Novel Design Of A Data Acquisition And Analysis System For Surface Plasmon Resonance Bioanalyzer Using Labview Virtual Instrument

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Abstract:*A novel data acquisition and analysis system has been developed for a surface plasmon resonance (SPR) bioanalyzer, which is based on the use of TSPR1k23 biosensor and composed of a microflow cell, a clamp, and a photoelectronic conversion device. A virtual instrument consists of a computer-based platform that is equipped with powerful application software and cost-effective hardware, which outperform the functions of the instrument for obtaining data from the biosensor. In this system, The PIC24HJ32GP302 microprocessor interfacing with a 16bit ADS8326 analog-to-digital converter is used to transform the photoelectronic signals from the CCD photodetector and the communication between the microprocessor and the computer is achieved through the USB-RS232C serial port converter adapter designed by CP2102 chip. The system software for describing the biomolecular interaction and sample concentration is programmed with LabVIEW graphic programming environment, which be mainly introduced in this paper. The software modules reveal important information for sensor golden surface that SPR signal can be identified as well and the values of response unit (RU), refractive index (RI) and sample concentration can be computed correspondingly. Because it is based on computer, the system's function is flexibly defined and meets user's requirement easily. This data acquisition and analysis system is more directviewing, economical , high efficient, friendly in comparison with other data acquisition and analysis system based on VB language or assemble language. Some biochemistry experimental results show that it is a highly performance data acquisition and analysis system.*

Key words—*Virtual Instrument; LabVIEW; bioanalyzer; single chip*

I. INTRODUCTION

In the past ten years, the surface plasmon resonance (SPR) phenomenon has been extensively exploited for the design of biochemical analyzers. The SPR biochemical analyzers have been utilized for the analysis of biomolecular interactions (BIA) and the detection of chemical and biological analytes owing to sensitive, on-line monitoring and unlabelled technology [1]. In addition, it has been used for detection of various chemical and biological compounds in some important fields such as food safety (e.g. bacteria [2], protein [3]), environmental protection (e.g. pesticide [4]) and medical diagnostics (e.g. DNA and hormones [5]).

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However, it has been a shift in focus on developing biosensors for the rapid detection of assays[6]. Recently, what people expected were how to develop the SPR bioanalyzer forward to miniaturization, integration and intelligence[7],[8]. With the rapid development of computer technology, modern bioanalyzers are dominated by computer technology. *Virtual Instrument* (VI), the perfect union through modern computer technology and instrument technology, has become a much significant technology in the field of *Computer Auxiliary Test* (CAT) nowadays[9]. VI takes advantage of a graphic software to link up with instrument module and makes the best use of computer's powerful graphic interface and data processing capacity for providing measurement data used to analyze and display. Obviously, VI changed the idea of traditional instruments with functionality defined by the manufacturer, and therefore the operation mode can't be set by users. Users can build up their own automatic measurement system quickly when VI technology was chosen for instrument design. There is no doubt that incorporating VI technology into SPR bioanalyzer would, surely, enhance the performance of this biomolecular analyzer [10]. There are two kinds of popular development tools for VI in recent years, one is based on text programming languages (e.g. C, C++, VB, Labwindows/CVI etc); the other is based on graphic programming language (e.g. LabVIEW, AgilentVEE etc). Thereamong, LabVIEW is a graphic VI development tool of the widest applications, the fastest evolvement, and the most powerful functions. Biacore[11], Autolab and IBIS have also developed data acquisition and analysis systems for SPR instruments, which are, however, all based on VB. In this paper, we designed a data acquisition and analysis system for this SPR bioanalyzer based on LabVIEW.

II. SYSTEM DESIGN

A.Basic idea of system design

The system was designed mainly for market requirement, thus in the process of making technical scheme, novelty and economy of the instrument, universality and reliability of each device, commonality of hardware or software development were fully considered so that the development period could possibly be cut down and system upgraded. Three parts that composed the system argued in this paper were data

acquisition system, data processing software system and communication system. A structural diagram of the system is illustrated in Figure1. Specially, the raw analog voltage signals out of the CCD device would need to be amplified and then to be converted to the SPR signals. The three parameters values (refractive index (RI) values, response unit (RU) values, concentration values) were produced by processing the SPR signals using LabVIEW software.

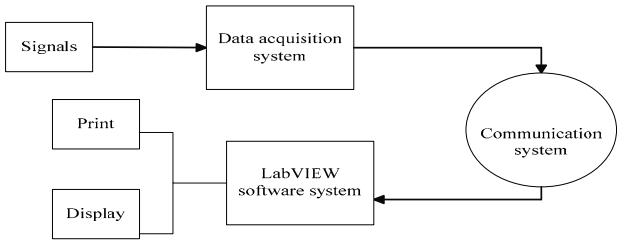

Figure 1. Structural diagram of the data acquisition and analysis system

B.Data acquisition system

For improving signal antidisturbance, a voltage follower was used before signal being digitized. The data acquisition system incorporates ADS8326 as the A/D converter which offers 16-bit, excellent linearity and very low noise and distortion enough to digitize sensor outputs to high resolution, and PIC24HJ32GP302 as the microcontroller which integrates 128KB flash memory and 8KB internal memory RAM and is quite adequate for compact embedded system. The microcontroller takes charge of receiving sample command from computer and transferring data in RAM to computer.

