Seismic Signals analysis And Identification

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Abstract Great deals of signals obtained from field-testing have been processed in time and frequency domain with Short Time Fourier Transform and wavelet package transform techniques. On the basis of far distance seismic signal, target recognition has been made by BP neural network, the result indicates that the recognition ratio is as high as 85% on the eigenvector of wavelet package decompose, and shows that the eigenvector of wavelet package decompose has better performance.

Key words seismic signal; target identification; wavelet and wavelet package; eigenvector

地震动信号的分析与目标识别*

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【摘要】通过外场实验获得关于轮式车、履带式车的大量地震动信号，在时-频域应用多种方法对信号进行处理，得到相应的特征矢量。利用改进的BP网络对远距离的地震动信号进行目标识别，基于小波及小波包分解能量分布特征的识别率可达85%以上，这种特征矢量具有较好的可分性。

关 键 词 地震动信号; 目标识别; 小波及小波包; 特征矢量

中图分类号 O231; U270.9 **文献标识码** A

The seismic signal, caused by the target moving on the ground, propagates from near field to far, it relates not only to the situation that how a target inspirits earth surface but also to the coupling existing between sensor and earth surface. Meanwhile, the seismic signal is affected by other factors when it is propagating. These factors include the appearance, the geological construction and other conditions of the ground in which the seismic signal is propagating. As a result, the signal caused by the moving target and collected by the sensors placed in the distance, is a kind of non-balanced random signal. When the above signal is processed, its characteristics can be abstracted, and they are the essential bases to class and identify object. From the point of mathematics, in order to obtain the essential characteristics of signal, the process to abstract characteristics from signal is to transform the original data and to form mapping between multi-dimension measurement space and relative simply space. Certainly, the abstracted characteristics should be representative, typical and steady. Tank and wheeled vehicle are the typical ground objects on the battlefield.

1 Analysis of Signal in Time and Frequency Domain

The intensity and frequency composition of sesimic signal mostly lie on the type of moving target itself and

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the distance between target and sensor, meanwhile it is in matter of circumjacent noise nearly. The nearer the distance between sensors from the target, the more intensive the signal is, and the more there is high-frequency components. Whereas, the farther the distance from sensor to the target, the less intensive the sensor signal is, and the high-frequency components is less and less by attenuation. So, in the strict sense of the word, the signal caused by the moving target is non-balanced random signal. In order to obtain the essential characteristics of non-balanced random signal, the analysis should be carried out simultaneously in time-domain and in frequency-domain, viz., abstracting signal characteristics in two-dimension space. So, the emphasis of this article is focused on analyzing the signal both in time-domain and in frequency-domain. Fig 1 and Fig 2 show the signal caused by tank and wheeled vehicle respectively.

