

## Research Article

### GUI Based Computer Programs for Analyzing Dynamic Signals Detected from a Physical Earthquake Model

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**Abstract:** Many methods are available to be used as tools for data analysis, such as Fast Fourier Transform (FFT) and Hilbert Huang Transform (HHT). However, the raw data need to be pre-processed before applying those methods. To deal with considerable raw data, it should be processed in a fast and efficient way. In this research, the dynamic signal data are obtained from physical earthquake models. To process the huge amount of data is always complicated and time consuming. Customized GUI programs to pre-process and post-process data has been designed to make the raw signal data express its physical meaning rapid by a combination of the manual and automatic process. The research uses animations to display the signal change in time that the signal detected can be shown by a graph which is close to physical phenomena and makes the physical data meaning become more obvious.

**Keywords:** Data processing, GUI (Graphical User Interface), physical earthquake model

## INTRODUCTION

Recently, the computer technology has been significantly improved enabling computers to record and store enormous signals. Digital signals are usually found in the engineering research field. For the reasons of higher accuracy, less distortion and large data capability digital signals are preferred to analog signals. For example, music is transformed from analog signal to digital signal and then recorded on a CD. The sampling rate of a CD usually is 44.1 kHz and the resolution is 16 bits. This means for every second it records 44,100 points data and every point has the bandwidth 65,536. Hence, a few seconds digital signals must be too huge to process manually; computer aided programs are essential for data processing and presentation of digital signals. Fortunately, because of the advancement of computer software, one can easily prepare a customized program for special requirements.

As a result, many researchers used GUI in data processing programs to increase efficiency. Brennan *et al.* (2005) used the GUI to process shear modulus data in an earthquake physical model. Gonzalez *et al.* (2006) used GUI in signal processing for making the data of the earthquake model to be visualized.

In this study, we used the physical earthquake model developed in National Central University Geotechnical Centrifuge Laboratory for data collection

and case studies. Earthquake model is a dynamic experiment which uses transducer such as accelerometer, pour water pressure meter and Linear Variable Differential Transformer (LVDT). We used high-precision sampling rate and resolution to record the data from the transducers during tests. All the programs developed in this research were written in Matlab. By the designed environment of Matlab, the customized programs was produced and tested to meet the research demands.

The purpose of this research is to increase the efficiency of the physical dynamic earthquake data in the NCU centrifuge lab. All the data were recorded from the transducers embed in soil model which were placed on a shaking table in geotechnical centrifuge. Due to the demand of the experimental system, the sampling rate was up to 50 k/s. In one test model, there were more than ten to twenty transducers to record data which implies the data recorded was very huge. In this research, three GUI programs are proposed to process different types of dynamic signal to save time and costs of data processing.

## MATERIALS AND METHODS

This research employed Matlab to design three GUI programs. GUI programs can not only serve users

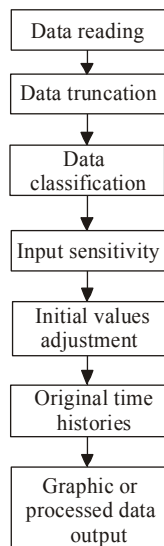


Fig. 1: Data processing in common way

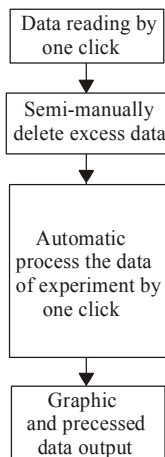


Fig. 2: Data processing by using Program 1

with great data processing interface, but can also provide an easy way for those who do not familiar with computer language. The proposed three programs are discussed below:

**Program 1-raw data processing program:** In order to process raw data rapidly and efficiently, GUI concept was adapted to develop the raw data processing program. Features of the program includes fast data readability, semi-artificial selection of data, fully automatic input with transducer sensitivity, automatic graphs and can input the scaling factor of the model to transform data to the corresponding value. The output of this program is in a compatible format for other applications. In addition, the program can save manual processing time and data is graphically presented. It is expected to improve data processing operation efficiency.

