We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Instrument Design, Measurement and Analysis of Cardiovascular Dynamics Based on LabVIEW

Wei He[1], Hanguang Xiao[1,2], Songnong Li[1] and Delmo Correia[1]
[1]Chongqing University,
[2]Chongqing University of Technology,
China

1. Introduction

With the increasing aging of population, cardiovascular diseases have become one of the most common diseases. It has been recognized as the leading killer of the 21st century by World Health Organization (He & Yu 2010). It is believed that one-third of deaths around the world result from cardiovascular disease, but many of them died from absence of timely detection of the diseases (Mark 2003). Therefore, timely and accurate detection and diagnosis of this kind of diseases are of great significance for prophylaxis and treatment. For this purpose, more powerful instruments are needed to be developed.

In recent years, LabVIEW have been wildly used in various fields as a powerful development environment and platform based on graphical and dataflow programming language (Johnson & Jennings 1997; Whitley & Blackwell 2001; Klinger 2003; Bitter et al. 2007). LabVIEW-based research and development of medical instruments is one of the most outstanding representatives in the R&D of virtual instruments (He & Yu 2010).

In this chapter, we will introduce the design of our independently developed product, which is named as YF/XGYD atherosclerosis detection system developed by LabVIEW. Three aspects of the system will be mainly described, namely overall design of the hardware system, the brief design and LabVIEW realization of the software system, and the clinical measurement and analysis of hemodynamic parameters of cardiovascular system, such as pulse wave velocity (PWV) and arterial stiffness index (ASI).

In the first part of the chapter, we will mainly described the overall design of the hardware system, such as the measure method of analog signals of blood pressure, the design and realization of the signal processing circuit, the design of digit circuit and loop of aeration and deflation, and the circuit of motor control.

In the second part of the chapter, the overall framework of the software system will be displayed in a block diagram. Then, the interface design of the software system is described, for example the main interface, test interface and record interface. In addition, we will show how to build and manage the patient database of the software system.

Finally, the basic principle, measurement and analysis of two key parameters are introduced, namely PWV and ASI. We would like to apply the system to clinical test and discuss the performances of the system.

2. Design of a cardiovascular dynamics parameters measuring instrument

The cardiovascular dynamics parameters measuring instrument is mainly composed of two parts: the hardware system and the software system. In what follows, the overall design of hardware and software systems of YF/XGYD Artery Stiffness Measuring Instrument (YF/XGYD) developed by Chongqing University are mainly described in this chapter.

2.1 Design of hardware system

The hardware circuit and gas path system of YF/XGYD is mainly composed of three parts: analog signals detecting circuit; digital control circuit; charge-discharge gas loop of electromotor. The overall design of hardware system is displayed in the following block diagram (Fig. 1).
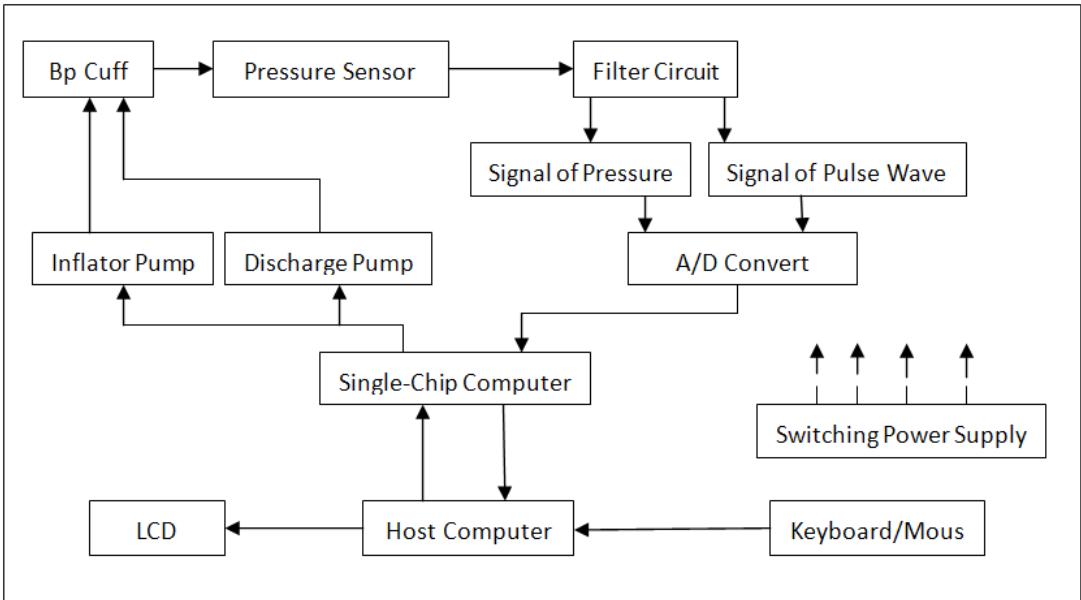

Fig. 1. The overall design of hardware system

In testing, place the object in sitting position, the brachial cuff is used around the left upper arm, near elbow joint, and the wrist cuff is used around the radial artery. The cuff is inflated by air pump under the control of single-chip computer. Simultaneously, pressure pulse signals in the cuff are collected through pressure sensors. When pressure of cuff reaches the preconcert set point, inflation of cuff is stopped. In the same time, pulsation of brachial artery stops because of the pressure of cuff. Then pressure of cuff decreases gradually when the deflation valve is working slowly according to programs in the single-chip computer. Brachial artery begins pulsing when pressure of cuff decreases below systolic pressure, and the pulsation increases as pressure of cuff decreases. Through pressure sensors, pulsation signals of cuff pressure, brachial artery and radial artery are converted into voltage signals. After these voltage signals are amplified and under filtering processing, we get three signals of appropriate amplitude. These signals include one signal of cuff pressure and two signals of pulse wave. Then these three signals are A/D converted into digital signals, with these digital signals to be analyzed and processed in single-chip computer. These digital signals can be sent to and then analyzed and processed thoroughly in host computer through RS232 series communication by single-chip computer. These contents of analysis and processing in

host computer include that: real-time displays and records pressure waves of brachial artery, radial artery and cuff pressure; calculates parameter values through existing algorithm; saves tester's information, parameter values and waveforms; evaluates the artery's health condition of the object.

The YF/XGYD artery stiffness measuring instrument and the field testing can be seen in Fig. 2.

Fig. 2. The YF/XGYD artery stiffness measuring instrument and the field testing

2.2 Design of software system

2.2.1 The overall block diagram of software system

The software system of YF/XGYD is based on virtual instrument LabVIEW 8.5. It is mainly used to collect and preprocess data signals, analyze and calculate blood flow parameters, and store, replay and print test results. The whole block diagram can be seen in Fig. 3. Through utilizing the powerful function of data acquisition and digital signal processing of LabVIEW 8.5, we can collect and process these signals of pulse wave and cuff pressure. In addition, LabVIEW 8.5 has well function of database management and many kinds of tools and methods. So it can manage many different types of database. Users can utilize data control to access, add, delete and inquire existing different types of database. And users can utilize Visual System Manager (VSM) to establish and maintain many different types of database and generate database application program. Because those well functions of database management in LabVIEW 8.5, through programming we achieved storage management of patient file, including: database maintenance, query answering, statistical analysis and printing.

