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Microseismic Real-time Monitoring System Based on Virtual Instruments

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Abstract

Geological disasters such as rock burst coal and gas outburst in coal mines have inevitable link with micro-seismic phenomenon intrinsically. Monitoring the underground microseismic signals could determine the scope and extent of the underground rock and provide strong evidence for underground mine safety monitoring. A microseismic real-time monitoring system design based on virtual instrument was presented, using thirty two channels front microseismic signal processing unit, data acquisition card DAQ-6343, realizing multi-channel analog microseismic signals acquisition, achieved a real-time monitoring and analysis of microseismic signals combined with the microseismic method and improved adaptive wavelet transform processing algorithms in the LabVIEW platform. System monitoring results agree well with the actual mine earthquake, the error of obtained positioning results is small, realizing a real-time microseismic monitoring and analysis.

Keywords: *Microseismic signals, Real-time Monitoring, Virtual instrument, Positioning, Adaptive wavelet transform*

1. Introduction

Microseismic monitoring method is a new monitoring method developed in recent years, microseismic safety monitoring system is used to monitor the vibration produced by shock broken or other objects and make the evaluation on the destruction conditions and the security situation of the monitoring object, to provide the basis for prediction and control of disasters. Microseismic detection system can be widely used in mining rock rupture location monitoring and is effective tool for forecast mine pressure, mine water inrush, coal and gas outburst, rock burst, also could determine the height of water flowing fractured zone and reasonable location of roadway layout according to the scope and extent of monitored rock. Therefore, it is necessary to design and develop a safe and effective safety microseismic monitoring systems [1-2]. Currently some microseismic monitoring systems are based on DSP or other microcontroller, which are difficult to achieve the desired effect of the acquisition and to complete the implementation of advanced algorithms because of limited resources [3-4]. This design of microseismic safety monitoring system is based on the IPC and thirty two channels data acquisition card to acquisition microseismic signals. The graphical programming software capabilities and flexible data processing capabilities of LabVIEW, combined with microseismic methods and improved adaptive wavelet transform processing technology, the acquisition and filtering and analysis of microseismic signals were completed, which could determine the height and spatial location of fractured zone, in order to show the nature of the spatial location of fracture source and rupture time for underground mines safety testing.

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2. Microseismic Monitoring Technology

Microseismic monitoring technology is geophysical techniques to detect the impact of production activities and the ground state by observing and analyzing tiny event generated by production activities. Microseismic monitoring is currently more advanced monitoring technology in the world, particularly because of the development of computer processing power over the past decades. Advances in geophysics and application of digital seismic monitoring technology provide the necessary technical foundation for microseismic studies on more small-scale and weaker signals. Currently microseismic monitoring technology has been widely used in the fracturing caused by ground water, dams, mining, geotechnical engineering. Through the use of real-time monitoring rock rupture, microseismic monitoring technology could timely delineate hazard zones, which to some extent to achieve disaster prediction and prevention, to have great significance in reducing casualties，to plays an important role in the geological disaster monitoring, mining and mine safety sector.

3. Virtual Instrument

3.1. Virtual Instrument Introduction

Virtual Instrument [5-6] is instrument system using a PC monitor instead of the panel functions of traditional instrument and using the mouse and keyboard of PC to control and drive various of function buttons, in which the I/O interface device finish the data acquisition and condition and the LabVIEW software finish data analysis and processing, expression and storage in order to achieve varieties of computer-based instrument function. Essence of virtual instrument technology is full use of computer technology to expand the functionality of traditional instruments, as far as possible using a common hardware, and the software is the key to the virtual instrument. When the basic hardware test circuit determines different instruments function can be achieved through different procedures, the user can design their own instrument system according to their needs. Using of computer software and hardware resources can break through the limitations of traditional instruments in data collection and conditioning, analysis and processing and storage and other terms of expression, to achieve results which traditional instruments could not achieve. Virtual instrument widely used in teaching research, physical core exploration, remote monitoring, remote fault diagnosis, industrial process automation and control, electronic metering, medical analysis, acoustic analysis and other aspects.

3.2. LabVIEW

LabVIEW [7-9] (Laboratory Virtual Instrument Engineering) is a graphical programming language, which is widely accepted by industry and academia and research laboratories and regarded as standard software in data acquisition and instrument control. The powerful and flexible software LabVIEW integrated all the functions of hardware and data acquisition cards which meet GPIB, VXI, RS-232 and RS-485 agreements, but also built standard library functions to facilitate the application of TCP/IP, ActiveX and other software. It is easy to create their own virtual instruments by using LabVIEW, and its graphical interface makes programming and using process interesting. LabVIEW development platform combined with USB data acquisition card (DAQ) were used to collect microseismic signals and real-time deal with and analyze waveform.