Figure 1 presents the procedure of the raw data pre-processing in general. The raw data must be contrasted from the number of transducers by factitious and

processed by sensitivity one by one. This process is very complex and time consuming. As a result, mistakes are common. Increasing the number of transducers means more data are recorded by the computer, hence, data processing time increases. Program 1 can read raw data which include the header and can distinguish data among transducers. Moreover, it is fully automatic to input the corresponding transducer sensitivity. Irrespective of the number transducers added in the model, the time of processing data is almost the same. Comparison between conventional methods and the program developed is shown in Fig. 1 and 2.

The following is the introduction of input handle.

**Read data:** It's a pop-up where users can select raw data.

**Scaling factor:** It input scaling factor by the different state of testing model.

**Start time:** It controls the beginning of shaking time and truncates the unwanted data.

**End time:** It controls the end of shaking time and truncates the unwanted data.

**Cut off:** After clicking this button, the program will begin processing data. The initial step is to average the first one hundred data points to make initial value zero. After truncating the unwanted data and automatically processing the corresponding transducer sensitivity, the data is plotted in a figure (Fig. 3). All the complicated processing data procedure is completed in this step. By reading the raw data which include the header, it uses the function "for" loops and discriminant to determine the sensitivity of corresponding transducers. Also, it transforms the raw voltage data to become the physical meaning data. In general, this process is time consuming and errors are very likely.

**Plot:** It's a pop-up window where users can differentiate, adjust and output the drawing.

**Output data:** It outputs the calculated data into a common file for other purposes.

**Program 2-hysteresis loops processing program:** In some situations, the processed signal will be overlapped. In such cases, the hysteresis loops are the overlap signal. Hysteresis loop is the relationship between stress and strain during the repeated shear action. It can represent the material properties. Within a period of time, the amount of cumulative variations of stress and strain will become a circle. This slope and area of the circle represent the shear modulus and the damping ratio. Most earthquakes have long return periods and the hysteresis loops will become as much

