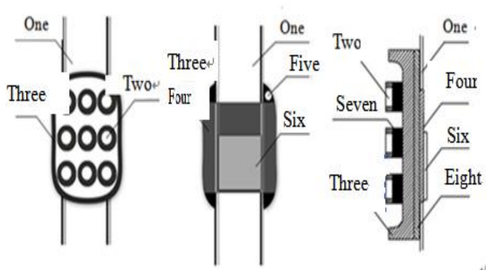
Figure 1. Heart sound with the typical curve of the spectral characteristics of the interior noise

III. A HEART SOUND ACQUISITION DEVICE FOR AUTOMOTIVE ACTIVE SAFETY

In order to achieve real-time monitoring of cardiac health condition of the driver, the heart sound acquisition device was designed as an automobile active safety. The device configuration is installed on the car safety belt. The device not only can collect but also can finish the pretreatment of heart sound signal and classify the cardiac physiological state of the driver. According to such equipment, an alarm will alert when the physiological state of the heart is abnormal. Heart sound acquisition probe arrays are installed in the wall of a deformable elliptical acoustic cavity while the signal processing circuit, sound and light alarm were fixed at the top of the noise cavity; but what was configured in the cavity was an embedded lithium rectangular nylon sleeve, which cuffs can be installed on the car safety belt. Such kind of sleeves can be adjusted up and down along the seat belt position so effortlessly that it is possible to collect the heart sound signal without much effort. Recently, the device has applied for a Chinese invention patent, as shown in Figure 2.

When the driver plugs the seat belt, the heart sound monitoring device will changed into working state; once the monitoring device does not detect heart sounds heart sounds, the light will shine, the driver is required along the seat belt up and down to adjust the position of the heart sound monitoring device in the chest; when heart sounds are detected, the light does not shine. The device provides real-time monitoring of the cardiac physiological state of the driver; with this, we can make rapid analysis of the collected heart sound signals though the internal processor, or transmitted to the onboard computer processing. According to the classification of the heart sound, we can determine the health status of the driver. Once the abnormal sound is found, lights will flash, an audible alarm will appear and the abnormal sound signal will be transmitted to the automotive active safety systems for further processing. The device is not only used in lithium battery-powered, but also ultra-low-power processor applied internally to improve working time of the signal acquisition. Once the seat belt is not properly plugged, the device will power off, reducing the power consumption.

In order to improve the reliability of the classification and identification of heart sound signals, that means we need to eliminate automotive environmental noise to the greatest extent as well as the rapid and effective algorithm to correctly identify the classification of heart sounds.



1. Seat belts. 2. Heart sound acquisition probe array. 3. The oval sound insulation cavity. 4. A rectangular nylon sleeve. 5. Sound and light alarm. 6. Lithium battery. 7. Memory materials. 8. The signal processing circuit module.

Figure 2. Heart sound acquisition monitoring device for an automobile active safety

IV. HEART SOUND SIGNAL EXTRACTION METHOD

A. Heart sound signal model in the automotive environment

Order the heart sound signal as:

$$S(t)=s_1(t)+s_2(t)+s_3(t)+s_4(t)=\sum_{i=1}^{4} s_i(t) \tag{1}$$

is the car background noise, including trumpet sound, motor sound, brakes sound, voice and other noise, etc, then $gN(t)=gN_1(t)+gN_2(t)+gN_3(t)+\cdots\cdots$, the model of the heart sounds in the automotive environment is:

$$\sum_k x_k(t)=\sum_{i=1}^{4} s_i(t)+\sum_j gN_j(t) \tag{2}$$

B. Heart sound signal separation method based on ICA

For heart sound signals and interior noise characteristics, in this paper, we use the Independent Component Analysis (ICA) [6] method to separate heart sound signal from the interior noise, according to the mixed model of formula (2), and let $X=[x_1,x_2,x_3\cdots x_k]^T$ be its deviation matrix is [7]:

$$D=\sum_{j=1}^{K}\left(X^T-\frac{1}{N}\sum_{j=1}^{N}x_j^T\right) \tag{3}$$

We can get the covariance matrix: $C=\frac{1}{N}\sum_{j=1}^{N}DD^T$, the orthogonal eigenvector is $V=[v_1,v_2,\cdots v_m]$, there are m largest Eigen values $\lambda_1\geq\lambda_2\geq\lambda_3\geq\cdots\lambda_m$, then, whitening matrix P can be obtained:

$$P=V\left(\frac{1}{N}\Lambda\right)^{\frac{1}{2}}=\sqrt{N}V\Lambda^{\frac{1}{2}} \tag{4}$$

