Troubleshooting Microprocessor Based System using An Object Oriented Expert System

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***Abstract* -The paper presents an object oriented fault diagnostic expert system framework which analyses observations from the unit under test when fault occurs and infers the causes of failures. The frame work is characterized by two basic features. The first includes a fault diagnostic strategy which utilizes the fault classification and checks knowledge about unit under test. The fault classification knowledge reduces the complexity in fault diagnosis by partitioning the fault section. The second characteristic is object oriented inference mechanism using backward chaining with message passing within objects. The refractoriness and recency property of inference mechanism improve efficiency in fault diagnosis. The developed framework demonstrates its effectiveness and superiority compared to earlier approaches.**

Keywords- Inference mechanism; object; Fault diagnosis.

I. Introduction

Expert Systems have traditionally been built using large collection of rules based on empirical associations; Interest has built up recently in use of Artificial Intelligence techniques that reason from first principles i.e. from an understanding of causality of the device being diagnosed. Randall Davis [1] discussed causal interaction model for fault diagnosis. Expert system that reason based on understanding of the structure and function of the unit under test has been explored in number of domains, including medicine [2-3], computer fault diagnosis [4], automobile engine fault diagnosis [5], and electronics equipment fault diagnosis [6]. Proposed work focuses on the last domain.

Fault diagnosis methodology operates on observed erroneous behavior and hardware structure of the unit under test. The erroneous behavior consists of responses of different components on the output lines on specific input values. Development of a methodology which determines possible sources of causes in minimum time for a specified fault is basic aim of the research. In digital components, there is fixed deterministic flow of signals from input to output. The signals are binary in nature and flow through various components.

In keeping with the notion of reasoning from first principles, a scheme is proposed herewith to develop a system capable of reasoning in a fashion similar to an experienced electronic engineer. In particular, the system is built by capturing skill exhibited by an engineer who can diagnose faults from schematic even though he may never have seen that particular unit before. However, the average person who does not possess the experience has to check all components that may be faulty. It leads to low efficiency in troubleshooting process and is not acceptable for large & complex devices. Diagnosing a faulty component from an electronic circuit board is challenging problem. Applying artificial intelligence approach to solve this problem is true motivation behind this research. Fault diagnosis requires expertise and knowledge in specific domain. Initial focus of research is to develop a rule based expert system for fault diagnosis in microprocessor system and then explore it to object oriented framework to evaluate the correctness compared to other approaches.

II. Brief Review on Major Existing Methods for Fault Diagnosis

A. Expert Systems (ES)

Many expert systems have been developed for fault diagnosis in different domains. C. Angeli [7] discussed diagnostic expert system for real time application using functional reasoning. To handle online diagnostic constraints, model based approach was proposed for fault diagnosis in real time application.

Jinyu Qu, Liyan Liary [8] proposed a production rule based expert system for electronic control automatic transmission fault diagnosis. Here every fault and cause of fault (fault reason) has been assigned aunique codes and both are stored in database. Rule base is designed for mapping relationship between fault reasons and fault types using AND/OR form of forward reasoning.

Ioan Borlea, Adrain Buta [9] devised an expert system for fault diagnosis in Timisoara 220 KV Substation. Fault diagnosis method uses reasoning based on rules inferred from operation of substation’s primary equipment and main bus bar and auto transformer protections.

Chen Jingie, Chen Xia xia [10] presented the traditional airborne electronic equipment fault diagnostic system. It executes the dynamic processing by subsystems, then summaries information and makes the integrated diagnosis by the expert system which is embedded in flash memory. It uses forward extract rule base approach for inference mechanism.

Ting Han,Bo Li, Linei Xu [11] has proposed a universal fault diagnosis expert system based on Bayesian network, it utilizes expert knowledge to diagnose the possible root causes and the corresponding probabilities for maintenance decision making support. Bayesian network is used as an inference engine for raw data analysis. Authors has tested the system on production line of a chipset factory and obtained satisfactory results.

