RESEARCH OF MULTI SENSOR INTELLIGENT SYSTEM SIGNAL FUSION AND RECONSTRUCTION

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Abstract- This paper studies some key technology of multifunctional sensor signal reconstruction. The multifunctional sensor signal reconstruction problem, presented a multifunctional sensor signal reconstruction method based on B spline and the extended Calman filter. The method of inverse model of the process was studied, gives a method to estimate signal reconstruction accuracy and computation. Genetic algorithm is proposed to balance the multifunctional sensor signal reconstruction accuracy and computation based on. In order to further reduce the sampling effort of large quantities of multifunctional sensor signal reconstruction, is proposed based on the reduction method clustering multifunctional sensor sample selection method, to select the reasonable distribution, suitable for inverse training data model. A new direction to study the theory of multi sensor information fusion is to design and analysis more efficient processing of multi sensor intelligent system is proposed and developed. With the continuous improvement of the intelligent system requirements, research on information fusion of multi-sensor system is affected by the people more and more attention.

Index terms*:* Multi-sensor, signal reconstruction, complex, sample detection

I. INTRODUCTION

As one of the three major pillars of the modern information industry sensing technology, which is the basis of information technology and computer technology, has been widely used in scientific research, industrial production and people all aspects of life [1]. At present, with the development of integrated circuit technology, materials technology and computer technology, sensor increasingly miniaturization, multifunction, and measurement accuracy is also improved by. Thus, the sensor is getting more and more deeply into all aspects of human social life and production [2, 17]. The sensor is the development of science and technology foundation of information era, the research and development of new sensors and sensing technology is an inevitable requirement of the times [3].

Simple systems generally use only a single sensor, fixed task. However for the intelligent system and autonomous system, people found that a single sensor can not satisfy the need of target recognition, and operating environment, especially in the uncertain environment [4]. In the sensor in the measuring process, because the object to be measured is all kinds of feelings, and target acquisition and conversion, the way is not the same. Therefore, a single sensor to provide information is often incomplete, with greater uncertainty, occasionally even wrong. With the development of science and technology, sensor of various new technologies emerging increased sensor types., improvement of performance and compact structure have promoted the development of multi sensor system [5]. For example, a powerful intelligent robot usually of two dimensional vision sensor, 3D vision sensor, distance sensor, proximity sensor, sensor tactile sensors and torque sensors in different types. Multi sensor system will lead to the quantity of information increase rapidly each sensor and the information of space, time, different expressions, credibility is not the same, focus and has different purposes, and it puts forward new demands for information processing and management.

Recently, multi sensor information fusion research and development in the research of intelligent systems and various autonomous system, is being paid more and more attention. Intelligent system and autonomic system must work in a variety of uncertain environment, and this kind of certainty is not only reflected in the environmental perception and description method, is shown in the generation and implementation process in decision making [6-9]. The intelligent systems and autonomous systems in uncertain successfully complete a variety of tasks in the environment, the prerequisite is the multi-sensor system must be correctly, quickly describe the surrounding environment characteristics, improve the performance of the following four aspects:

increasing the system information receiving and processing time, space, resolution and frequency coverage, avoid blind; improve the system positioning, navigation, tracking accuracy and system redundancy, effectively reveal the organic connection between the information, to enhance the ability of system to the environment characteristic mode attribute recognition decision; improve the system robustness and anti-interference ability; improve the system receives the information rate and update rate.

Multifunctional sensor is studied in this paper, is one of the main development direction of modern sensor. At present, provides a broad space of the MEMS technology, chip technology and integrated circuit technology for the development of multifunctional sensor, but also put forward higher, more urgent requirements. As everyone knows, for a sensitive component, its sensitivity may not only associated with a physical quantity, often may be affected by other physical quantities (such as temperature, humidity and other common) effect. So, in the work process, very easy to cause measurement error, so that the sensor accuracy is greatly decreased, this phenomenon is called cross sensitivity. In order to overcome this drawback, nature is the relationship between multifunctional sensor using the sensitive components and the physical quantity at the same time, will be more sensitive components are integrated together to form a many to many relationship, not only to overcome the influence of cross sensitivity, precision, and to realize the simultaneous measurement of multiple physical quantity.

