Design of Fault Diagnosis System Based on Fuzzy Inference for a New Type Equipment

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Abstract. Aimed at the puzzle of non-bijection between cause and symptom of the fault for a new type equipment system, the paper built the mathematical model of fuzzy inference by means of inference mechanism of fuzzy relation. In the paper, it designed the overall scheme of fault diagnosis system, and realized the function of system fault diagnosis by means of VC++ programming language according to the diagnosis flow of system. Through actual example validation, it shows that it satisfies the accuracy of fault diagnosis for a new type equipment system. The fault diagnosis of weapon equipment has always been an important topic for military research. With the change of war mode, higher requirements have been put forward for weapon equipment support technology. A new type of equipment is widely used in the land war, so some faults also appear one after another. In the long-term research, it is found that there is a fuzzy relationship between these fault phenomena and the causes. A fault does not correspond to a fault cause in modern mathematics, fuzzy mathematics can clarify the relationship between fault symptoms and fault causes in the equipment system. In this paper, the fuzzy fault diagnosis method is used to build a general fault diagnosis system to realize the fast and accurate analysis and diagnosis of faults.

1. The principle and model of fault diagnosis based on fuzzy relation

Because of the complex relationship between the fault symptoms and the fault causes of the equipment system, it is necessary to analyze and sort out the fault phenomena and the fault mechanism of the equipment system first, then the fault symptom set and the fault cause set can be established, and the fuzzy relation matrix can be determined by the expert knowledge.

First of all, according to the experts and test data, the set of fault symptoms is set as \( X \). There are \( m \) kinds of phenomena, which can be expressed as \( X = (x_1, x_2, \ldots, x_m) \), which is recorded as an \( m \)-dimension fault symptom space.

Similarly, set the failure cause set as \( Y \), there are \( n \) causes of all failures, expressed as \( Y = (y_1, y_2, \ldots, y_n) \), which is recorded as a \( n \)-dimensional fault cause space.

Secondly, the fuzzy relation matrix is determined. The membership degree between the fault symptom and the fault cause constitutes the fuzzy relation matrix. There is no definite formula for the membership relation between the two, which is mostly determined according to the experience of experts. In this way, the fuzzy relation matrix \( \tilde{R} \) is formed.
Finally, according to the mathematical model of fuzzy diagnosis, i.e. \( Y = X \circ R \), the fault reason can be found out. The mathematical model of fuzzy diagnosis can be expressed as

\[
Y = X \circ R = (x_1, x_2, ..., x_m) \circ \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \cdots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \cdots & \tilde{r}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{m1} & \tilde{r}_{m2} & \cdots & \tilde{r}_{mn} \end{bmatrix} = (y_1, y_2, ..., y_n)
\]

After getting the fault reason \( Y \), according to the principle of maximum membership degree, the main cause of fault can be determined.

2. The Scheme Design of fault diagnosis system

2.1. The basic requirements for system design
(a) The system environment
The operating system is Chinese Windows 7, and the database system is Microsoft Access 2010.
(b) The development environment
The development environment is Microsoft Visual C ++ 6.0, and the development language is object-oriented C ++ language.

2.2. The overall scheme design of the system
After analyzing the fault of equipment system and the diagnosis method based on fuzzy reasoning, the overall scheme of fault diagnosis system is designed as shown in Figure 1.
On the basis of the overall function analysis, the fault fuzzy diagnosis software system adopts the modular design idea. The overall task function is divided into 9 sub units. Corresponding to each task function sub unit, the equipment information module, simple diagnosis module, fuzzy fault knowledge module, fuzzy diagnosis module, fault statistics and mechanism analysis module, database module are designed and implemented Human machine interface module, user management module and system help module.

3. The realization of fuzzy diagnosis function module

3.1. The fuzzy fault diagnosis process
In the overall scheme, the core module is the fuzzy diagnosis and reasoning module, which embodies the essential function of the whole system. This paper takes this module as an example to analyze the implementation process of this function module. See Table 1 for the control of fault fuzzy diagnosis module.

3.2. The VC++ programming of diagnosis
The fuzzy diagnosis module is the core module of the fuzzy diagnosis system of a certain type of equipment system. Its main function is to infer and calculate the fault cause according to the fault symptoms.