$\Lambda=diag(\lambda_1,\lambda_2,\lambda_3,\cdots\lambda_m)$, and $P^TCP=I$, $\overline{y}=P^TX$, using these data in the use of albino to calculate the inverse matrix $W=[\overline{w_1},\overline{w_2},\cdots\overline{w_m}]$ that meeting statistical independence conditions, ICA can usually be estimated by using steepness:

$$kurt(\overline{w}^T\overline{y})=E[(\overline{w}^T\overline{y})^4]-3(E[(\overline{w}^T\overline{y})^2])^2+\lambda(1-E[(\overline{w}^T\overline{y})^2]) \tag{5}$$

Inverse matrix W can be obtained by changing the steepness of the maximization. Then, the isolated heart sound signal is:

$$\begin{bmatrix} s' \\ gN'_1 \\ \vdots \\ gN'_j \end{bmatrix}=W\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_k \end{bmatrix} \tag{6}$$

C. Heart Sound Signal Certainty Degree (HSSCD)

In order to determine the signal separated from $X(t)$, which is the heart sound signal and which is the car background noise, we have introduced a new parameter- "Heart sound signal certainty degree (HSSCD)".

Order the probability density function of separated signal $S_k(t)$ as:

$$P(S_k)=\int_{S_{k1}}^{S_{k2}} p(S_k)dS_k \tag{7}$$

However, this description can only be used when S_k is in the positive distribution state, in order to resolve the negative S_k exists, we introduce:

$$RI_S=-\frac{1}{2}\log_2\left\{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}W_{S_k}(t,\omega)dtd\omega\right\} \tag{8}$$

where W_{S_k} is the signal S_k the Wigner-View distribution, that is:

$$W_{S_k}(t)=\frac{1}{2\pi}\int S_k^*\left(t-\frac{1}{2}t\right)S_k\left(t+\frac{1}{2}t\right)e^{-j\omega}dt \tag{9}$$

Our definition of heart sounds certainty is:

$$HSSCD=\frac{(RI_s)_{\text{Compare signal}}}{(RI_s)_{\text{standard heart sound signal}}} \tag{10}$$

HSSCD has quantitatively described the overall performance of closeness of a signal with standard heart sound signal in the amount of information and complexity. Figure 3 is time-domain waveform diagram of the heart sound signal and a variety of automotive background noise; Table 1 is a signal corresponding HSSCD value.

We can have the following conclusions by the HSSCD analysis.

Judgment 1: when HSSCD = 1, that is exactly the same two heart sound signals;

Judgment 2: when HSSCD is approaching 1, indicating that the detection signal can be classified as a heart sound signal;

Judgment 3: when the HSSCD value is smaller, it signals, does not belong to the heart sound signal.

Experiments show that HSSCD have little relationship with the signal change in sampling frequency and length, even if there is a difference in length and the sampling frequency of the two signals, HSSCD remains essentially unchanged.

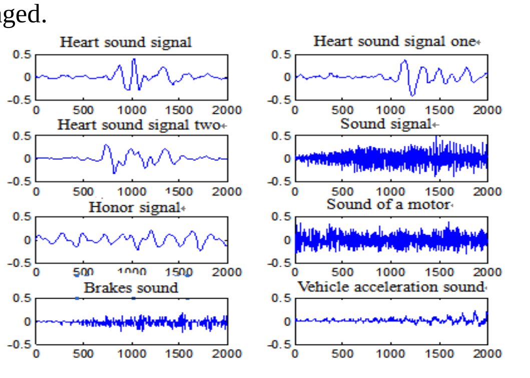


Figure 3. Waveform diagram of the part of the heart sound signals and car background noise

TABLE I. VARIOUS SIGNALS CORRESPONDING HSSCD VALUE IN FIGURE 1

Signal Type	*HSSCD*	*Signal Type*	*HSSCD*
Heart sound signal	***1***	***Horn sound***	***0.8678***
Heart sound signal 1	***1.0991***	***Sound of a motor***	***0.3585***
Heart sound signal 2	***0.9941***	***Brakes sound***	***0.4536***
Sound signal	***0.4807***	***Acceleration sound***	***0.7323***

V. HEART SOUND SIGNAL EXTRACTION METHODA KIND OF STATISTICAL CHARACTERISTIC PARAMETERS：THE HEART SOUND INDEPENDENT WAVELET FUNCTION

Feature Extraction of heart sound is to find a kind of transformation. This transformation can convert the original heart sound signal into a certain state of feature space, but also be able to save all the original information, so that to lay the foundation for the classification and identification of heart sounds.

