Case-Based Fault Diagnostic System

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ABSTRACT

Nowadays, case-based fault diagnostic (CBFD) systems have become important and widely applied problem solving technologies. They are based on the assumption that “similar faults have similar diagnosis”. On the other hand, CBFD systems still suffer from some limitations. Common ones of them are: (1) failure of CBFD to have the needed diagnosis for the new faults that have no similar cases in the case library. (2) Limited memorization when increasing the number of stored cases in the library. The proposed research introduces incorporating the neural network into the case based system to enable the system to diagnose all the faults. Neural networks have proved their success in the classification and diagnosis problems. The suggested system uses the neural network to diagnose the new faults (cases) that cannot be diagnosed by the traditional CBR diagnostic system. Besides, the proposed system can use the another neural network to control adding and deleting the cases in the library to manage the size of the cases in the case library. However, the suggested system has improved the performance of the case based fault diagnostic system when applied for the motor rolling bearing as a case of study.

Key Words: case-based reasoning, Motor Rolling Bearing vibration, fault diagnosis, neural network,

1- INTRODUCTION

Recently, there has been great importance for the fault diagnostic case based reasoning (CBR) systems in many fields. CBR is a well known and newly emerging artificial intelligence technique different from other reasoning approaches based on rule and on model. It has the advantages of simplified knowledge acquisition, high solution efficiency and easy knowledge accumulating. It is widely used in many research fields such as fault and disease diagnosis, market planning, engineering designing and so on. CBR reuses the past cases and experiences in a database called the case base to find a similar solution to the problem of a new situation. In a CBR system, the key factors that influence the retrieving of similar cases to adapt them till achieve the needed solution. One of the main limitations of the case based systems is they cannot find diagnosis of the faults when faced with new ones that are not having similar stored cases in the case library (1,2). Another limitation for the case based fault diagnostic system is the increasing of the number of the stored cases in the case library due to: (1) the natural of the fault diagnostic processes is dealing with a great number of cases to cover the multiple combinations of the components and events appeared in the modern complex systems that represent the space of the problem. (2) any high accuracy CBR diagnostic system required a lot of cases in the case library to retrieve the similar case(s) and adapt it (them) till solve the new fault diagnostic cases especially for the modern complex systems (3,4).

On the other hand, it is found that the neural networks (NN) have proved their great success for the classification, diagnosis, pattern recognition, etc. However, the proposed system introduces using NN to diagnose the new faults that cannot be found in the library and feed it to the case based library.
to be used in the future. Besides, the proposed system introduces the uses of NN to classify the cases in the case library into various classes for maintaining the CBR systems.

The reminder of this paper is organized as: Section 2 represents the CBR diagnostic system. Section 3 represents an overview of the neural networks. Section 4 deals with the proposed systems. Section 5 represents the applicability of the proposed system for diagnosis of the motor rolling bearing and its evaluation. While, section 6 deals with the conclusion.

2- CASE BASED REASONING:

CBR is a problem solving technique which complements the solution, acting as a memory of past cases which can be consulted in order to identify similar cases for the new problem. CBR is described as a cyclical process comprising of the four - Re’s. These are: (1) retrieve the most similar case, (2) re-use the case to attempt to solve the problem, (3) revise the proposed solution if necessary and (4) retain the solution as part of the new case as shown in figure (1).

In a case-based system, a problem is matched against cases in the case base, and one or more similar cases are retrieved. Case indexing involves assigning indices to cases to facilitate their retrieval. A solution suggested by the matching cases is then reused. Unless the retrieved case is a close match, the solution will probably have to be revised, producing a new case that can be retained. The components of a case-based system are the input module, the case memory, retriever, the case adapter and a module to update cases (5-7).

