Signal Collection Method of Wireless Radio Frequency Gas Sensor Array Based on Virtual Instrument

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Abstract. The traditional multi-dimensional array tactile sensor research and application can not have the characteristics of flexibility and multi-dimensional force measurement, so there is a big gap in the acquisition of sensor array signal, it is difficult to extract relevant information and make corresponding actions in complex environment. Based on this, a method of wireless RF gas sensor array signal acquisition based on virtual instrument is proposed. By mining the flexible three-dimensional force and temperature composite sensor array numerical characteristics of virtual instrument, the flexible sensitive value of sensor array is improved, and the flexible three-dimensional force sensor array signal acquisition and temperature compensation are designed, so as to effectively reduce the temperature to three-dimensional force detection The influence of measurement can improve the signal acquisition performance of wireless radio frequency gas sensor array. The experiment proves that compared with the traditional dedicated array acquisition method, the wireless RF gas sensor array signal acquisition method based on virtual instruments is easy to implement, flexible to use, and cost-effective, which can be used by researchers for reference.

Keywords: Virtual instrument · Radio frequency gas · Sensor · Signal acquisition

1 Introduction

With the development of sensor technology and signal processing methods, the functional requirements of sensor data acquisition device are also changing. The collection, analysis, processing and display of sensor array signal is one of the important research trends of current social development. Traditional sensor data collection devices are generally designed for a single sensor. Even multi-channel collection devices are often only for data collection of different sensors, and the requirements for synchronous signal collection are not very high [1]. Usually the data processed by the sensors are array signals. Therefore, this paper analyzes the structure of sensor synchronous acquisition module from the functional point of view, describes the construction process of array acquisition and bidirectional safe grasping of auxiliary target, so as to achieve the purpose of human-computer interaction.

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2 Signal Collection Method of Wireless Radio Frequency Gas Sensor Array

2.1 Multi Card Cascade Construction of Wireless RF Gas Sensor

With the development of signal processing and computers, especially with the introduction of virtual instruments, users are more willing to accept graphical representations and use computer technology to process the entire process of information. In the research of acquisition and display, the same kind of sensors are often arranged in a certain geometric shape, using the spatial characteristics of the signal to enhance the signal and effectively extract the spatial information of the signal [2]. Array sensing signal has a high requirement for synchronous acquisition. Generally, the acquisition card based on single channel design is not suitable for array sensing signal acquisition. According to the structural characteristics of the flexible three-dimensional force sensor array, the A/D conversion accuracy, sampling rate and other related values are converted and standardized. The 32-bit high-performance and low-power microcontroller stm32f103vet6 based on the armcortex-m3 core is selected. Its biggest advantage is fast acquisition and Processing data [3]. Multi channel A/D conversion is integrated in the system, with 12 bit accuracy and the fastest conversion speed of 1 μ s. It is equipped with more than 2 independent ADC controllers, which can quickly collect multiple analog signals at the same time. And build a DMA module that is independent of the Cortex-M3 core and parallel with the CPU to connect the peripheral mapped registers and access them at high speed, and its transmission is not controlled by the CPU [4]. ADC module is initialized to continuous conversion mode, ADC channel 0–8 is selected for DMA transmission, and software filtering is added to ensure the stability and reliability of data transmission. The specific frame structure is shown in the Fig. 1 below.

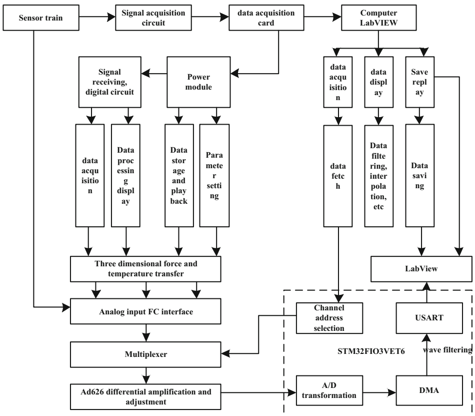

Fig. 1. Multi-card cascade construction framework of sensor signals

Based on the above frame structure, the flexible three-dimensional force value of the radio frequency gas sensor is analyzed. The composite sensor array is composed of