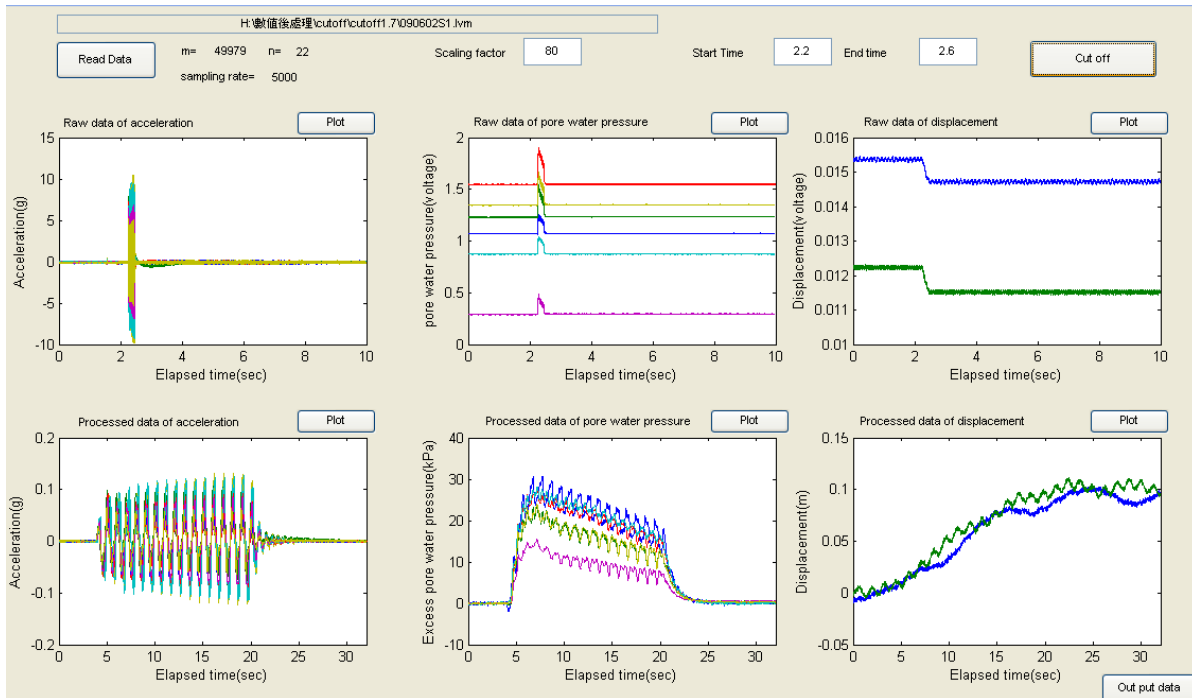


Fig. 3: Program 1-Interface of raw data processing program

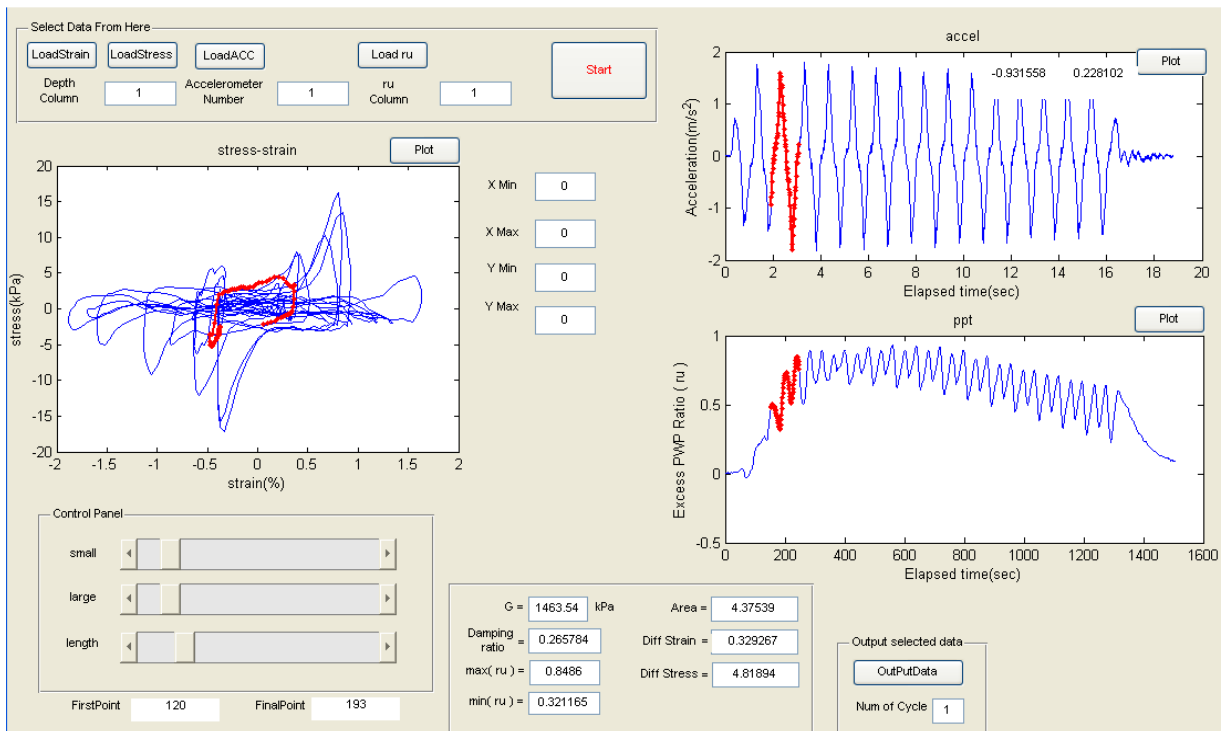


Fig. 4: Program 2-Interface of hysteresis loops processing program

as the length of the period. The hysteresis loop is not the time-domain data in two-dimensional figure, but the time-term is still an important factor to analysis hysteresis loops. This is the most difficult part to interpret data of hysteresis loops.

To analysis this kind of data, hysteresis loops must be divided into sections by section and then compared with other time-domain signals. In order to observe the signals carefully, it uses semi-artificial to operate the signal change. Mark the signals where be concerned

with on the correspondent hysteresis loops, acceleration and excess pore water pressure data. Calculate the area and the physical meaning of the hysteresis loop, such as shear modulus and damping ratio. Finally segmented output the data after artificial observation.

Figure 4 shows the program interface. The left side resembles hysteresis loops. It is a convenient tool to observe the development of hysteresis loops with acceleration and excess pore water transducer. The interface of this program has several classes with handles. The first class is the File Reading Area, second class is the Real-Time Graphics Area, thirdly is the Data Selection Area and lastly is the computation area. The followings are the detail description for the four functions:

**The file reading area:** there are several buttons which appear in a pop-up window. The button allows users to select the stress, strain, acceleration and other required data depending on user's needs.

