Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(6):820-826

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Design of intelligent sensor based on BP neural network and ZigBee wireless sensor network

Yun Wang[#] and Kunpeng Xie[@]

[#]*College of Computer and Information Engineering, Xinxiang University, Henan Xinxiang, China*
[@]*Henan College of Finance & Taxation, Henan Zhengzhou, China*

ABSTRACT

Intelligent sensor is a sensor in addition to the basic function, zero, self calibration, self calibration and has the function of automatic adjustment, along with logic judgment and the ability of information processing, can be a measurement signal conditioning or signal processing. Multilayer BP neural network is a one-way transmission of feedforward network, and it uses the error output estimation error directly leading layer to output layer, and then the error estimation error of a layer. The paper proposes design of intelligent sensor based on BP neural network and ZigBee Wireless Sensor Network. Experiments show that the proposed intelligent sensor has higher efficiency.

Keywords: BP neural network; ZigBee; Wireless Sensor Network; Intelligent sensor.

INTRODUCTION

In ZigBee network, the physical device supports two types of, full function device (Full Function Device, FFD) and reduced function devices (Reduced Function Device, RFD). Full function device (FFD) support all topological structure, can be used as a network coordinator (Coordinator) can also be used as a routing node and terminal sensor node, with the function of the controller; reduced function devices (RFD) can transmit information to FFD or from FFD to receive information.

Wireless sensor network node generally consists of a sensor module, data processing module, data transmission module and power management module is composed of four parts [1]. The sensor module is responsible for collecting the monitored area information and complete the data conversion, acquisition of information can include temperature, humidity, light intensity, acceleration and atmospheric pressure; data processing module is responsible for the control of the node processing operation, routing protocol, synchronous positioning, power management and task management; data communication module for wireless communication with the other nodes exchange control messages, and send and receive data.

BP neural network is a kind of three or more than three layers of neural network, including input layer, middle layer (hidden layer and the output layer). The connection between the upper and lower, and it is between each layer of neurons without connection. When a pair of learning samples provided to the network, neuron activation values from the input layer to the output layer of the middle layer of communication, network input response in each neuron in the output layer [2]. Next, according to reduce the target output and error direction, from the output layer after each middle layer gradually modify connection weights, and finally back to the input layer, this algorithm is called "error back propagation algorithm, namely BP algorithm."

The intelligent sensor has strong real-time performance; especially the dynamic measurement often requires data acquisition, calculation, processing and output within a few microseconds. A series of smart sensor are carried out under the support program. Such as the function of how much, basic performance, convenient use, reliable work,

mostly in a certain extent depends on the software design and the quality of the software; there are five main types of it. Including the scale conversion, digital adjustable digit zero, and it is nonlinear compensation, temperature compensation, filtering technology. The paper proposes design of intelligent sensor based on BP neural network and ZigBee Wireless Sensor Network.

2. Using ZigBee Wireless Sensor Network to Building Intelligent Sensor

ZigBee wireless communication technology is a new short distance wireless communication technology, with low power consumption, low rate, low delay and other characteristics, has a strong network capability and large network capacity, can be widely used in consumer electronics, home furnishing and building automation, industrial control, medical equipment and other fields. Because of its unique characteristics, the preferred technology of ZigBee wireless technology and wireless sensor networks, with broad prospects for development. ZigBee protocol uses the open system interface (051) hierarchical structure, the physical layer and media access layer by the IEEE802.15.4 working group to develop, and the network layer, security layer and application framework layer by the ZigBee alliance establishment.

Although Wi-Fi transmission speed can reach 11Mbps, the transmission distance can reach 100 meters, but its price is expensive relative to teach, and large power consumption, poor network ability. ZigBee technology focuses on the low cost, low power consumption and low rate wireless communication market, so it is very suitable for the application in the Internet of things in wireless sensor networks.

The intelligent sensor has a sensor information processing function [3]. Intelligent sensor with micro processor, has the ability of collecting, processing, exchange of information, is a product of integrated sensor and microprocessor combines. The sensory system intelligent robot consists of multiple sensor assembled, collecting information to the computer for processing, while the use of intelligent sensor can be decentralized information processing, thereby reducing costs. Compared with the general sensor, intelligent sensor has the following three advantages: through software technology can realize the information acquisition of high precision, and low cost; has the certain ability of programming automation; functional diversity.