Feature Extraction of heart sound has many forms, such as a time-domain characteristics parameters extracted cardiac cycle, heart rate, and adjacent interval of the first heart sound and second heart sounds, Extracting the spectral characteristics of the heart sounds, linear predictive spectral coefficients, Mel frequency spectral coefficients [11] as the characteristic parameters of frequency. These characteristic values can be used for classification and identification of the heart sounds. According to the characteristics of the heart sounds, this article uses the heart sound independent wavelet function as a new kind of statistical characteristic.

A. Description of independent sub-band function

For one channel of the heart sound signal s(t), if we can brake it into q layers data segment Z_q, with equal length (q=1,2, ⋯Q), independent component analysis and signal divided into layers, by finding a full rank separation matrix, thereby defining the output signal [b1,b2,⋯b_Q], including the information of heart sound signal s(t) as independent as possible, this group statistically independent function with each other in the time domain, which is what we call cluster of independent sub-wave function [5].

The Independent sub-wave function is derived in the following way: (a) layers of the signal. This process can be understood as hierarchical linear transformation of the signal; (b) Analysis of the independent components of the signal. The result of this process is hierarchical signal matrix solutions mixing matrix and the hierarchical signals are converted into mutually independent vectors matrix. This process can also be considered to be the projection of the vector direction independent of each of the sub-wave function. From more experiments, we draw more conclusions, as explained below:

The independent sub-wave function has strong local characteristics of the time domain, since the independent sub-wave function obtained by the different signals are varied, DFT (Discrete Fourier Transformation), DCT (Discrete Cosine Transformation) transform guide [9] to the base function to the various signals are very similar, showing obvious global characteristics in the time domain.

The independent sub-wave function has strong local characteristics of the frequency domain because the frequency characteristic curves of the different signals acquired independent sub- wave function are different.

These characteristics indicate that the independent sub-wave functions can characterize on the signal not overlapped as a characteristic parameter, the identification and classification of the heart sounds may be used as an effective feature parameter.

B. Algorithm realization of heart sound independent sub-wave function

Specific steps to obtain heart sounds independent sub-wave function are as follows:

1) Stratify heart sound signal s(t). Signal layering is equivalent to a set of orthogonal base projection, and the hierarchical signal had orthogonally, using independent component analysis of the signal, while the length of each of the hierarchical signal should remain the same. Hierarchical method can meet these two conditions, such as wavelet hierarchical method, EMD (Empirical mode decomposition) hierarchical method;

2) Remove the mean, and preliminary bleach the stratified signal;

3) Independent component analysis of the hierarchical signal after pretreatment, eventually to get heart sound independent sub-wave function cluster.

Figure 4 (a) is a single cycle of heart sound signal s, first use empirical mode of EMD decomposition t that broke s into a series of approximate simple component signal combination, that is:

$$s_k(t) = \sum_{l=1}^{L} \lambda_l Z_l + r \tag{11}$$

Z_l is the number one intrinsic mode function IMF, which is self-adaptive decomposition by the nature of the signal; r is the residual function of the average trend of the representative signal, λ_l is a coefficient, Figure 4 (b) is the result of empirical mode decomposition. $S_k(t)$ will be merged into two groups hierarchical signals $s_{11}(t)$ and $s_{12}(t)$ with equal amplitude, as shown in Figure 4 (c); then we use fastica (fixed point iterative algorithm), Infomax (information maximization algorithm), and dwt_ica, three algorithms to process $s_{11}(t)$ and $s_{12}(t)$ statistically and independently , to obtain the heart sound independent sub-wave, as shown in Figure 4 (d), (e), (f) below. We can see from the figure that the same sample points of independent heart sounds sub-wave as the source signal, but these three ways to get the heart sounds independent sub-waves are very different in magnitude. When using the dwt_ica algorithm, the independent heart sound sub-wave obtained is basically the same, however when obtained with fastica and infomax method, there is slightly different in the heart sound independent sub-wave b_{1f}, b_{2f}, b_{1i}, b_{2i}, especially, the infomax method has a significant uncertainty; its best result shows the effect can be better than dwt_ica, FastICA algorithm, but sometimes appears to be worse than those two methods. Cluster of independent sub-wave function shown in the picture is the average of the three test results. (Wherein the x-axis is the sample point, the y-axis is the amplitude.)

