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PC-Drum : A PC-based Seismic Recording and Analysis System

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Abstract

A low cost PC-based seismic data recording and analysis system has been developed for the purpose of replacing conventional analog seismic recorders in developing countries. The system records three channel seismic signals into hard disk in win-format, and plots the seismogram on virtual drums on screen like a helicoder. The data is time-stamped by GPS clock. The seismograms in the last few days can be browsed while recording the new data. The system also provides a utility to view an event in zoom-in window, and to pick phases without stopping the recording and plotting new data.

Key words : PC-based data logger, Data logger, Seismic data analysis

1. Background

Before appearance of digital systems, paper helicorders[1)] were widely used to record seismograms. The disadvantages of such systems are low dynamic range, and inability of computer data analysis. Various digital seismic recording systems have been developed to overcome the drawbacks of analog systems[2,3)]. These digital systems are generally stand-alone, box-instruments that measure signals, convert to digital ones and store the data internally. Data are transferred typically either by moving storage device from the recorder to a computer or by connecting the recorder to a computer through communication cable such as RS232 or Ethernet. These instruments have higher performance and widely used in modern observations. However it is often difficult to deploy them in developing countries due to the high cost. In general, the price of such an instrument is over one million Japanese yen.

With technological advancement of PC in the last two decades, it has become possible to develop a PC-based seismic data recording and analysis system with low cost[4-10)]. We developed a system named PC-Drum that consists of a PC, an A/D conversion board and a GPS clock[11)]. The analog signals from a seismometer are digitized by the A/D board, and time-stamped by GPS clock. The digital data are then plotted on virtual drums on screen and recorded into the hard disk in win-format for post-processing. The PC-Drum combines the data acquisition and storage capability of a stand-alone digital seismic recorder with an analog drum monitor, and automatic event detection and analysis capabilities of PCs.

The cost for a PC-Drum is about one hundred thousands Japanese yen at present and will become lower. The PC-Drum can be installed and operated easily on a Windows PCs that are widely used in developing countries. The software of PC-Drum has been upgraded to improve its reliability and user-friendliness since the first version[11)]. The following are descriptions of its implementation and performance in detail.

2. System implementation

The configuration of PC-Drum is shown in **Fig. 1**. The system consists of an A/D conversion board, a GPS clock and the host computer. The A/D board plugged in the PCI bus of the host PC converts analog signals from the seismometer into digital ones. The GPS clock receives the

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ranging signal and navigation code from the satellites, decodes them and outputs the time and position information through the RS232C port. It also outputs 1PPS（pulse per second） and 10KPPS for synchronization.

We use the A/D conversion board 6034E manufactured by the National Instruments for our system[12]（**Fig. 2a**）. The 6034E features 16 single end channels （8 differential channels） of 16-bit analog input with system timing controller for time-related functions. The system timing controller functions provide an easy way to synchronize the AD conversion to the external timing signal. The 6034E is also suitable for continuous high-speed data logging in multi-task operation environment, since it has direct memory access ability. Its analog input range is from ±50mV to ±10V. The corresponding resolution ranges from 33.8μV to 1.025mV, which can deal with analog signals from seismometer without or with minimum pre-amplification.

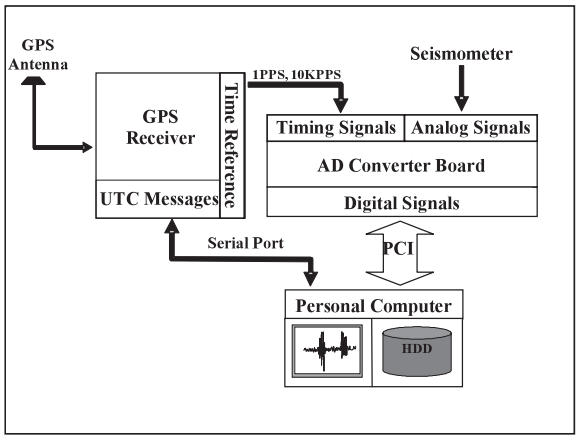
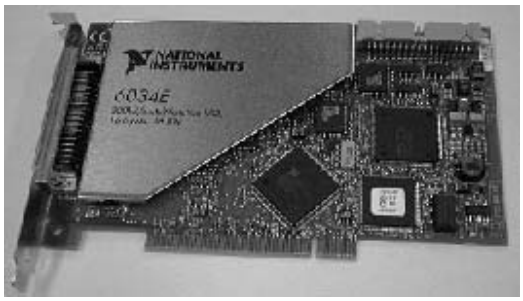


Fig. 1 Configuration of the PC-based seismic data recording and analysis system.