Sebastien Gebus,Kauko Leivisa[12] dicussed how defect related knowledge on an electronic assembly line can be integrated in decision making process at an operational and organizational level. It focuses particularly on the efficient acquisition of shallow knowledge concerned with production. Authors concluded that, the effective decision support system is essential to provide workers with information necessary to identify the causes of problems and takes appropriate action to solve it.

John W.Coffey, Alberto J. Canas, et al.[13] has discussed EI-Tech expert system to provide performance support and training for electronic technicians in troubleshooting RD-379A(V)/UNH, a redundant, fault tolerant, air traffic control recorder system.

Ning Yang,Shaocheng Zhang Xu et al.[14] built an expert system for vibration fault diagnosis in large steam turbine generator set. Knowledge base is constructed using production rules and inference engine is based on confidence factors, a mathematical model is proposed by authors to calculate Confidence Factor (CF)during reasoning process. Diagnostic system consist of two parts: data acquisition system and fault diagnostic expert system. Data acquisition system is responsible for collecting vibration signals and the diagnostic expert system analyses it.

B. Artificial Neural Netwoks (ANNs) :

Many neural network models were suggested for fault diagnosis and prediction problems. Yong Chun Liang, Xiao-Yun Sun et al.[15] proposed a combinatorial probabilistic neural network(PNN) model for fault diagnosis of power transformers. PNN model is based on Bayesian classification. Four PNN models for fault classification are proposed to classify normal heat fault, partial discharge fault, general over heating faults and severe overheating faults. Authors obtained better accuracy compared to other approaches.

An adaptive neural network based fault detection and diagnosis using unmeasured states is proposed by C.S.Liu,S-J Zhang,S.-S. Hu.[16]. Authors built a fault diagnostic architecture for unknown nonlinear systems with unmeasured states. A radial basis function (RBF) and adaptive RBF neural network approaches are used to approximate the model of unknown systems and for on line updates respectively.

Yanghong Tan, Yigang He, Chun Cui et al.[17] has proposed a neural network and genetic algorithm based approach for analog fault diagnosis . By understanding the measurable voltage deviation in the deviation space the unified fault vectors for single, double and triple faults are characterized. The classification of faults is done using artificial neural network.

C. Hybrid intelligent Systems (HISs) :

The combination of neural network and rule based expert system is proposed by Rye Senjen, Muriel De Beler [18]. The reasoning mechanism is implemented using neural networks. The hybrid system is developed for performance monitoring and fault diagnosis in telecommunication networks. Here performance monitoring is carried out using neural network and fault diagnosis is carried out using rule based expert systems.

Damian Grzechca,Jerzy Rutkowski [19] discussed Neuro-Fuzzy approach to time domain electronic circuits fault diagnosis. Proposed method belongs to Simulation Before Test (SBT) technique , a simple step input is given to unit under test and response is analyzed. The information acquired such as a rise time ,input output delay, overshoot are fuzzyfied and fuzzy neural dictionary is created. Feed forward back propagation network classifier algorithm is demonstrated with analog filter circuit.

D. Petri–Nets (PN) :

Petri Nets are used for multiprocessing and on line system modeling. Antonio Ramfrez-Trevino,Elvia Ruiz-Beltran et al.[20] proposed an online model-based for fault diagnosis of discrete event systems. Model of the system is built using the interpreted Petri Nets (IPN).Model includes all system states as well as all possible faulty states.IPN modeling methodology follows a modular bottom-up strategy. A diagnostic algorithm is used to diagnose the faulty component.

A fuzzy petri-nets approach for fault diagnosis for electro mechanical equipment is discussed by Qunming Li,Ling Zhu,Zhen Xu [21] . The information flow in fuzzy petri net model (FFDPN) is driven inversely, and the production rules are defined backwards. The author has demonstrated how this proposed model can be used for other domains as well.