2.2.2 User interface design of software system

The user interface is very important component in interactive software system. A good user interface should have the advantages, such as perfect performance, simplified operation, reliable operation and accurate interpretation of results. Every part of the architecture block diagram of software system (Fig. 3) corresponds with function module and user interface in software system, respectively.
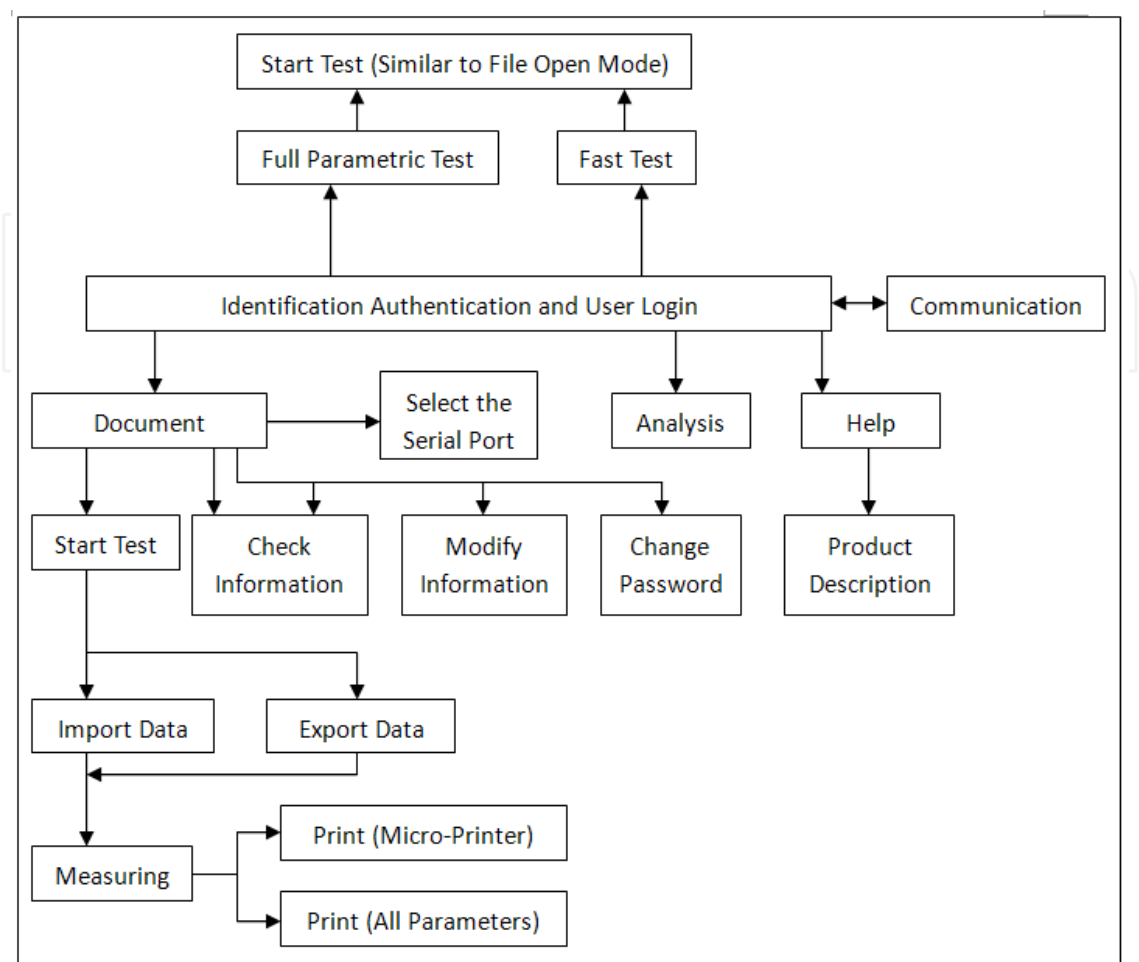
Fig. 3. The architecture block diagram of software system

1. Main window of the software system

To ensure the security of the software system, users could set a password in the secret code dialogue window which will be popped out when user starts the system. Only after entering the correct password, user can enter the main window.

Users could utilize the function menus in the main window to achieve a variety of processing operations. The window interfaces in the system be generated by menu tool (Menu Editor) in LabVIEW 8.5 are all standard Windows pull-down menu system. To make the system easy to operate and make users easy to master, we take into account the following principles in the design of the menu: in design, organize system menu on the basis of functions, so users could know clearly structure and function of the system when they browse the menu; to give a meaningful title to menu against the specified function; to set hotkeys for these staple menus; to organize menu item according to frequency of utilization.

The main window and its LabVIEW program code of YF/XGYD can be seen in Fig. 4 and Fig. 5, respectively. The main window is relatively simple; in addition, in terms of function set-up, it includes three pull-down menus (the File, the Analysis and the Help) and three function-buttons (the Fast Test, the Full Parametric Test and the Exit).
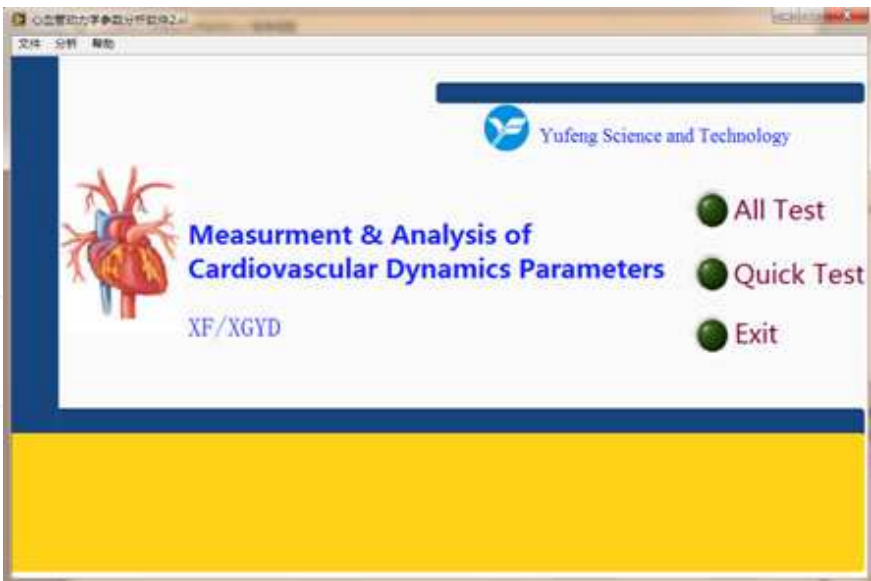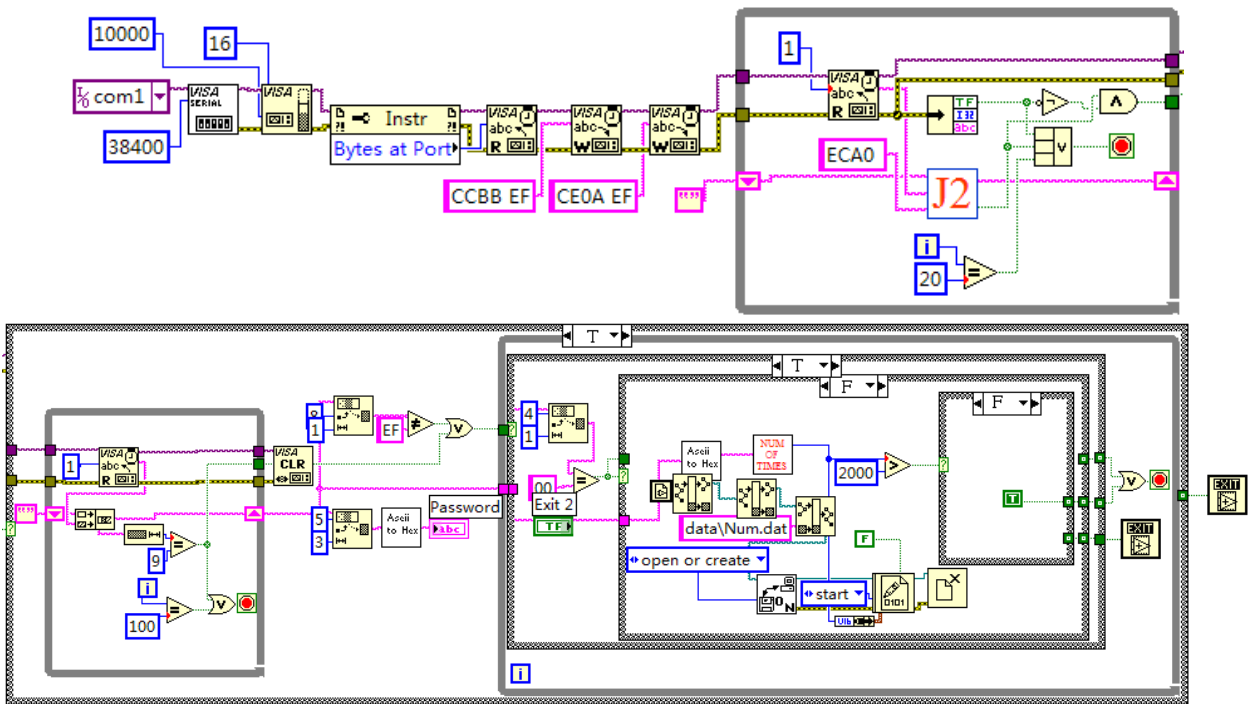
Fig. 4. Main window of YF/XGYD system

Fig. 5. LabVIEW program code of the main window

2. Test window of the software system

When the YF/XGYD system measures the cardiovascular active state of human, the system software will carry out data communications and synchronously draw graphics of these measuring signals. Furthermore, to visually and intuitively describe the process of inflation and deflation in cuff, the system can utilize progress bar control to dynamically simulate rising and falling of mercury column in sphygmomanometer when charging and discharging gas in blood press measurement by the stethoscope. The full parametric test window and its LabVIEW program code of YF/XGYD can be seen in Fig. 6 and Fig. 7, respectively.

The interface (shown in Fig. 6) can be divided into three areas, such as the Function Button Area, the Test Waveform Display Area, and the Personal Data and Test Results Display Area.

