

Research on Apple Odor Collection and Identification

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Abstract: Odor is an important quality factor in the selection of the apple. How to quickly and accurately detect the odor of apples is a subject in food, gardening and computer science. With the development of sensor technology, network communication technology and embedded computer technology, the electronic nose research becomes a hot topic. This paper carries on exploratory research for the apple odor detection based on the characteristics of apple odors. It designs a portable apple odor detection system with six S_nO_2 gas sensors as its odor collector and TMS320VC5402 as its processor. There are other hardware such as high precision A/D converter MAX1403, a 3×5 keyboard, and LCD in the system. It introduces interface circuit DSP to A/D converter and keyboard with the characteristics of different varieties of apples odors. In order to have a better human-computer interaction function, the system designs LCD interface circuit to display test results. A BP neural network is applied in the pattern recognition of apple odors. It studies on the extraction method of characteristic value, the improving for BP algorithm, the BP neural network transplanting to DSP platform. This system can automatically identify apple odor and its application will provide a new method for apple quality identification. Copyright © 2016 IFSA Publishing, S. L.

Keywords: Apple odor, Gas sensor, TMS320VC5402, Electronic nose, Pattern recognition.

1. Introduction

Apple has always been an important fruit in the world, and it is identified as one of 11 kinds of superior agricultural products by Ministry of Agriculture in China. Because of concern about the quality of apple, fast and accurate detection of apple quality has always been a hot research subject of horticulture, agronomy, computer, and electronics. There are many indicators for apple division, and the basic quality requirements, in fresh apple grading standards in China, is the full fruit, fresh and clean, no abnormal smell or taste, fully developed, with good maturity for sale or storage. It is visible that smell plays an important role in the characterization of the apple [1]. However, due to the

complex composition and the sensory organs subjective effects, odor is more difficult to identify than other characters of apple, which has become focal and difficult points in research. At present, the electronic nose system, which uses odor sensor array to collect data and PC to process data, has been successfully tested and applied. However, such electronic nose requires a computer to process data, and is not convenient to detect the smell of apples at the scene. This article describes an apple odor detection system. It contains a core processor, which is a DSP chip TMS320VC5402, and a device for collecting odors, which is constituted by odor sensors. It is a system for sample collection, A/D conversion, nonlinear pattern recognition as a whole.

2. System Design Scheme

The system consists of the following components: odor sensor array, data acquisition module, the control module for device, information display module and the processing system with DSP core. Data processing is: odor signals that acquisition device obtained is pretreated and then A/D conversion; after the signal feature extraction, signal is input to the processor DSP core in the form of a digital matrix; the digital matrix is computed and processed by the processor according to the relevant instructions, and finally display the results on the LCD screen. Apple quality level tentatively scheduled for three levels, the good, bad and disabled. Fig. 1 shows a block diagram of the system.

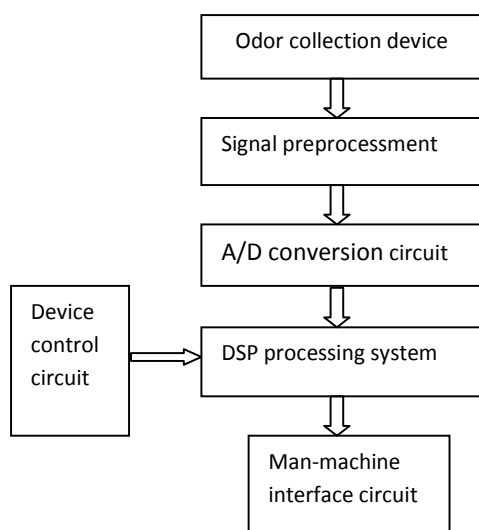


Fig. 1. Block diagram of the system for apple odor research.

TMS320VC5402 core device the system used is the TI Company's mainstream products. C5000 DSP platform is the most popular consumer digital market, which is particularly suitable for personal and portable products, and VC5402 is the higher cost of fixed-point digital signal processors [2].