4 × 4 three-dimensional force sensor and 3 × 3 temperature sensor, which are arranged in a concave convex structure. The three-dimensional force sensor is arranged in a cross shaped four fork structure with the specification of 10 mm × 10 mm [5]. Under normal circumstances, the radio frequency gas sensor is composed of a 5 mm × 3.5 mm size interdigitated electrode. During operation, a temperature sensitive film is prone to appear. The temperature sensor made by the interdigitated electrode has a resistance that is linear with the temperature increase in the temperature measurement range. The added features require synchronous acquisition and can be triggered using the conversion start command of the AD chip. However, the A/D conversion chips are all working in time-series beats, which may cause a beat time error [6]. A more reliable way is to use timing control, which can ensure the simultaneous conversion of A/D signals. The specific conversion mode is as follows (Fig. 2).

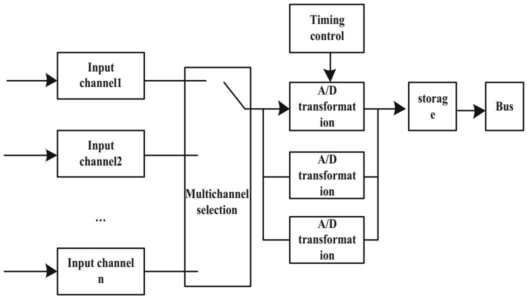

Fig. 2. Sensor signal A/D conversion mode

Generally, the composite array sensor consists of 16 three-dimensional force sensitive units and 9 temperature sensitive units, in which each three-dimensional force sensitive unit outputs four resistance signals. In order to reduce the mutual interference between sensitive units and give full play to the performance of MCU, it is necessary to design appropriate array acquisition circuit [7]. Row and column scanning is an effective way to save I/O port, but there is mutual coupling interference noise between sensitive units. Voltage mirror method is a common method to eliminate the coupling interference between resistive array units.

In the 3 × 3 array, the unselected row signals are grounded to reduce coupling interference of sensitive units. Single point acquisition is the easiest way to eliminate mutual coupling of sensitive units. With multi-channel analog switches, multi-channel data collection can be completed. Among them, 8 pieces of CD4051 are used to select the sensitive unit of the three-dimensional force sensor, and 1 piece of CD74HCT4067 is used as the temperature sensor acquisition channel [8, 9]. Due to the use of tactile array sensor, only through multi-channel selection circuit can the output signal of sensor be obtained orderly. CD4051 chip is used to control the acquisition sequence of sensor array. CD4051 is a single 8-channel digital control analog electronic switch, which has a series of advantages such as low-pass impedance, low cut-off leakage current, etc. among them, A, B, C are binary control input and INH input. Using the method of row and column scanning, the signal of the sensor array is connected to the

CD4051, and the signal acquisition of each sensor unit in the sensor array is controlled by the control chip ATMAGEI6. The ATmegal6 chip is based on the enhanced AVRRISC structure with high performance and low power consumption. AVR microcontroller, because the chip has more advanced instruction set and single clock cycle instruction execution time, the data throughput rate of ATmegal6 reaches 1MIPS/MHz, which can alleviate the contradiction between power consumption and processing speed of sensor signal acquisition.

2.2 Beamforming Algorithm of Sensor Array Signal

In the application environment of wireless sensor networks, network nodes complete the network topology through self-organization. Network nodes collaborate to perceive, collect, and process information of interest in the network coverage area. The wireless sensor network can collect and process specific information of the covered area at any time [10, 11]. When the sampling rate does not meet the intermediate frequency sampling theorem, the decimator with polyphase filter structure can be used to realize digital down conversion. The data obtained from A/D is first decomposed by orthogonal method, and the processing method is consistent with the low-pass filtering method. However, this method has a disadvantage that the down-conversion coefficient used is more complicated than the down-conversion coefficient used by the sampling rate to satisfy the intermediate frequency sampling theorem. The low-pass filtering method filters the orthogonally decomposed signal first and then extracts it. The polyphase filter structure based on the decimator first extracts the orthogonally decomposed signal and then filters it to reduce the extracted data rate. Filtering is achieved through multiplexing [12, 13]. In order to improve the accuracy of information acquisition, a typical depth structure beamforming algorithm is proposed. If there are m hidden layers in a deep belief network, and a^{n} represents the nth hidden layer vector, the deep belief network model can be expressed as follows:

$$\Delta p = \mathrm{m}\left(m|a^1\right)\left(a^1|a^2\right)\ldots\mathrm{m}\left(a^{\mathrm{n}-1}|a^n\right) \tag{1}$$

