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Adaptive Regulation and Partial Failure Recovery of Immune Network

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Abstract

In order to solve the problem that taking network reconfiguration when the circuit is partial failure leads to a waste of computing resources and long repair time, the article proposes a way to limit the failure influence in a local scope through adaptively regulating the immune network. On the basis reviewing of immune network theory, a immune network structured representation method is raised. In order to make the immune network have fault tolerant ability, adaptively adjusting the structure of the immune network can dynamically change the immune network function. Lastly, a partial failure recovery experiment of the motor control circuits is applied to test the performance of immune network adaptive regulation.

Keywords: *immune network, adaptive regulation, structured, partial failure recovery*

1. Introduction

In 1974, based on the modern immunological research and awareness of antibody molecules uniqueness, an America Nobel Prize winner Jerne, came up the famous Idiotypic Network Theory [1] on count of the Clone Selection Theory and elaborated the self-adaptive adjustment of immune system for immune response in detail. In view of Jerne's work, Perelson proposed the idiotypic network model based on probability in 1989 and focused on the state transfer of individual genetic networks [2]. In Perelson's study, Lymphocytes are not isolated, but exchange information through the lymphatic network, another more, antibodies and antigens interconnect to form a network reaction. Subsequent researchers continuously went deep into immune theory [3], model design [4], algorithms realization [5] and engineering application [6] and got lots of outstanding achievements.

On the basis of the study in artificial immune system, the article synthetically compares the artificial theory and development of immune network, recognizes that the core of the immune network is adaptive adjustment [7], further more, adaptability is based on learning mechanism of immune network. Hence, structured representation of immune network is firstly studied, then the morphology of immune network is changed through adaptive regulation, finally a partial failover experiment of combinational logic circuit is done to test the performance of immune network adaptive regulation.

2. Structured Representation of Immune Network

Artificial immune network is composed with circuit PE (programmable element) units [8], immune cells and some connected lines, the network structure is shown as in Figure 1.

Each of circuit PE unit and immune cell in network is regarded as a node and the network connect lines are takan as information chains, there upon, an artificial immune network S can be structured into a network with n nodes and m information chains. If a immune network has no error, in otherwords, all of the n nodes and m information chains are normal.In this case the network is called as autograph. Supposed that c_i is a node and l_j is a chain, thus an artificial immune network S can be expressed as:

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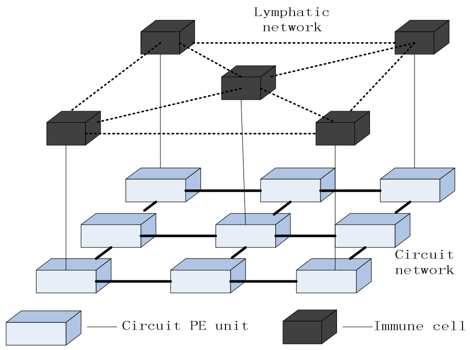

Figure 1. The structure of immune network

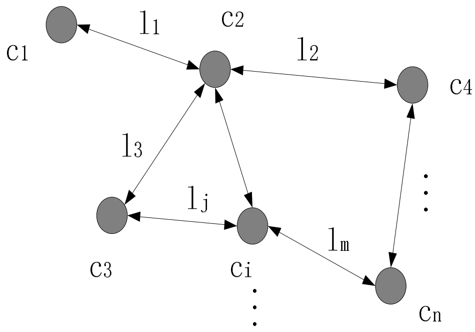

Figure 2. The initial structured immune network

$$\begin{cases} S = (C, L) \\ C = \{c_i \mid i = 1,2,...n\} \\ L = \{l_j \mid j = 1,2,...m\} \end{cases}$$

In that expression, C is represented all nodes in the artificial immune network S; L is on behalf of all chains in the immune network [9]. The initial structured schemtic diagram of Immune network is shown as in Figure 2.

The priority can be set according to task allocation in the collection C, then orderly each node is selected by the importance of nodes. The Figure 2 shows the node priority of initial state. Supposed that s (S) is the state of immune network, s(c_i) is the state of c_i. s(l_j) is the state of the information chains. Normal (x) is defined as a normal state function, the function expression is shown as:

$$Normal(x) = \begin{cases} 1 \quad , \quad x \quad is \quad normal \\ 0 \quad , \quad x \quad is \quad abnormal \end{cases}$$

Therefore, the relationship between the state of immune net S and its nodes and information chains can be expressed as the following:

$$Normal(s(S)) = \prod_{i=1}^{n} Normal(s(c_i)) \bullet \prod_{j=1}^{m} Normal(s(l_j))$$

When any nodes or information chains in immune network S appears failure, the system changes into the abnormal state ,which is called Non-self [10] .On the basis of that, the operation of Non-self and Self might realize the adaptive regulation and failure self-repair application of immune network in the help of the algorithms.