The number of external components CC2430 rarely, it uses non balanced antenna, because the connection of non balance transformer can make better the performance of the antenna. Current CC2430 wireless microcontroller in the standby power consumption is only 0.2 μ A, current operating at 32 kHz crystal clock when the consumption of less than 1 μ A. Therefore, the use of small battery life can be as long as 10 year.

The ZigBee protocol uses hierarchical structure; each layer layer provides a series of special services: data entity provides data transmission services; management entity provides all other services. SAP service access point SAP layer provides interfaces; service primitives are supported by every SAP number to achieve the desired function. The hierarchical architecture of ZigBee standard is based on OSI seven layer models according to the actual need to define on the market and application.

Router mainly realize the expansion of network and routing messages, as the parent node in the network is potential, allowing the device to access the network more, routing nodes can only exist in a tree network and mesh network. The terminal equipment is the edge nodes of the network is connected with the monitoring object, is responsible for the actual, the device only with their parent node active communication, information routing specific all turn coordinator and router by its parent node and network with routing function completed. Each node is usually an embedded system, has collected data, receiving the order, processing of data, and receiving wireless data transmission, processing power, storage capacity, communication ability of each node is relatively limited.

The sensor node is designed in this paper the realization mechanism is serial communication module with IEEE/ZigBee transmission module to replace the traditional, information will be collected data wirelessly sends out. The node also package IEEE/ZigBee wireless communication module, microcontroller module, the sensor module and interface, DC power supply module and an external memory.

With P4_5 O, the CE signal in low level, and chip select K9F1208 effective; given P4_4 1, the CLE signal into a high level, so that the K9F1208 command allows signal effectively; with P4_3 O, the ALE signal in low level, so that the K9F1208 addresses allow signal without effect; the last empty write command the word of rK9F1208DATA, makes the WE signal in low level, the K9F1208 command register to receive from the data bus to the command word, and perform the appropriate action.

The nodes of wireless sensor network are composed of a software layer and hardware layer together to achieve functional [4]. Construction of wireless sensor network in the application of ZigBee chip, ZigBee chip hardware

built-in part of the function of physical layer and MAC layer, other top settlement outside of MPU, by writing to the MPU, to achieve the ZigBee protocol. Figure 1 is the internal structure of graph nodes. Node application part device according to different position control (such as temperature, sound, vibration, pressure, motion or reducing pollutants) play a different role. The device is very small, very cheap, mass-produced and deployment, so their resources (energy, storage, computation speed and bandwidth) limited. Each node has a wireless "> radio transceiver, a very small micro controller and an energy (usually battery). These devices to help each other and it are to transfer data to a computer.

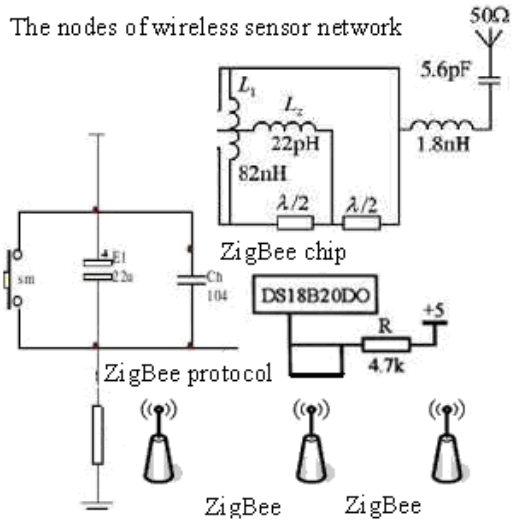

Fig. 1. Construction of wireless sensor network in the application of ZigBee chip

The intelligent sensor has strong real-time performance; especially the dynamic measurement often requires data acquisition, calculation, processing and output within a few microseconds. A series of smart sensor are carried out under the support program. Such as the function of how much, basic performance, convenient use, reliable work, mostly in a certain extent depends on the software design and the quality of the software; there are five main types of. Including the scale conversion, digital zeroing, nonlinear compensation, and it is temperature compensation, digital filter technology.