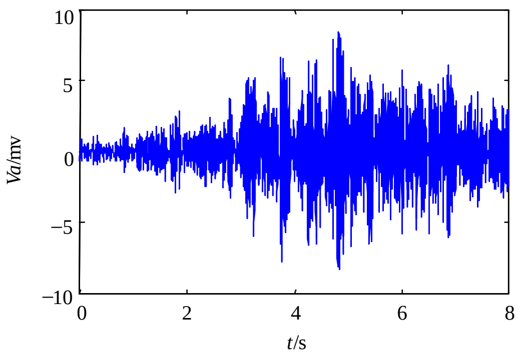

Fig 1　Seismic signal caused by wheeled vehicle

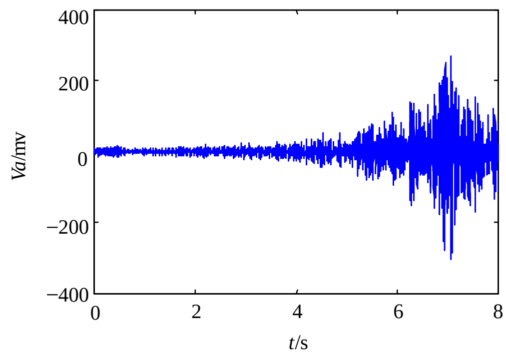

Fig 2　Seismic signal caused by tracked vehicle

In the experiment to collect seismic signal, the moving target is wheel vehicle and tank, they run on the uncultured field at different speed respectively, and there is no obvious noise source right round. Table 1 shows the relationship between signal' s maximum amplitude with target distance from sensors. In the later data processing, if the maximum of signal time-domain amplitude is in 1～5 mv, then the distance from target to sensors is considered near, and if in 10～50 mv then the distance is considered far. According to these two conditions, signal has been processed respectively.

Table 1　The corresponding relation between the maximum amplitude of signal in time domain and the distance from target to sensor

Type of vehicle	Velocity		Time-domain maximum amplitude/mV					
			1	2	4~5	10	20	40~50
Wheel vehicle		Low-velocity/m	150	130	100	80	50	40
		Medium -velocity/m	200	150	120	100	60	40
		High-velocity/m	200	180	160	140	60	40
Tank	T59	Low-velocity/m	180	170	160	100	80	50
		Mid-velocity/m	250	200	180	100	80	60
		High-velocity/m	300	250	190	160	100	60
	T62	Low-velocity/m	160	140	100	70	60	40
		Mid-velocity/m	240	200	180	160	100	60
		High-velocity/m	320	300	250	200	150	100

1.1　Short-time Fourier Transform

The expression of Short Time Fourier Transform(STFT) is[1]:

$$F(w,t)=\int_R f(t)g(t-t)\mathrm{e}^{-\mathrm{j}wt}\mathrm{d}t \tag{1}$$

Where e^{-jwt} is used to limit frequency, and $g(t)$ to time. STFT expresses local spectrum of $f(t)$ at the time near t and it reflects the characteristics of $f(t)$ in frequency-domain as well as in time-domain at the same time.

The result of STFT is a matrix. The singular value of a matrix is its inherent property and is steady; it can be used for target recognition. The singular value of a matrix is defined as following[2]:

If $\boldsymbol{A} \in R^{m\times n}$, and $m \geq n$, then exists orthogonal matrix, $U \in R^{m\times m}$ and $V \in R^{n\times n}$, meet the equation:

$$U^T \boldsymbol{A} V = diag(s_1, s_2, \cdots, s_p) \tag{2}$$

In the formula, $p = \min(m,n)$, $s_1 \geq s_2 \geq \cdots \geq s_p \geq 0$。 s_i , $i = 1,2,\cdots,p$ is the singular value of matrix $\boldsymbol{A}$, namely, it is the square root of l_i which is the eigenvalue of matrix $\boldsymbol{A}\boldsymbol{A}^H$,that is, $s_i = \sqrt{l_i}$.

Because the singular value of a matrix is steady, when the matrix $\boldsymbol{A}$ is changed tinily, the alteration of the singular value is less than $\boldsymbol{A}$'s second power norm. After being normalized, matrix's singular value owns the property named proportion invariance. In addition, the singular value of a matrix has characteristics of rotation invariance; it means that after being implemented turning transform (i.e. multiplied by a unitary matrix P), the new-produced matrix has the same singular value as matrix $\boldsymbol{A}$. So, the singular value of a matrix can effectively embody its characteristics.

In the testing, choosing sampling frequency of 0.5 kHz, sensors collect data which length is 8 192. According to the property of used sensors and spectrum analysis experience of such data, STFT is actualized to collected data. In the process of transform, "time window" is 0.5 and is overlapped 50%. Then the singular value of the matrix produced by the STFT is abstracted, so, a 62-dimension characteristic is obtained.