II. RELATED KNOWLEDGE OVERVIEW

2.1The measuring principle of multifunctional sensor

The trust function, which satisfies the weak axiom of probability theory, to distinguish the difference between uncertainty and do not know [10]. Applied to multi sensor touch together, it will be the uncertainty of sensor information expressed as reliability, processing sensor information merging rules using the information credibility [11]. For any one target set by G, θ basic reliability m describes the reliability of size (0-1). m (G) is called the credibility, if meet the following conditions:

$$m(\phi)=0,\ \sum_{G\subset\theta} m(G)=1 \tag{1}$$

For any set of objectives, the theory of decision evidence also put forward the concept of belief functions:

$$\mathrm{Bel}(G) = \sum_{x \subseteq G} m(x) \tag{2}$$

By defining the basic reliability m, easy to launch:

$$\mathrm{Bel}(\phi) = \mathrm{m}(\phi) = 0 \;\; \mathrm{Bel}(\Theta) = \sum_{G \subset \theta} m(G) = 1 \tag{3}$$

The basic set, equal value of credibility and trust function.

At the same time, for any goal set G, theoretical definition of decision:

$$\mathrm{Pl}(G) = 1 - \mathrm{Bel}(\overline{G}) \tag{4}$$

$$\mathrm{Bel}(G) + \mathrm{Bel}(\overline{G}) \leq \sum_{x \subseteq \Theta} m(x) = 1 \tag{5}$$

Let m_1, m_2 is according to the basic probabilistic independent information obtained, m= $m_1 \oplus m_2$ by merging rules, basic probability m for the new:

$$m(A_k) = \frac{\sum\limits_{A_X \cap A_Y \neq A_k} m_1(A_{1i}) m_2(A_{2j})}{1 - \sum\limits_{A_X \cap A_Y \neq \phi} m_1(A_{1i}) m_2(A_{2j})} \tag{6}$$

And the $A_k \neq \varphi$, the theory of decision evidence of multiple sensor qualitative information fusion process is shown in Figure 1.The molecular significance is in A and the product of A collection, the basic probability assignment to the product of the product. When the collection is empty, this formula does not hold.

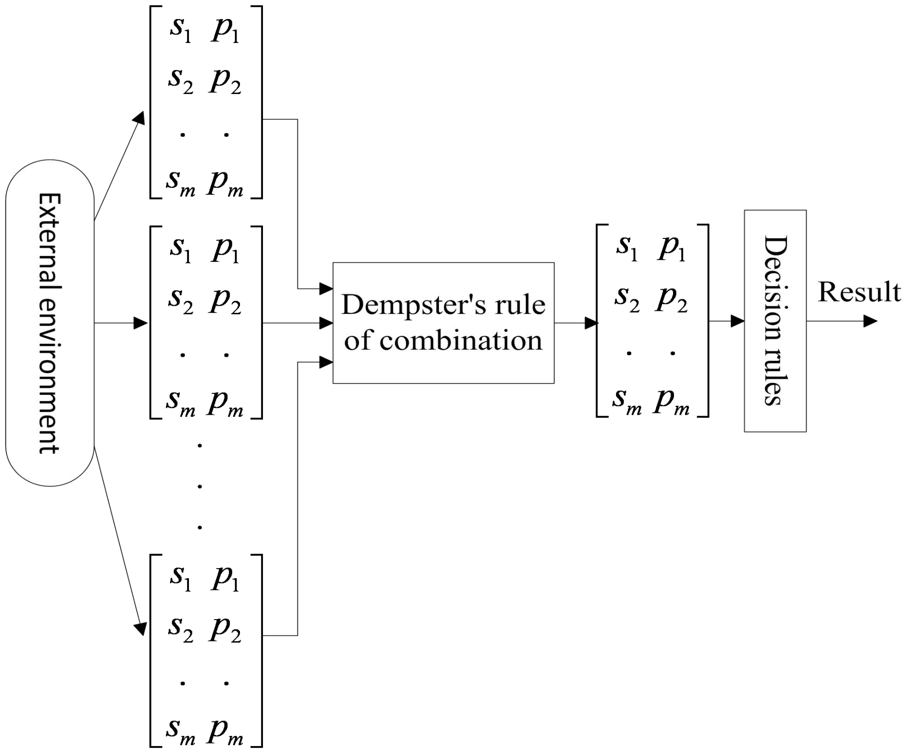


Figure 1. The theory of decision evidence of multiple sensor qualitative information fusion process