The IEEE802.15.4 standard on-chip uses ZigBee products. CC2430 using the latest SmartRF03 technology and 0.18 μ mCMOS process, and it is using 7 × 7 mm QLP48 package. The chip includes RF transceiver, also integrates enhanced 8051MCU, 32 / 64 / 128 KB Flash memory, 8 KB RAM, ADC, DMA and watchdog. CC2430 works in the 2.4GHz band, with low voltage (2 ~ 3.6 V) power supply, and the power consumption is very low (27 mA when receiving data, send data for 25 mA), high sensitivity (-97 dBm), the maximum output is 24dBm, the maximum transfer rate of 250 KB / s.

When the serial data into the XBee Pro module through the DIN pin, the data will be stored in the DI buffer, until it is sent out by the antenna transmitter; when the antenna receives RF data, receive data first enters the DO buffer, and then sent to the host serial. Under certain conditions, the module may not be able to process on the data in the receiving buffer immediately, this time on the need to CTS flow control in order to avoid receiving buffer overflow problem caused by the large number of serial data input. XBee Pro module through UART interface is directly connected with the UART interface controller, the hardware interface is very simple and practical.

In this paper, called the multiple subroutine modules is used to process the corresponding function. Initialization module to initialize the system and ZigBee module, frequency of the system to ensure the normal work of the RF oscillator frequency at 32 MHz; the information query module to query the nearby communication node; communication link module is used to establish the data link monitoring region between the nodes; data communication module is used for receiving and analysis to the wireless sensor network node the data information, processing data information is sent out.

Zigbee data acquisition module installed on the unit is building one layer or more convenient meter reading meter reading position. When the Zigbee module to receive data through the LED driver chip data output to the LED display, so the meter reading personnel can clearly reading, of which the first two used to display the occupants of the room, after six used to display water meter data corresponding to the room number. The keyboard is used to control the LED display. Among them, the intelligent keyboard and LED driver and USB driver chip RIC16C63 and

USBN9602 chip were used.

Zigbee network protocol, each node has two addresses: 64 IEEE MAC address and 16 bit network address. Each one using Zigbee protocol communication device has a unique 64 bit MAC address, the address is 24 bit OUI and 40 bit manufacturers address allocation, by OUI buy assigned by IEEE, since all of the OUI are specified by IEEE, so the 64 IEEE MAC address with a global uniqueness [5]. When the device is executing joins the network operation, they will use the extended address their communication. Successful entry into the Zigbee network, the network will be assigned a 16 bit network address to the equipment. Thus, the equipment can be used in other devices of the address and the network of communication, as is shown by equation1.

$$STD=\sqrt{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(F(i,j)-MEAN)^2/(M\times N)} \quad (1)$$

ZigBee can use satellite, sheet and mesh network structure, which is composed of a main node management of a number of child nodes, up to a master node can manage 254 child nodes; at the same time, the master node can also be composed of a layer of network node management, most can be composed of 65000 node network. ZigBee provides three levels of security, including non security settings, use access control list (ACL) to prevent illegal access to data and the use of Advanced Encryption Standard (AES128) symmetric cipher, with flexible and determine its safety properties.

Zigbee2007, Zigbee2006, DIGIMESH. The effective range with the setting module is automatically added to the network, and data communication with an arbitrary module network. Advantages are: module automatic networking, this distance can be extended. All the modules are a common type (outdoor visibility range 100M) and enhanced (outdoor room distance 1.6KM) two if need farther module, you can also use DIGIXtend products (distance to reach 64KM).

Intelligent sensor is a sensor in addition to the basic function, zero, self calibration, self calibration and has the function of automatic adjustment, along with logic judgment and the ability of information processing, can be a measurement signal conditioning or signal processing.