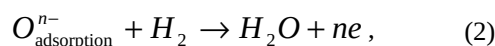
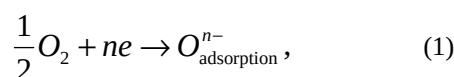
3. Hardware Design for Odor Acquisition

3.1. The Design of Odor Collection Chamber

Apple odor generally composes of ethylene, formic acid, acetic acid, propionic acid, butyric acid, octanoic acid and other volatile acids and esters thereof, methanol, ethanol, acetaldehyde, etc. based on food chemistry research, and therefore choose tin oxide odor sensors which is sensitive to these gases to make up sensor array. This design uses six thick metal tin oxide sensor (TGS800, TGS822, TGS824, TGS825, TGS2602, TGS2610) which are produced by

Figaro company in Japan. Each sensor in sensor array has a different sensitivity to the smell test, TGS2602 sensitive to toluene, ethanol and TGS822 more sensitive to alcohol [3].

Working principle of the S_nO_2 gas sensors is: when the surface-sensitive layer of S_nO_2 gas sensor contact with air, oxygen in the air is adsorbed onto the surface of the sensitive layer by the electron affinity of the molecule and get electrons from a surface of the semiconductor to form O_2^- , O^- , O^{2-} and other acceptor-type surface level, in the result of surface resistance increasing; if a reducing gas such as H_2 , CO gas is detected as being in contact with the surface, the redox reactions is happened, and the surface resistance drops with oxidizes the trapped electrons returned to the semiconductor. It can detect the gas used of changes in surface resistance of gas sensors. The above-described process can be described in three chemical reaction formulas:



where e is the electron charge.

In addition, if there are structural dislocations in the portion those semiconductor die contacts with, it would form barrier at the point of dislocations that can hinder movement of carriers. This barrier changes its height due to the adsorption of gas, which also changes the gas sensor resistance. Due to the difference of the sensitive material, the thickness of the sensitive layer, doped with rare metals, the heating and operating temperatures, ambient temperature and humidity and other conditions, various sensors are sensitivity to different gas molecules.

The test apparatus for odor acquisition is shown in Fig. 2. Apple is placed in a semi-closed container, called resettlement room. The sensor array is placed in a reaction chamber, the volume of which is as small as possible, and temperature control equipment is installed in it. In order to save space, six sensors are arranged in line. In order not to distribute to other odor, the reaction chamber is made of stainless steel. Valve 1 and Valve 2 are the intake and exhaust ports.

Due to the limited space of the reaction chamber, the volume of temperature control equipment cannot be too large. By comparing the advantages and disadvantages of microcontroller-based temperature control circuit and analog circuit for temperature control equipment, it chooses the analog circuit. The reason is that its size is small and can set up flexible drive power, although the accuracy of analog circuits is lower than microcontroller-based temperature control circuit. Temperature control device emulation circuit is shown in Fig. 3.

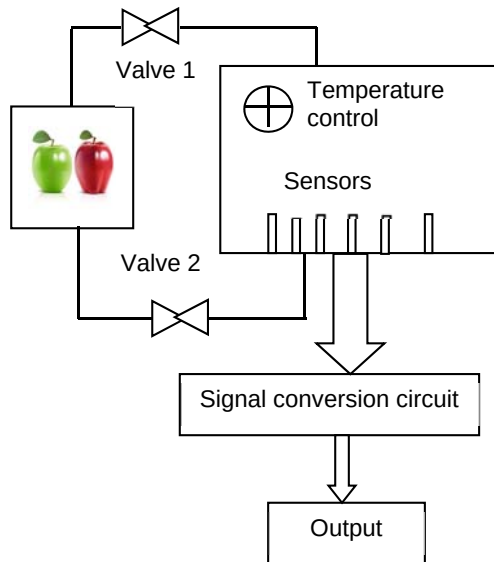


Fig. 2. The schematic of odor capture device.

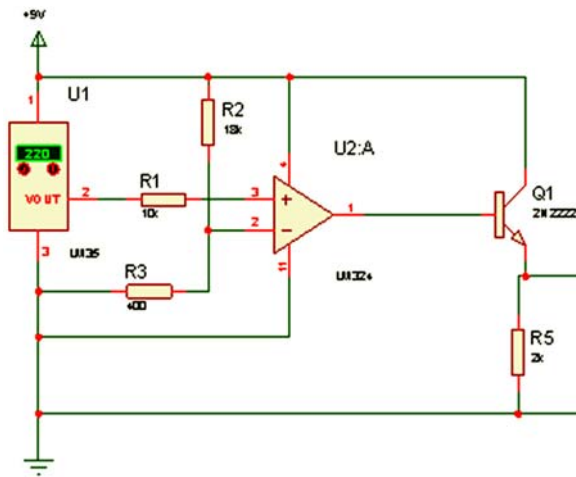


Fig. 3. Temperature control device emulation circuit.