Coefficient description of reconfiguration similarity: two heart sounds independent sub-wave similarity coefficients between the heart sound signals reconstructed with the original heart sound signal is the bigger the better; Irrelevancy describes with correlation coefficient r, which is the metric of independent heart sounds sub-wave of irrelevance degree, relevance between b1 and b2 is the smaller the better. Compare the data results shown in Table 2; the value in the table is the average results of the three experiments.

Using the data shown in the table, we can make a decision from the signal remodeling, the effect of the three algorithms are both good. Judging from the relevance of independent heart sounds wavelet, effects using fastica [9] or dwt_ica [9] algorithm are good, but the wavelet relevance obtained using infomax algorithm is significantly bigger. Analyzing from the time spent in computation, dwt_ica algorithm is the most efficient.

In summary, dwt_ica algorithm shows obvious advantages in all aspects, so we will use dwt_ica algorithm to get the heart sound independent sub-wave function. A heart sound signal stratified results and three BSP algorithms of obtaining independent sub-wave function as shown in Figure 4.

TABLE II. THREE BSP ALGORITHMS EFFECTS OF OBTAINING INDEPENDENT SUB-WAVE FUNCTION

Three BSP algorithms	*Reconfigurability*	*Correlation*	*Computing time(s)*	*Comprehensive Evaluation*
fastica	*0.9979*	*0.0000*	*0.4836*	*Good*
dwt_ica	*0.9983*	*0.0000*	*0.0624*	*Very good*
infomax	*0.9919*	*0.4352*	*0.4212*	*Not bad*

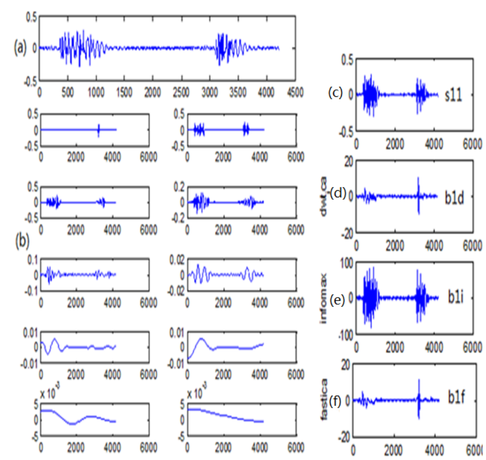


Figure 4. A heart sound signal stratified results and three BSP algorithms of obtaining independent sub-wave function

VI. HEART SOUND SIGNAL EXTRACTION METHOD: HEART SOUND CLASSIFICATION AND RECOGNITION

The process of heart sound classification and identification is essentially an automated pattern matching process, as shown in Figure 5.There are many heart sound classification and recognition algorithms, such as statistical identification method, neural network identification method [11]. In this paper, as a new statistical characteristic parameter, the heart sounds independent sub-wave function, need a pattern matching method; so, we define a similar distance to identify the distance of the independent wave function of two heart sound signals.

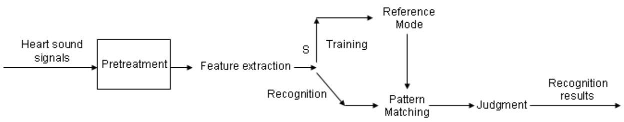


Figure 5. Heart sounds to identify general method

Suppose that the independent sub-wave function digital of the standard heart sound signal as signal of the independent sub-wave function digital to be identified as, then, the similar distance will be:

$$d_k = 1 - \frac{\left|\sum_{n=1}^{N} b_i^c(t) b_j^s(t)\right|}{\sqrt{\sum_{n=1}^{N}(b_i^c(t))^2 \sum_{n=1}^{N}(b_j^s(t))^2}} \tag{12}$$

The smaller the similar distance d_k is, $b_i^c(t)$ and $b_j^s(t)$ will be more similar; when d_k =0, then $b_j^s(t) = b_i^c(t)$, which means they are exactly the same.

Therefore, after the signal preprocessing, to use the independent sub-wave function of the heart sounds to do pattern matching, find their similar distance, and classify accordingly identification.