In industrial production, not for some product quality index by using the traditional sensor (e.g., viscosity, and it is hardness, surface roughness, composition, color and taste etc.) for rapid direct measurement and online control. A certain amount of production process and using the function relationship between intelligent sensor can directly measure and product quality index of (such as temperature, pressure, flow, etc.) are calculated by use of the established mathematical models of neural network and expert system technology, can be inferred from the quality of the products.

3. Using BP Neural Network to Construction Intelligent Sensor

BP (Back Propagation) neural network, namely the error back propagation error back-propagation learning process, the reverse forward propagation and error propagation consists of two processes. The input layer of each neuron receives input information from the outside world, and passed to the neuronal intermediate layer; the middle layer is the internal information processing layer, is responsible for the information transform, according to the ability of information demands, the middle layer can be designed as single hidden layer and hidden layer structure; the last hidden layer transfer to the output layer neurons information, after further treatment, complete forward propagation process of a learning, the output layer the outside world to output the results of information processing.

The neural network is learning or training. The so-called training, is in the sample set (or called the training set) input to the process of the neural network, according to certain rules, connection weights adjustment between neurons, so that the network can store the relationship between sample set in the connection weight matrix way, which makes the network to accept input, to give the appropriate output [6]. Learning is one of the most important functions of neural network. Neural network is through continuous simulation and learning of the neural network, the simulation results and performance error change curve correction network parameters finally get the weights of the network, an optimal threshold value and other parameters. Neural network evaluation of changing network parameters is the basis of learning rules. The learning rule of neural network is generally divided into supervised learning, unsupervised learning two rules.

This paper designs a BP network, the following function approximation formula 2: implementation of the nonlinear function approximation. Among them, 2, 4 respectively, k=1, simulation, by adjusting the parameters (such as the hidden layer node number of hidden layer nodes) that frequency and signal, the relationship between the hidden

layer nodes and function approximation ability.

$$g(x)=1+\sin(k*pi/4*x) \quad (2)$$

Neural network is obtained by applying a series of neurons connected together, is a kind of interconnection system complex, interconnected model variety, mainly has the following several types: 1, to the network, feed forward network, each layer of neurons received only a layer of neurons in the input, output and no relationship with neuron layer and the next layer, also won't give the front layer transmits a signal feedback. Input signal through layer is by layer sequence mode conversion, and ultimately by the output layer. 2, the feedback network in feedback network, from the output layer to the input layer with signal feedback, make adjustment feedback on the input of network weights and threshold, to improve the performance of network learning.

RBF network has the advantages of simple structure, simple training, and its learning convergence speed, can approximate any nonlinear curve, and has the unique characteristics of best approximation, and have no local minima; but the RBF neural network, how to choose the appropriate radial basis function, how to determine the number of hidden layer neurons, in order to make the network learning to ask precision, at the same time, hidden layer neuron center is hard to find, these are the important reasons causing the RBF neural network is widely used.

With the error back propagation correction unceasingly, network to the correct input mode response rate rising. With appropriate parameters, network convergence to have a smaller variance. BP neural network is as the most basic three layer feedforward network, including input layer, hidden layer and output layer. Figure 2 shows the principle of BP neural network structure diagram.

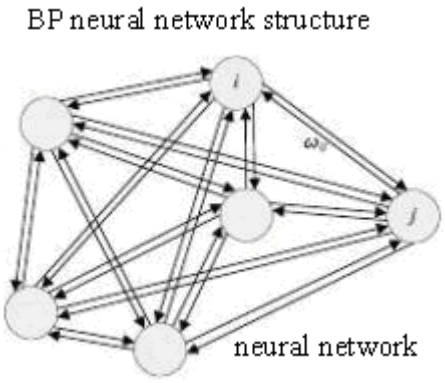

Fig. 2. The principle of BP neural network structure diagram

In order to support the information processing model, there are three important technologies is formed and fusion, which is a wireless sensor network, low power embedded computer and intelligent sensor. The computer and the intelligent sensor technology are developing quickly and relatively mature. Wireless sensor network is still in the formation. In order to provide perceived environmental condition to the workers, we must construct the model, implementation of infrastructure wireless intelligent sensor network based on. Construction of perception environment using wireless sensor network has a built-in intelligent sensor - regardless of whether the user can obviously feel the - called smart sensor.