**The real-time graphics area:** It has three axes available for drawing. It uses blue line to draw the whole data and red line to draw considerable data.

**The data selection area:** There are three scrolls at the lower left side of the interface (Fig. 4). The three scrolls can control the selected range (the red lines) which be plotted on the axes. These scrolls are the most important UI in this program. It can provide an easy way to select the concerned data.

**The calculation area:** The program is designed to calculate the area and slope of the hysteresis loops which are selected. And then it can obtain the shear modulus, damping ratio, mean stress, mean strain and so on soil dynamic property.

Finally, after choosing the concerned hysteresis loops, it can easily output the data for subsequent processing. As mentioned before, this program can save a lot of time in the processing of data and determination of data becomes more accurate and is simplified.

**Program 3-the animation of dynamic model:** "Time" is an important factor in the dynamic signal. The two-dimensional or three-dimensional figure can only show some parts of the data. If using animation to show three-dimensional data, it can demonstrate more complex information. In the animation, the physical meaning of the signal can be intuitively interpreted and observed as shown in Fig. 5 and 6.

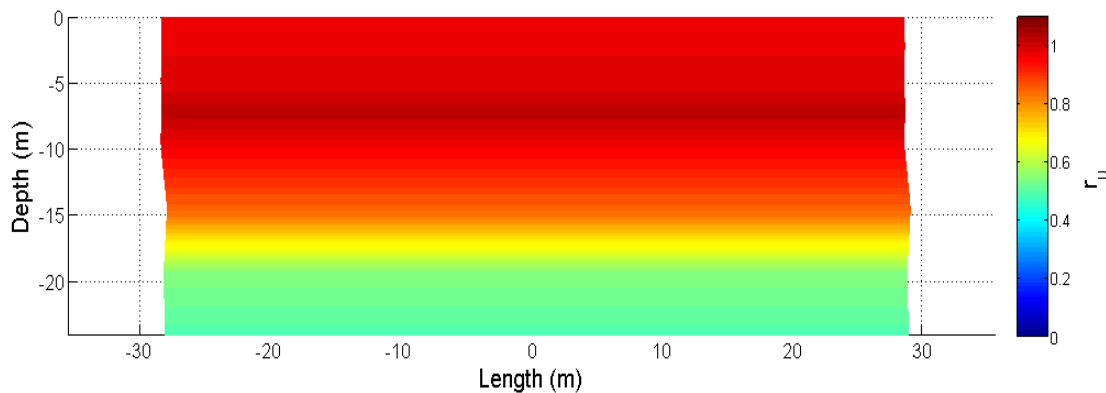


Fig. 5: Experimental data of liquefaction soil layer model presented by program 3

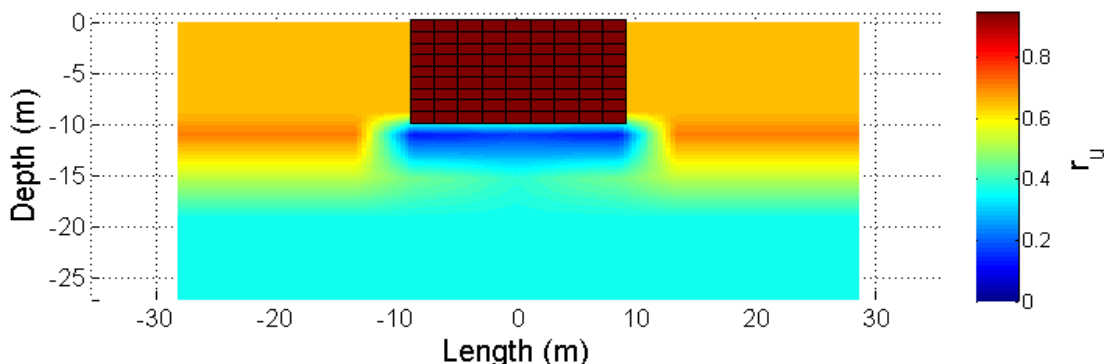


Fig. 6: Experimental data of liquefaction soil layer embedded tunnel model presented by program 3