2.2 Multi sensor signal reconstruction accuracy and computation

Objective decision making that information fusion system set is composed of some basic goal incompatible. Corresponding to the above 0, the possible combinations of decision for these basic objectives, corresponding to the above the target set.

Observation is the sensor produces a basic confidence in the target set. That is we to the possibilities that the goal set contains environmental objectives. In other words, the basic probability describes the perception of sensor target. Each sensor can be a basic confidence in the target set in the system N. A sensor at the same time observation, we can get the N basic credibility. The group of basic credibility is the foundation of decision.

2.3 Signal reconstruction of the mean square error

The measured output value as the measuring circuit output voltage V and ultrasonic transit time T_{tof}, and the temperature of the solution T, and reflect the physical quantity is three solution of sodium chloride and sucrose concentration of C_{NaCl} and $C_{Sucrose}$, can be expressed by the following equation:

$$\begin{cases} V_o = f_1(C_{Sucrose}, C_{NaCl}, T) \\ T_{tof} = f_2(C_{Sucrose}, C_{NaCl}, T) \end{cases} \tag{7}$$

Variables are one to one correspondence, so we can write the inverse model of the formula as shown in formula:

$$\begin{cases} C_{NaCl} = g_1(V_o, T_{tof}, T) \\ C_{Sucrose} = g_2(V_o, T_{tof}, T) \end{cases} \tag{8}$$

Use of type (8) of the experimental data, the formula (7) function in G1 and G2 were estimated, so as to obtain multifunctional sensor approximate inverse model.

$$\begin{cases} \hat{C}_{NaCl} = \hat{g}_1(V_o, T_{tof}, T) \\ \hat{C}_{Sucrose} = \hat{g}_2(V_o, T_{tof}, T) \end{cases} \tag{9}$$

III. STRUCTURE DESIGN AND MEASURING PRINCIPLE OF MULTI – SENSOR

3.1The basic structure of multi sensor

It can be seen from Figure 2, the whole process of osmotic dehydration, multifunctional sensor always work in the off tank, completely soaked in three in solution, cut off from the outside world, so the influences of operating conditions on the measurement mainly concentrated in temperature. In addition, the other on the sensor of conditions of use is mainly from the food into three for nutrient solution, but its content is very small, the impact is negligible [12, 13].