Chunlai Zhou, Zhongcheng Jiang [22] devised a fault diagnosis approach for TV transmitters based on Fuzzy PetriNets. All the knowledge of fault diagnosis is summarized into fuzzy rules, these fuzzy rules then translated into fuzzy petri nets by using an algorithm. A parallel reasoning algorithm is proposed for reasoning in fault diagnosis

E. Fuzzy Logic (FL) :

To handle incomplete and linguistic knowledge fuzzy logic is used. As per survey fuzzy logic is applied to may fields for handling inexact situations. Yan Qu et al. [23] discussed fuzzy diagnostic expert system for electric control engine. Comix fuzzy reasoning method is used in inference engine. Proposed expert system includes knowledge base, reasoning machine, explain system, management system and human machine interface modules.

An intelligent fault diagnosis framework based on fuzzy integrals is built by M. Karakose I et al.[24]. The method consist two frameworks. The first framework used to identify the relations between features and a specified fault and the second framework integrates different diagnostic algorithms to improve accuracy rate. Approach is experimented on 0.37 KW induction motor, where broken rotor bar and stator faults were evaluated to validate the model.

An electronic equipment fault diagnosis in air crafts using fuzzy fault tree is described by Lians Xiao- lin et al. [25]. The complexity, ambiguity and uncertainty in fault diagnosis process for equipment fault diagnosis is modeled using fuzzy fault tree. The list of the most suspected faults is given by the system with fuzzy measures.

III. Architecture of Rule Based Expert System

Rule based expert systems have a wide range of applications for diagnostic tasks where expertise with deep knowledge is rarely available. The architecture of basic expert system is shown in Figure 1. The system consists of knowledge base, inference engine and user interface. The expert knowledge is elicited by knowledge engineer and represented in suitable knowledge structures. The knowledge base is constructed using production rules. It describes the action that should be taken if a symptom is observed. The main feature of rule based system is empirical association between premises and conclusions in the knowledge base. These associations further describe cause effect relationship to establish logical reasoning.

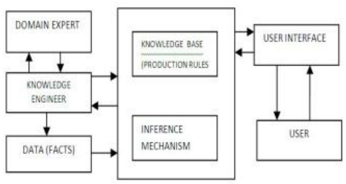

Figure 1. Basic Structure of Rule-Based Expert System.

For fault diagnosis in a typical microprocessor system board, 60 different faults have been considered. Diagnostic rules are typically of the form if <X is true> Then < add Y to the suspect list>.

An example from the rule base, is

IF (1) Pin_30 of 8085 is low continuously AND
(2) +5 v present at pin no.40 of 8085 AND
(3) CLOCK pin 1 is pulsating
THEN The IC 8085 faulty.

This rule "fire" if conditions (1), (2) and (3) were found to be true then component listed in the "then" statement get added to the list of suspect faulty components.

Inference engine uses depth first search technique with back ward reasoning. The expert system diagnoses the fault by interacting with the user. The results obtained using this system for typical faults are listed in Table 1.

TABLE I. RESULTS OBTAINED USING RULE BASED EXPERT SYSTEM

FaultQuery	**List of possible Faults**
1.System is dead	Power supply faulty Power supply connector loose connections Power cable defective
2. Keyboard not working	8279 faulty Keyboard faulty
3. 8253 port A not working in Mode 0	8253 faulty
4. Memory read from C000 H not working	Ram _6116 faulty 74ls138_U6 faulty

IV. Architecture of the Proposed Object Oriented Expert System

The overall architecture of the object oriented expert system is shown in Fig. 2. The system consists of knowledge base, inference mechanism, user interface. Knowledge base consists of declarative knowledge and procedural knowledge. Inference mechanism uses backward chaining & message passing technique. To get observations from the unit under test user interface is provided. The object attribute values obtained during diagnosis are stored in working memory.