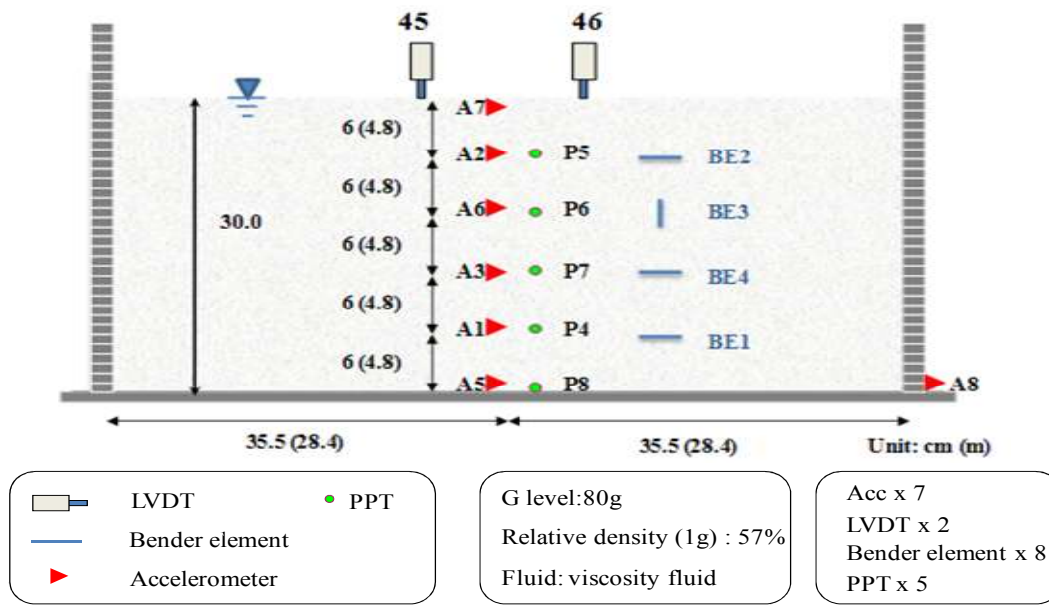


Fig. 7: Typical soil container setting with transducers

Figure 7 shows a typical soil container for setting a lot of transducers and soil for the physical earthquake model to study the soil deformation. The container will be set on a shaking table in the centrifuge and begin the earthquake tests when the centrifuge spins up to 80 times of gravity. The animation should show the soil layer displacement, settlement and the excess pore water pressure change during the test. The transducer is less intensive to show a high resolution animation, so it established a three-dimensional matrix sized 300 x 300 x 300. Put the corresponding data into the matrix and define the location of the soil layer and the excess pore water pressure value. Use interpolation to fill the blacks in the matrix and finally it will have a greater resolution. Use the function “surf” to draw three dimensional figures. The program uses colors to

represent excess pore water pressure. All outputs from the program are animations.

## RESULTS AND DISCUSSION

Program 1 can be employed in all kinds of test results data in the NCU centrifuge lab. Data can easily be converted into a physical value and to facilitate observation and analysis. Figure 3 shows a typical case. The raw data have many different types of sensors. With the program, the data obtained from different types of sensors can be processed automatically.

Program 2 has been widely used in the earthquake soil model. Without using this program, separate drawings of the hysteresis loops and analysis of the shear modulus of one test may last days. Using this

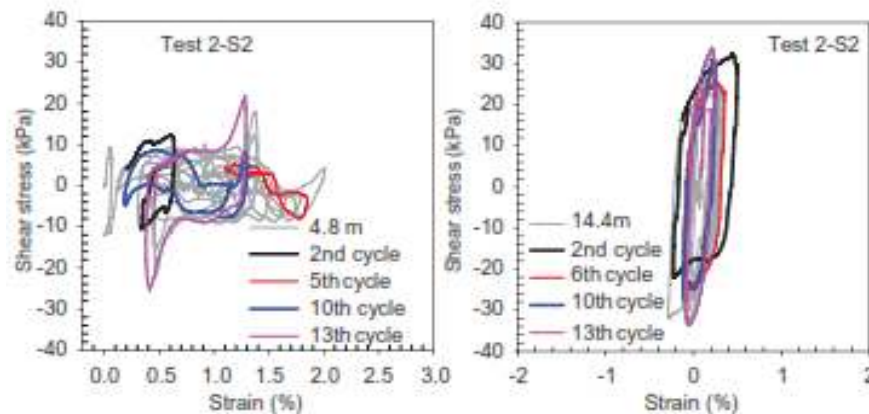


Fig. 8: Histories of shear stress-strain at various depths (Lee *et al.*, 2010)