C.Data communication system

Portable apparatus controlled by personal computer (PC) are necessary to update RS232 to USB interface which possesses the characters of Plug-and-Play and high speed, and is also a feasible way to achieve data acquisition. CP2102, a Single-
chip USB to UART Bridge produced by Silicon, was applied in the system, changing USB 2.0 to UART. The CP2102 is highly-integrated USB to UART bridge controller providing a simple solution for updating RS-232 to USB using a minimum of components and PCB space.

D.Data processing software system

PC-based custom software is predominant in the use of graphic user interface for manipulating instrument functions, performing automated experiments, and storing or analyzing obtained data. *Software just be Instrument* is a slogan of NI (National Instrument) who is the promoter of Virtual Instrument. In this study, LabVIEW graphic programming language is selected in this software design (HPSPR-8000). All self-produced software modules are developed with LabVIEW development system. LabVIEW is a user friendly and powerful graphical development environment used for signal acquisition, measurement analysis, and data presentation [12]. By incorporating LabVIEW, the results in this work can be obtained faster, more precise and also easier.

III. SOFTWARE DESCRIPTION

A packet program, HPSPR-8000, is designed and developed upon the TSPR1K23 biosensor using LabVIEW programming language. The system software of the HPSPR-8000 is consisted of three sections: sensor initialization, SPR dynamic analysis, and sample concentration analysis. All program modules are developed and written by ourselves, no LabVIEW add-ons are used. The software architecture is shown as flowchart illustrated in Figure 2.

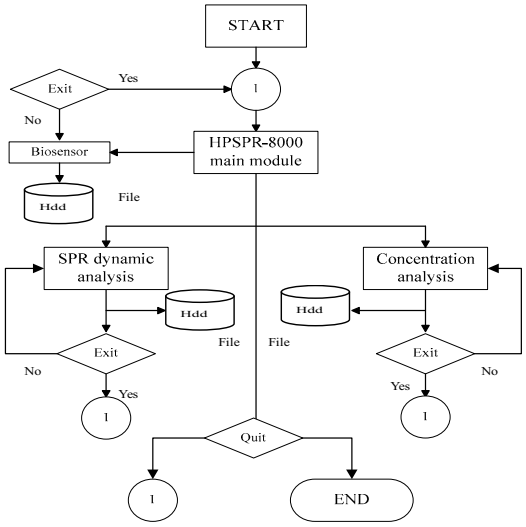

Figure 2. A flowchart in the software design on HPSPR-8000 bioanalyzer

Acquired SPR signal can be analyzed for calculating the RU, RI and concentration values of a sample and recorded to the hardisk simultaneously. All subroutine modules are called from the HPSPR-8000 main module shown in Figure 3, which will be explained in following sections.

Figure 3. A front-panel for the main program of HPSPR-8000 bioanalyzer

Sensor initialization It's required to initialize the biosensor before carrying on SPR dynamic analysis. In this work, 2 steps should be executed: link up to the sensor and set sensor parameters to achieve good performance. However, the sensor initialization has not to be conducted every time. Figure 4 showed this module.

SPR dynamic analysis With sample flowing over the sensor surface, acquired CCD signals, as digitized by data acquisition board are processed into sample SPR signals which can be displayed if it is desired. Meanwhile, RU and RI values are obtained from SPR signal analysis using the first-order centroid algorithm. It can also be displayed in real-time [13] [14]. In Figure 5, the RU-t curves and SPR signals of a sample solution can be appeared on display in three-channel format, simultaneously.

Concentration analysis A calibration method for building a model was established to obtain sample concentration values. In this paper, five RU values with different standard concentrations were selected to build the calibration concentration model by using the linear least squares method[15]. Every sample solution concentration should be performed 3 - 5 times to obtain a RU value, which lasts for15-25 minutes. A initial value should be set by cursor positioning and the D-value of terminal value was automatically achieved and recorded at the end of 5 minutes period. While the measurements of 5 different concentrations were over, 5 RU values will be recorded and each value is corresponding to the sample standard concentration. Measurement module for actual biological assays with three-channel was showed in figure 6, and module for concentration analysis of biological samples was showed in figure 7.