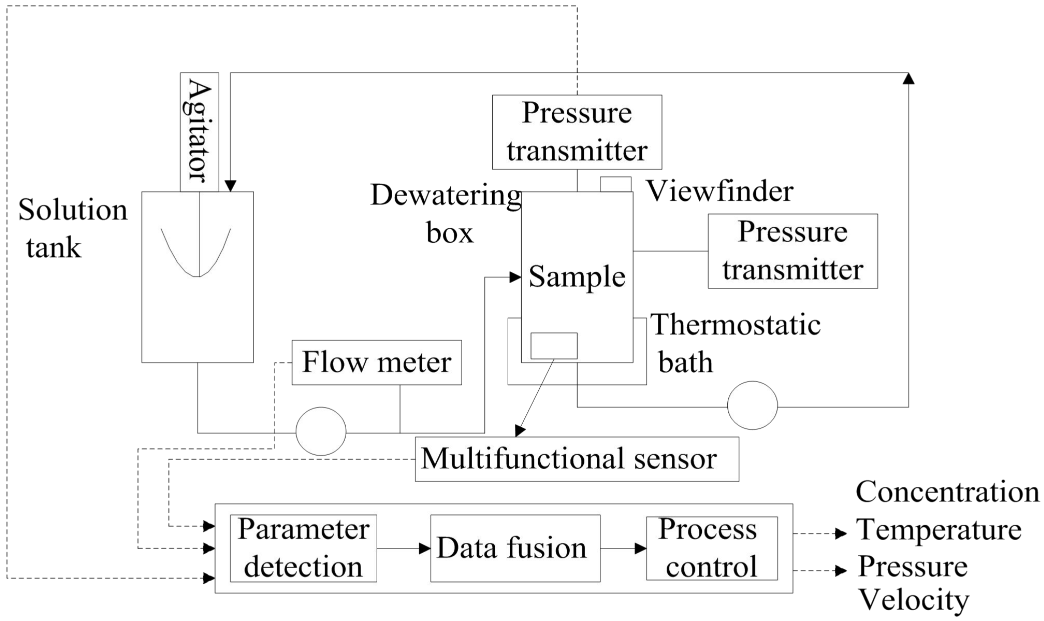


Figure 2. The whole process of osmotic dehydration

3.2 Principle of genetic algorithm

Genetic algorithm to solve the problem, the general can be described as a function of the maximum (or minimum) mathematical programming problems:

The basic steps of the genetic algorithm in order to better, first briefly explain several basic concepts, namely, population, individual chromosome, gene, encoding, selection operator, crossover operator, mutation operator and fitness function:

1) Refers to the original biological cells, the main carrier of genetic material, is a kind of tiny is a filamentous compound, have genetic factor gene.

2) Gene: gene to chromosome is used to represent the individual characteristics, the genetic algorithm for binary number one.

3) The individual: chromosome characteristic entity.

4) Population: a collection of individual chromosomes with a feature called population or population.

5) Code: This refers to the genetic information according to certain patterns are arranged, in the genetic algorithm, the feasible solutions of the problem, the solution space is transformed into genetic algorithm can deal with the search space, called a code.

6) Decoding: the inverse process of encoding, the conversion of binary code to the solution space.

3.3Signal reconstruction method based on the extended Calman filter

B spline algorithm is an important tool for the nonlinear curve or surface complex structure. Constructed by B spline curve or surface has good low order smooth characteristic, establishment of multifunctional sensor inverse model can effectively avoid under fitting and over fitting phenomenon by it, so as to improve the accuracy of signal reconstruction.

The sample data point in the two-dimensional space is given column {(xj, yj)}$_{j=1}$, and node x direction represented by the symbol t. Considering that xj usually increasing sequence, remember:

$$t_0 = \min_j x_j = x_0 = a,\ t_{N+1} = \max_j x_j = x_n = b \tag{10}$$

Node sequence determined after k or k-1, order B spline basis function of $B_i^k(x)\ (i = -k+1, \ldots, N)$ can be defined through the DeBoor-Cox recursive calculation:

$$\begin{cases} B_i^1(x) = \begin{cases} 1, & t_i < x < t_{i+1} \\ 0, & \text{else} \end{cases} \\ B_i^k(x) = \dfrac{x - t_i}{t_{i+k-1} - t_i} B_i^{k-1}(x) + \dfrac{t_{i+k} - x}{t_{i+k} - t_{i+1}} B_{i+1}^{k-1}(x) \end{cases} \tag{11}$$

Using sample data points $\left\{(x_j, y_j)\right\}_{j=1}^{n}$, obtain the matrix form of linear equations:

$$Y_n = P_{n,N} C_N + E_n \tag{12}$$

$$Y_n = \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_n \end{bmatrix} \quad E_n = \begin{bmatrix} e_1 \\ e_2 \\ \cdots \\ e_n \end{bmatrix} \quad C_N = \begin{bmatrix} c_{-k+1} \\ c_{-k+2} \\ \cdots \\ c_N \end{bmatrix} \tag{13}$$

$$P_{n,N} = \begin{bmatrix} p_{1,-k+1} & p_{1,-k+2} & \cdots & p_{1,\mathrm{N}} \\ p_{2,-k+1} & p_{2,-k+2} & \cdots & p_{2,\mathrm{N}} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n,-k+1} & p_{n,-k+2} & \cdots & p_{n,\mathrm{N}} \end{bmatrix} \tag{14}$$

IV. RESULTS AND SIMULATION

4.1The experimental system

Ultrasonic acoustic vibration frequency is greater than 20 kHz; its essence is a kind of mechanical wave, with a beam of and a good direction, strong penetrating ability, propagation distance and so on in a liquid. Because ultrasonic in the solutions of different solutes, different concentration, velocity of propagation are different, therefore the issue by ultrasonic detection in the tested solution propagation velocity measurement solution of solute concentration [15, 16, 18-20].