The conditional probability $\mathrm{p}\left(a^n|\mathrm{a}^{n+1}\right)$ can be expressed as:

$$\mathrm{p}\left(a^n|\mathrm{a}^{n+1}\right) = \lambda\left(-l_m^n - \sum_{k=1}^{n+1} w_{km}^n h_k^{n+1}\right) \tag{2}$$

In the formula, l_m^n represents the m th node of the n th layer, w^n represents the weight matrix of the n th layer, and λ can be expressed as:

$$\lambda(\mathrm{q}) = \frac{\Delta p - w_{km}^n}{1 + \exp \mathrm{p}\left(a^n|\mathrm{a}^{n+1}\right)} \tag{3}$$

In order to obtain depth information, you need to obtain a set of data layer by layer, and in order to obtain the final depth data and conduct supervised training, at this time the signal sampling feature frequency is greater than the information problem under normal circumstances, there will be signal deviation, which can be expressed for:

$$W(a)_{\min}=\sum_{i=1}^{n}\lambda(\mathrm{q})+h_k^{n+1} \tag{4}$$

The function of fault information collection is further standardized, which can be expressed as follows:

$$W(\mathrm{b})_{\min}=\Delta p\sum_{i=1}^{\mathrm{m}}W(a)_{\min}-\lambda(\mathrm{q}) \tag{5}$$

If the array signal in the sensor can be recorded as a vector of $\mathrm{k}_1,\cdots,k_{\mathrm{m}}\in 2^m$ information; $\lambda_1,\cdots,\lambda_{\mathrm{m}}$ is the amount of information loss; y represents the coefficient of the function; δ represents the conjugate function; a represents the original information variable; b represents the The variable of the fault information function; $t\geq 0$ is the function parameter. Then each array information variable c_i corresponds to an D_i algorithm that stores variables as:

$$D_i=\frac{k_{\mathrm{m}}\left(c_i^t a-D_i\right)^2\cdot y(a)}{2\lambda_{\mathrm{m}}[W(\mathrm{b})_{\min}+W(a)_{\min}]+t}-|b|_i \tag{6}$$

Furthermore, the constrained array function of signal feature acquisition is calculated:

$$f(a)_{\min}=t\|D_i-Fa\|_3^3+n\|\mathrm{b}\|_2 \tag{7}$$

Among them: F belongs to the matrix of n fault information; $t\succ 0$ is the parameter of information constraint. A linear equation algorithm is used to describe the information collection situation, and the upper or lower limit of the data in the interval [0,5] is selected as the collection quantity, which is 5 or 10. Based on the above algorithm, the sensor array signal characteristics can be effectively collected.

2.3 The Realization of Sensor Array Signal Acquisition

Acess2003 database is used for operation. Create a data table through DB Tool Create Table.vi in the LabVIEW database toolkit, so that users can directly create and delete files in the database in Lab VIEW software. Through this VI, a table named user is established in the database to store the data of all users in the module, such as number, user name, user password, user authority and last login time. A table named pressure is established to store the collected pressure signals, including test time, tester and collected data value. A table named temperature is established to store the collected data the collected signal includes test time, tester and collected data value, so as to realize signal conditioning. The specific steps are shown in the Fig. 3.