VII. THE EXPERIMENTAL RESULTS

A. *The acquisition and separation of heart sounds*

In the vehicle initiative safety of heart sound acquisition device needs to set sampling frequency, channel parameters, etc. Frequency of the heart sound concentrates on the range of frequency from 10 to 400 Hz while heart murmur is below 1500 Hz. According to sampling law, we can avoid distortion when sampling rate is at least more than 3000 Hz. In the environment where vehicle noise is relatively large, we use 4 channels and 11025 Hz sampling rate. A group of acquisition results are shown in Figure 6(a). Then, according to the extraction method of heart sound signal stated in the section 3 and blind separation of four aliasing signal based on ICA [9], we can get four separation signal shown in Figure 6(b).

In order to judge the heart sound and the vehicle background noise from the four separated signals, we analyze the sound signal with heart sound signal certainty (HSSCD), and discover that the HSSCD of separated signal 1 is 0.9869, which is heart sound signal; the HSSCD of separated signal 2 is 0.4765, which is speech signal; the HSSCD of separated signal 3 is 0.3275, which is motor sound signal; and the HSSCD of separated signal 4 is 0.4532, that is brake sound signal. Through sound transmitter, we can verify the conclusion. In fact, we just need to extract heart sound signal, and do not need to spend time on the other signals.

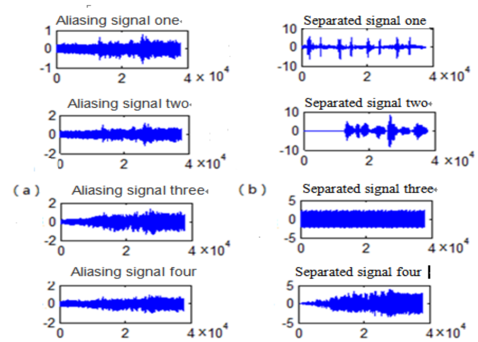


Figure 6. The extraction and separation of signal in heart sound acquisition device

B. *The heart sound signal pretreatment*

The main task of the heart sound signal pretreatment is as follows [11]: (1) determine the beginning and the end point of the first heart sound and the second heart sound of each of the signal in a section of heart sound signal; (2) find out the beginning and end point in a periodic heart sound signal, and calculate the heart rate for displaying the characteristics of heart sounds better, highlighting the main component of heart sounds which are quite useful for the heart sounds identifying. Firstly, calculate the energy spectrum of the heart sound signal, namely separated signal 1 shown in Figure 7(a). According to the envelope extraction method based on Hilbert transformation [5], we can extract heart sounds envelope, and the result is shown in Figure 7(b). Then, we can get normalization energy envelope shown in Figure 7(c) with the threshold taken from the average of the envelope. The optimized envelope can reflect the section of heart sound signal more accurately than the envelope directly obtained. Among them, every broader pulse respectively represents the first heart sound, and the narrower respectively stands for the second heart sound. Thus, we can easily calculate heart sounds interval and heartbeat. Lastly, we section heart sounds according to the period, and the result is shown in the Figure 7(d).

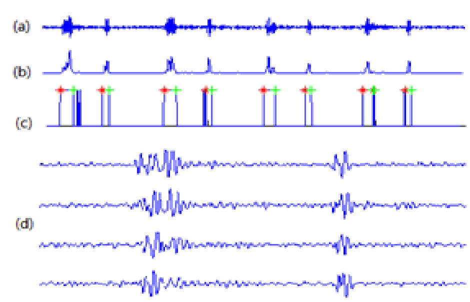


Figure 7. The heart sound signal pretreatment

C. *The classification identification of heart sound signals*

In the identification mode, the heart sound information in the database is a standard group. The database includes normal heart sounds (like the compare heart sound signal 1), and abnormal heart sounds (like the compare heart sound signal 2 which is premature beat heart sound, and the compare heart sound signal 3 which is fibrillation heart sound). Take discretionarily a periodic heart sound signal from the signals in Figure 7(d) as the test group. They are shown in Figure 8(a).

The standard group and the test group are required to use the same signal equipment and own the same magnification. They should not have saturated distortion (the best control is about the 70 ~ 80% of the maximum distortion amplitude). Then, we can extract heart sound wavelet function which is taken as a kind of statistical characteristic parameters from these data. Set the independent wavelet function of heart sound signal of the standard group as $b_i^c(t)$ and the function of the identified heart sound signal as. Then, calculate their average similarity distance by the formula (13), which is respectively 0.0790, 0.6114, 0.8942. Choose directly the one which has the smallest similarity distance as the results of identification result, and this tested signal is the normal heart sound one. The similar phase diagram is shown in Figure 8(b). We can find out intuitively that the testing signal of classification recognition is most similar to the normal heart sound signal and the similar phase diagram is a thin oblique line of 45°. Several hundred classification identification experiments show that the same person's recognition rate at the same time is 100%, and the recognition rate at different time from the same person is up to 97%. For some specific person, the recognition rate is up to 99%, if we constantly update the normal database with the new acquisition of heart sounds. If we only classify heart sounds as normal heart sounds and abnormal, we would have a better classification recognition efficiency and effect. It basically reaches the level of practical application.