The three element concentration measurement of multifunctional sensor and its matching circuit, need to obtain sample data for signal reconstruction of the. In this paper, multifunctional sensor signal reconstruction experiment data acquisition process, as shown in Figure 3.

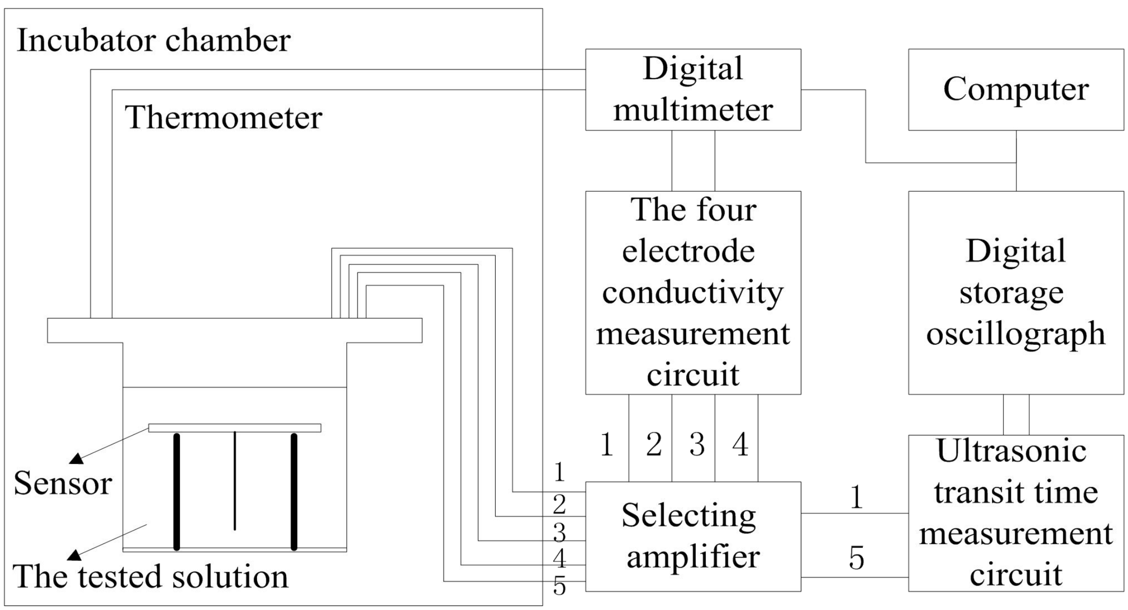
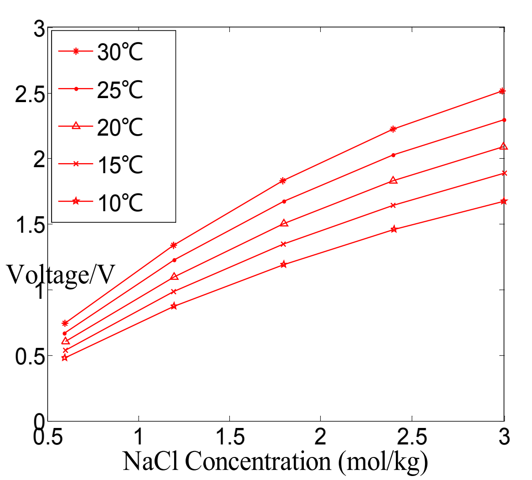


Figure 3. Multifunctional sensor signal reconstruction experiment data acquisition process