1.2 Wavelet and Wavelet Package Decompose

The essence of wavelets transform is multi-resolving rate or multi-scale analysis. Orthogonal wavelets transform resolve only to scale space (V space) by its multi-scale rate analysis, not to wavelets space (W space). So, in the phrase plate, with increasing of scale, the "time-domain windows" of corresponding wavelets base function becomes wide whilst its "frequency-domain windows" becomes narrow. Such distribution property both in time-domain and in frequency-domain is useful in many cases, but it cannot meet the demand very well that the higher resolving rate is needed in local frequency domain. By the wavelets package, wavelets space W_j can be analyzed further, and the "frequency window", which becomes wider and wider with the decreasing of j in the process of wavelets translation, is divided further.

Let the coefficients of wavelets base filters is h_n and g_n respectively, meanwhile, scale function $j(t)$ is noted $u_0(t)$ and wavelets function $y(t)$ is $u_1(t)$, consequently, the double-scale equation becomes as the following[3]:

$$\begin{cases} u_0(t) = \sqrt{2}\sum_{k\in Z} h_k u_0(2t-k) \\ u_1(t) = \sqrt{2}\sum_{k\in Z} g_k u_0(2t-k) \end{cases} \tag{3}$$

Wavelets package is a function set including scale function $u_0(t)$ and wavelets base function $u_1(t)$, moreover, they have relations each other and its function set $\{u_n(t)\}_{n\in Z}$ defined by the following formula[4]:

$$\begin{cases} u_{2n}(t) = \sqrt{2}\sum_{k\in Z} h_k u_n(2t-k) \\ u_{2n+1}(t) = \sqrt{2}\sum_{k\in Z} g_k u_n(2t-k) \end{cases} \tag{4}$$

In the process of analysis using wavelets package, all of "frequency window" is divided more minutely with increasing of scale, and data length become half after filter group functioning once. Therefore, a set of data whose original length is 2^N and its sampling frequency is f_s, is applied wavelets package transform at the L-th scale, it will be divided n=2^L series along frequency-axis. Each of series has width of $f_s/2^L$ and the first frequency of the

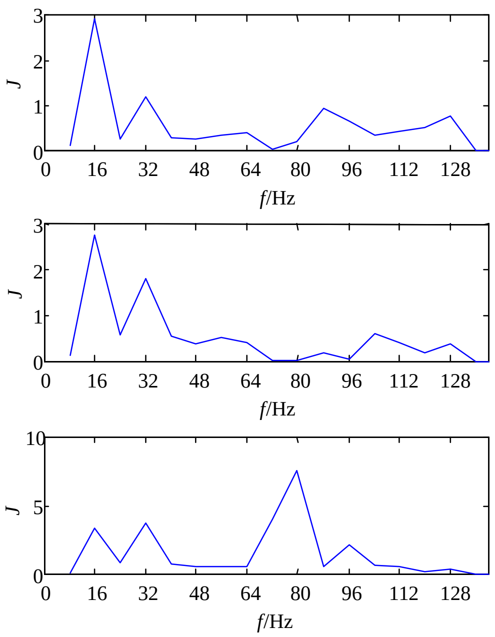

Fig 3　Energy distribution of signal from wheeled vehicle in long-distance

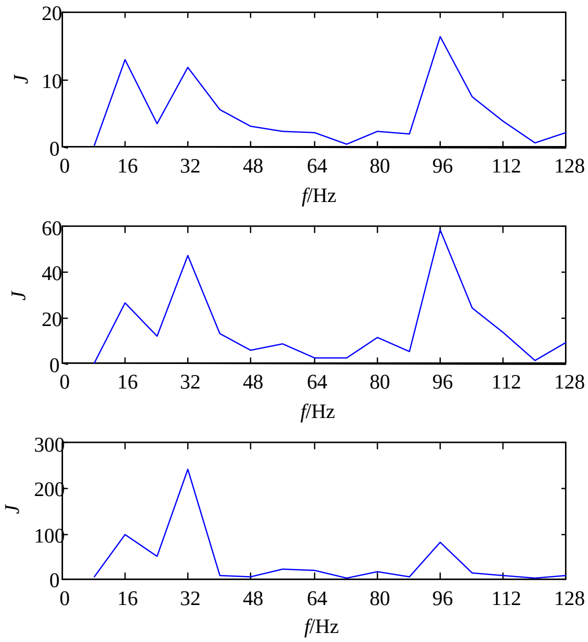

Fig 4　Energy distribution of signal from tracked vehicle in long-distance

n-th series is f_n=$(n-1)f_s/2^L$.