3- NEURAL NETWORKS:

Neural networks are composed of many massively connected simple neurons. Resembling more or less their biological counterparts in structure, neural networks (NNs) are representational and computational models processing information in a parallel distributed fashion. NNs are very useful for analyzing complex problems where the relationships between input and output data are not very well known, such as pattern and speech recognition, machine vision, robotics, signal processing and optimization. Feed-forward neural networks and recurrent neural networks are two major classes of artificial neural networks. Feed-forward neural networks, such as the popular multilayer perceptron,
are usually used as representational models trained using a learning rule based on a set of input–output sample data. A popular learning rule is the widely used back-propagation (BP) algorithm (also known as the generalized delta rule). It is mainly used in diagnosis, pattern recognition, function approximation, classification, etc. The structure of BP algorithm is shown in fig. (2), where

\[ \mathbf{X} = [x_1, x_2, ..., x_R] \quad , \quad r = 1, 2, ...., R \] is the input vector. \( R \) is the number of the input-layer neurons; \( \omega_{1ir} \) is the weight between \( i \) th hidden-layer neuron and \( r \) th input-layer neuron; \( \omega_{2ji} \) is the weight between \( j \) th output-layer neuron and \( i \) th hidden-layer neuron \((8)\). 

\[ \mathbf{B}_1 = [b_1, b_2, ..., b_i, ..., b_{S_1}] \quad , \quad i = 1, 2, ..., S_1 \] is the bias vector of hidden-layer neurons; \( S_1 \) is the number of hidden-layer neurons; \( \mathbf{B}_2 = \{b_1, b_2, ..., b_j, ..., b_{S_2}\} \quad , \quad j = 1, 2, ..., S_2 \) is the bias vector of output-layer neurons; \( S_2 \) is the number of output-layer neurons; The activation functions of hidden- and output-layer neurons are \( f_1 \) and \( f_2 \), which are sigmoid and linear functions, respectively. \( Y=(y_1, y_2, ..., y_{S_2}) \) and \( T=(t_1, t_2, ..., t_{S_2}) \) are the actual and target output vectors of the network \((9)\).

![Fig. (2): the structure of BP neural network](image)

It has also been demonstrated that neural networks trained with a limited number of training samples possess a good generalization capability \((10)\).

4- PROPOSED SYSTEM:

Modern technology provides different types of machines, equipments and the complex devices all over the world. Fault diagnosis of the modern systems cannot be achieved using the traditional diagnostic methods. Recently, case based systems have proved their success in solving the fault diagnosis problems. But, they suffer from failure when faced with new faults that was not diagnosed or a similar for them have been diagnosed and stored in the case library. Also, it suffers from increasing the number of cases in their libraries.

The proposed system introduces new method to diagnose all the faults can face the case based fault diagnostic system by incorporating the neural network. The proposed system can use two modules. The first one uses the case based fault diagnostic module. While, the second uses the neural network module. Also, another neural network is used to maintain the size of the case library.

When the proposed system is faced with a new fault, firstly the case based diagnostic system is applied. It searches its case library for a similar case(s). If it is (they are) found similar case(s), the proposed system retrieves these cases and ranking them. The higher ranked similar case is used to be adapted by the case based system for diagnose the similar faults. On the other hand, when the case
based diagnostic system failed to find a solution, the proposed system feed the new fault for the neural network to diagnose it. Either the new fault is diagnosed by adapting the retrieved case(s) or by the neural network, the new case that represented by the fault and its diagnosis are returned to the case library to be store for the future uses.

When the cases stored in the library have uncontrolled growth, many problems appeared as the memorization, the complexity of the retrieval and adaptation processes [10-12]. To overcome this problem, the proposed CBR diagnostic systems can automatically maintaining the size of the case-base as well as detecting problem cases in the case library are therefore crucial to the future success of CBR systems by using another neural network. It implements policies for revising the organization or contents (representation, domain content, accounting information, or implementation) of the case-base in order to facilitate future reasoning for a particular set of performance objectives.

Neural Network computes all the coverage values of the records, and selects the record with the highest coverage as the representative case for that class. Future addition and deletion of cases will depend on the coverage value generated by the neural network. So, the proposed system can control adding the cases for the case library. Thus, the performance of the indexing and retrieval processes can be improved.