The fuzzy diagnosis module is mainly completed by CFaultDN class. This class implements the mathematical model of fuzzy diagnosis, in which the fuzzy relation matrix is represented by a two-dimensional array that can be dynamically changed in size and edited, and the fault symptom and the fault cause are represented by a one-dimensional array that can be dynamically changed in size and edited, respectively.

The fuzzy diagnosis module uses the CArray in the MFC template library to realize the function of dynamic array. CArray includes two template parameters. The first is the variable type of the array element of the CArray class, and the second is the parameter type of the function call. The relational matrix is a two-dimensional array of double type, which is defined as CArray<CArray<double, double>, double> Matrix, the input fault symptom vector is an int type one-dimensional array, which is defined as CArray<int, int> Omen.

The specific process of fuzzy diagnosis is as follows:
(1) Select the appropriate failure mode in the failure mode list.
(2) Determine the fault symptom set. In the symptom list, select "1" as the fault symptom, and "0" as the unchecked symptom.
(3) The membership degree of fault cause is calculated according to the input symptom vector and the fuzzy relation matrix of fault under this mode.
(4) Sort according to the degree of membership.
(5) Provide the maintenance strategy for each fault reason.
(6) After the diagnosis, the user can choose to save the operation, input the vehicle number of the current diagnosis and the implemented maintenance measures. The diagnosis record function is
implemented by CCarSelDlg class; for the historical diagnosis information recorded, the query function is implemented by CExpRecord class.

The main programming codes are as follows:

```cpp
void CFaultDN::OnBtnAcount()
{
    for(int i = 0; i < 6; i++)
    {
        if (m_listXianXIang.GetItemState(i, LVIS_SELECTED) == LVIS_SELECTED || m_listXianXIang.GetCheck(i))
        {
            m_iOenInfo[i] = 1;
        }
        else
        {
            m_iOenInfo[i] = 0;
        }
        CString strModeNum = "";
        int intModeNum = m_combMode.GetCurSel() + 1;
        strModeNum.Format("%d", intModeNum);
        CString strXianXiangNum = m_listXianXIang.GetItemText(i, 1);
        int j, recordcount;
        CString sql = "";
        sql.Format("SELECT * FROM Subjection where Mode number='%s' and Fault phenomenon='%s'", strModeNum, strXianXiangNum);
        try
        {
            m_pRecordset.CreateInstance("ADODB.Recordset");
            m_pRecordset->Open((_variant_t)sql, (_variant_t)((IDispatch*)theApp.m_pConnection, true), adOpenStatic, adLockOptimistic, adCmdText);
            recordcount = m_pRecordset->GetRecordCount(); // Get records total.
            if (!m_pRecordset->adoEOF)
            {
                for (j = 0; j < recordcount; j++)
                {
                    CString strYinZi = (LPCTSTR)(_bstr_t)m_pRecordset->GetCollect("Membership factor");
                    if ("
                        == strYinZi)
                    {
                        m_fSubjectionInfo[i][j] = 0;
                    }
                    else
                    {
                        m_fSubjectionInfo[i][j] = (float)atof((char *)(LPTSTR)(LPCTSTR)strYinZi);
                    }
                    m_pRecordset->MoveNext();
                }
            }
            m_pRecordset->Close();
        }
        catch(_com_error e) // Catching anomalies
        {
            CString temp;
            temp.Format("anomalies: %s", e.ErrorMessage());
            AfxMessageBox(temp);
            return;
        }
        for(int k = 0; k < 4; k++)
        {
            m_fYuanyinInfo[k] = 0.00F;
        }
        for(int m = 0; m < 4; m++)
        {
            for(k = 0; k < 6; k++)
            {
                m_fYuanyinInfo[m] += (float)m_iOenInfo[k] * m_fSubjectionInfo[k][m];
            }
        }
        CResultInfoDlg dlg;
        for(i = 0; i < 3; i++)
        {
            dlg.m_fYuanyinInfo[i] = m_fYuanyinInfo[i];
        }
        dlg.DoModal();
    }
}
```
4. Conclusion
The fuzzy mathematics and the principle of the maximum membership are used as the basic algorithm to solve the problem of the complex mathematical model and the uncertainty of the qualitative diagnosis. The theoretical and experimental results show that the fuzzy diagnosis can give the quantitative fault diagnosis results accurately, which is of great significance for the accurate diagnosis of new equipment system faults and the improvement of system reliability.

References
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