3. The Partial Failure Recovery Application of Artificial Immune Network

3.1. Adaptive Regulation of Immune Network

The c_i , i=1,2,…n ,is the basic circuit PE unit node of artificial immune network S, if all the basic function nodes of immune network can normally work, immune network S works regularly and the network S is called the normal state at this moment. The immune nodes composed by immune cells are represented as m_k , k=1,2,…, The goal of adaptive regulation in an immune network is to repair the failed function nodes with immune nodes. Assumed that the node c_d appears partial failure after it is damaged , immune node is taken as a replacement node, then the injured node is replaced by immune node. The output of the damaged node must be shielted to prevent the entire system damage before related information chain is repaired resulted. With the adaptive adjusting algorithm, the network structure is adjusted to protect the largest function of injured network based on the damaged node type and its priority. The steps of the algorithm is described as following:

Step 1: the function, priority and information chain of injured node is firstly determined in proper order;

Step 2: the priority and the configuration information of information chain are temporarily stored;

Step 3: information chains output of related injured node are sheild;

Step 4: the function immune node is adjusted to the same function of damaged node, then the injured node of this lacation is replaced by the immune node;

Step 5: After replacing injured node, the temporarily stored information is downloaded and original network configuration is retrievaled.

3.2. The Hardware Platform

Adaptive regulation adjustment experiment of artificial immune network is taken on an experimental platform of brushless DC motor control system, which uses language HDL to implement hardware connection, and implements algorithm description with c++. In the experiment, in order to find the optimal individual[11] 'the algorithm does a fitness assessment according to the input/output relation.The I/O connection is consisted with the PE unit circuit network. when the optimal individual is computed out , it is download to hardware so as to automatically generate circuit structure. The physical diaggram of DC motor control circuit is shown in Figure 3, and Figure 4 is the structure of reconfigurable the PE circuit network.

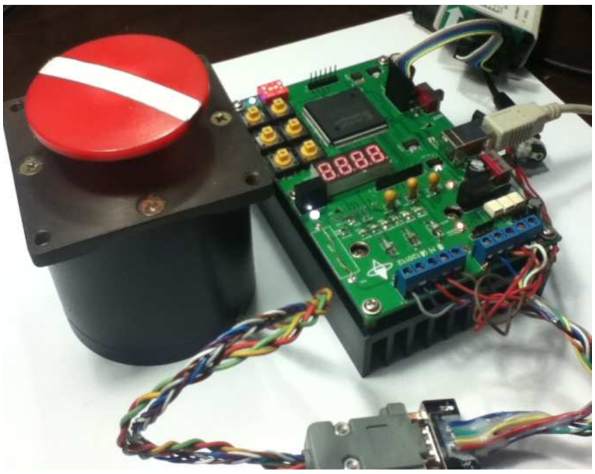

Figure 3. The physical diaggram of DC motor control circuit

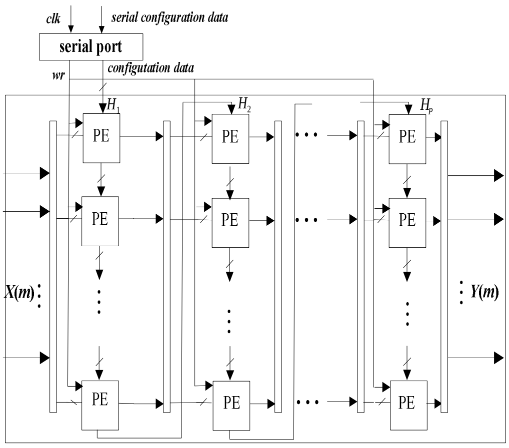

Figure 4. Reconfigurable the PE circuit network

According to the target circuit requirement, it can not only choose a variety of different logic gate as a functional unit, but also increase the number of species and the door. In Figure 5, AND, OR, NOT, XOR are chose as basic functional units, 4 choose 1 multiple selector is selected as optional unit. Change multiple selector configuration bits to make different circuit function come true. Signal input is selected by switching the eight choose 1 multiple. Each input of each PE unit can choose a signal as input from the top of the eight signals. The cascade method of the PE units is shown in the Figure 6. The configuration information of PE unit can be modified to achieve input signal selection. Further more, modify the configuration information of PE unit network to make the circuit network function change come true.