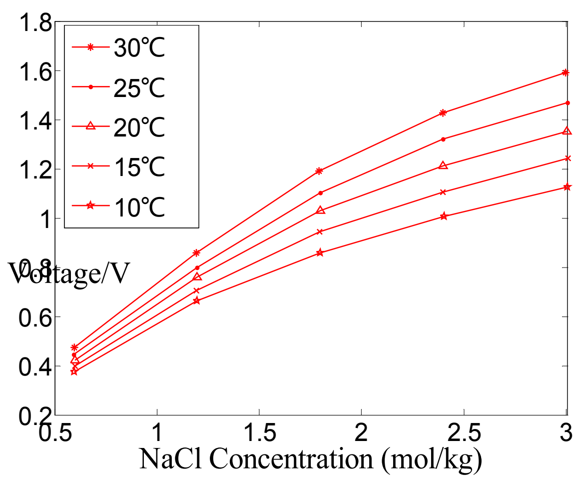
Using the digital multi-meter acquisition thermometer and a four electrode conductivity measurement circuit, the digital storage oscilloscope for echo ultrasonic transit time, input the signal to the computer system, thus forming the sample data, the methods used to study the reconstruction signal multifunctional sensor. Oscilloscope simultaneously measurement of ultrasonic transmitting and receiving signals, and is used for measuring the time difference between the two. The delay circuit is used for controlling the opening and closing of analog switch, when the signal generator signal after a period of time, the automatic control of analog switch, the received echo signal oscilloscope. Through this set of matching circuit can be conveniently measured in solution in the ultrasonic transit time.

4.2 Acquisition and analysis of experimental data

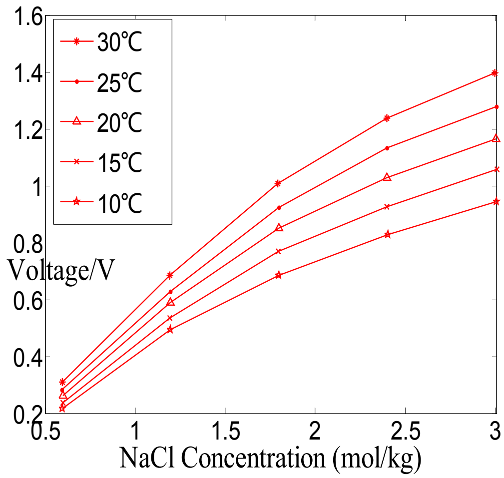
In order to simulate the actual osmotic dehydration conditions, and ensure the stability and consistency of the three element solution, the sample solution consists of distilled water, sodium chloride and sucrose mixture ratio, in which sodium chloride and sucrose were analytically pure. Figure 4 is a multifunctional sensor transit time result diagram. In order to illustrate the influence of temperature on the output of multifunctional sensor, all graphs are given output results under different temperature.



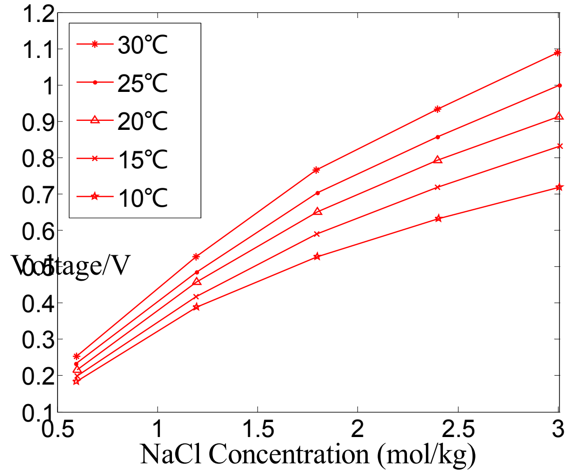
a) sucrose concentration 0.3 mol/kg



b) sucrose concentration 0.9 mol/kg



c) sucrose concentration 1.2 mol/kg



d) sucrose concentration 1.5 mol/kg

Figure 4. The multifunctional sensor transit time result diagram

4.3 Multi sensor signal reconstruction

Multifunctional sensor is capable of measuring a plurality of measured variables of the sensor at the same time. In theory, as long as the measuring range, the value of all variables can be measured. However, due to the measurement is the need of time, can not be measured in all the possible variables are things advanced line, especially for a plurality of measured multifunctional sensor, we can obtain some values measured. How to value, to derive all value, is the signal reconstruction problem to solve.