From literatures and experiences, it is well known that the main frequency of seismic signal produced by moving target is less than 150 Hz. Accordingly, the signal collected by sampling frequency of 0.5 KHz is analyzed with first-level wavelets, thereafter it is analyzed with 5-level wavelets package, then the energy distribution chart can be obtained in which frequency range of each part is 8 Hz. Figure 3 and figure 4 show signal's energy distribution when wheeled vehicle and tank moving at far distance, respectively. According to the energy distribution chart, the conclusion can be made that when target is near to sensors, signal caused by wheel vehicle is the strongest at 3～4 and 7～8 frequency sections, and tank signal is the strongest at 4～5 frequency section; When target is far away from sensors, the 3～4 frequency section has the strongest component for wheel vehicle and tank signal energy is same at 3～4 and 6～7 frequency section, but the signal energy is very low at all of other sections.

2　Target Identification Based on above Energy Distribution Feature

After the eigenvector of energy distribution is normalized, it has been inputted into BP- neural network which topologic construction is 32*15*1; the identification result is shown in table 2. Therefore, it is proved that energy distribution obtained by wavelets and wavelets package decompose is a good characteristic to identify object.

Table 2　Identification result by feature extraction based on wavelet and wavelet package decompose

Target sample	Wheel vehicle		Tank	
Distance	Near	Far	Near	Far
Training sample number	10	10	20	20
Identified sample number	17	38	67	77
Identification result	17	34	54	68
Identification rate/%	100.0	89.5	89.6	88.3

3 Conclusion

In this paper, the seismic signal caused by wheeled vehicle and tank at different distance is implemented STFT, wavelet transform and wavelets package decompose, then the singular value of SFFT transform matrix and energy characteristic of wavelets or wavelets package decompose are abstracted. At last, BP- neural network is used to identify object on the basis of said characteristics. The result of identification demonstrates that according to the energy characteristic after wavelets and wavelets package transform, a higher identification rate can be obtained, especially in the condition of moving target far from sensor. Moreover, wavelets and wavelets package decompose has quicker identification rate than SFFT.

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·成果与专利·

苯基及取代苯基酰亚胺系有机电子晶体及其制备方法

苯基及取代苯基酰亚胺系有机电子晶体及其制备方法给出了一类新型有机电子晶体材料，它采用邻苯二甲酸酐与苯胺或取代苯胺合成苯基或取代苯基邻苯二甲酰亚胺化合物，其取代苯胺是用烃基、卤族元素来取代苯胺中苯环里的一个或几个氢(H)元素后生成的。将该类化合物经晶体生长和极化处理后就可制成高度有序、定向、纯净的无色的相对应的酰亚胺系有机电子晶体。该系列有机晶体具有优良的介电、压电、铁电、驻极体、敏感和换能等电子学与光学性能，在电子科学领域有广阔的应用前景。

一种用于检测微量水分的α-三氧化铝绝对湿度传感器

一种用于检测微量水分的α-三氧化铝绝对湿度传感器公开了一种用于检测微量水分的-Al_2O_3绝对湿度传感器，其特点是采用了两次阳极氧化的方法分别生成的α-Al_2O_3膜和致密非晶Al_2O_3膜作为本发明的绝对湿度传感器的复合湿敏介质层。本发明性能优良，具有很好的长期稳定性，长期使用不需校正湿度曲线，能检测的微量水分低达1 ppmv，是一种方便，实用的检测微量水分的新型绝对湿度传感器。

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