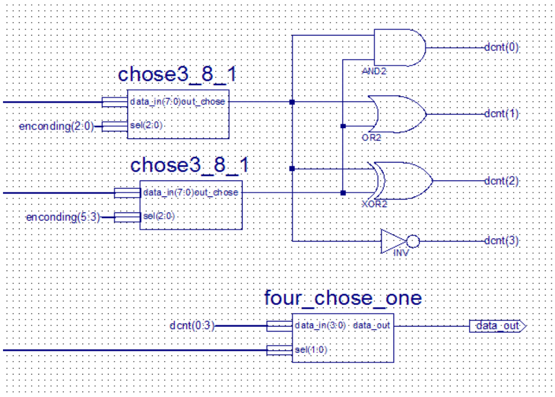

Figure 5. The basic PE units of DC motor control circuit

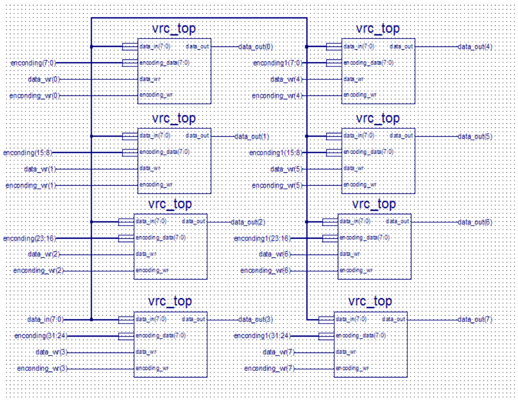

Figure 6. The combination of PE units

The experiment simulates the SA-1 (stuck-at-1) failure [12] ,which appears in analog and digital circuits. A SA-1 failure means that the circuit output is fixed at 1. When the C1 node injects SA failure, owing to the fixed output , it causes subsequent PE units getting the wrong output, consequently, the whole motor circuit is abnormal as a result of local single node error . At this point, the immune network S gets into abnormal state.

Firstly, a network troubleshooting analysis is taken to locate the abnormal node c1 through the algorithm. In order to limit the node abnormal in a local scope, the output relationship of abnormal node must be shielt. An 8-bit registers is designed to store the PE unit 8-bit configuration information.The circuitry is shown as Figure 7:

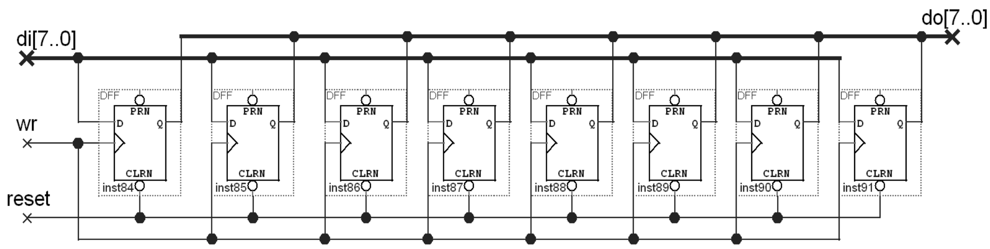

Figure 7. register circuitry

The register is consist of 8 D trigger, which storage and parallelly transmit the 8-bit configuration data, including the abnormal node function and information chain relationships. Normally, if WR is in falling edge, the momery downloads data; else it keeps data. when reset is in low level, the data is zero-cleared.

3.3. Failure Recovery

The next, the abnormal node is replaced by nearby immune node, the operation is not a simple physical alternative, but an intelligent feature alternative to abnormal node with the algorithm. The configuration information is extracted from the registers after replacement, the algorithm reconfigures information chain adaptively, as shown in Figure 8.

Information chains l1, l2, l12 are no longer selected, in other words, information chain are disconnected. the new links l1', l2' is adjusted to the input nodes IN0, IN2; immune information chain Lm0 to lm3 need to be linked selectively with a new link to lm2 and other information chains remain vacant, Figure 9 is the new immune network after the local adaptive adjustment. Lastly, output shielding is unlocked to recovery link. The fitness assession is maken to new network. adaptive adjustment is got end after it comes to repair requirement. Run immune network S' to make the repair come true. The Final repaired DC motor circuit is as shown in Figure 10.