（a）



（b）

Fig. 2 （a） The photographs for the 16-bit A/D conversion card PCI6034, and （b） the GPS receiver Jupiter.

GPS clock used in the PC-Drum is Jupiter[13] of SPA Corporation（**Fig. 2b**）. The GPS provides 1PPS and 10KPPS synchronized to coordinated universal time （UTC）. The accuracy of the pulses is±0.5μs deviation from the UTC in navigation mode, which is precise enough for seismic data logging. The 1PPS starts the AD conversion and the 10KPPS is used for the timing of every successive sample. The UTC time is decoded from binary message format 1108 given from the serial port of the GPS receiver every second.

The software for the PC-drum is developed to configure and control the data acquisition hardware, and to display, record and analyze the data. This software is a multithreaded application that runs in Windows-based PCs. The main thread with the highest priority is responsible for collecting seismic signals and the time and recording them in hard disk in win-format. The second thread is used to display the waveforms on virtual drums and browse the previous seismograms. The third one provides zoom-in window to display the seismograms in detail. The last two threads have the lower priority than that of the main thread.

3. System performance

The main window for a PC-drum is shown in **Fig. 3**. The PC-Drum works in “real-time mode” by default. In this mode, the waveform data is plotted on the virtual drums and displayed on the screen in real time. The virtual drum rotates slowly from up to down and the pen on the top moves from left to right as time is passing like a conventional analog helicorder. The data for the three components are plotted on three virtual drums simultaneously. The screen can be switched to another virtual drum by choosing a component selector in the bottom tool bar. The data with UTC time stamp are recorded in win-format into the hard disk. One file contains one-minute data for all the three channels. The present time is displayed on the status bar while the PC-Drum is working in this mode. The seismogram for one day is plotted on one page on the virtual drum by default.

The PC-Drum also has the “browsing mode”. The red circle button in the tool bar is used to switch between the real-time mode and the browsing mode. The virtual drum

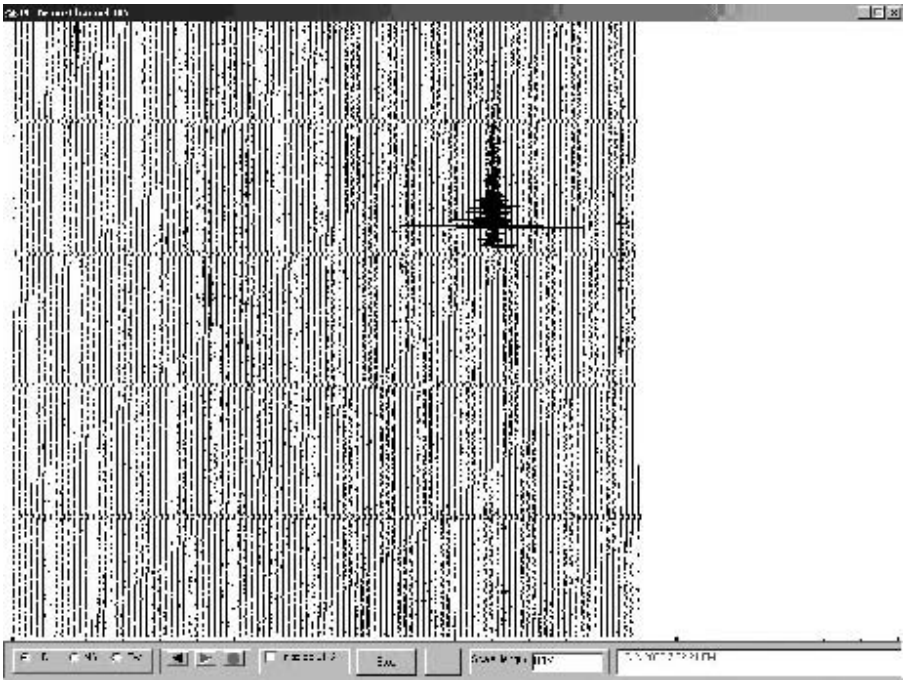


Fig. 3 The main window of PC-Drum application.