3.2. The Design of Core Processing Circuit

The resistance values of sensor are difference in the case of different gas concentrations sensor. According to this feature, the resistance value can be converted into a continuous signal by the voltage value conversion circuit, and these voltages can be approximated representation of the original odor signal. There are N sensors in the gas sensor array, so that if the sensor array is used to measure M -gas, the response of the sensor array is M random process collection according to the M gases. It can be described in the formulas:

$$E(t) = \begin{bmatrix} \xi_{11}(t) & \xi_{12}(t) & \dots & \xi_{1M}(t) \\ \xi_{21}(t) & \xi_{22}(t) & \dots & \xi_{2M}(t) \\ \dots & \dots & \dots & \dots \\ \xi_{N1}(t) & \xi_{N2}(t) & \dots & \xi_{NM}(t) \end{bmatrix}, t \in T \quad (4)$$

As can be seen from the data output the sensor array, the data processing cannot be accomplished by simple data calculations.

Before processing and analysis of the data, it must convert the analog signal into digital signal which collects by the sensors, that is A/D conversion. Because the signals are low-frequency small-signal and the high accuracy requirements for data processing system, the precision is must be considered in the choice of A/D converter. MAX1403 produced by MAXIM Company has the features of high precision, multi-function, low power consumption, and it can provide conversion results through the serial digital interface. When the master clock frequency is 2.4576 MHz or 1.024 MHz, the on-chip digital filter can process line frequency and associated harmonic frequencies, and set the magnitude of these frequencies to zero, so that it can get better filtering effect without external filter. At the same time, it also helps to improve the quality of the digital signal output from the A/D converter.

This design uses TMS320VC5402 DSP as the core device. TMS320C5000 DSP platform is the TI Company's mainstream products, and C5000 DSP platform, which is particularly suitable for personal and portable products, is most popular in the digital consumer markets. C54x DSP is currently the mainstream products in application, because of its high performance and low cost [3]. TI's VC5402 is the higher cost of fixed-point digital signal processors launched in October 1999, and its main features are as follows:

Advanced reformed Harvard architecture, operating speed is up to 100MIPS.

Advanced multi-bus architecture, there are three 16-bit data bus and a memory program memory bus.

There is a 40-bit arithmetic logic unit (ALU).

There are 8 auxiliary registers and a software stack that allows the use of the industry's most advanced fixed-point DSP C language compiler.

The data / programs addressing space is $1 \text{ M} \times 6 \text{ bit}$, and it built-in $4 \text{ K} \times 16 \text{ bit}$ ROM and $16 \text{ K} \times 16 \text{ bit}$ RAM.

It built-in programmable wait state generator, PLL clock generator, two multi-channel buffered serial port, one 8-bit parallel PHI port in communication with the outside, two 16-bit timers, and 6-channel DMA control device.

Low power consumption, the power supply has 3 V and 1.8 V.

The interface circuit between A/D converter and TMS320VC5402 is shown in Fig. 4.

For ease of viewing the test results, this design makes a man-machine interface circuit in hardware. It includes a parallel interface, keyboard circuit, the liquid crystal display circuit, RS232, FLASH memory and RAM memory. It designs a 3×5 matrix keyboard. Due to the limited resources of TMS320VC5402 chip I/O port, it expands into the latch 74HC573 I/O port to form non-coding keyboard. Specific definitions of key codes include data acquisition and transmission

control, scroll up and down and clear the screen, data storage and other functions.

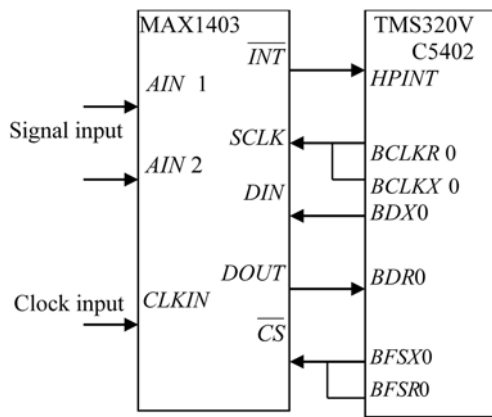


Fig. 4. The interface circuit between A/D converter and TMS320VC5402.