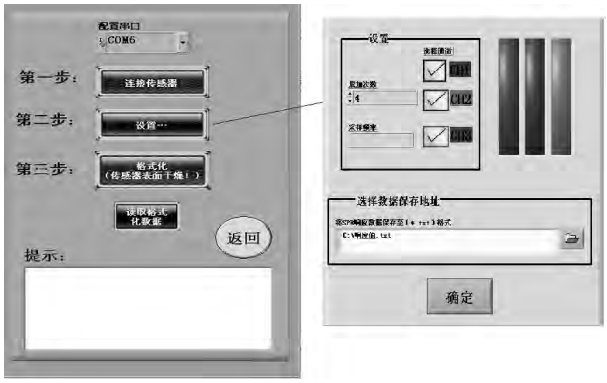

Figure 4. Sensor initialization module

Figure 5. Dynamic analysis module for SPR monitoring

Figure 6 Module for masuring RU values of standard sample solution

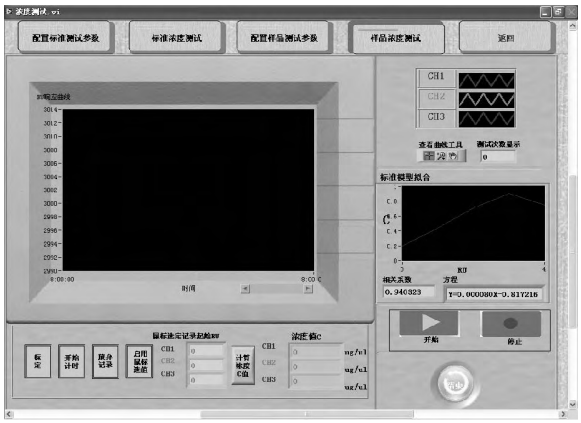

Figure 7.Concentration analysis module

IV. EXPERIMENTAL CONFIGURATION

In the SPR sensor response experiments, the refractive indices of the ethanol solutions at different concentrations of 0.2μg/ml 0.4μg/ml, 0.6μg/ml, 0.8μg/ml and 1.0 μg/ml were measured using the HPSPR-8000 biochemical analyzer with TSPR1k23 biosensor. The three-channel Spreeta modules were from Nomadics, Inc. (Stillwater, USA), which were fabricated with the gold slide bound to the sensor modules. The software LabVIEW8.2 was from National Instruments and microprocessors (PIC24FJ64A, PIC16F876A) were provided by Microchip Technology Consulting Co Ltd. (Shanghai, China).

As the core part of a laboratory biomolecular interaction analyzer[16], a novel, inexpensive, flexible virtual instrument-based system has been designed to perform the optoelectronic signal acquisition, flowing sample control and curve analysis. A schematic diagram of this approach is illustrated in Figure 8. The SPR curve (RU (Response Unit)-PP (Pixel Position)), Response curve (RU-t) and Raw curve (Unnormalization) were obtained by calculating the response signals, which were transduced using the TSPR1k23 biosensor, and displayed on the computer in real time.

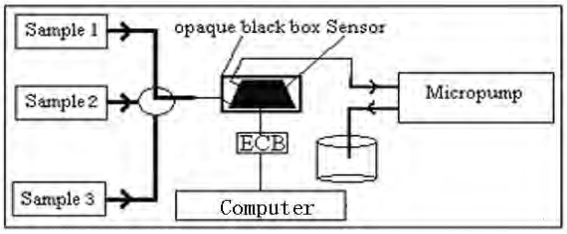

Figure.8 Schematic representation of the construction of the HSPR-8000 bioanalyzer

V. RESULTS AND DISCUSSION

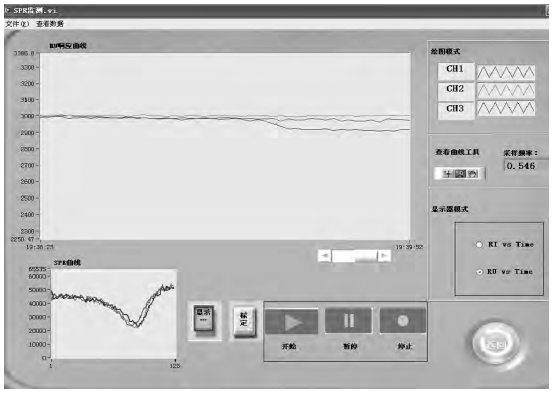

Figure 9 SPR dynamic analysis of a deionized water sample with three-channel

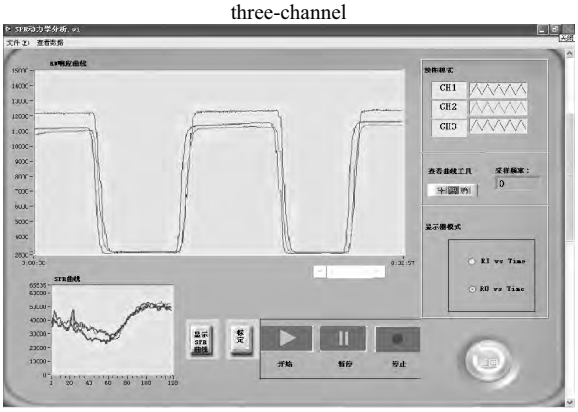

Figure 10 Dynamic analysis of an ethanol sample(0.2μg/ml) with three-channel flowcell for repeativeness