Fig. 6. The full parametric test window

Fig. 7. A part of LabVIEW program code of the full parametric test window

According to the needs of testing procedure, users could choose the Measuring Button, the Save Button, the Refresh Button, the Analysis Button, the Reset Button and the Print Button, respectively. When user clicks the Measuring Button, YF/XGYD system enters testing

status. In this state, the host computer begins to communicate with the slave computer; in the meantime, cuffs are inflated; then the system displays real-time waveform variation value of three-way signals in the Test Waveform Display Area. These waveforms can be seen in Fig. 8.

White -----Pulse Wave Curve of Brachial Artery

Green -----Pulse Wave Curve of Radial Artery

Red -----Curve of Cuff Pressure
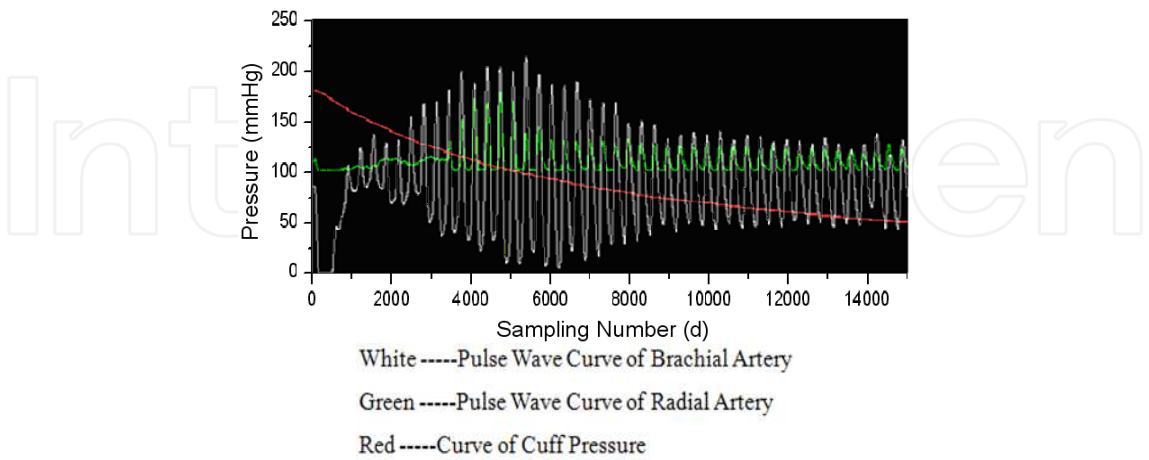
Fig. 8. Graphs of pulse wave and cuff pressure

The roles of function buttons are: the Measuring Button, to begin testing; the Save Button, to save measuring results, personal data, measuring waveforms, etc.; the Reset Button, to eject the Input Tester Data Sub Interface and re-input tester basic information (including ID, name, gender, age, height and weight) in this sub-interface; the Refresh Button, to empty personal data and measuring waveforms and wait for next test; the Analysis Button, to enter the Parametric Analysis Interface of Patient who have been tested (the interface and its LabVIEW program code can be seen in Fig. 9 and Fig. 10, respectively), and to look over Diastolic initiation wave, Systolic decent wave and other cardiovascular parameters of patients; the Print Button, to print measuring results.
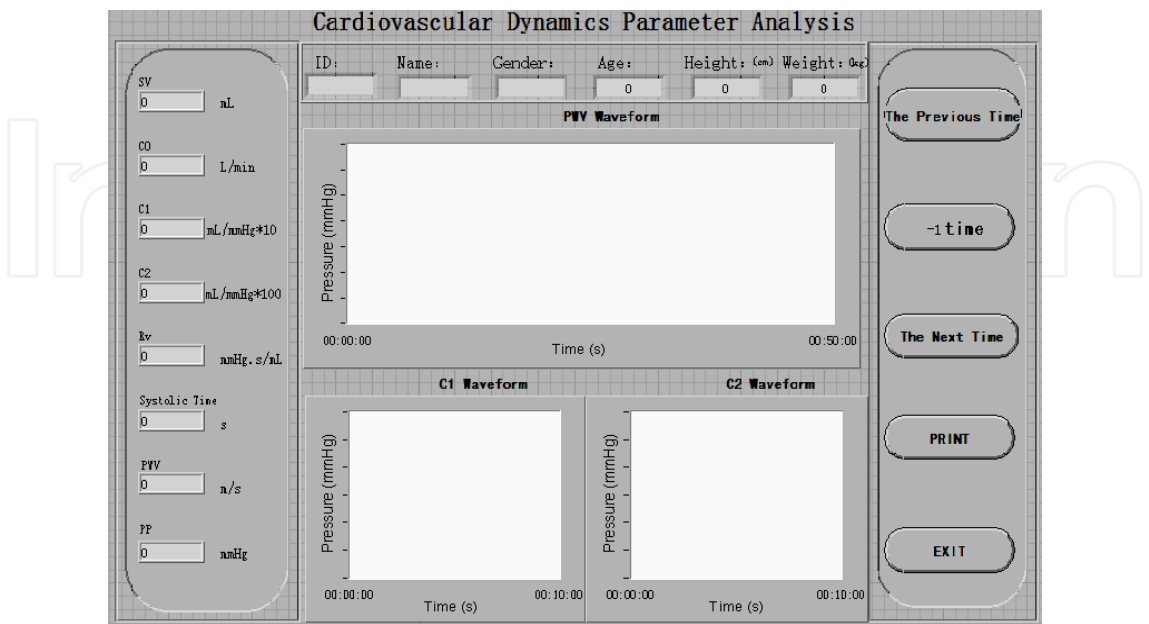
Fig. 9. Parametric analysis interface
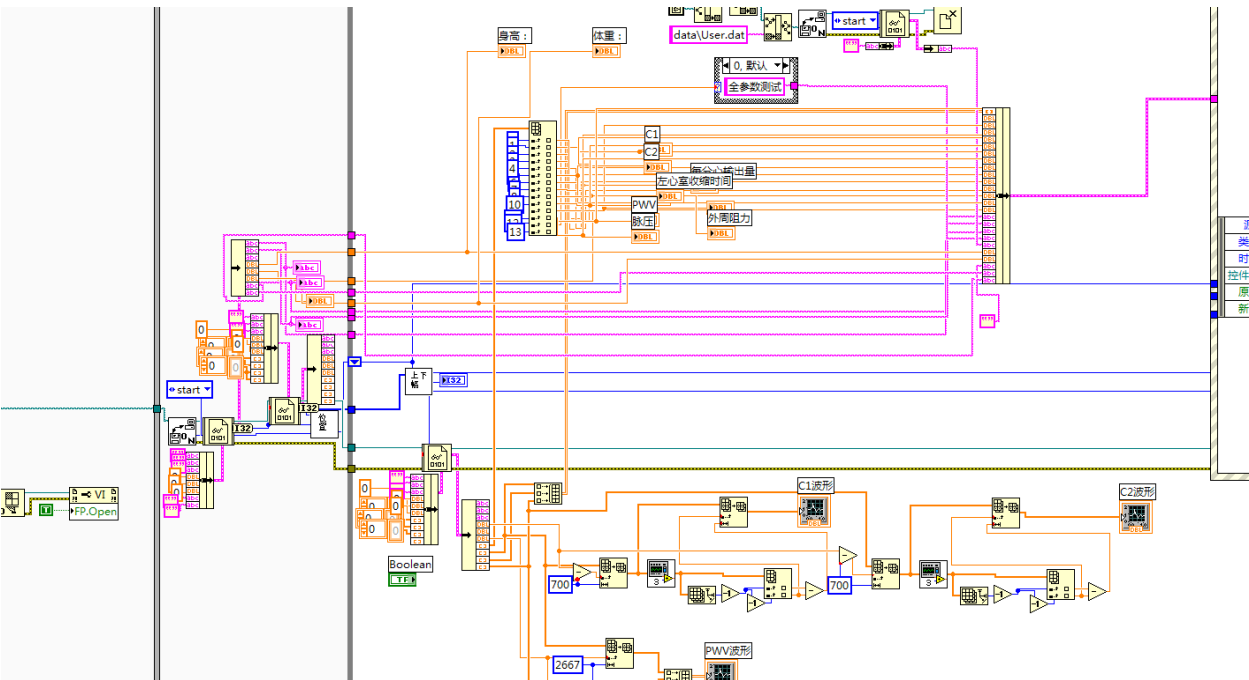
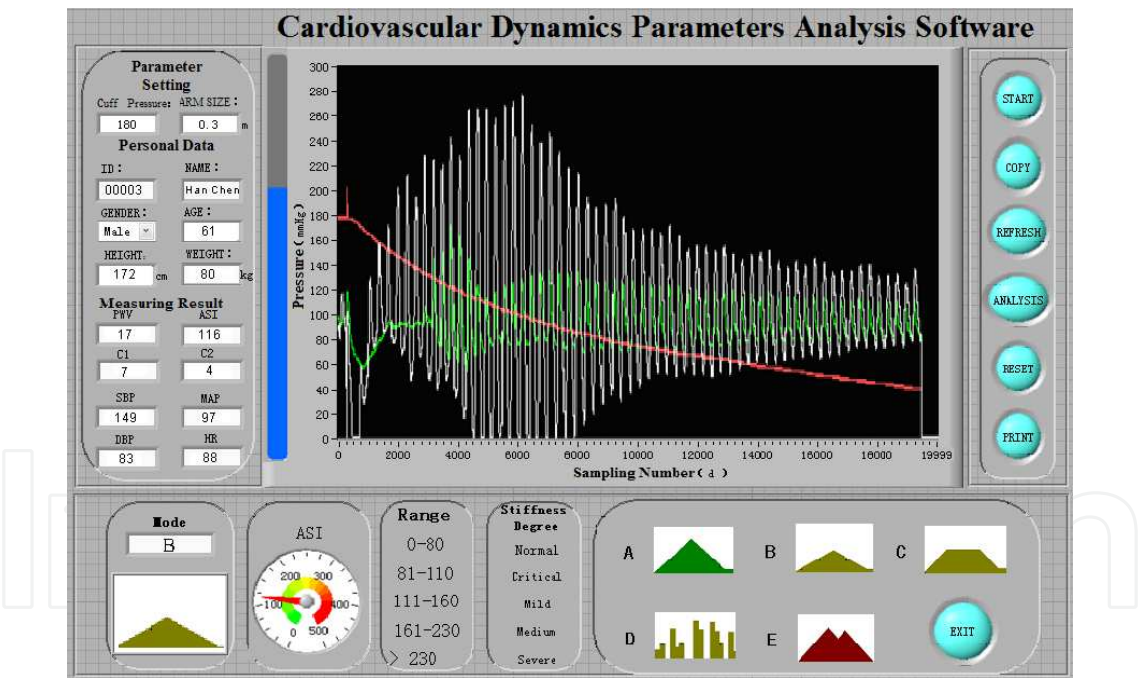Fig. 10. A part of LabVIEW program code of the parametric analysis interface

