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USING INTELLECTUAL MEANS FOR DIAGNOSIS OF WIRELESS SENSOR NETWORK

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ВИКОРИСТАННЯ ІНТЕЛЕКТУАЛЬНИХ ЗАСОБІВ ДЛЯ ДІАГНОСТУВАННЯ БЕЗДРОТОВОЇ СЕНСОРНОЇ МЕРЕЖІ

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The paper discusses the adaptive neuro-fuzzy inference system ANFIS for intellectual diagnostics of large-scale wireless sensor networks. The solution for functional diagnostics of wireless sensor network is realized by the expert system designed on the knowledge base in the form of a neuron-fuzzy network.
***Keywords**: ANFIS, wireless sensor network, diagnostic parameters, neural network, fault detection, fault tolerance.*

1. Introduction

Last advances in low-power wireless technologies have enabled us to expand of wireless sensor networks (WSN) on different new networked systems. There is wide variety of WSN applications, such as environment monitoring, scientific observation, emergency detection, field surveillance, and structure monitoring, and so on. In those applications, hundreds or even thousands of sensor nodes are assumed to be deployed in the target fields. Besides many algorithmic studies that focus on designing efficient schemes or protocols to coordinate large-scale sensor networks, there are also systematic studies that make efforts in optimizing sensor networks in practice, which are usually tested on lab scale test beds or small scale deployments.

In the general case, WSN is a cluster of the small nodes that are organized into a supportive network. It comprises from the sets of spatially disseminated independent devices using sensors to monitor the physical or environmental conditions: temperature, light, sound, pressure, humidity, vibration etc.

Remote sensor devices commonly have insufficient vitality and transmission limit, which cannot coordinate the transmission of a substantial number of information gathered by sensor nodes. WSN are normally fault-prone and their good quality is vigorously impacted by issues. A fault is essentially a sudden change in a framework, in spite of the fact that it might happen because of different reasons including battery exhaustion, radio impediment, de - synchronization, or separation. These failed nodes may decrease the quality of service (QoS) of the entire WSN. That is why it is important to study the fault detection methods for nodes in WSN.

Existing approaches to diagnosing sensor networks are generally sink-based and grounded on actively pulling state information from all sensor nodes to the central point what is referred to as "centralized analysis". However, the sink-based diagnosis tools incur huge communication overhead to the traffic sensitive sensor networks. Also, due to the unreliable wireless communications, sink often obtains incomplete and sometimes suspicious information, leading to highly inaccurate judgments. We observe that it is always more difficult to obtain state information from the problematic or critical regions.

2. Releated works

The WSN node status can be divided into two types [1-3]: normal and faulty. Faulty in turn can be "permanent" or "static". The so-called "permanent" means failed nodes will remain faulty until they are replaced, and the so-called "static" means new faults will not generated during fault detection. In [2, 3], node faults of WSN were divided into two categories: hard and soft. The so-called "hard fault" occurs when a sensor node cannot communicate with other nodes due to the failure of a certain module (e.g., communication failure due to the failure of the communication module, energy depletion of node, being out of the communication range of entire mobile network because of the nodes moving and so on). The so-called "soft fault" happened when the failed nodes can continue to work and communicate with other nodes (hardware and software of communication module are normal) but the data sensed or transmitted is not correct.

In [4] is given the fault types of the classification for the WSN: data-centric viewpoint; system centric viewpoint; distributed viewpoint; duration viewpoint; and component viewpoint. The intelligent diagnostic

system (IDS) is proposed in [5, 6]. Expert diagnosis of the IDS uses neuro-fuzzy knowledge base. For the formation of logical conclusions knowledge is used in the form of fuzzy function with linguistic variables [7]. The use of the IDS with neuro-fuzzy knowledge base to solve problems of diagnosing complex technical objects extends the capabilities of such a class of intellectual systems, allows for an expert estimation of more variants, with increasing the reliability and accuracy of the obtained results, with equal computational resources.

3. Setting the task

WSN node faults are usually due to the following causes: the failure of modules (such as communication and sensing module) due to fabrication process problems, environmental factors, enemy attacks and so on; battery power depletion; being out of the communication range of the entire network.