Multifunctional sensor and its inverse model based signal reconstruction principle as shown in Figure 5. Because the cross sensitivity of sensitive materials, each of the output (y_1, y_2,…y_m) multifunctional sensor are input to the (x_1,x_2,…x_m). Multifunctional sensor signal reconstruction based on inverse model is to establish an inverse model, in this model, all output sensor as input, each with a measured x estimation.

Fig. 5 measured physical variables, namely x, and convert it to usable signal, usually into electrical signals, namely y. Thus, the input and output characteristics of multifunctional sensor can be expressed as the form of 15. Seen from Eq. 15, between the input and output variables of multifunctional sensor does not correspond to the one, a measured variable change sensor will cause all the output change; on the contrary, the change of output is not only means the change in one input, there may be multiple input common change results.

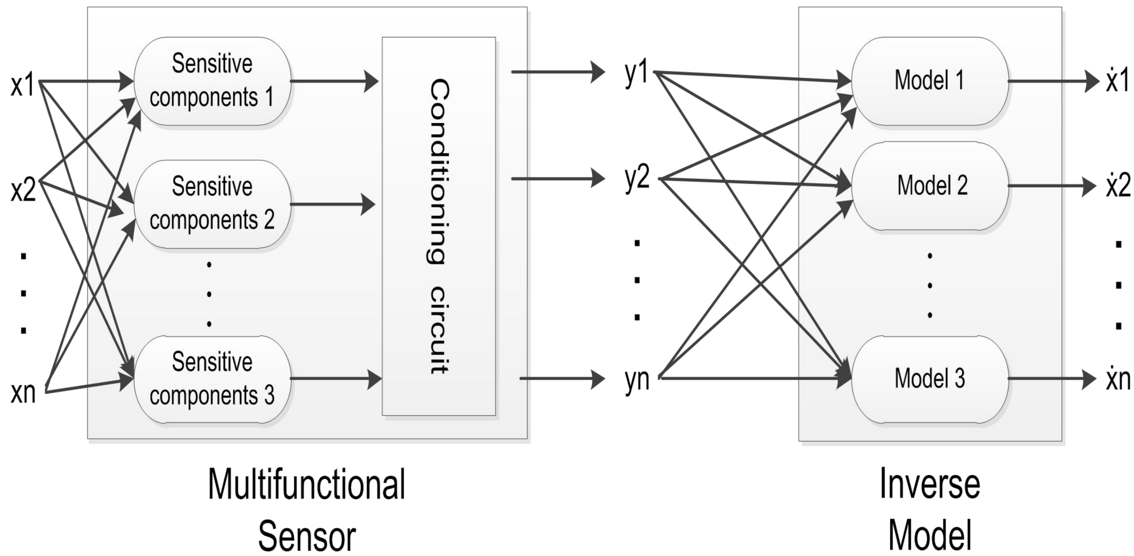


Figure 5. Multifunctional sensor and its inverse model based signal reconstruction principle

In order to establish the inverse model, and decompose it into multiple models, each model is all sensors output as input, but the output is measured in a single variable, as shown in the following formula.

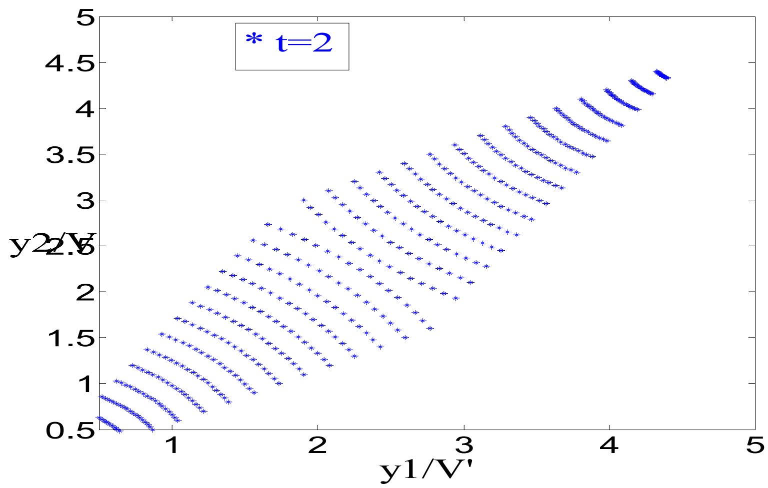
$$\begin{cases} \hat{x}_1 = \hat{g}_1(\mathrm{y}_1,...,\mathrm{y}_m) \\ \quad ... \\ \hat{x}_n = \hat{g}_n(\mathrm{y}_1,...,\mathrm{y}_m) \end{cases} \tag{15}$$