Fig. 11. Measuring results interface

These test results are displayed in the Personal Data and Test Results Display Area. These results include personal data, such as ID, name, gender, age, height and weight, and test results, such as systolic pressure, diastolic pressure, mean pressure, heart rate, pulse wave velocity [PWV], artery stiffness index [ASI], large artery compliance [C1], and small artery compliance [C2]. According to measured values of each parameter, the YF/XGYD system can estimate the cardiovascular status of the object. For example, the system can utilize vivid Graphic Correlation method to estimate the range of ASI value; waveform envelope shape

of pulse wave is divided into five types (A, B, C, D, and E), so the system can synthetically estimate general situation of artery elasticity. In Fig. 11, we can clearly see a 61-year-old patient's test result: systolic pressure is 149mmHg, ASI is 116, and waveform type of pulse wave is B, and so on. The test result indicates that the patient whose arteries are already mild stiffness has the tendency of potential artery disease.

In addition, the system software has the Test Waveform Display Area interface. User can utilize the interface to examine, delete, recover and print patient's personal data and waveforms and results of each record. In order to facilitate contrastive analysis, different parametric results of every test are all displayed on the interface. Fig. 12 showes a patient's two test records (ASI is 200 in the first time and 190 in the second time) which reflect that the patient's arteries are moderately stiff.
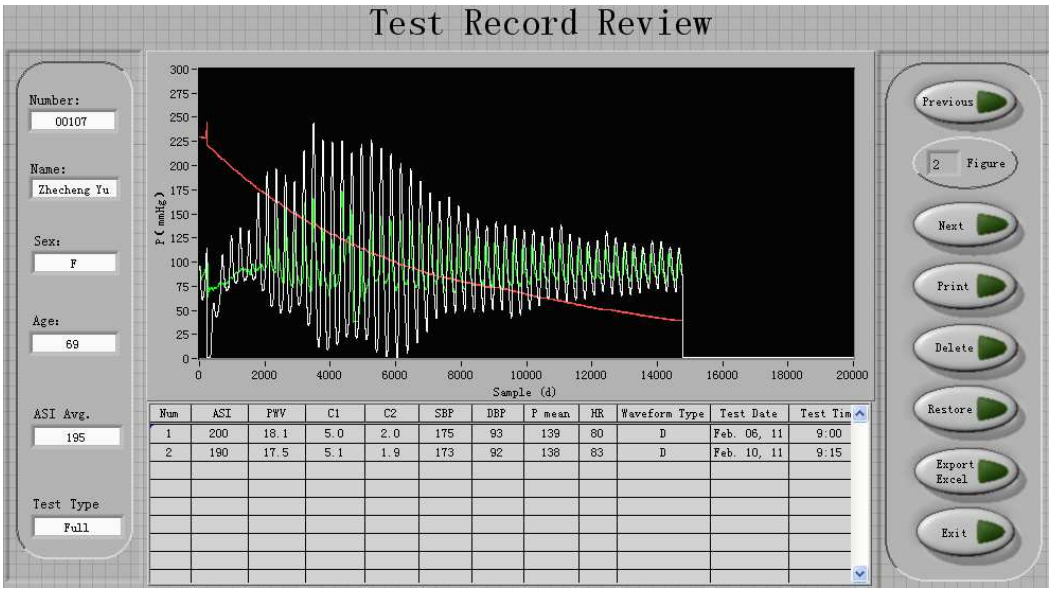
Fig. 12. Test waveform display area interface

2.2.3 Database of software system

1. Establishment of database

The medical signal database with three data tables is created strictly in accordance with the relational model of database. The tables are: ① the table of patient's basic information, including ID, name, gender, age, height and weight; ② the table of patient's basic parameter, including pulse wave, cuff wave, heart rate, systolic pressure, diastolic pressure, mean pressure and stroke volume; ③ the table of diagnostic results, to save the corresponding results in the field of diagnostic results.

2. Operation of database

The operation of database includes data browsing, data query and database editor that adds, modifies and deletes patient data. Inquiry statistic is a very important function in management system. The YF/XGYD system utilizes LabVIEW 8.5 well database management function to achieve the inquiry and statistics of relevant data. It takes a great of convenience to clinical and scientific researches. The edit function of database can achieve these operations to add, modify and delete patient records. Choosing the corresponding

option in the menu, user can achieve the maintenance of patient records. According to the actual need, user can choose the print option in the menu to print patient records. It takes a great of convenience to analysis of patient's condition.
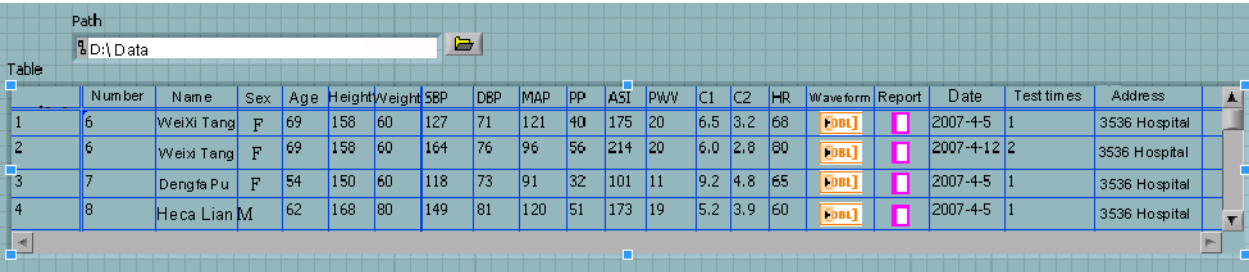
3. Data management module

Data store can be divided into file store and database store in LabVIEW 8.5. Database store can overcome the constraints imposed by file store which is proven unfavourable to data query and management, so the YF/XGYD system utilizes database to store data in the development of virtual instrument system. This improves running efficiency of the system. Through Open Database Connectivity (ODBC), LabVIEW communicates with the database. User needs to name database and install drivers in ODBC. Through third-party software (LabSQL), software communication interface between LabSQL and LabVIEW database is created. Users can utilize the interface to log in local or network database and establish, store, modify and manage this database. Data exchange between application program and database is achieved by calling the SQL execution module.

4. Data storage module

Users can respectively choose the independent storage and the statistics storage to store measuring data. Users can look over measuring waveforms, parameters and results of patient by the independent storage ways or save patient's measuring results to LabVIEW tables in the manner of statistical model by the statistics storage ways. At the same time, the system can create a homonymous Excel electronic spreadsheet. On account of large amount of waveform data, the method of examining data in Excel is inconvenient. The method of examining data in LabVIEW table will become necessary means for improving performance of examining data. And users can look over and compare large categories of waveforms by this method.