3.3. Experimental Procedure and Phenomenon

Experimental procedure for the experimental device designed as follows:

- 1) Open the Valve 1 for holding ventilation, and open the temperature control switch in the reaction chamber, and then wait 2 minutes.
- 2) Close the Valve 1, open the Valve 2, and apple is moved into the sample gas generation chamber, sealed to wait 5 minutes to step 3.
- 3) Open the collection procedures to begin collecting data.
- 4) Shut off the Valve 2, and it is the time for response between gas sample and the sensors.
- 5) Stop the acquisition program, and open reaction chamber to remove the apples. The reaction chamber is sealed five minutes to restore.
- 6) The next test.

Tests under the following three conditions: the reaction chamber is empty, put into an apple that general maturity, and put into a rotten apple. The output voltage waveform of sensors measured is shown in Fig. 5, Fig. 6 and Fig. 7.

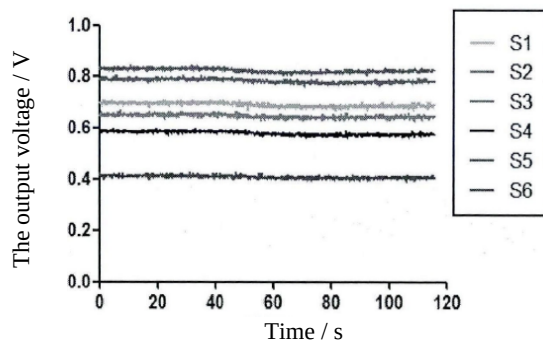


Fig. 5. Sensor array response profiles of background air circuit.

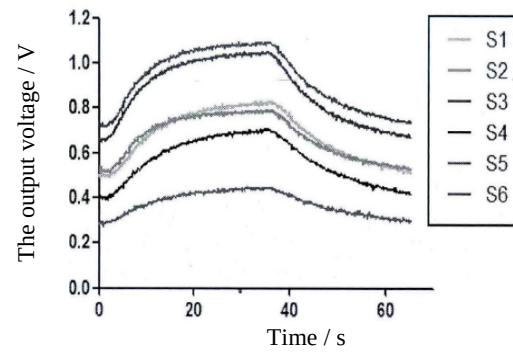


Fig. 6. Sensor array response profiles of an apple that general maturity circuit.

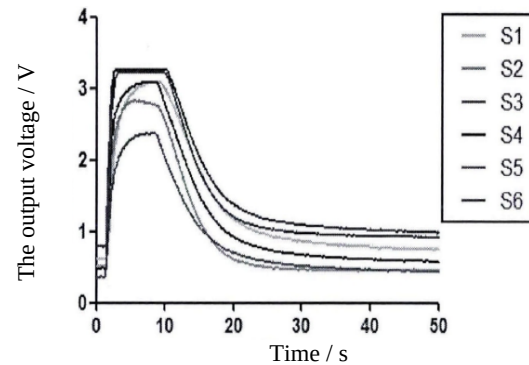


Fig. 7. Sensor array response profiles of a rotten apple.

The above test results show that S_nO_2 gas sensors have clear response to apple odors. With the improvement of maturity the odor concentration has a greater change, so that the response voltage from sensors for the smell concentration of rotten apples quickly reaches their peaks [4].

4. Odor Recognition Based Neural Network

4.1. Pattern Recognition Model

According to the data to identify an apple either good or bad is called apple odor pattern recognition. A pattern recognition system typically includes four main sections: obtaining and pre-processing of the raw data, feature extraction and selection, classification or clustering, after deal with. Pattern recognition are generally divided into supervised and unsupervised pattern recognition system [5]. For this design, the data experimental samples have been identified, and therefore it belongs to supervision pattern recognition. Identification process is divided into decision-making phase and design phase, as shown in Fig. 8.