$$\begin{cases} y_1 = f_1(x_1,...,x_n) \\ \quad ... \\ y_m = f_m(x_1,...,x_n) \end{cases} \tag{16}$$

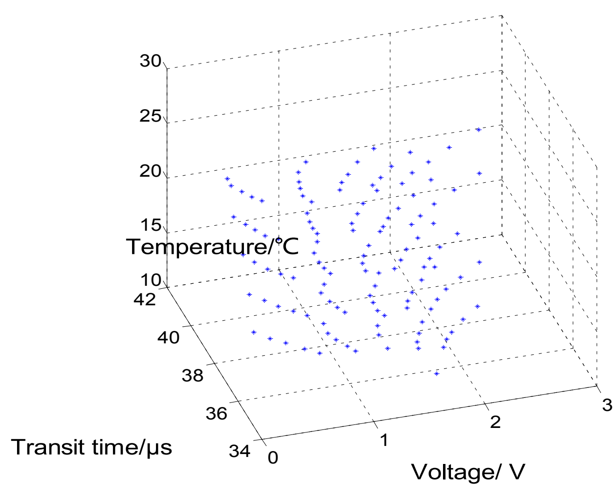
A curve fitting method of the B sample can be used for single input single output sensor signal reconstruction. The multifunctional sensor with multi input and multi output, you need to use high dimensional B spline. Firstly, a multi input multi output system is divided into a plurality of multi input single output system. Then, for each one of the multi input single output system, using a high dimensional B spline to fit. Thus a inverse model of multifunctional sensor input and multi output can be described by a plurality of high dimensional B spline model, the number of B spline model is equal to the number of the multifunctional sensor is measured.

4.4The simulation and experimental results

The simulation experiment to select two input two output sensor system simulation model principle of the sensor network, simple structure, intuitive, and has good nonlinear characteristic curve, input output curve and multifunctional sensor actual very similar. Figure 6 (a) shows that, the parameter i increase, will lead to sample data nonlinearity increases, distribution becomes more and more irregular. The validation data as obtained in domain [0.1-0.9], the sampling interval is 0.025.



(a) Sample data nonlinearity increases;



(b) The sample data acquired through the uniform grid sampling

Figure 6. The simulation experiment

Although the sample data are acquired through the uniform grid sampling, but as shown in Figure 6 (b), distribution of sample data obtained are extremely uneven, showing a large nonlinear. For signal reconstruction of the multifunctional sensor, B spline was used to establish the inverse model. Because the concentration of simultaneous measurement of sodium chloride and sucrose multifunctional sensor of two solutes, which are establishing the inverse model.

V. CONCLUSION

This paper describes the design of a multifunction sensor capable of simultaneous measurement of two three dimensional of solute concentration in solution, the multifunctional sensor principle of four electrode conductivity measurement and ultrasonic measurement based on three dimensional, is capable of simultaneously measuring the conductivity of solution and ultrasonic transit time, and achieve the measurement of three element solution of two kinds of solute concentration. Research on signal reconstruction method of multifunctional sensor, B spline as the inverse model of multifunctional sensor, the model not only can inverse system fitted well to the multifunctional sensor, and has the advantages of simple structure, less parameters, easy realization. By using the extended least squares method of Calman filter instead of traditional control, estimation of coefficient B spline model, the parameter identification process is recursive process, without once all the data processing, and can effectively avoid the matrix relates to least square method when computing the even is the inverse operation of high dimension matrix, suitable for programming and microprocessor. Experiments show that, signal reconstruction, the proposed method, the maximum relative error of reconstruction of less than 1.3%, the mean square error is less than 0.01, and is suitable for use in a microprocessor.

VI. ACKNOWLEDGEMENT

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