Dynamic response of capacitive sensors due to the electrostatic attraction between the plates is small, energy need minimal, because the movable part of it can be very small, very thin, the quality is light, so the natural frequency is very high, dynamic response time is short, can rate work in a few THz frequency, especially suitable for dynamic measurement. And because of its dielectric loss is small, can use high frequency power supply, so the system works in high frequency. It can also be used for the measurement of rapid change.

Intelligent sensor market growth makes the intelligent sensor standard emerge as the times require. The IEEE1451 standard defines a standard transducer interface module (STIM), of which, including sensor interface, signal conditioning and conversion, calibration, linear and network communication. In essence, the standard for intelligent sensor with plug and play function, this can be connected to the intelligent sensor network. The standard is composed of IEEE 1451.1, 1451.2, P1451.3 and P1451.4. At present, the new IEEE1451.5 (wireless sensor communication interface standard) formed the contention of a hundred schools of thought with the situation of the ZigBee alliance, Z-Wave alliance, Wireless USB sensor networks.

In BP network, as long as the proper hidden layers and hidden nodes, the nonlinear mapping relationship between BP networks can approximate arbitrary, and BP algorithm is a global approximation method, has good generalization ability [7]. The so-called generalization ability refers to the ability of neural network for fresh samples. Usually expect the training samples to train the network has good generalization ability; also is the ability to give a reasonable response of the new input. Deficiency of BP network is the BP algorithm takes a long training time, slow convergence, and is easy to fall into local extremum, determine the number of hidden layer and hidden node number has been no better method, as is shown by equation(3).

$$\delta_{oj}(k)=-\frac{\partial E}{\partial Net_j(k)};\frac{\partial E}{\partial w_{ij}}=\frac{\partial E}{\partial Net_j(k)}\cdot\frac{\partial Net_j(k)}{\partial w_{ij}} \tag{3}$$

Where this error function $E(k)=\frac{1}{2}\sum_{u=1}^{p}[d_i(k)-y_i(k)]^2$, and note: $Net_j(k)=\sum_{i=1}^{p}w_{ij}\theta_i$, and $a_p=-1, w_{jp}=x_j$, the sample number $k=1,2,\cdots,N$ (number of samples). The network layer node number of input and output layer nodes need according to the specific problem analysis. The input layer neurons may accord need to solve problems and data representation method to determine. Nodes in the output layer according to the user requirements to determine the node is needed, the predicted results obtained contains number. The selection of the hidden layer nodes is a very complicated problem. There is a hidden layer of the neural network, as long as the number of hidden layer node is enough, can approximate any nonlinear function.

4. Design of Intelligent Sensor based on BP Neural Network and ZigBee Wireless Sensor Network

Intelligent sensor parameters may be varied. But the composition from the function module, it mainly includes data acquisition module, compensation and correction module, data processing module, data communication module, man-machine interface and task management and scheduling module and other functional units. Thus the intelligent sensor SOC design process based on IP: universal module model is first established intelligent sensor; then divide each module function specification, making the interface protocol between modules and standard; then design a series of general purpose IP nuclear; finally the required common IP nuclear build together constitute the intelligent the complete sensor system.

In wireless sensor networks, FFD is forwarding and routing capabilities have enough storage space to store routing information, and the processing ability to control the corresponding enhancement. ZigBee also supports third kinds of nodes, namely network host or gateway nodes, routing and to external system interface or coordination with other networks. FFD sometimes play the role of the gateway. A network requires only a network coordinator, other devices can be RFD, also can be FFD. RFD prices are much cheaper than the FFD, the system resource occupied only about 4 kB, and therefore the overall network cost is relatively low.