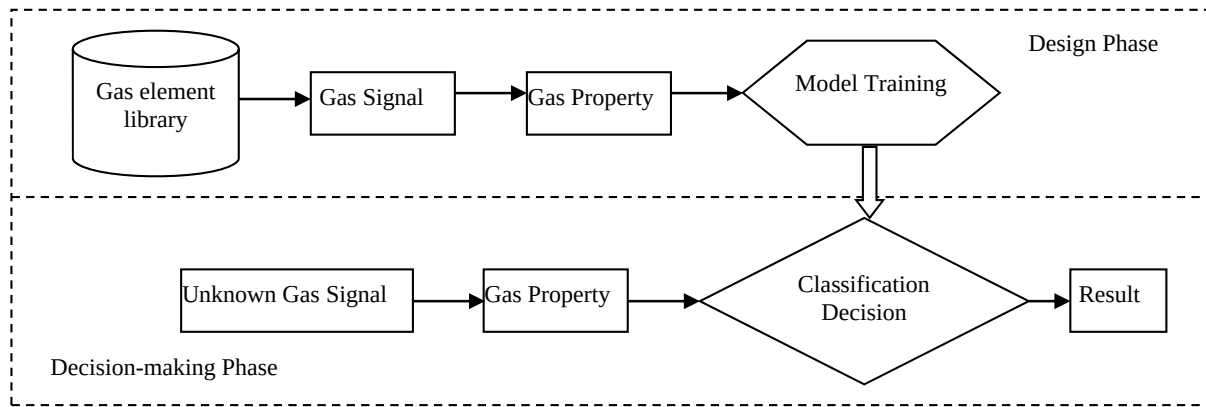


Fig. 8. The block diagram of pattern recognition system for gas.

The workflow of decision-making stage is as follow. First, the sensor devices collect apple odor signal and transform it in order to convey it into the DSP; as a result, it become digitized time-series signal. Then, this original signal is pretreated such as normalization, in order to divide it into a number of smaller pieces, called frames, according to a certain time window, but the split is also determined according to actual needs and algorithms. This step can turn a continuous signal into relatively isolated elements as the basic unit of recognition. The next step is feature extraction. Each frame signal is extracted into a feature vector as pattern recognition sample after a certain signal processing, and task of the system is to identify which one in gas element library related to the samples.

The workflow of design stage is as follow. First, various apple odor collected, after signal processing, is stored in digital form as a basic recognition unit, named gas element library. Then, extract the data elements in the library and make up the gas signal reflecting certain characteristics of the gas, which is the reference for unknown signal. Finally, this gas signal is extracted feature vector with the same characteristics of unknown signal extraction method. This process is called data training. Reasonable training algorithm is the key of pattern recognition and is the core issue of classifier design.

4.2. Feature Extraction

The basic task of feature extracted in this design is to describe the information contained in the original data with less characteristic value by mathematical methods. There are great differences at feature extraction in the method for different problems [6]. The principle of feature extraction is the extracted features expressed the most information based on the desires of the issue. General studies take only the steady-state response of the sensor, but in fact the gas sensor response is a dynamic process, if only to extract the value of the steady-state response will lose a lot of useful information. After analysis of experimental data, this study takes the maximum value as the

extraction method. Extract four values: the maximum value, the time between the starting point to maximum, the relative value between the maximum value and the initial value, and the integral value at time t , shown in Fig. 9.

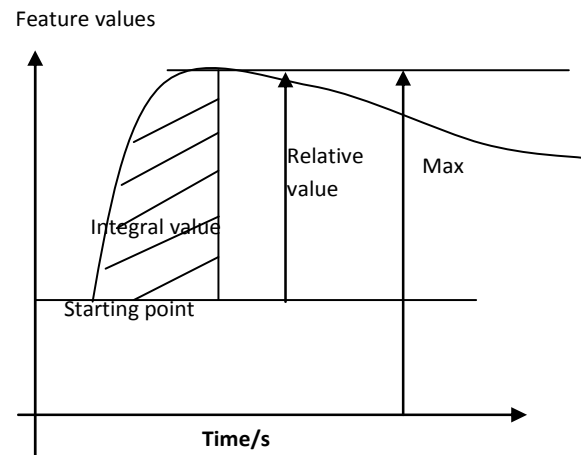


Fig. 9. The schematic feature values.

4.3. BP Neural Network Implemented on DSP Platform

Neural network is a complex network system consists of a wealth of basic information processing unit interconnected neurons. Artificial neurons simulate biological neuron, which biological neuron structure determines the structure of artificial neuron, and artificial has neural synapses or connections, a group of signal accumulation unit and the activation function and other functions.