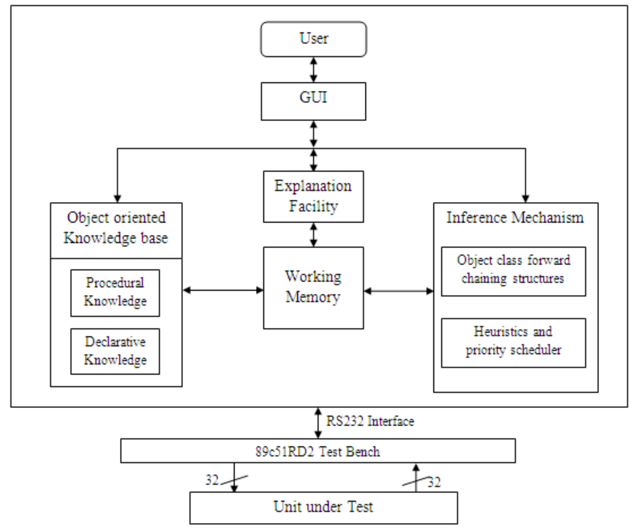

Figure 2. Architecture of the Object Oriented Expert System.

For off line testing of the components like 74Ls138 decoder a test bench interface is provided using RS232 port. Test bench uses 89c51RD2 microcontroller with 32 input /output test probes.

V. Object Oriented Knowledge Representation

The object oriented knowledge base is lumped by many objects, and is a modular, uniform and structured paradigm. It can be uploaded easily which increases generality of the system. Again, by using inheritance property, knowledge reusage increases as compared to structured representation. The complex data types like heuristics can be implemented as attributes in object oriented knowledge base. Under the microprocessor super class there are many sub classes like CLASS_8255, CLASS_8279, CLASS_8253, CLASS_6116, CLASS_2764. The super class inherits all common attributes of sub classes. The pin no. of ICs acts as objects. The status of the pin can be obtained by passing the object attributes novice technician and the attribute values get stored in working memory.

The connectivity between the components is described using frame structures and the functional behavior of the components is described using object-rules. The system uses fault classification and checks knowledge. The fault classification knowledge isolates the object space as per the selected fault query. It is represented as a FAULT_ISOLATE class. This class uses metaknowledge, which determines valid classes for the selected fault query with priority. After the fault query is selected the FAULT_ISOLATE class analyses the fault query by getting the attribute values form the user

For example following part of metaknowledge is applicable for the microprocessor system.

1. If there is fault in power supply, checking the behavior of circuit components which depends on it not necessary.
2. If microprocessor chip is faulty, then check knowledge about the program is invalid.

Checks knowledge describes functional behavior of components. It uses object-rules associations within the respective sub class. Interconnection between the components is represented using frames and slots. Declarative knowledge assists inference mechanism and novice technician in fault diagnosis by providing information about component connectivity. Pseudo code for frame representation in Visual Prolog is shown in Fig.3. Here, frame is constructed to represent pin connections of 8255 IC with FRC connector on circuit board. Frame name is 8255, slot 1 represents pin no.1 of 8255 IC, and the description of the pin name is given in facet. Another facet is used to represent its connection with FRC connector pin no.1.Next again, slot2 describe pin no.2. of 8255 and its connection to FRC connector pin no.2. like this all pins and their connections is represented. For addition of new component assertz predicate is used to update knowledge base.

```
assertz(frame("8255",[slot("PIN_01",[facet("NAME","P1.0"),facet("
CONNECT_TO","01FRC1")]), slot("PIN_02",[facet("NAME","P1.1"),facet
("CONNECT_TO","02FRC1")]), slot("PIN_03",[facet("NAME","P1.2"),f
acet("CONNECT_TO","03FRC1")]), slot("PIN_04",[facet("NAME","
P1.3"),facet("CONNECT_TO","04FRC1")]), slot("PIN_05",[facet("
NAME","P1.4"),facet("CONNECT_TO","05FRC1")]), slot("PIN_06",
[facet("NAME","P1.5"),facet("CONNECT_TO","06FRC1")]), slot("PI
N_07",[facet("NAME","P1.6"),facet("CONNECT_TO","07FRC1")]),
```