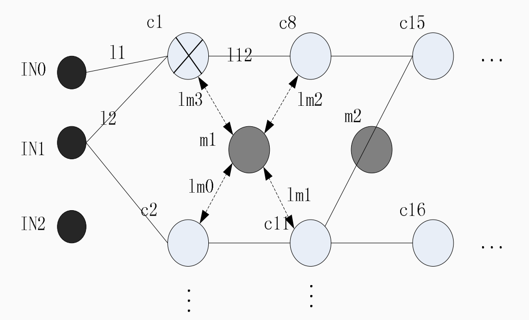

Figure 8. Local single node failure of immune network

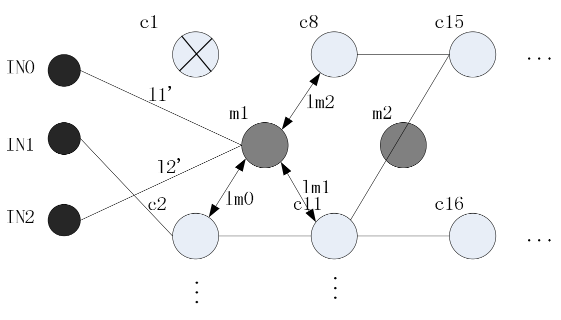

Figure 9. adaptive adjustment of local Immune network

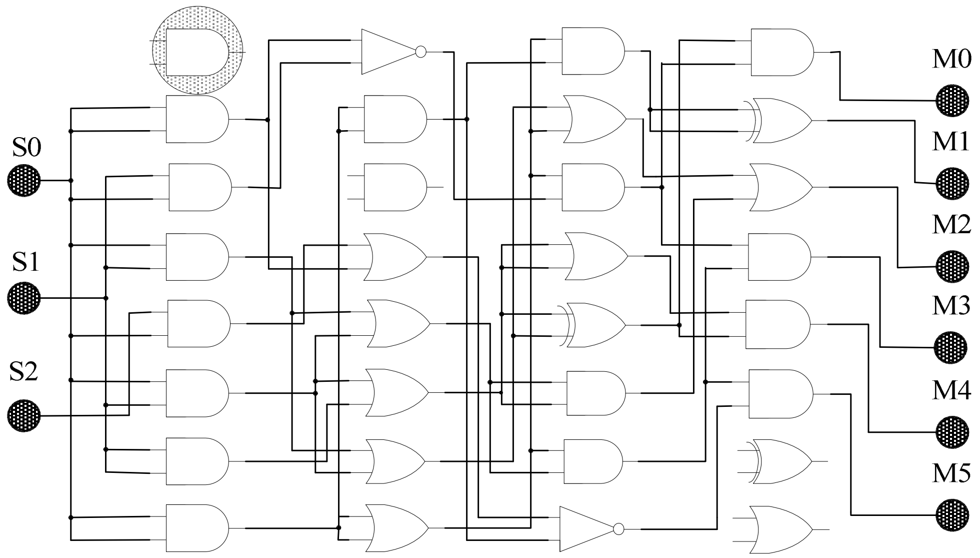

Figure 10. The Final repaired DC motor circuit

The immune network adds immune node into the PE unit node network and restores network functionality ,then achieves fault repair in a motor control circuit. It is thus clear that self-adaptive regulation of artificial immune network is an effective and useful newly method. After expanding the method, it can be applied to communication, control, industrial, military and other fields.

4. Conclusion

Adaptive regulation of immune network can not only tolerate node failure, but also maximize guarantee the reliability of the network. The impact of faulty unit is limited in the local scope with the help of immune node, which avoids reconstruction of the entire network. The system failure ,due to a few nodes failures, is avoided and it not only reduces unnecessary waste of computing resources, but also wins precious repair time to fault correcting of critical equipment.

For the past few years, although study of artificial immune network have achieved amazing results. compared with the theory of artificial neural networks and other mature, this technology is still lack a massy mathematical foundation and rigorous mathematical analysis. Learning, memory, self organizing and self research to network is not enough and integrate application is lack to practical network including internet, traffic networks, power networks, disaster warning network. So, more research on high reliability artificial immune network is necessary, and this technology will appliy to engineering practice and the realitic network system might be continually improved with such immune network system.

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