BP algorithm is one of the most common, the most influential algorithms by far. The basic idea of this algorithm is: make squared error of the sample between output as desired and actual output as a criterion function, use the gradient descent method, starting from the output layer, correct weights layer by layer so that the criterion function minimum [7]. The entire network consists of three layers, namely: an

input layer, a hidden layer and output layer, which may have more than one hidden layer. There is connection between adjacent layers of neurons with each other, but there is no connection between the inner layers of neurons, and the output of the previous layer is the input of the next layer. Characteristics of the entire network depend on the threshold between adjacent neuron connection weights and neurons.

BP neural network design steps are as follows.

1) Design input and output layer

The number of neuron number on input layer is equal to the number of sensors in gas sensor array, and the number of neuron number on output layer is equal to the number of recognition results. This design has six sensors, and the input of the neural network is the output of the 6 gas sensors; results to be recognized are three, which is raw, ripe and rotten.

2) Select the number of hidden units

Selecting the number of hidden units is a very complex issue. If there are too few hidden units, network training requirements may not be achieved, or the trained network is not strong enough, and it does not recognize previously seen sample, fault tolerance poor. But if there are too many hidden units, learning time will be too long; the deviation is not necessarily the best, so there is an optimum number of a hidden unit.

It can select the number of hidden layer units according to the following several formulas [8].

$$k < \sum_{i=0}^n C(\frac{n_1}{i}) \quad (n_1 \geq i), \quad (5)$$

$$C(\frac{n_1}{i}) = 0 \quad (n_1 < i), \quad (6)$$

where k is the number of samples, n_1 is the number of hidden units, n is the number of input units.

$$n_1 = \sqrt{n + m} + a, \quad (7)$$

$$n_1 = \log_2 n, \quad (8)$$

where n the number of input units, n_1 is the number of hidden units, m is the number of output units, a is a constant between 0-10.

For function approximation of BP neural network, the number of hidden units is related to the functions and their precision to be approached.

3) Select the value of initial weights

Due to the nonlinearity, there is a great relationship between the initial value and the learning whether the local minimum or not and whether the convergence. An important requirement is to make the initial weights of each neuron close to zero when enter cumulative, and it will ensure that does not fall on those flat areas at start. Weight generally takes a relatively small random value, so it can ensure that each neuron advances in where their conversion

function greatest changing at the beginning [9]. So it needs to be normalized for input samples.

The network topology is 6-8-3, namely: the input is the signal of the six gas sensors, and the output is the three results. According to the characteristics of the experimental hardware platform and real-time and non-destructive testing requirements, target MSE take 0.01. BP program design process is shown in Fig. 10.

4) Recognition results and error

The expected value of the three kinds of recognition results is as follow.

[1 0 0]-----Ripeness apple

[0 1 0]-----Immature apple

[0 0 1]-----Rotten apple

DSP-based BP recognition results are shown in Table 1.

Table 1. BP recognition results.

No.	Actual state	Test Results	Recognition results
1.	Ripeness	0.99101 0.00524 0.00337	Ripeness
2.	Ripeness	0.99532 0.00106 0.00213	Ripeness
3.	Ripeness	0.99487 0.00213 0.00145	Ripeness
4.	Ripeness	0.99624 0.00009 0.00208	Ripeness
5.	Ripeness	0.99356 0.00476 0.00135	Ripeness
6.	Ripeness	0.99496 0.00457 0.00132	Ripeness
7.	Ripeness	0.98335 0.00876 0.00357	Ripeness
8.	Ripeness	0.99765 0.00008 0.00196	Ripeness
9.	Ripeness	0.99546 0.00358 0.00215	Ripeness
10.	Immature	0.00324 0.99574 0.00125	Immature
11.	Immature	0.00108 0.99713 0.00214	Immature
12.	Immature	0.00457 0.99201 0.00102	Immature
13.	Immature	0.00723 0.99105 0.00121	Immature
14.	Immature	0.00653 0.99218 0.00054	Immature
15.	Immature	0.00576 0.99312 0.00143	Immature
16.	Rotten	0.00576 0.00004 0.99301	Rotten
17.	Rotten	0.00312 0.00045 0.99445	Rotten
18.	Rotten	0.00463 0.00132 0.99423	Rotten
19.	Rotten	0.00634 0.00057 0.99187	Rotten
20.	Rotten	0.00723 0.00034 0.99112	Rotten