Figure 3. Pseudo Code For Frame Representation

VI. INFERENCE MECHANISM

Inference mechanism uses backward chaining mechanism to find causes of fault. It uses conflict resolution strategy by selecting one object to fire from conflict set. Using object oriented structure the most recent observation will be treated as most promising and will be inherited from other objects like human expert does. For the present diagnostic approach only one fault query is selected at a time. On selection of the query from the user the system first isolates fault and applies the objects from isolated class, every node act as an object under sub class. System applies Depth First Search (DFS) strategy for searching the object tree. As the search starts from left side the most promising object is kept at left side as per expert judgment. Search proceeds by passing attributes and getting positive responses from user till fault is diagnosed. If attribute value is not positive the tree traversing stops at that sub node and backtracks till next node. As fault diagnosis is complex and probabilistic process, there is likelihood that other probable faults also get diagnosed under the same observed symptoms. To identify most promising one, confidence Value (CV) is computed. Every sub class is associated with confidence value attribute. The confidence value of the conclusion is obtained by taking minimum of attribute values associated with objects under that class and multiplying it with class attribute value. A threshold is kept to limit the suspected fault list. Conclusions whose confidence values are greater than threshold get displayed as most suspected faults.

As an example, the fault query “Display not working” is selected by the user, fault isolate class isolates the fault area after getting attribute value, and activates DISPLAY_CLASS, under this class Object (pin_3_of_FND_507_+5v,<attribute><attribute value>) passes the query to user to get status of pin no.3 of display. The attribute value obtained is supposing not positive and get stored in the working memory. As shown in Fig. 4. As per DFS next object from the tree get fired. To diagnose the track open fault there is necessary of checking the status of pin _3_U11_74ls145 and FND 507 pin no.3 again suppose it is positive but since status of FND 507 pin no3 checked previously and inherited it skips it and fires next object. Since pin_1_74245and pin 32-35_8279 are checked in the previous diagnosis it skips it and returns with track open fault

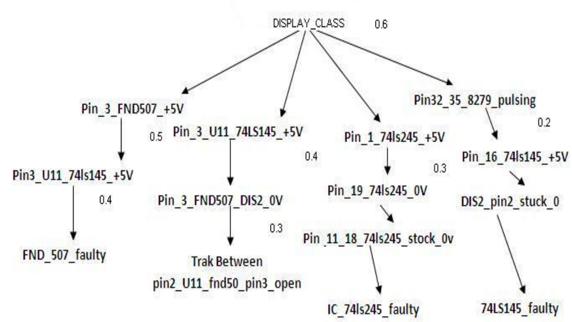

Figure 4. Object Search Tree

VII. RESULTS

Table1. Shows the results obtained for some typical faults in 8085 microprocessor board using two approaches. For the first fault query ”system not getting started” rule based approach uses five rules to diagnose four faults while object oriented approach has fired only two objects and diagnosed fault correctly. The results obtained by two approaches are compared and validated by industrial experts. Fault diagnosis using Object oriented approach is more accurate and uses less object search space and hence memory. Similarly 80 different faults are considered and validated by industrial experts and found correct.

VIII. CONCLUSION

This work is an attempt to speed up the fault diagnosis process using expert knowledge base and inference mechanism. Using object oriented approach problem domain divides naturally and diagnosis is carried out as expert troubleshooter as predicted. Using inheritance property the inference mechanism efficiency is increased and becomes more flexible and modular. As discussed in results, object oriented approach takes less time to diagnose the fault compared to other approaches. As per validation report, results obtained using object oriented approach is 85% accurate.

TABLE II. RESULT OBTAINED FOR TYPICAL FAULT

S No	Fault Query	Diagnosed Faults	
		Using Rule Based Approach	**Using Object Oriented Approach**
1.	System not getting started	8085 processor 74ls373 latch Crystal Diode in reset logic (No. of Rules fired = 5)	8085 faulty (No. of objects fired -02) CV = 0.8
2.	No display power is ON	EPROM 2764 6162 RAM No. Of rules 03	2764 No of objects -01 CV =0.7
3.	Data Not getting written to C100 onwards	74HS32 U18 8085 Strapping P6,P17 Open Rules - 03	Strapping P6 open Object- 01 Cv =0.6
4	Input Port Of 8255 is not working in input mode	74ls138U7 8255, 8085 Rules -03	8255 Objects -02 Cv =0.8
5.	8253 is not working in mode 0	74LS138 U7 8253 STRAPPING P18 Rules -04	8253 Objects 01 Cv =0.8

REFERENCES

[1] R.Davis "Reasoning from First Principles in Electronic Troubleshooting ," International Journal of Man Machine Studies,pp. 403-423,Nov.1983.