Users can directly call Excel electronic spreadsheet for statistic analysis by SPSS software. A set of clinical test results after being evaluated and saved is shown in Fig. 13, which is displayed under the LabVIEW environment. Excel electronic spreadsheet and this LabVIEW table have same file name and path, but different formats. Users can choose to analyze the whole measuring data or a certain measuring data or multiple measuring data to contrast and analyze by statistical method. Users can analyze in term of the repeatability these data which are gained by repeated measuring the same people. These measuring results of multiple hospitals can be saved as the same document and displayed synchronously. By and large, the efficiency of clinical analysis is greatly improved through the improvement of database.

Fig. 13. A set of clinical test results

3. Algorithm, encoding and measurement of arteriosclerosis parameter

Many parameters of artery system can be measured by YF/XGYD system. PWV and ASI are the two most commonly used parameters among them. We mainly introduced the method of calculation, the programming of LabVIEW and the process of measurement of the two parameters.

3.1 Pulse wave velocity (PWV)
3.1.1 Definition of PWV

The systole and diastole of heart lead to the periodic change of blood pressures in whole arterial system, and the periodic contraction and dilatation of arterial wall, which force the pulse wave to propagate along blood vessels from heart to whole body(McDonald 1974; Qiao & Wu 2000). PWV is mainly decided by the arterial physical parameters, such as arterial wall thickness and Young's modulus of elasticity. Therefore, PWV can reflect the changes of these parameters, and judge whether arteriosclerosis or not (Takenaka & Kobayashi 2004).

3.1.2 Calculation of PWV

In the system, a noninvasive method is used to measure the brachial-radial PWV (commonly abbreviated as BRPWV) by detecting, collecting and analyzing the pulse signals at brachial artery and radial artery simultaneously. BRPWV is commonly used for the degree assessment of human arteriosclerosis (Zhang et al. 2005).

Because pulse wave propagates from heart to peripheral arteries, pulse wave arrive at brachial artery firstly, then radial artery (McDonald 1974; Qiao & Wu 2000; Mark 2003). We can measure the time difference Δt of wave arriving at two measure point at brachial and radial artery, and the distance ΔL of two measuring points, namely the distance of two pressure sensors in two cuffs. Then we can calculate BRPWV as Eq. 1.

$$PWV = \frac{\Delta L}{\Delta t} \tag{1}$$

In order to obtain Δt, the foot of the pulse wave need to be detected, namely the takeoff point D. Because of the existence of interference factors, the ideal pulse wave is hard to be obtained, namely the takeoff point D is not the trough location of pulse wave. In Fig. 14, point A is the trough of pulse wave, and point D is the takeoff point which is needed to detect. Obviously, the two points are not the same point, so the point D is needed to calculate using a special algorithm.

The algorithm of detecting the takeoff point D:

Step 1.   find the trough A (x_1, y_1) and peak B (x_2, y_2) of the pulse wave;

Step 2.   establish the equation of line AB:

$$(y_1 - y_2)x + (x_2 - x_1)y + (x_1 y_2 - x_2 y_1) = 0 \tag{2}$$

Step 3.   calculate the distance from a point on the waveform between A and B to the line AB, and find the maximal distance from a point which is the takeoff point D.

After detecting the takeoff points of the brachial and radial pulse wave, the x coordinate different value of the two points is the time difference Δt. The schematic figure of calculating Δt is showed in Fig. 14.
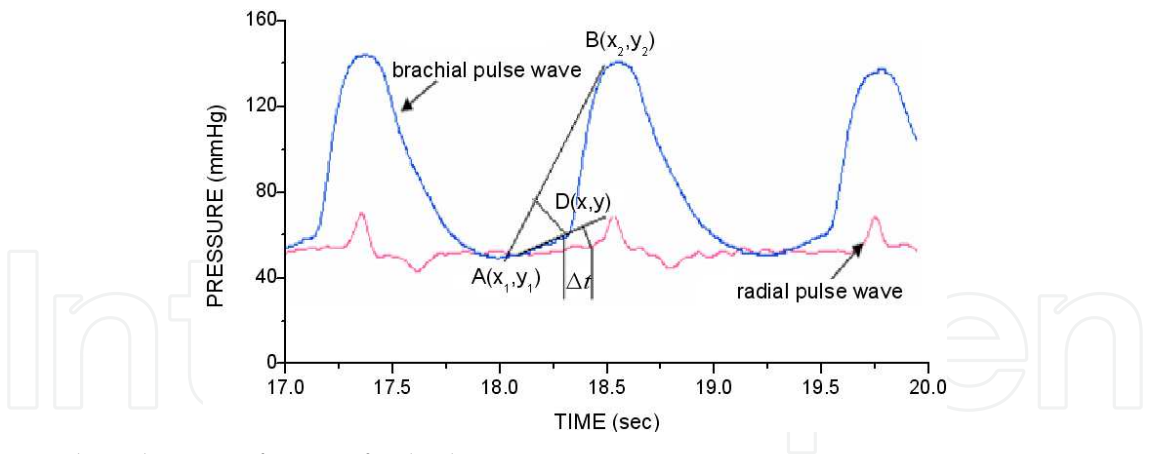
Fig. 14. The schematic figure of calculating Δt

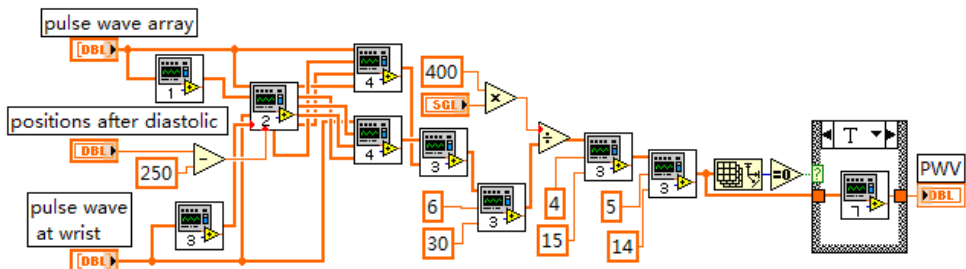### 3.1.3 LabVIEW code of calculation of PWV

Fig. 15. LabVIEW graphical code of calculation of PWV

The LabVIEW graphical code of calculating PWV is showed as Fig. 15. There are four subprograms called by the main program in Fig. 15. The subprogram 1 and 3 are used for finding the trough and peak of the pulse wave, respectively. The subprogram 2 is used to establish the equation of the line AB. The takeoff points of the brachial and radial artery and the time difference are calculated by the subprogram 4 and 5. In order to improve the accuracy, the subprogram 6 and 7 are used to find several time differences of lower relative error and calculating the mean of them. The LabVIEW graphical codes of the subprogram 2 and 4 are showed in Fig. 16 and 17.
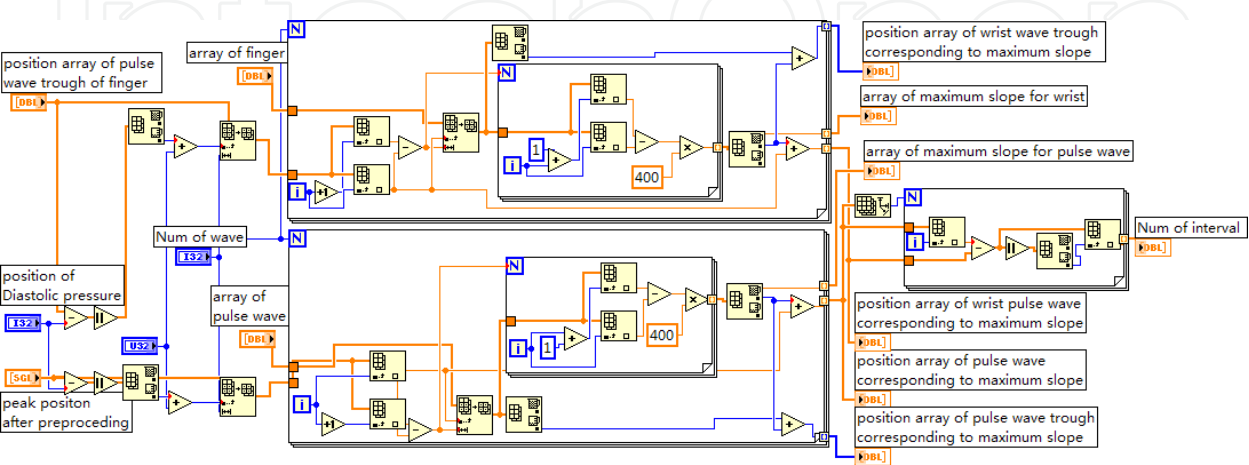
Fig. 16. The LabVIEW graphical codes of the subprogram 2
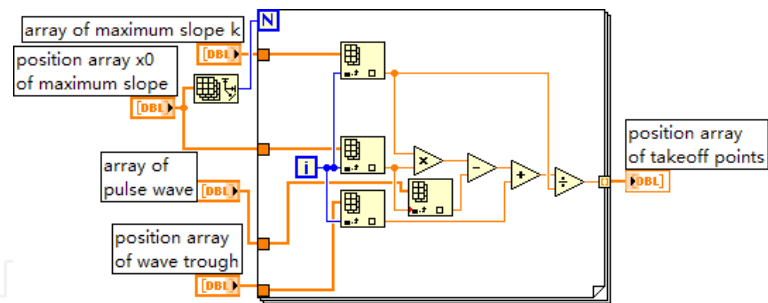
Fig. 17. The LabVIEW graphical codes of the subprogram 4

3.2 Arterial stiffness factor (ASI)
3.2.1 Definition of ASI

ASI is an important nondimensional parameter which represents the degree of blood-vessel stiffness (Sunthareswaran 2003; Quan et al. 2006). ASI can indicate arterial wall elasticity, and serve as an independent predictor of cardiovascular diseases. It is also an important parameter of YF/XGYD system.