4. System Design

4.1. Hardware Design

Microseismic signals are low frequency weak signals, with frequency about two hundreds Hz to one thousand and five hundred Hz. According to the characteristics of this signals, a micro-seismic signal acquisition and processing system based on virtual instrument was designed making advantage of virtual instrument powerful data processing capabilities, it is mainly composed of microseismic detectors, amplifiers, low-pass filter, data acquisition card DAQ-6343, IPC components. System hardware components are shown in Figure1. The DAQ-6343 series USB board was used for design and data acquisition, DAQ-6343 have thirty two analog inputs, up to 500KS per second simultaneous sampling rate and 16 bit A / D resolution. In addition the board have driver Program with the LabVIEW interface, which could easily achieve real-time signal acquisition and processing in the LabVIEW platform. Microseismic signals were extracted out from the background signals by microseismic detector, then amplified and filtered and extracted into IPC through USB data acquisition card, to collect real-time monitoring signals. The monitoring signals were done filtering processing through LabVIEW software to remove noise and extract the microseismic signals from the background signals and were also used for microseismic sources inversion.

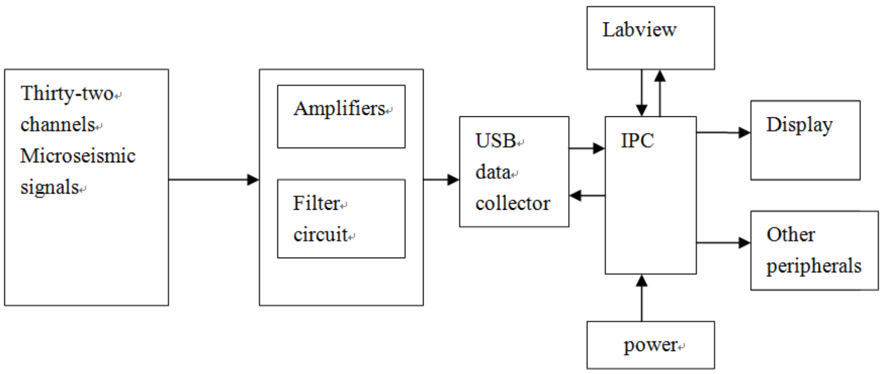

Figure 1. Microseismic System Composition

The energy of microseismic signals reflected from underground deep and shallow layers interface vary widely, and the system was designed collection points in different locations to ensure that the microseismic signals reflected from deep and shallow layers can be recorded in order to determine the location of sources and fully analyze the geological structure, and then the signals from acquisition channels were sent to the IPC for data processing and analysis as shown in Figure 1.

4.2. Amplifiers

Because of the large changes in the working environment, preamplifier should be designed programmable gain, to ensure that the instrument has sufficient amplification capacity and dynamic range to accommodate record requirements of micro-seismic signals with different strength. High-precision amplifier INA114 was used as preamplifier circuit of sensor signals in the systems, with programmable gain. According to the system requirement, the appropriate resistors were selected, and the opening and closing of different switches were controlled by program, resulting in different final output gain. Figure 2 showed the basic connection requirements.