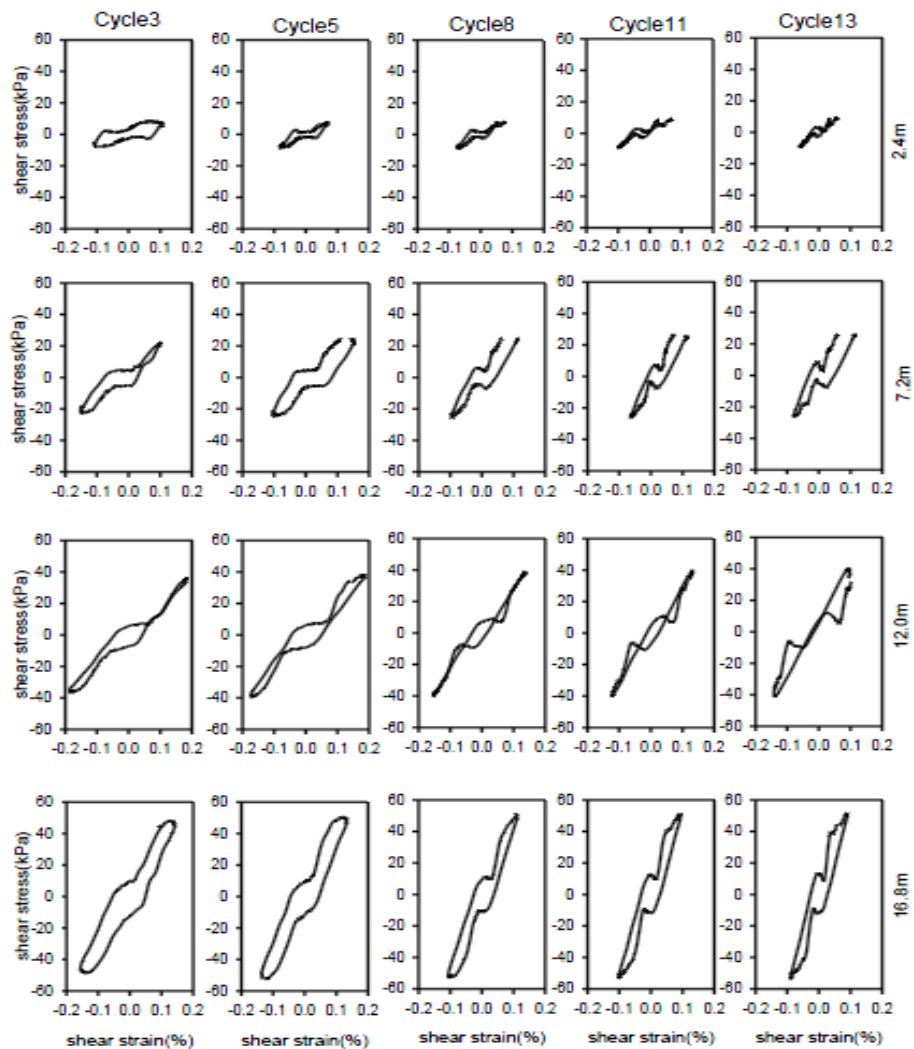


Fig. 9: Histories of hysteresis loops at various depths (Kwan, 2010)

program, about 150 hysteresis loops can be outputted from the data in a few hours. When drawing the hysteresis loops, it can be comprehended by observing the data whether it is reasonable or not. Lee *et al.* (2010) and Kwan (2010) used this program assist the analysis as shown in Fig 8 and 9, respectively.

Program 3 is a good presentation tool in many different model cases. It is usually used in briefings or conferences to explain the overview of the result data. It has been used in clean sand model, layered sand model and tunnel model.

### SUMMARY AND CONCLUSION

The programs which were developed in this research increase the dynamic signal processing ability of large-scale physical earthquake model data. It does not only advance the efficiency of data processing, but also makes the data to be visualized hence, improved

analysis. These programs have successfully applied in many experiments for different purposes in the Geotechnical Centrifuge Laboratory of NCU. Besides, the programs will play a significant role in the future by adding more functions from FFT or HHT to further data processing capabilities.

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