3.2.2 Calculation of ASI

In the system, we use the whole pulse waveform and the pressure curve of cuff to calculate ASI (Yao et al. 2007). Generally, we find out two peaks at the front and back of the maximum peak, which are closest approach to 80% of the maximum peak. Then, two cuff pressures corresponding to the two peaks can be obtained by a subprogram. Finally, ASI is calculated by multiplying the difference of the two cuff pressures by a special factor.

In the measurement of ASI, the maximum peak P_{Max} of the whole pulse wave is obtained firstly, namely the MAP of the pulse wave. Secondly, we need to find out two peaks of pulse wave whose values are the most approach to $P_{Max} * 80\%$ at the front and back of the maximum peak. The difference of two cuff pressures corresponding to the two peaks multiplies a special factor to get ASI. The schematic diagram of calculating ASI is showed as Fig. 18. The equation of calculation is as follows:

$$ASI = K * \left(P_1 - P_2 \right)$$

Where, K is the correction factor which is relate to the particular case of tester, such as smoking, sex, age, and health.
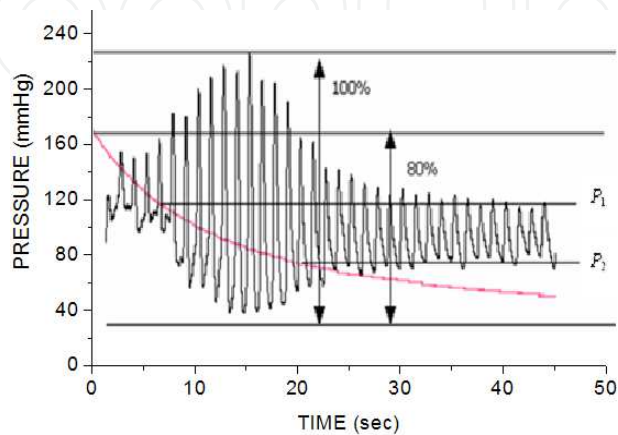

Fig. 18. The schematic diagram of calculating ASI

In LabVIEW, we use a subprogram VI to realize the calculation of ASI. The graphical code of the subprogram is showed as Fig. 19.
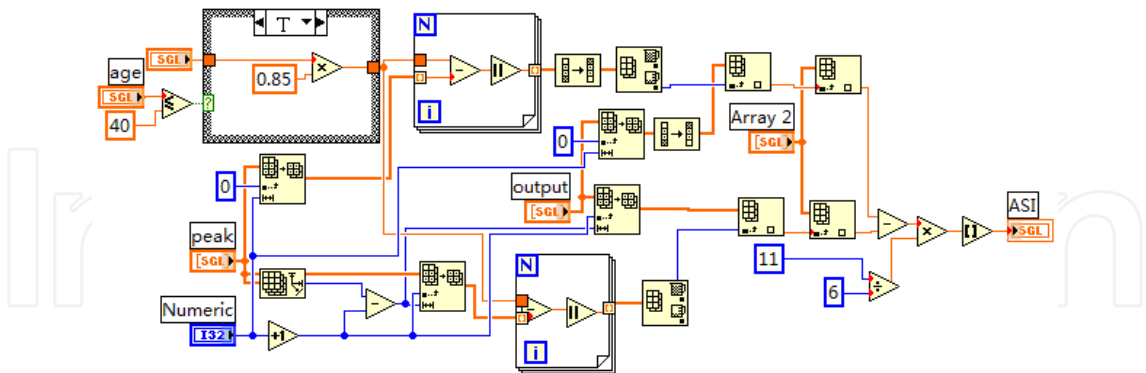

Fig. 19. The graphical code of calculating ASI

3.2.3 Singular wave processing in actual measurement of ASI

In actual measurement of ASI, the pulse wave signal is greatly influenced by environment around the tested body (Quan, He et al. 2006; Quan et al. 2006; Yao, He et al. 2007). For example, the saltation of respiration and the body shaking may product a few singular waveforms. This kind of interferences will not only influence the data collection, and may even generate invalid data. In order to remove the influence of singular waveform, we need to conduct a series of signal processing, such as filtering processing of moving average, deleting adjacent-wave, high peak and low peak, etc.

1. Deleting adjacent wave processing

In measurement, there are some adjacent waves generated from interference as shown in Fig. 20. Pulse adjacent wave likely cause the detecting error of the systolic blood pressure and diastolic blood pressure. So we need to remove these pulse adjacent waves. Through a lot of waveform analysis, we summarize a method for detecting adjacent wave: if the time difference of two adjacent peaks is less than 100 sampling points, the two waves corresponding to the two adjacent peaks are judged to be adjacent wave. Fig. 21 showed the graphical code of adjacent wave processing.
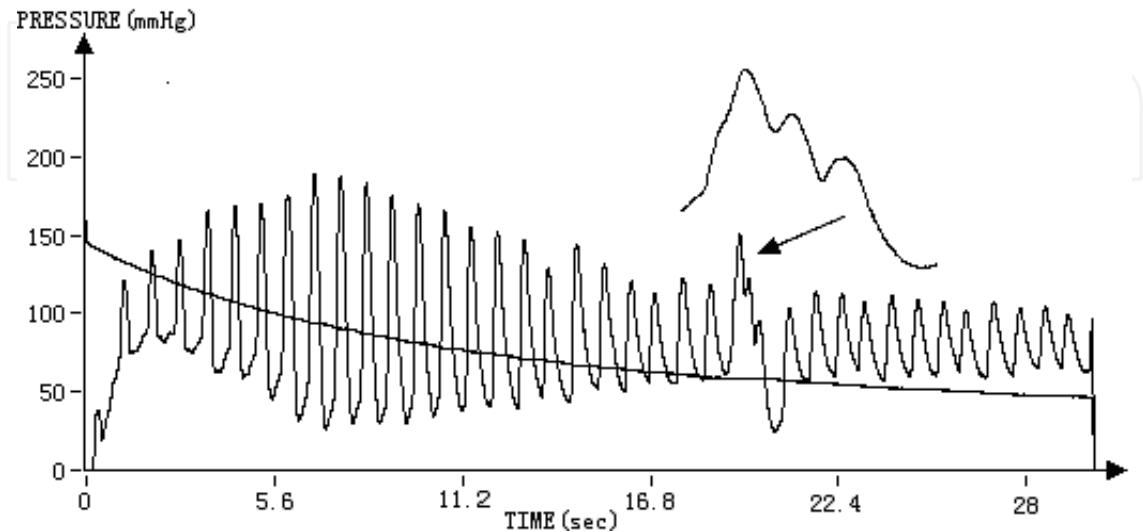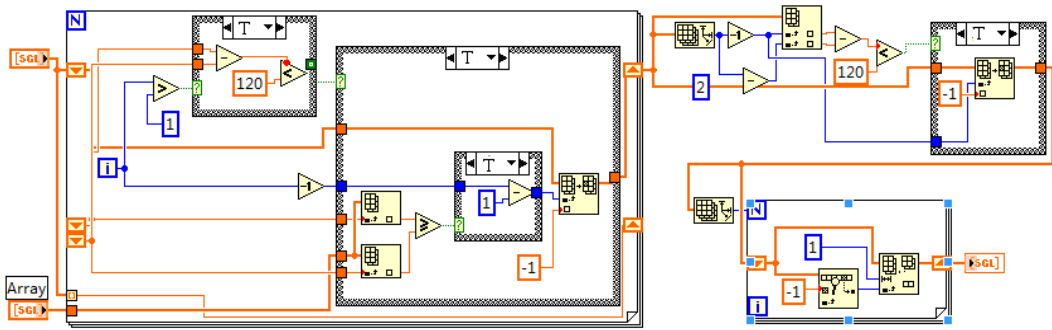

Fig. 20. Processing adjacent wave

Fig. 21. The graphical code of adjacent wave processing

2.   Deleting sharp peak processing

In measurement, a vibration of a part of body or other reasons probably cause the phenomenon of sharp peak in pulse wave as shown in Fig. 22. If the system applies the singular sharp peak in analysis, the singular wave will be misjudged to be the position of mean blood pressure. So system must delete these singular sharp peaks.