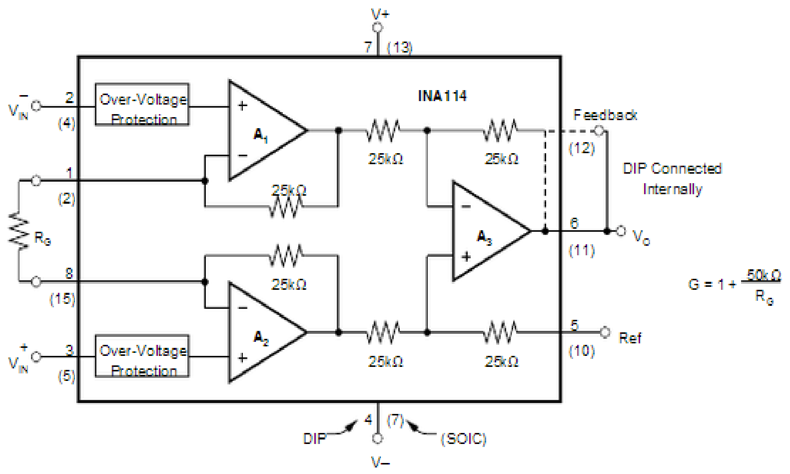

Figure 2. Basic Connection Requirements

4.3. Filter Circuits

In the system monitoring process, many interference signals will inevitably mixed into the system with effective signals in the surrounding environment and work environments. If not separated, it could not make the right judgments. Although the filtering may be implemented in software, interference signals will make the system does not work if not done hardware filtering first in practice, so it is necessary to carry out the hardware filtering. Whether the system working properly and whether the data collected is credible, concerned the stability and reliability of the system. This system is mainly used to collect the detector signals buried below the surfaces, so whether the hardware circuit of the input channel work normally is very critical. And in the hardware circuit of input channel, the detector as the vibration signals into an electrical signal is a key component, and whether it work normally will be related to the function of the whole system. Channel self-test was used in the working state detection for each input channel of systems, mainly for detecting devices. The main principle of detection is determined according to the impedance value of detectors.

4.4. System Software Design

The software of the system was implemented in LabVIEW platform, the software design block diagram was shown in Figure 3.

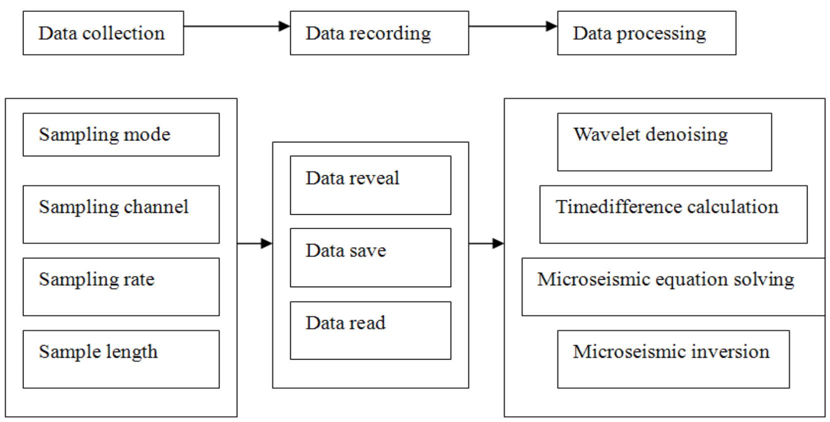

Figure 3. The System Software Design

Data collection include status settings and operating parameters settings of master control station and each collection, such as sample rate, sample length, preamplifier gain, etc. Data recording section include recycling、storing the collection data of each collection station and saving the seismic data in standard formats, as well as displaying the collection data preliminarily. Data processing include getting high precision analysis on gathering station coordinates in real time, doing seismic data denoising to extract microseismic signals, and doing microseismic sources positioning inversion.

5. Microseismic Location

The general process of microseismic monitoring are: (1) Determine the monitoring methods according to the monitoring purposes , then establish the seismic velocity model of work area, design the observation system to determine the relevant parameters and collect data; (2) Detect microseismic events, calculate the distance from the sources to measuring points according to time differences of vertical and horizontal wave, determine the specific location of the microseismic source, and provide high-precision speed parameter of relevant layers (3). Analysize the variation of microseismic events, source parameters, fracturing parameters along with the time to provide useful information to the user.

5.1. Principle of Microseismic Location

The occurrence of microseismic has close relationship with rock fracture. Typically, the more active areas of microseismic, the more possibility of rock ruptures. Therefore, the microseismic monitoring technology can be used as the main technical to monitor rock fracture. Since the spread velocity of P-wave in rock was faster than S-wave and it is easier to identify the first arrival time, so usually P-wave was used for positioning. Since the spread velocity of P-wave was fast, and the area monitored by the position software was a small area for a radius of several hundred meters, it can be assumed that the P-wave spread at constant velocity V, then the relationship between the MS sources and the m detectors are as follows:

$$\sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2} = v(t_i - t) \qquad (1)$$

Where, x_i, y_i, z_i are spatial coordinates for micro-seismic monitoring stations, with units of m; t_i is P-wave arrival time of the monitored micro-seismic signals, with units of ms, x, y, z, t are spatial coordinates of source and time of micro-seismic occurred. Just choosing four equations to consist one equation can determine the spatial location of the source and the time of occurrence.