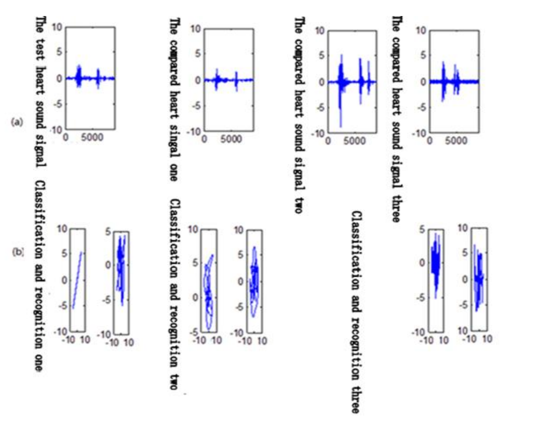


Figure 8. The effect of classification and identification experiments.

VIII. Conclusion and Future Work

This paper presented a method based on classification and recognition of heart sound detection for vehicle active safety. Through the analysis of the main characteristics between heart sound signals and car background noise, designed in the car on the heart sound acquisition, separation, classification of soft and hardware scheme, compared fastica, dwt_ica, infomax three algorithms to obtain the effect of heart sound independent wave function, the dwt_ica algorithm the results of comprehensive evaluation is best, and discussed the heart sound signal model, noisy sound mixing signal separation model and heart sound recognition model. It is the foundation of designing simple information recognition system. In addition, the article also raised effective classification technology, such as heart sounds determined (HSSCD). Similar distance mode matching method for heart sound independent characteristic parameters of the wave function and normalized envelope heart sound cycle segmentation technology, it reduced the calculation and increased the recognition rate, and it opens a new way for the practical application of heart sound identification.

In the future, we will further improve the calculation speed and practical application.

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Reference

[1] D. Rus, R. Gray, and D. Kotz, Transportable Information Agents [J], 1997, pp. 215-238.

[2] Xiao X. Q. and Wang Q. D., Study on automotive active safety technology based on driving behavior and intention, China Mechanical Engineering, OCT. 2010, pp. 2390-2393.

[3] A. K. Jain, A. Ross, and S. Prabhakar, An Introduction to Biometric Recognition [J], IEEE Transactions on Circuits and Systems for Video Technology, vol.14. 2004, pp. 4-20.

[4] Zhao L., Li Q., Shao Q. Y., and Zhu X. L., Studies on the comparison of normal and abnormal heart sound signals[J], Chinese Journal of Medical Physics, vol. 3. 2000, pp. 26-28.

[5] Cheng X. F., Ma Y., and Tao Y. W., Three-stage heart sound identification technology based on data fusion [J], Chinese Journal of Scientific Instrument, August. 2010, pp. 1712-1720.

[6] Maglogiannis I., Loukis E., and Zafiropoulos E, Support Vectors Machine-based identification of heart valve diseases using heart sounds. Comput Methods Programs Biomed (Ireland), Jul. 2009, 95, pp. 47-61.

[7] Cheng X. F. and Tao Y. W., Heart Sound Recognition--A Prospective Candidate for Biometric Identification [J], Advanced Materials Research, vol. 225. 2011, pp. 433-436.

[8] Kumar D., Carvalho P., and Antunes M., Heart murmur recognition and segmentation by complexity signatures. Conf Proc IEEE Eng Med Biol Soc (United States), 2008, pp. 2128-32.

[9] Cheng X. F. and Ma Y., A Single-Channel Mixed Signal BSS New Method of Does Not Use the Prior-Knowledg [J], ACTA ELECTRONICA SINICA, 2011, pp. 2317-2321.

[10] Gil. J. J., Single-Channel Singnal Separation Using Time-Domai Basis Functions [J], IEEE Signal Processing Letters, vol. 10. 2003, pp.168-171.

[11] Cheng X. F., Ma Y., and Liu C., Research on heart sound identification technology [J], Sci China Inf Sci, vol. 55. 2012, pp. 281–292.

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