Through a lot of waveform analysis, we summarize a method for detecting singular sharp peak: (1) if the value of a certain point A of all pulse peaks surpasses 30 of front and back point of the point A; (2) if the value of a certain point A of all pulse peaks is more than 30 of front point, 10 of back point and 30 of back two points of the point A; (3) if the value of a certain point A of all pulse peaks is more than 30 of back point,10 of front point and 30 of front two points of the point A; we judge the point A is a singular peak when anyone condition is right. Fig. 23 shows the graphical code of sharp peak processing.
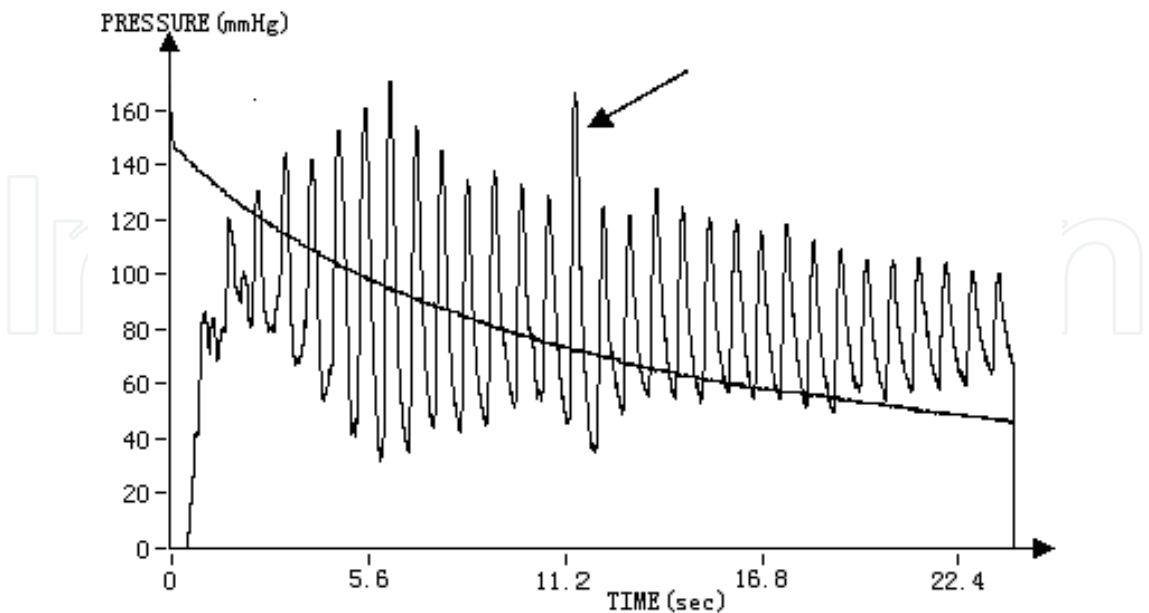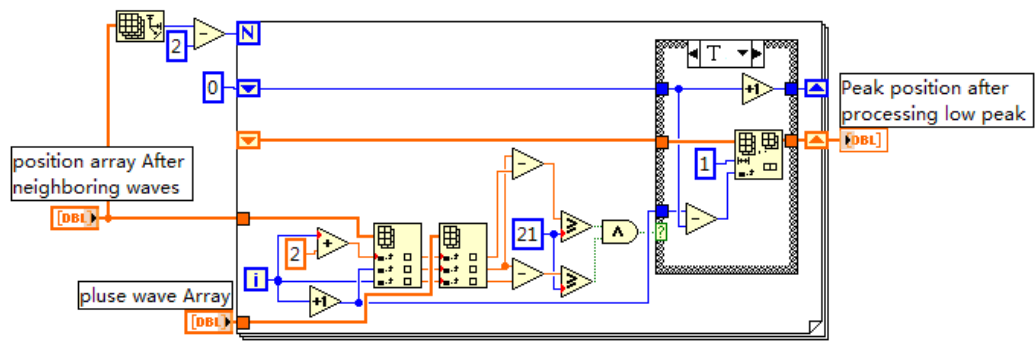

Fig. 22. Processing sharp peak

Fig. 23. The graphical code of sharp peak processing

3. Deleting low peak processing

Singular low peak cause measurement error of the systolic blood pressure and diastolic blood pressure easily. So we must detect and remove them from pulse wave for the performance of the system. An example of singular low peak is shown in Fig. 24. Through a lot of waveform analysis, we summarize a method for detecting singular low peak: if a certain peak A of pulse peaks is lower than 15 of the front and back peaks of the peak A, the peak A is judged to be a wrong peak.
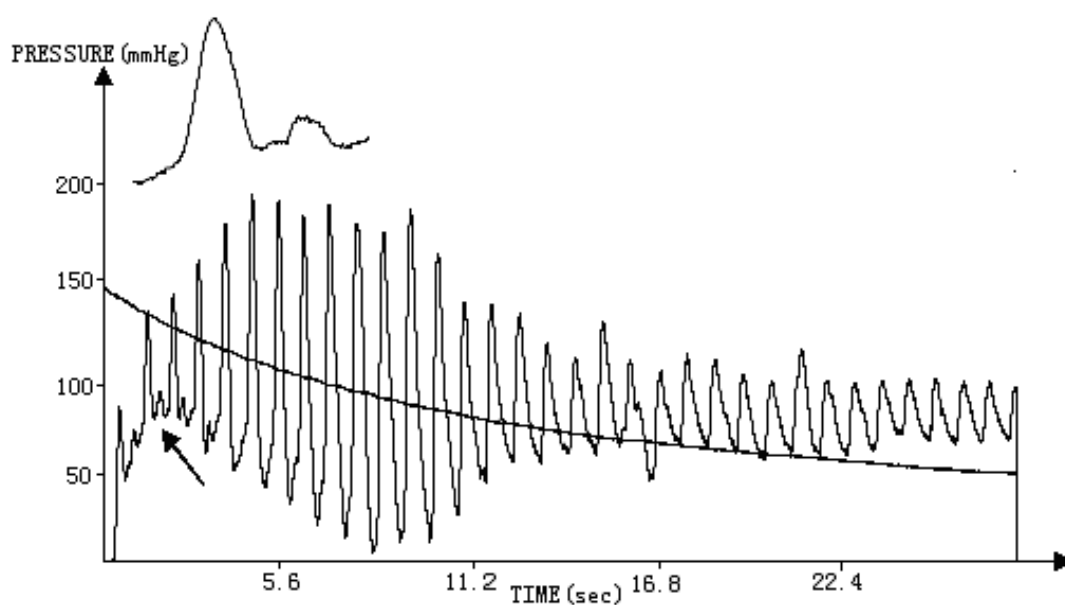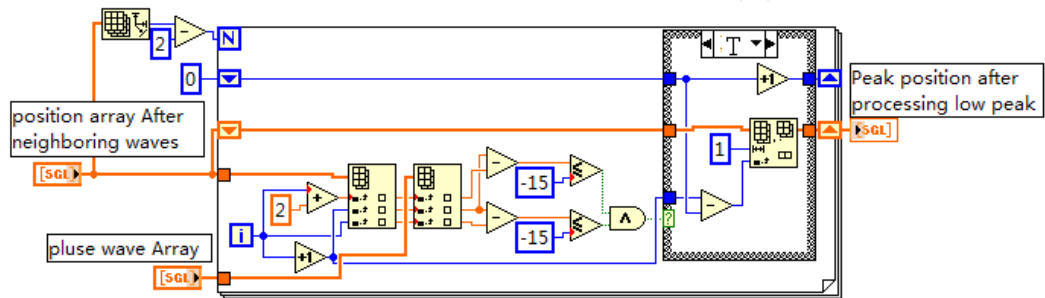

Fig. 24. Processing low peak

Fig. 25. The graphical code of singular low peak processing

3.2.4 The display of ASI diagnose result

ASI is usually divided into five types corresponding to the five status of vessel: normal, critical, arteriosclerosis, arrhythmia and arteriosclerosis, and cardiac function defect and arteriosclerosis. For different types, there are five intervals of ASI and five basic pulse waveforms corresponding to the five vessel types as shown in Table 1.
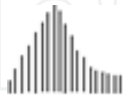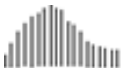
type	ASI	Basic type of pulse waveform	pulse waveform	diagnosis
A	0-70			normal
B	71-120			critical
C	121-180			arteriosclerosis
D	181-300			arrhythmia and arteriosclerosis
E	300-			cardiac function defect and arteriosclerosis

Table 1. Pulse waveform and diagnosis corresponding to different ASI

4. Clinical research

4.1 PWV clinical research

For validating the effectiveness and reliability of the system in PWV measurement, we conducted clinical trials with cardiologists in the second affiliated hospital Chongqing medical university. In clinical trials, we selected 199 participants without diabetes, coronary heart disease and hyperlipidemia, and divided them into three groups according to the result of blood pressure measurement and Chinese hypertension guidelines, which is shown in Table 2.