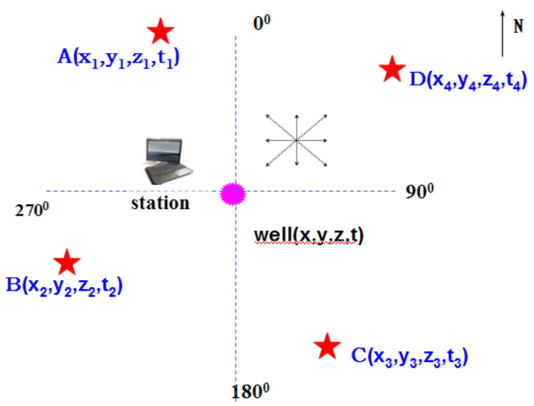

Figure 4. Microseismic Principle

As shown in Figure 4, four of the relationship of MS source and m detectors consist equations

$$\sqrt{(x_1-x)^2+(y_1-y)^2+(z_1-z)^2}=v(t_1-t)$$
$$\sqrt{(x_2-x)^2+(y_2-y)^2+(z_2-z)^2}=v(t_2-t)$$
$$\sqrt{(x_3-x)^2+(y_3-y)^2+(z_3-z)^2}=v(t_3-t)$$
$$\sqrt{(x_4-x)^2+(y_4-y)^2+(z_4-z)^2}=v(t_4-t) \quad (2)$$

Only the input of each detector space coordinates and arrival time of microseismic waves can solve the spatial coordinates of the microseismic source and the arrival time of occurrence, which the coordinate values can be measured in advance and the arrival time of microseismic waves could be measured by the detector.

5.2. Wavelet Denoising

In the actual monitoring ideal envelope waveform was not obvious due to noises, and therefore it need to filter out the noises and extract the microseismic waves. The wavelet transform overcome the shortcomings that Fourier transform could not take the time resolution and frequency resolution into account in signal analysis, and the time window and frequency domain window can change through mother wavelet compression and shift, which can be multi-resolution analysis, so wavelet analysis was used for signal extraction and de-noising by many domestic and foreign researchers. Wavelet analysis as a better time-frequency analysis methods, in recent years have been applied to all areas and achieved good results. Wavelet threshold transform was mainly used for noise removal and micro-seismic wave extraction. The following three denoising processing methods were used in wavelet denoising system based on LabVIEW platform.

5.2.1. Threshold Denoising: Wavelet threshold denoising was threshold processing of high frequency coefficient according to the characteristics of noise manifests high-frequency signals, if the coefficients less than the threshold it was considered by the noise and set zero, if the coefficients greater than the threshold value it correspond to the useful signals and should be retained, thereby to achieve the purpose of denoising. The choices of traditional threshold are the hard threshold processing and soft threshold processing. Soft threshold processing is comparing the absolute value of signals and the threshold, when the absolute value of data is less than or equal to the threshold, set it to zero, when greater than the threshold, it becomes the difference between the point with a threshold value. The hard threshold is comparing the absolute value of signals and the threshold, if less than or equal to the threshold the point was set zero, greater than the threshold value it remains unchanged. The obtained micro-seismic signals were shown in Figure 5, and the microseismic signals after denoising were shown in Figure6, preferably separated from the original signals.