5. Conclusions

This article describes an apple odor detection system based on DSP and BP neural network. The system includes sample acquisition, A/D conversion, and nonlinear pattern recognition. It uses gas sensors to gather apples odors, via the signal processing and pattern recognition to identify the state of maturity of the apples. The main contents of the thesis include:

1) Choices gas sensors and its array. It takes six S_nO_2 gas sensors to make up array, and sets the temperature control system of reaction chamber, and sets air switching equipment between the reaction chamber and outside, and satisfy the gas sensors' requirements of the environmental. Experimental device is designed to capture the odors, and it sets up experimental procedures combined with other hardware circuitry and pattern recognition algorithms.

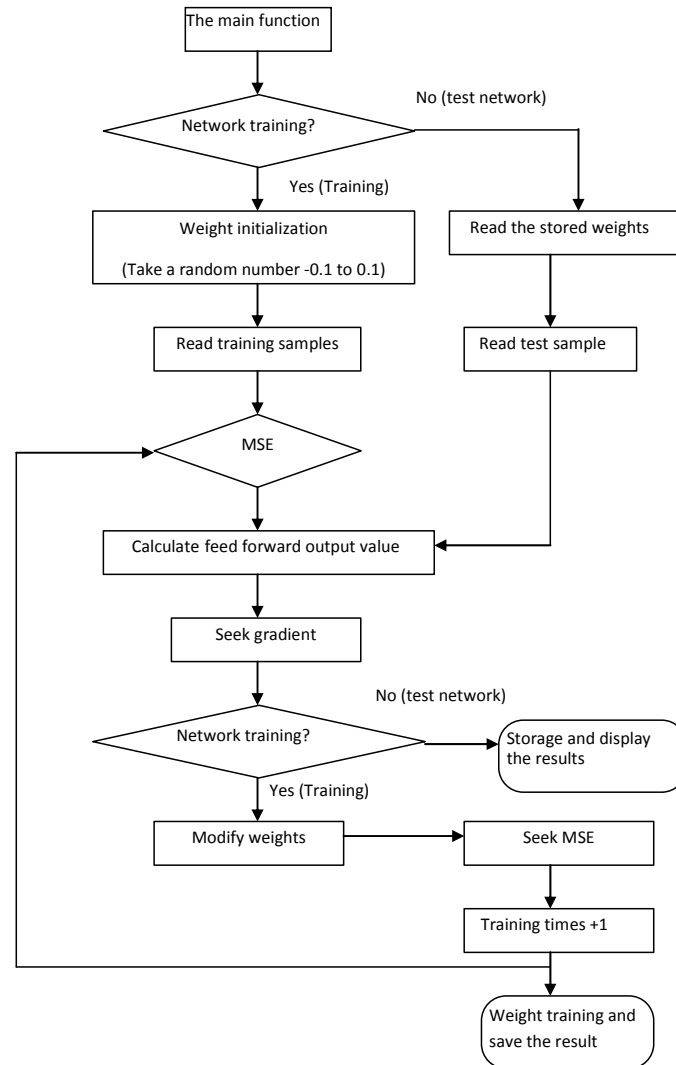


Fig. 10. BP neural network design process.

2) Design the hardware processing circuit. It uses cost-effective TMS320VC5402 chip as the processor, high precision MAX1403 as A/D converter, and introduces the interface circuit between DSP and A/D converter. Sets a 3×5 keyboard, and introduces DSP and keyboard interface with the different characteristics among varieties of apples. In order to achieve human-computer interaction better, the system design interface circuit between DSP and LCD, and the results can display on the LCD.

3) Sets pattern recognition system based on the neural network. Research on the software design of BP neural network on the DSP platform, and achieve the porting and testing work on the hardware.

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Parvej Ahmad Alvi

MEMS Pressure Sensors:
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So far, no book has described the step by step fabrication process sequence along with flow chart for fabrication of micro pressure sensors, and therefore, the book has been written taking into account various aspects of fabrication and designing of the pressure sensors as well as fabrication process optimization. A complete experimental detail before and after each step of fabrication of the sensor has also been discussed. This leads to the uniqueness of the book.

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