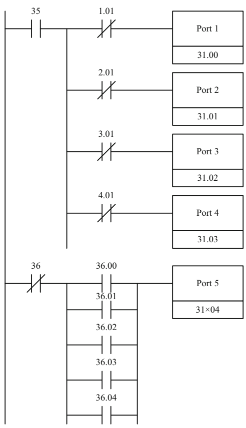

Fig. 3. Sensor array signal conditioning steps

Based on the above steps of signal conditioning, analyzing the signal characteristics of sensor array, a unique signal conditioning circuit is designed according to the different characteristics of acoustic, magnetic, vibration and infrared signals of sensor array, and the conditioned sensor signal is output to the subsequent acquisition module. Because the signal to be measured is a weak signal, the subsequent voltage signal is also very small and the amplitude is uncertain. In order to make the signal amplitude moderate, the signal needs to be amplified. The general-purpose operational amplifier cannot directly amplify the weak signal. Instrumentation amplifiers and instrumentation amplifiers must be used. It has the characteristics of high input impedance, low output impedance, strong resistance to common mode interference, low temperature drift, low offset voltage and high stable gain; in addition, before sampling, the signal must be processed by anti aliasing filter to remove the high-frequency noise, and the signal is in the low-frequency range. Therefore, the second-order Butterworth low-pass filter is used, which has flat amplitude frequency characteristics and good attenuation characteristics, so it is used in many filter circuit designs. Considering the background noise, frequency resolution and storage burden of the host, in the high-speed sampling mode, the number of sampling points of a single trigger is set to 20480, and the frequency resolution reaches 45.8 KHz. Next, this paper analyzes the performance of the high-speed array signal acquisition method in high sampling rate mode from two angles of signal measurement and error analysis. And record the correlation coefficient, as follows (Table 1):

Table 1. High sampling rate array signal data acquisition

Data index	Sampling points (SNR/DB)	Resolution
Array signal media value	11.15102	0.05481
Arithmetic mean	8.01813	0.18101
Weighted average	11.48411	0.04841

Further use DSN to access the output of the database sensor array associated with it through the analog switch through the signal amplification, adjustment circuit and sent to the MCU for A/D conversion. Select AD626 to zero-adjust the sensor unit, select the appropriate gain and send it to the microprocessor through the low-pass filter. The processed data is sent to the upper computer through the serial port to display the three-dimensional force and temperature test results. In the design of data acquisition software, the user information and equipment information are managed on the macro level and the data sampling time is designed on the micro level. It is designed in strict accordance with the real business process of data collection under the safe environment, and its sequence is: equipment calibration, parameter setting, data storage, data calculation display and export. Combined with virtual instrument technology, a set of VXI based data acquisition needs to be analyzed and processed, so as to view the processing results on site. According to different test applications to write different test assemblies, scalable functionality and versatility. Signal analysis dynamically displays the data processing process, which is convenient for users to analyze the collected data and finally give the results of signal analysis.

(1) Data playback: the array signal acquisition channels are many and the amount of data is large. The data playback function provides collected information, such as sampling rate, acquisition time and channel vector, etc.; it is convenient for users to view the acquisition data at any time and channel, and provides time-domain data display or power spectrum display.
(2) Beamforming: In order to extend the versatility, linear array and planar array beamforming are provided. The user can set various weighting methods or pour in custom weights, and view the configured beam pattern. According to the parameters set by the user, beamforming displays the output signals of each beam in real time, so that the user can compare the output results of each beam to analyze the collected data. Corresponding to the output of each beam, the detection output of each beam is given to facilitate the user to view the detection target.
(3) Azimuth estimation: azimuth estimation is one of the main purposes of array signal processing, which provides conventional and high-resolution azimuth estimation methods. In the application of underwater acoustic equipment testing, it is required to be able to distinguish coherent source and target. MUSIC algorithm is used for high-resolution azimuth estimation and spatial smoothing technology is used for coherent source and target decoherence. Based on this, the data collection process is regulated, as shown in the Fig. 4.

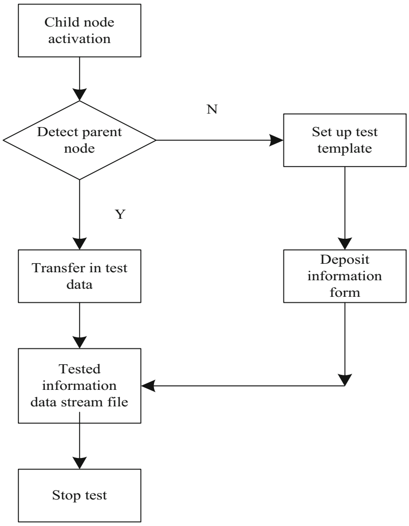

Fig. 4. Data collection process.