in browsing mode can be rotated upward or downward by a mouse to view the whole seismogram without stopping data acquisition working background. It is easy to browse a few past pages by clicking Right Arrowhead or Left Arrowhead buttons in the bottom tool bar. The maximal pages depend on the memory size of the computer.

Due to the limited space of the screen, it is difficult to display the seismogram in detail. The PC-drum provides a zoom window to magnify a part of seismograms. All three channels can be displayed in zoom window（**Fig. 4**）. The amplitude scales for the three components can be adjusted independently. The seismograms can be enlarged or shrunk along time-axis by adjusting the horizontal scale. The seismograms can be scrolled horizontally to view adjacent waveform data.

The zoom window also provides tools to pick phase information for P-wave, S-wave and F-P time of an event. The type, quality and polarity of the phase are selected with assistance of tool buttons. The maximal peak-to-peak amplitudes is calculated and labeled over the seismogram automatically（**Fig. 4**）. The phase information is then saved into a separate file in ASCII format.

The PC-Drum also provides the data to other machine through the network without interrupting the data acquisition （**Fig. 5**）. For example, an operator can create a report of phase information with assistant of zoom window and transmit it to another PC in the next room, or national and international data center over the network. A seismologist in the data center can then access waveform data and make further analyses.

In addition, the PC-Drum can also read data in win-format from local hard disk or other storage on the network to plot the seismograms. This function makes it possible to convert the past data into image format.

Besides these main functions, the PC-drum keeps some useful features of an analog drum. The red scale bar at the bottom helps an operator make primary measurements of amplitude. The time axis on the bottom and time marks superimposed to seismograms are used to estimate the start and end times for an event. The narrow, middle and wide time marks are used to indicate the times for every minute, every ten minutes and every hour, respectively. The PC-drum also has its own special features. The time for a location to which the mouse points is given on the status bar in browsing mode. The PC-drum can alarm operator by beep sound and blink of alarm button when an event is detected. The scale for the event can be specified by selecting a proper threshold for the signal amplitude.

We also developed a file conversion program called as WinToDimas to convert win-format into an ASCII format file for DIMAS（Display, Interactive Manipulation and Analysis of Seismograms）application[14]. DIMAS is a powerful application to make an initial analysis based on single station three component waveform data. The PC-Drum with assistance of DIMAS is an essential tool for developing countries where there are few seismic