The main purpose of this work is the development of automated methods for intelligent functional diagnosis for WSN.

In the process of achieving the main goal, the following tasks are formulated and solved: conducting a continuous analysis of the technical state of the WSN in the process of functioning without disturbing functional links; operational receipt of information about the technical state of the WSN at an arbitrary time; elimination of the need for additional stimulus signals for WSN in the diagnostic process; possibility of predicting deviations of the technical state of the WSN from normal in the process of obtaining current data from sensors.

4. Intellectual diagnostic of wireless sensor network

Information part of IDS provides accumulation, storage and transfer of information to other parts of it, and also implements the interface of the end user. Data from sensors is unstructured and requires further processing. The need for real-time decision-making results in the fact that the number of decision trees constructed according to incoming data should be equal to the number of counts (analogue of conveyor data processing). Tree decision trees for each time interval require significant memory costs for the IDS, so averaging for input data is usually used to reduce such costs. However, information on current changes in data from sensors over a period of time may be lost, which is a significant disadvantage of the methods for calculating averages. The problem of a significant amount of complex object data can be solved by using these data as a training sample for neuro-fuzzy knowledge base.

There are mainly two sorts of node faults in WSN. The primary type is function fault, in which the sensor node cannot convey the data packet suitably. The second type is data fault, in which the node can convey the information bundle effectively yet the information gathered by sensor node is off base.

To evaluate the health of a sensor node, a binary logic function X is often used with a set of its values {0,1}. At the same time, if x is 1, then the node is operational and if x is 0, then the node is inoperable. However, fuzzy **X** values are required to use in the IDS.

For the fuzzification of input the crisp values convert of the input variables **X** and output variables **Y** into fuzzy, select the appropriate distribution functions and the number and values terms.

We consider a crisp variable between “0” and “1” and it has five terms with the following limits. – "0-0.1" - "Very Close to 0" ; – "0.1-0.2" - "Close to 0"; – "0.2-0.8" - "AverageValue"; – “0.8-0.9” - “Close to1”; – "0.9-1" - "Very Close to 1".

We apply this fuzzification for all input variables and for output variables. At the figure 1 is shown five membership functions of the input variable X.

To implement the diagnostic algorithms, we use the MatLab and ANFIS system.

The adaptive network-based fuzzy inference systems (ANFIS) is used to solve problems related to parameter identification. ANFIS is basically a graphical network representation of Sugeno-type fuzzy systems endowed with the neural learning capabilities. The network is comprised of nodes with specific functions collected in layers. ANFIS is able to construct a network realization of IF / THEN rules. All computations can be presented in a diagram form. ANFIS normally has 5 layers of neurons of which neurons in the same layer are of the same function family.

Layer 1 (L1): Each node generates the membership grades of a linguistic label.

Layer 2 (L2): Each node calculates the firing strength of each rule using the *min* or *prod* operator. In general, any other fuzzy AND operation can be used.

Layer 3 (L3): The nodes calculate the ratios of the rule’s firing strength to the sum of all the rules firing strength. The result is a *normalised firing strength*.