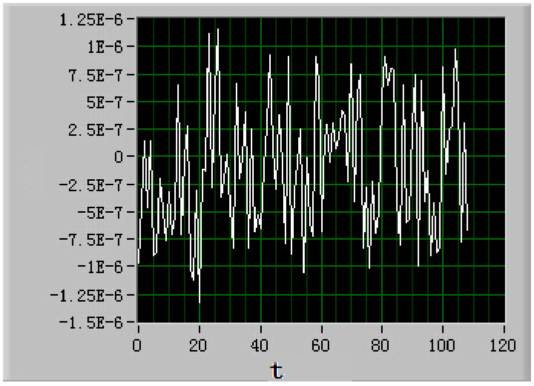

Figure 5. Collected Microseismic Signals

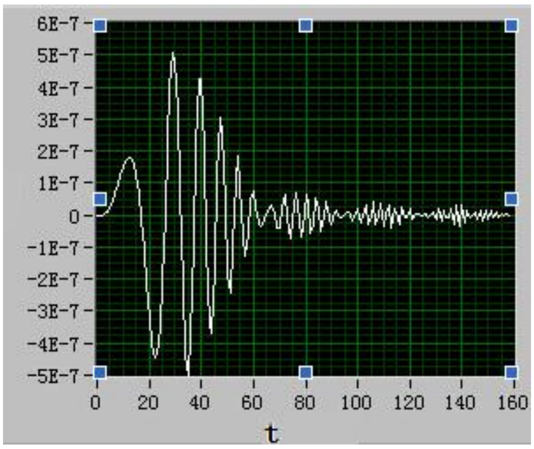

Figure 6. Microseismic Signals After Threshold Denoising

5.2.2. Adaptive Threshold Denoising

Traditional threshold function will produce the phenonmenon of over-kill, perform poor in practical applications. Since the noise has a negative singularity, its magnitude and dense degree decreases with the increase of scale, but the signal is the opposite. With the increase of the scale, amplitude and dense modulus degree of maxima controlled by the noise quickly reduced and amplitude and dense modulus degree of maxima of the signal will be significantly increased. It can be seen that using the same scale thresholds on the same level are clearly inappropriate, because at a lower scale it will removes useful information and at the largest scale it will leave parts of the noise. Because of some flaws in hard and soft threshold function, there was a certain bias in reconstructed signal, so it is need to improve threshold function. Adaptive threshold is a adaptive threshold selection algorithm using the wavelet transform coefficients of minimum risk mount as threshold. the microseismic signals after adaptive threshold de-noising were shown in Figure 7, with a better signal to noise ratio improvement.

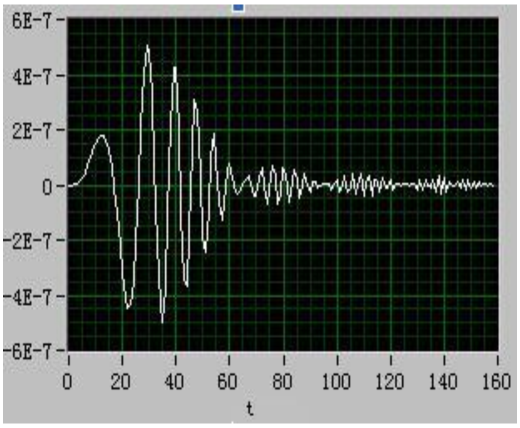

Figure 7. Microseismic Signals after Adaptive Threshold Denoising

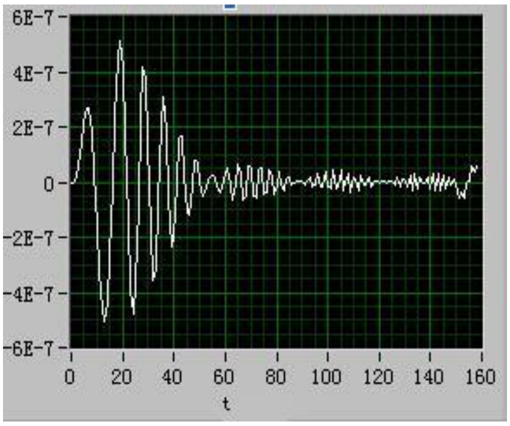

Figure 8. Microseismic Signals after Wavelet Transform

5.2.3. Wavelet Packet Transform

Wavelet packet transform is the promotion of the wavelet transform, is a more detailed analysis and reconstruction methods. It divide the band by multiple-levels, further divide the high frequency portion which wavelet analysis could not be subdivided and can adaptively select the appropriate frequency band so as to match the signal spectrum according to the characteristics of the analyzed signals, thereby improving time-frequency resolution. Typically, wavelet packet noise reduction steps are as follows: The first was wavelet packet decomposition of the signal: Choose a wavelet and determine a wavelet decomposition level N, then do N-layer wavelet packet decomposition on the seismic waves signal S. A represented a low frequency, D represented high frequency, the end serial number represented wavelet packet decomposition layers, namely the scale number. The original signal S is equivalent to:

$$S = AAA3 + DAA3 + ADA3 + DDA3 + AAD3 + DAD3 + ADD3 + DDD3 \quad (3)$$

The second was to calculate the optimal tree: Compute the best tree for a given entropy criteria, commonly used entropy criteria were Shannon, threshold, norm, log energy, sure and user and so on. The third was thresholding quantization of wavelet packet decomposition coefficiences: Select a threshold and do coefficiences thresholding quantization for each wavelet packet decomposition coefficiences. Wavelet transform coefficient values are compared with a threshold, it is believed that the values smaller than the threshold value were generated by the noise and set to zero, the values greater than the threshold values were corresponding to the signal mutation point and retained in order to achieve the purpose of denoising. The microseismic signals after wavelet packet transform were shown in Figure8, with the signal to noise ratio improve 11.23dB.