The proposed system uses a three layer neural networks with a single hidden layer. It uses 28 neurons. It uses the back-propagation neural network algorithm for the training process.

5- APPLICABILITY OF THE PROPOSED SYSTEM AND ITS RESULTS

The proposed system can be applied for diagnosis different types of faults' devices or systems. In the present research, it has been applied for diagnosis the motor rolling bearing that has a great importance in the many application areas.

Generally, rolling bearings consist of two concentric rings, called the inner raceway and outer raceway, with a set of rolling elements running in their tracks. Standard shapes of rolling elements include the ball, cylindrical roller, tapered roller, needle roller, and symmetrical and unsymmetrical barrel roller. Typically, the rolling elements in a bearing are guided in a cage that ensures uniform spacing and prevents mutual contact. There are five basic motions that are used to describe the dynamics of bearing elements, with each movement having a corresponding frequency. These five frequencies are denoted as the shaft rotational frequency (Fs), the fundamental cage frequency (Fs), the ball pass inner raceway frequency (FBPI), the ball pass outer raceway frequency (FBPO), and the ball rotational frequency (FB) [13-14]. These features represented the cases for the case library and the neural network for the diagnostic system.

The proposed system is used 220 cases for the motor bearing to training the neural network. It has used 105 cases for testing the diagnosis of the motor rolling bearing.

To evaluate the proposed system, its results, traditional case based fault diagnostic system and a neural network fault diagnostic system are compared. Table (1) represents this comparison. From the obtained results, the proposed system proves its goodness by increasing the accuracy of the fault diagnostic process and decrease the run-time of its operation. While, evaluating the maintaining of the case library by comparing the performance of the proposed system with the traditional case based fault diagnostic system without the neural network for maintaining the case library as represented in Table (2).
**Table (1):** A comparison between the proposed diagnostic system, a traditional case based system and a neural network system

<table>
<thead>
<tr>
<th>Diagnostic System</th>
<th>Average Accuracy</th>
<th>Average Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed System</td>
<td>98.5 %</td>
<td>2.5 min.</td>
</tr>
<tr>
<td>Traditional CBR fault diagnostic System</td>
<td>89.1 %</td>
<td>5.0 min.</td>
</tr>
<tr>
<td>Neural Network diagnostic System</td>
<td>76.2 %</td>
<td>6.1 min.</td>
</tr>
</tbody>
</table>

**Table (2):** A comparison between the proposed diagnostic system, a traditional case based system and a neural network system.

<table>
<thead>
<tr>
<th>Diagnostic System</th>
<th>Average Accuracy</th>
<th>Average Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed System</td>
<td>95.5 %</td>
<td>1.8 min.</td>
</tr>
<tr>
<td>Traditional CBR fault diagnostic System</td>
<td>80.3 %</td>
<td>4.2 min.</td>
</tr>
</tbody>
</table>

From the previous results, it is found that, the proposed system has proved its goodness by increasing the accuracy of the diagnostic process by enabling the fault diagnostic system to diagnose all the faults either that has similar cases in the case library or that has no similar ones but can diagnose with the incorporated neural network. Also, the proposed system decreases the time when applied for a real time application. It can decrease the time for the retrieval process by controlling the growth of the cases in the case library.

6- **CONCLUSION**

Although case based reasoning systems have proved its goodness for the fault diagnosis processes, they suffer from a failure when it faces with new faults that is not stored in their case library. On the other hand, neural networks have a proven ability in the area of nonlinear pattern classification, fault diagnosis, pattern recognition. After being trained, they contain expert knowledge and can correctly identify the different causes of faults.

The proposed system introduces a new case based fault diagnostic system. It can incorporate the neural network diagnosis algorithm to deal with the unmatched new cases with any stored cases in the case library. Besides, it uses another neural network to control adding and deleting the cases in the case library to manage the size of the case library.

The proposed system is applied for diagnosis of the motor rolling bearing. The obtained results indicate that incorporating a neural network in the case based system for bearing vibration diagnosis algorithm can increase its accuracy and decrease the diagnostic time.

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