And given all the weights W_{ij} , initial $(I=1,2,\cdots,p; j=1,2,\cdots,q; h=1,2,\cdots,n); n, p, q$ and neuron threshold values were layer unit number. The corresponding number unit input layer by K is sample value $S(k)[s_1(k)s_2(k)\cdots s_n(k)]^T$; as the activation value $s_h^{(k)}$, the weight matrix *V*, the A is activation of each unit values for the following formula 4.

$$a_i(k)=f(\sum_{h=1}^{n}v_{hi}s_h(k)+\theta_i)=f(\sum_{k=1}^{n}v_{hi}s_h(k)+\theta_j(k)) \tag{4}$$

The number of external is components CC2430 little. It uses a non balanced antenna, non balance transformer connected to better the performance of the antenna. The non balance transformer circuit composed of the capacitor C9 and the inductor L1, L2, L3 and a PCB microwave transmission line, the whole structure to meet the matching resistor RF input / output (50 ohms) requirements. Exchange of internal T/R switching circuit is between LNA and PA. R1, R2 bias resistor. The R1 is mainly used to provide working current suitable for crystal oscillator is 32 MHz. With 32 MHz quartz resonator and two capacitors (C1, C2) 32 MHz crystal are oscillator circuit. Voltage regulator voltage on all 1.8 V pins and internal power supply, Cl0, C12 decoupling capacitors are used for power supply filtering.

Zigbee remote terminal user module through the decoding mode is to intelligent data acquisition, and then through the module RF transmission to Zigbee data acquisition module. The collected data is sometimes delayed, the main

reasons may be caused by Zigbee RF part, and therefore, even after a lot of experiments, the RF modulation of Zigbee, the collected data is more accurate.

The development of intelligent sensor is mainly divided into three stages, namely, the intelligent digital phase compensation and calibration stage, intelligent and network stage. The third stage has reached sensor, signal detection and processing, logic judgment, two-way communication, closed loop control, self inspection and self diagnosis, intelligent correction and compensation calculation, function, network communication and other functions.

Wireless sensor network node of the network Zigbee input feature factor node layer neuron number is the system (variable) number; the output layer neuron node number is the number of target. Hidden layer nodes selected by selecting experience, usually set as input layer node number 75%. If the input layer has 7 nodes, 1 node in the output layer, the hidden layer can temporarily set to 5 nodes, which form a 7-5-1 BP neural network model. In the training, practical but also on the hidden layer nodes of different number 4, 5, 6 respectively, finally determine the network structure of the most reasonable. To determine the initial weights, the initial weights are not completely equal to a set of values. Have demonstrated, even determine the existence of a group of non equal the system error smaller weights, if the initial set of Wji values are equal to each other, they will always remain equal in the learning process. Therefore, in the process, we design a random number generator program, a random number generating a set of a 0.5~+0.5, as the initial weights of the network.

The topological structure of network layer is responsible for the establishment and maintenance of the network connection, the main functions include mechanism used in equipment connect and disconnect the network, as well as adopted in the frame information transmission in the process of security mechanism. In addition, also includes equipment route discovery and route maintenance and care. And, it is the network layer to complete a jump (one - hop) neighbor device discovery and relevant node information storage. A ZigBee coordinator to create a new network, addition of new equipment allocation short address etc.. And, the network layer is to provide the necessary functions, ensure that the ZigBee MAC layer of normal work, and to provide appropriate service interface for the application layer.

Intelligent sensors and communication sub stations bus network, intelligent sensor as from the machine, the measurement results are sent to the communication substation, the substation remote transmission to the monitoring computer. Zigbee is used for remote meter reading data by European standards, it has the following characteristics: two wire bus, not divided into positive and negative polarity, the construction is simple; the digital signal transmission level features unique, strong anti-interference ability; bus can provide a regulated power supply of 3.3v/3ma for each communication node, providing two power supply for instrument; can use any bus topology structure, system network low cost, flexible expansion.

CONCLUSION

The paper proposes design of intelligent sensor based on BP neural network and ZigBee Wireless Sensor Network. In ZigBee protocol in application layer is composed of application support sub layer, ZigBee equipment configuration layer and user application program. The application layer provides a high-level protocol stack management function, the user application program set by the manufacturer, it uses the application layer management protocol stack. BP network can learn and store a lot of input - output model mapping, without prior to reveal the mathematical equations describing the mapping relationship. Its learning rule is to use the method of steepest descent, to constantly adjust the network weights and threshold by back propagation network, the minimum error sum of squares.

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