Array signal processing is an important branch of digital signal processing. The construction of a set of transducer array signal acquisition and analysis is of great significance in the field test, the design and development of the self-guided signal processor, and the study of signal processing theory and algorithms. Based on the above steps, accurate collection of signals from the wireless radio frequency gas sensor array can be effectively achieved.

3 Analysis of Experimental Results

3.1 Experimental Parameter Setting

In order to verify the actual application effect of the signal acquisition method of the wireless radio frequency gas sensor array based on the virtual instrument, the experimental detection was carried out, using the tactile sensor array, data acquisition circuit, USB2080 multi-channel data acquisition card and Lab VIEW software made by the laboratory Designed program. The designed acquisition circuit is used to accurately collect the signals of sensor array. The real-time and effective acquisition and storage of sampling data are realized by the Lab VIEW programmable software developed by Ni company, and the signals measured by sensor array are effectively, intuitively and vividly displayed by a large number of 2D, 3D and other controls of Lab View software. Further set the experimental environment and parameters in a standard way, as shown in the Table 2 below:

Table 2. Experimental parameter settings

Name parameter	Name parameter
Host	$\leq$315 mm × 255 mm × 50 mm
The total amount	5.5 MB
Operating speed	$\leq$ 1 × 10^{-5} (Input power $\geq$−157.6 dBW)
Number of receiving channels	6 aisle
6 channels	1 ms ± 10 ns
Command function	Number of dependents that can be sent at the same time $\leq$ 100
Antenna cable length	$\leq$20 m
Counterweight	$\leq$3.5 Kg
Operating range	9–32

Place the sensor array in a BE-TH-80M8 constant temperature and humidity box, from 20 °C to 100°C, record the resistance value of any sensitive unit in the temperature sensor array every 10 °C, repeat 5 times, found in 20 $\sim$ the resistance value of the temperature-sensitive unit within 80 °C increases gently with increasing temperature. After 80 °C, the resistance value increases sharply. Considering the actual temperature measurement range and accuracy of the robot sensitive skin, 20–80 °C is selected as the effective range of the temperature sensor, the relationship between resistance and temperature in the measurement range can be expressed as $\Delta R = \mathrm{R}_0(1 + \mathrm{aT})$*RT is the temperature coefficient of resistance of the temperature sensor, R_0 is the initial resistance value, RT is the resistance value at temperature T, the transformation is: $\Delta R/\mathrm{R}_0$ = aT.

3.2 Error Analysis

Furthermore, we use labsql to access the database, and build a free, multi database, cross platform LabVIEW database access toolkit. Before using labsql toolkit to access the database, first create a computer database with data source name DSN in ODBC data source of windows operation, select performance maintenance command management tool command data source component, call ODBC data source Manager dialog box, and create a DSN named acquisitionsystem. After that, you can create a DSN in ODBC data source manager. In order to ensure the security of data collection and prevent illegal operations by unauthorized users, we have designed a login interface, that is, users can only log in after entering the correct user name and password, and different permissions are given to different users. Demand, convenient operation requirements and protection of different users, improve the security of signal acquisition and data storage.

Under the condition of cloud computing application coefficient of 0.18, the total amount of recorded signal data is 0.5×10^9 T, 1.0×10^9 T, 1.5×10^9 T, 2.0×10^9 T, 2.5×10^9 T, 3.0×10^9 T, 3.5×10^9 T, 4.0×10^9 T, 4.5×10^9 T, 5.0×10^9 T, 5.5×10^9 T, the error value of the experimental group and the control group changes. The detailed experimental comparison results are shown in the following Table 3:

Table 3. Error value change value record

Set value	The method of this paper the traditional method			The method of this paper the traditional method		
	Acquisition volume	Difference	Number of repetitions	Collection	Error value	Repeat times
0.5×10^9 T	25.13	1.35	1	22.64	2.65	1
1.0×10^9 T	26.45	1.46	1	22.95	2.32	2
1.5×10^9 T	25.49	1.63	0	23.48	2.15	2
2.0×10^9T	24.16	1.28	1	24.86	2.22	1
2.5×10^9 T	26.61	1.05	1	25.48	2.26	2
3.0×10^9 T	25.05	1.66	0	22.46	2.45	2
3.5×10^9 T	25.46	1.54	1	25.84	2.32	1
4.0×10^9 T	26.84	1.95	1	23.15	2.22	2
4.5×10^9 T	24.65	1.54	0	21.06	2.02	2
5.0×10^9 T	26.84	1.35	1	20.48	2.32	2
5.5×10^9 T	25.02	1.54	1	26.46	2.22	1

Based on the information in the above table, it is not difficult to see that, compared with the traditional signal acquisition method, the signal acquisition method of the wireless RF gas sensor array based on the virtual instrument proposed in this paper has significantly lower error rate value change compared with the traditional method, thus confirming that the error of the signal acquisition method of the wireless RF gas sensor array based on the virtual instrument is lower in the actual application process, the stability is relatively higher.

3.3 Acquisition Time

Further, the signal acquisition and detection efficiency of the wireless RF gas sensor array signal acquisition method based on virtual instrument in the operation process is compared and detected, and the detection results are recorded, as follows (Fig. 5):

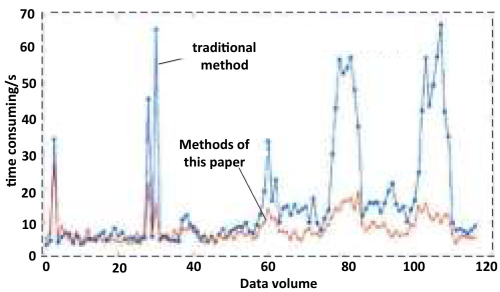

Fig. 5. Comparison test results

Based on the above test results, it can be seen that compared with the traditional methods, the time-consuming of the signal acquisition method based on the virtual instrument proposed in this paper is significantly lower in the practical application process, which confirms that the practical application effect of the signal acquisition method based on the virtual instrument proposed in this paper is relatively better and fully satisfied Research requirements.

3.4 Acquisition Accuracy

In order to further verify the effectiveness of the method in this paper, the traditional method and the method of wireless radio frequency gas sensor array signal acquisition accuracy are compared and analyzed, the comparison results are shown in Fig. 6.

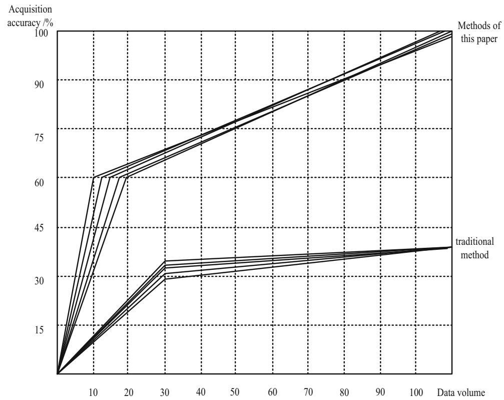

Fig. 6. Comparison of acquisition accuracy of two methods

According to Fig. 6, the highest signal acquisition accuracy rate of wireless radio frequency gas sensor array in this method can reach 100%, while that of traditional method is only 36%. It shows that the signal acquisition accuracy rate of wireless radio frequency gas sensor array in this method is higher than that of traditional method.

4 Conclusion

In this paper, a method of signal acquisition of wireless RF gas sensor array based on virtual instrument is proposed. Aiming at the problem of temperature interference in detection, a flexible sensor array signal acquisition and temperature compensation algorithm is designed. By temperature compensation of three-dimensional force sensor, the influence of temperature is effectively reduced, and the reliability of signal acquisition of wireless RF gas sensor array is improved Sex. In the later stage, the signal acquisition and processing can be integrated into the sensor array, and the data can be transmitted wirelessly to improve the practicality of the sensor array. The experimental results show that the wireless RF gas sensor array signal collection method can effectively improve the accuracy of signal collection.

5 Fund Projects

Research on temperature compensation method of silicon sapphire high temperature pressure sensor (CJGX2016-KY-YZK032).

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