6. Test Results

The number of stations determined with the project needs and specific circumstances of the equipments, and the system used thirty two stations to a mining area. The data read from the stations have some interference data, firstly the interference data were removed necessarily to left the valid data. The data less than four groups could not be used for positioning calculation, the event was recorded as invalid record. The four groups data can be calculated the results by once. The five groups data and the above need permutations and combinations calculation, there are a variety of combinations, the combination principle is based on monitoring the arrival time. The smaller arrival time was taking into combined to calculate, which were combination near the sources speaking from space, so positioning accuracy was higher. The disadvantage of the positioning method according to the beginning arrival time was the positioning is not very accurate in depth direction, because the sensors arranged at different depths were not easy, and the sensors to be disposed deeper were certainly difficult. Thus, the spread information of seismic wave in depth direction propagation was relatively small, so positioning accuracy is not high inevitably. Overall the results were within the error range. Figure 9 shows the distribution of micro-seismic source location and a straight line fitting diagram.

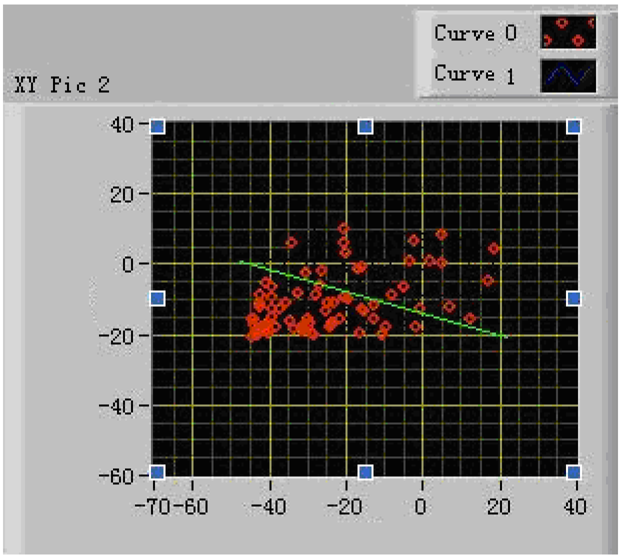

Figure 9. Sources Distribution and Straight Line Fitting

By processing monitoring data and the prediction of disaster, it preliminary verify that the system is effective. But micro-seismic technology is not very mature especially for the interference signals processing and micro-seismic positioning which remains to be further studied and requires a lot of experimental verification.

7. Conclusion

Microseismic monitoring system based on virtual instrument have powerful signals processing functions, rich and varied information expression, friendly interface and high accuracy, it is easy to maintain and operate and achieved good effect in the practical application. In addition, the software of the system has good scalability on LabVIEW, which provides a good platform for improving the design of the system. By processing on-site monitoring data and the prediction of disaster, it preliminary verify that the system is effective.

Acknowledgements

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References

[1] L. Donghui, L. Yong and W. Bin, "Real-time Detecting System for Microseism Based on LabVIEW", Computer Measurement &Control, **(2008)**.
[2] L. Feng-Qin, Z. Xing-min and J. Fu-Xing, "Microseismic monitoring system and application in underground coal mine", Coal Geology & Exploration, vol. 34, no. 4, **(2006)**.
[3] L. Nianping and L. Shixiong, "Study of Microseismic Monitor System based on Virtual Instrument", Express information Of Minig Industry, vol. 12, no. 12, **(2007)**.
[4] Z. Ruihong, L. Dachao, S. Sheng, W. Jianxing and Q. Lan, "Real-time Microseismic Monitoring System Based on virtual instrument", Metal Mine, vol. 417, no. 03, **(2011)**.
[5] C. Dong and Y. Lin, "Development of virtual testing instrument based on LabVIEW and DAQ-PCI-4472", China Measurement Technology, **(2005)**.
[6] X. J. Jun and X. Pingzhen, "Liquid-level Control System Basedon NILabVIEW and DA Qboard", vol. 25, no. 4, **(2004)**.
[7] L. Guowei, C. Fangquan and L. Zuwei, vol. "The Realization and Application of DAQ System Based on LabVIEW and SerialPort", Modern Machinery, **(2003)**, pp. 57-72.
[8] H. Shikui, P. Yuning, X. Shuping and W. Dehuia, "Methods and Application of Mixed Programming with LabVIEW and Matlab", Research And Exploration In Laboratory, **(2004)**,pp. 67-71.
[9] G. Xu, Z. Chunmei and W. Shangjin, "Virtual Instrument Software Labview and Data Acquisition", Microcomputer Development, **(2003)**, pp. 77-79, **2003**.

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