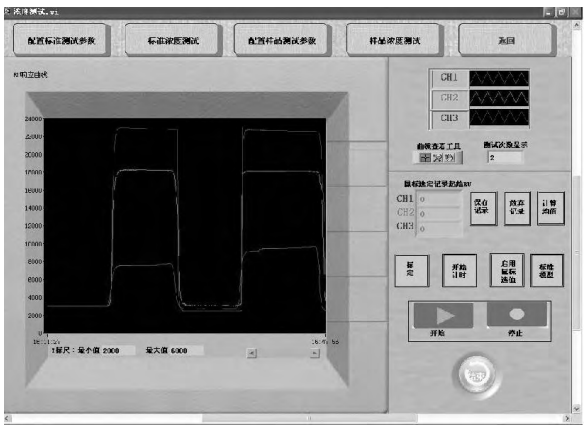

Figure 11. Measurement results of RU for 5 different ethanol concentrations (0.2μg/ml, 0.4μg/ml, 0.6μg/ml, 0.8μg/ml and 1.0 μg/ml)

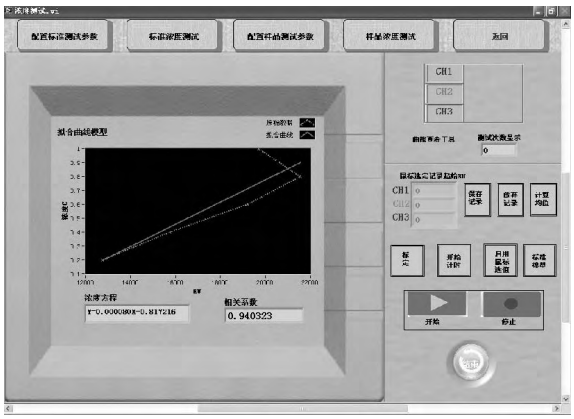

Figure 12. Calibration model of ethanol between RU and concentrations

Figure 9 shows the SPR curves (RU (Reponse Unit)-PP (Pixel Position)) and SPR response curves (RU (Reponse Unit)-T (Time)) based on first-order centroid algorithm for deionized water solution. The response values are taken between 2950 and 3020 from the three-channel SPR response curves and the PP values of the three dips are 94.92, 93.85 and 94.55, respectively.

Figure 10 shows the experimental results of SPR dynamic analysis of ethanol solutions at the concentration of 0.2μg/ml with three channels for the repeativeness. Repeated measurements of the RU values nine times were carried on and the RU curves in three-channel format all the time keep at respective level in evidence from which RSD (relative standard deviation) calculated from (1) and (2) was 7.334×10^{-3}, thus the achieving repeatability of the virtual instrument-based SPR biochemical analyzer is satisfied enough.

$$SD = \sqrt{\frac{1}{(n-1)}\sum\left(y_i - \bar{y}\right)^2} \tag{1}$$

$$RSD = \frac{SD}{\bar{y}} \tag{2}$$

Figure 11 shows the experimental results of concentration analysis of ethanol solutions at different concentrations of 0.2μg/ml 0.4μg/ml, 0.6μg/ml, 0.8μg/ml and 1.0 μg/ml with three channels for building a standard ethanol model. The three curves (see figure11) are SPR response curves of CH1, CH2 and CH3 at the concentrations of 0.2μg/ml, 0.4μg/ml and 0.6μg/ml, repectively. In figure 12, two curves are displayed on the screen: the green one is actual measurement curve, the red one is conducted by the linear least squares fitting technique. Of course, the latter is the calibration model that we need to establish, which was embedded in the EEPROM of the computer to do biological assays in direct mode.

VI. CONCLUSIONS

In this paper, we proposed and designed a data acquisition and analysis system for a surface plasmon

resonance bioanalyzer with the virtual instrument technology under LabVIEW8.2. Its flexibility and efficiency were demonstrated by the experiments based on the biosensor TSPR1K23 using the ethanol solutions at different concentrations of 0.2μg/ml 0.4μg/ml, 0.6μg/ml, 0.8μg/ml and 1.0 μg/ml with three channels, respectively. Experimental results showed that the high-sensitivity of the SPR biochemical analyzer can be achieved. Future work will involve the continuation of the laboratory tests as well as field trials to obtain bioanalyzers with high sensitivity and reliability by optimization of the flow cell volume and sample collection mode.

ACKNOWLEDGMENT

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