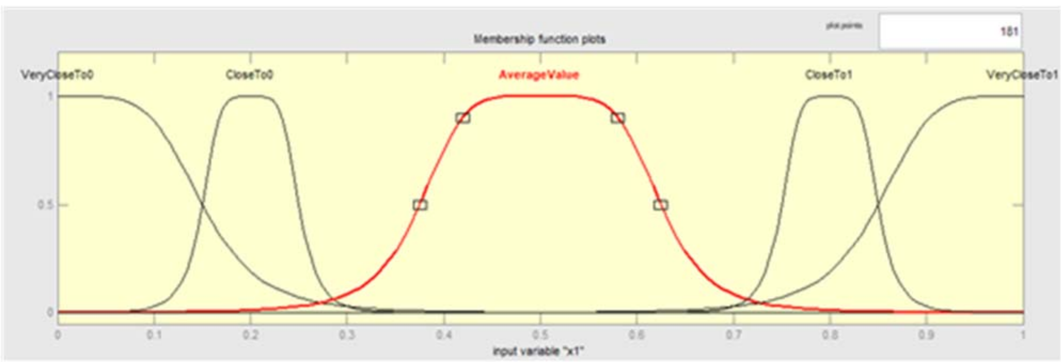

Fig. 1. Membership functions of the input variable X

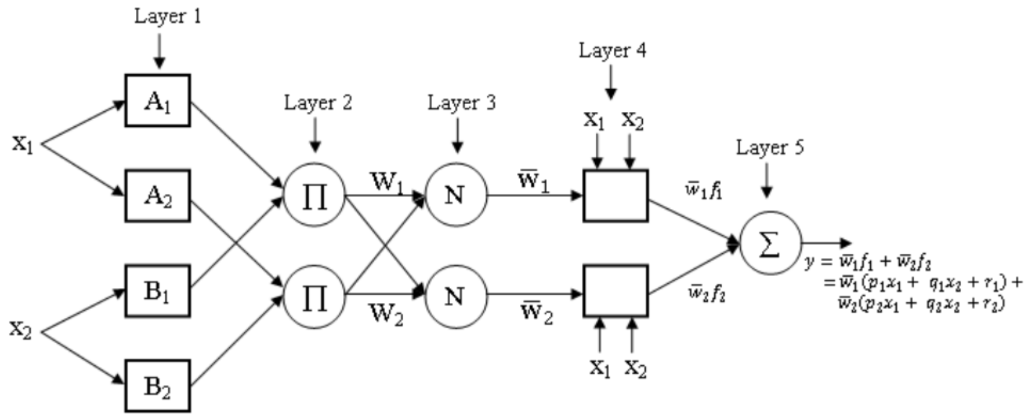

Fig. 2. Structure of the ANFIS network

Layer 4 (L4): The nodes compute a parameter function on the layer 3 output. Parameters in this layer are called *consequent parameters*.

Layer 5 (L5): Normally a single node that aggregates the overall outputs the summation of all incoming signals

For an example of the functioning of the IDS, we believe that it is possible to measure numerical values for 24 diagnostic parameters (DP1, ..., DP24). The values of the sensor readings are obtained at discrete moments of time t0, t1, t2, ..., ti. The time interval (ti+1-ti) between two adjacent dimensions is selected taking into account the speed of the change of diagnostic parameters. All 24 characteristics will play the role of diagnostic parameters in the process of intellectual diagnosis.

Conclusion

The IDS considered in this paper, along with the use of traditional knowledge base, allows us to use the neural networks and to formalize the above practical problems that arise during the operation of various technical objects to achieve the main goal of work.

The ANFIS algorithm is used in order to improve the efficiency and accuracy of diagnostic sensor node. Because of using different ways to train and simulate ANFIS data within a single wireless sensor node, we generate a kind of intelligent system.

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Кривуля Г.Ф., Сергієнко В.І. Використання інтелектуальних засобів для діагностування бездротової сенсорної мережі

Запропоновано систему адаптивного нейро-нечіткого висновку ANFIS для інтелектуальної діагностики масштабних бездротових сенсорних мереж. Рішення задачі функціональної діагностики реалізується експертною системою на основі бази знань у вигляді нейро-нечіткої мережі.

Ключові слова: *ANFIS, бездротова сенсорна мережа, діагностичні параметри, нейронна мережа, виявлення несправностей, відмовостійкість.*

Кривуля Г.Ф., Сергиенко В.И. Использование интеллектуальных средств для диагностирования беспроводной сенсорной сети

Предложено использование адаптивной системы нейро-нечеткого вывода ANFIS для интеллектуальной диагностики крупномасштабных беспроводных сенсорных сетей. Решение задачи функциональной диагностики реализуется экспертной системой на основе базы знаний в виде нейро-нечеткой сети

Ключевые слова: *ANFIS, беспроводная сенсорная сеть, диагностические параметры, нейронная сеть, обнаружение неисправностей, отказоустойчивость.*

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