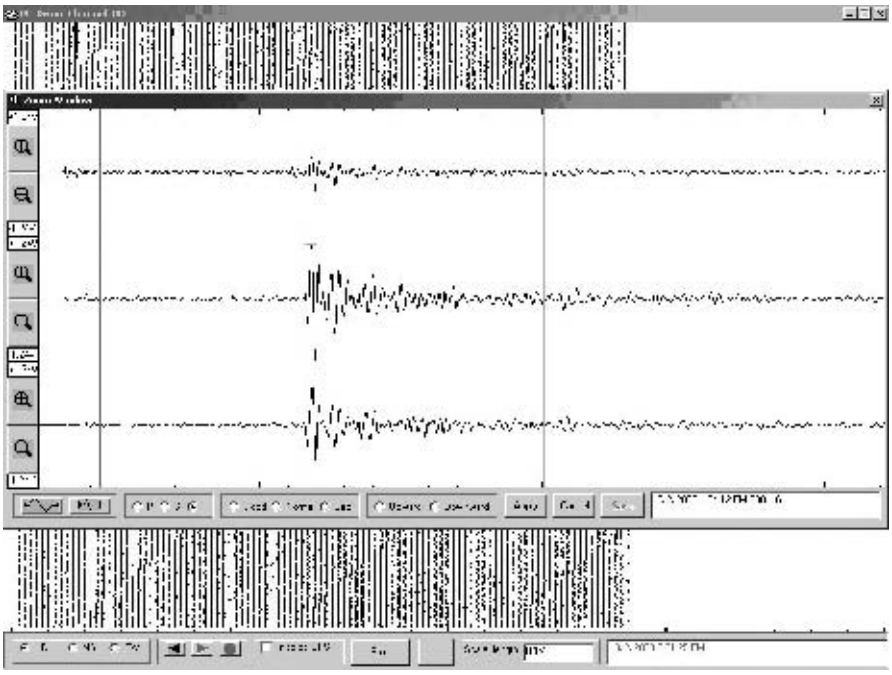


Fig. 4 Zoom-window for displaying seismogram in detail and picking phases. The phases are marked with vertical lines in different colors. The red lines stand for the phase of P-wave, green lines for the phase of S-wave and blue line for the end of event.

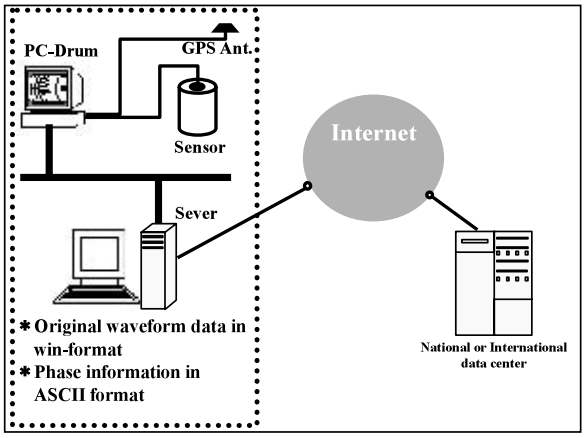


Fig. 5 A practical application of the PC-Drum.

Table 1 The minimum and recommended specifications for the host computer.

OS	Windows 98	Windows 2000 professional or above
CPU	Pentium 433MHz	Athlon 1.0GHz or above
RAM	64MB	256MB or above
HDD	1.0GB	40GB or above

stations over wide area without telemetry.

4. Practical application

A set of PC-Drum had been installed in our laboratory for test. A three component broadband seismometer CMG-4T was connected to the A/D board. We tested the PC-Drum under host PCs with different specifications. The minimum requirement for the host PC is listed in **Table 1**. The operations such as browsing previous pages, zoom window and remote data access had no any effects on the performance of data acquisition in background while the host PC with minimum specification is used. The remote data access was realized through local area network. The PC-Drum has been running for about 9 months without any trouble since the march 15, 2003. The recommended specifications for the host computer are also listed in **Table 1**.

We have installed a PC-Drum in Lemberg station in Indonesia in September 2003 in order to test the PC-Drum in a practical severe environment. The local operator reported that it has been working well until the middle of November, 2003.

5. Conclusions

The PC-Drum is a Windows-based seismic data logger that integrates data acquisition, display and simple analysis into one unit. In contrast to an analog drum

recorder, its features can be summarized as follows: it has higher dynamic range; the waveform data is stamped with precise time of GPS clock and stored in hard disk in win-format for post-processing or analysis over the network; it simulates the analog drum on screen and provides tools for phase picks and viewing the seismograms in zoom window. The PC-Drum can also be used to browse the past seismograms.

These features make PC-Drum a suitable alternative for analog drum recorders in developing countries with a minimal cost.

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PCドラム：パソコンを用いた地震データ集録と解析システム

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要　旨

PCドラムシステムは開発途上国で現在も使われている旧式のアナログドラム式地震波記録装置を小さなコストでディジタル化，高精度化，自動化，テレメータ化するために開発された．PCドラムシステムは，三つのアナログチャネルから取り込んだ波形データをディスクにＷＩＮフォーマットで記録しながら，スクリーン上の仮想ドラムの上に描画する．刻時にはGPS 時計を用いている．本物のドラムと異なり，スクリーン上で任意の成分に切り替えたり，拡大・縮小したり，過去に溯ってデータを表示したりできる．また，ズーム・ウィンドウ機能を利用し，走時，振幅の読み取りができる．

キーワード：パソコンを用いたデータロガー，データロガー，地震波解析