Group	Type	Case number	DBP(mmHg)	SBP(mmHg)
1	Normal	123	<120	<80
2	Normal but high	30	120-139	80-89
3	hypertension	45	≥ 140	≥ 90

Table 2. The definition of blood pressure levels and sub-table

In measurement, participants were in sitting posture and tranquillization with two different size cuffs around the brachial and radial artery. After recording the personal profile of participant, a test begins with an auto inflation of the two cuffs. The front panel of LabVIEW of the system shows the pressure curves of the two cuffs. At the end of deflation, all parameters of artery elasticity are calculated and displayed on the software of upper computer, which spends only two minutes. The measurement results are saved as Excel. Then, the statistic software SPSS11.5 was used to analysis the results. The difference among groups was analyzed with mean. The statistic result of PWV of each group is shown in Table 3. T test was used to analyze the difference significance as shown in Table 4.

	Group	Mean	Standard deviation	Standard error
PWV	1	14.63	4.59	0.63
	2	17.01	6.09	1.52
	3	18.99	5.37	0.89

Table 3. Statistics of PWV in each group

Among Group	t	Degree of freedom	P	Mean difference	Standard deviation of mean difference	95% confidence interval low	high
1 and 2	-3.092	151	0.003	-4.378	1.4161	-7.2047	-1.552
2 and 3	0.008	74	0.994	0.0139	1.7409	-3.4649	3.522
3 and 4	-3.914	167	0.000	-1.364	1.1151	-6.5823	-2.145

Table 4. Independent samples t test

From Table 4, we can see that P equals to 0.003 between group 1 and 2, and 0.000 between group 3 and 4, which means both differences were statistically significant. But P equals to 0.994 for group 2 and 3, which means the difference was not statistically significant. It might be relative to the small size of the samples.

The clinical trial demonstrates that PWV can reflect the difference among borderline hypertension, hypertension and normal group, and can be used as auxiliary hint for the diagnosis of hypertension.

4.2 ASI clinical trial

In order to validate the effectiveness of ASI, a clinical trial was conducted on 420 healthy adults. The participants were divided into four groups according to their age: 20 to 29, 30 to 45, 46 to 59, 60 to 75. The test result of ASI is shown in table 5 for each group.

age	male		female		P
	number	ASI	number	ASI	
20~29	36	78.55±12.71	34	71.29±10.47	>0.05
30~45	69	82.32±14.39	40	80.15±15.94	>0.05
46~59	42	85.34±13.12	61	83.29±11.94	>0.05
60~75	83	102.06±10.52	55	109.36±14.11	>0.05
P		<0.05		<0.05	

Table 5. The results of ASI measurement

Table 5 indicates that ASI is increasing with age gradually. The difference of ASI is very small about 75~85 in the group of age less than 60. But the difference of ASI is higher obviously in the group of age between 60 and 75. ASI of male and female subgroup reaches to 102 and 109 (P<0.05), respectively. The ASI difference of male and female subgroup in the other groups is small and not statistically significant (P>0.05). In addition, the repeatability of ASI measurement is better when the time interval of two measurements is more than 5 minutes.

5. Conclusion

In this chapter, the hardware and software design of the arterial elasticity measurement system were mainly introduced. According to the oscillography principle and pulse wave theory, two cuffs were used to collect the pulse signals of brachial and radial artery in the system and realized an invasive, easy and quick measurement of PWV and ASI. The effectiveness and reliability of the system were demonstrated by a lot of clinical trial and data. The system can diagnose the condition of arterial elasticity and the degree of arteriosclerosis. The study results have certain application value for epidemiological survey, disease prevention and early detection of cardiovascular diseases.

6. References

Bitter, R.; Mohiuddin, T. & Nawrocki, M. (2007). *LabVIEW advanced programming techniques*, CRC Press, ISBN 0849333253, Florida, USA

He, W. & Yu, C.X. (2010). *Measurement principle and clinical application of cardiovascular dynamic parameters*, Science Press, ISBN 9787030262813, Beijing, China

Johnson, G.W. & Jennings, R. (1997). *LabVIEW graphical programming: practical applications in instrumentation and control*, McGraw-Hill Professional, ISBN 007032915X, New York USA

Klinger, T. (2003). *Image processing with LabVIEW and IMAQ Vision*, Prentice Hall, ISBN 0-13-047415-0, New Jersey, USA

Mark, O.B. (2003). *Atlas of Cardiovascular Monitoring*, Science Press, ISBN 703010952, Beijing, China

McDonald, D.A. (1974). *Blood Flow in Arteries*, Edward Amold, ISBN 0713142138, London, England

Qiao, A. & Wu, S. (2000). Theories of Pulse Wave in Arteries. *Journal of biomedical engineering*, Vol.17, No.1, pp. 95-100, ISSN 1001-5515

Quan, X.; He, W. & Gu, L. (2006). Measurement and clinical study of atherogenic index *Chinese Medical Equipment Journal* . Vol.27, No.2, pp. 1-2, ISSN 1003-8868

Quan, X.; He, W. & Zhang, W. (2006). A New Algorithm for Oscillometric Blood Pressure Measurement *Space Medicine & Medical Engineering*, Vol.19, No.1, pp. 71-73, ISSN 1002-0837

Sunthareswaran, R. (2003). *Cardiovascular System*, Science Press, ISBN 703009689, Beijing, China

Takenaka, T. & Kobayashi, K. (2004). Pulse wave velocity as an indicator of arteriosclerosis in hemodialysis patients. *Atherosclerosis* Vol.176, No.2, pp. 405-409., ISSN 0021-9150

Whitley, K.N. & Blackwell, A.F. (2001). Visual programming in the wild: A survey of LabVIEW programmers. *Journal of Visual Languages & Computing*, Vol.12, No.4, pp. 435-472, ISSN 1045-926X

Yao, J.; He, W. & Quan, X. (2007). One Method of Removing Thorax Impedance Baseline Wander by Cubic Spline Interpolation. *Chinese Journal of Medical Physics*, Vol.6, No.5, pp. 371-374, ISSN 1005-202X

Zhang, W.; He, W. & Quan, X. (2005). Improvement and realization of blood pressure determination based on oscillation method. *Chinese Medical Equipment Journal*, Vol.26, No.11, pp. 5-6, ISSN 1003-8868
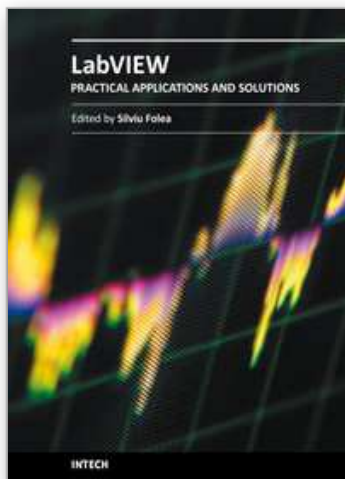
Practical Applications and Solutions Using LabVIEW™ Software

Edited by Dr. Silviu Folea

The book consists of 21 chapters which present interesting applications implemented using the LabVIEW environment, belonging to several distinct fields such as engineering, fault diagnosis, medicine, remote access laboratory, internet communications, chemistry, physics, etc. The virtual instruments designed and implemented in LabVIEW provide the advantages of being more intuitive, of reducing the implementation time and of being portable. The audience for this book includes PhD students, researchers, engineers and professionals who are interested in finding out new tools developed using LabVIEW. Some chapters present interesting ideas and very detailed solutions which offer the immediate possibility of making fast innovations and of generating better products for the market. The effort made by all the scientists who contributed to editing this book was significant and as a result new and viable applications were presented.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Wei He, Hanguang Xiao, Songnong Li and Delmo Correia (2011). Instrument Design, Measurement and Analysis of Cardiovascular Dynamics Based on LabVIEW, Practical Applications and Solutions Using LabVIEW™ Software, Dr. Silviu Folea (Ed.), ISBN: 978-953-307-650-8, InTech, Available from: http://www.intechopen.com/books/practical-applications-and-solutions-using-labview-software/instrument-design-measurement-and-analysis-of-cardiovascular-dynamics-based-on-labview

INTECH
open science | open minds