[2] "Rule Based Expert" *Systems, M.Sasikumar,S.Ramani* et al.

a. NarosaPublication 2007.

[3] B.G. Buchannan and R.O. Duda, "Principles of Rule-based Expert Systems," *Advances In Computers,* Vol.22, 1983, pp.163-21

[4] Roger T Hartley "CRIB: Computer Fault –finding ThroughKnowledge Engineering" *IEEE Computer* March 1984. PP 76-81.

[5] Suk I.Yoo, Il Kon Kim," DIAS1 : An Expert System for Diagnosing Automobiles with Electronic Control Units" International Journal on Expert Systems With Applications, Vol 4. PP 69-78,1992.

[6] F. Pipitone,"The FIS Electronics Troubleshooting System,"IEEE Computers,pp.68-76,July 1986.

[7] C.Angeli., "Diagnostic Expert Systems: From Expert's

a. Knowledge to Real –Time Systems. Advanced Knowledge Based Systems : Model ,Applications & Research. Vol.1. PP 50-

b. 73,2010.

[8] Jinyu Qu, Liyan Liang, " A Production Rule Based Expert System for Electronic Control Automatic Transmission Fault Diagnosis" Procc. Of 2009 IEEE International Conference on Test & Automation.

[9] Ioan Borlea ,Adrian Buta" DIASE –Expert System Fault Diagnosis for Timisoara 22kv Substation" Proc of Eurocon 2005. PP 251 255.

[10] Chen Jingjie,Chen Xiaxia," Research on Embedded Airborne

a. Electronic Fault Diagnosis Expert System" Proceedings of

b. International Conference on Tests & Automation, 2010.

[11] Ting Han,Bo Li, Limei Xu ," A Universal Fault Diagnostic Expert System Based on Bayesian Network" Proceedings of 2008 IEEE International Conference on Computer Sc. & Software Engineering.PP 260-265.

[12] Sebastien Gebus, Kauko Leiviska," Knowledge acquisition for

a. decision support systems on an electronic assembly line"

b. International Journal on Expert Systems with Applications, Elsevier, 2007 PP94-101

[13] John W.Coffey, Alberto J. Canas et al. "Knowledge modeling and the creation of EI-Tech: a performance support and training system for electronic technicians", *International Journal on Expert Systems with Applications,* Elsevier Vol 25.2003, PP 483-492.

[14] Ning Yang,Shaocheng Zhang et al. " An Expert System for

a. Vibration fault Diagnosis of Large Steam Turbine Generator Set", Proc. IEEE International Conference on Test Automation, 2011.PP 217-221.

[15] Yong- Chun LiANG, Xiao- Yun Sun,Dong –Hui Liu et al. "Applications Of Combinatorial Probabilistic Nural Network In Fault Diagnosis Of Power Transformer" Procc. Of Sixth IEEE

a. International Conference on Machine Learning and Cybernetics,

b. 2007.1115-111.

[16] C.-S. Liu,S.-J. Zhang, S.-S. Hu ," Adaptive neural –network –based fault detection and diagnosis using unmeasured states", International Journal on IET Control Theory Applications 2008 Vol2. No.12. PP 1066-1076.

[17] Yanghong Tan,Yigang He,Chun Cui and Guanyuan Qiu," A Novel Method for Analog Fault Diagnosis Based on Neural Networks and Genetic Algorithms" IEEE Transaction on Instrumentation and Measurement. Vol.57, No.11 Nov.2008. PP 2631-2635.

Rye Senjen,Muriel de Beler,Chris Leckie et al. " Hybrid Expert Systems for Monitoring and Fault Diagnosis" IEEE Computer 1993. PP 235-236.

[18] Damian Grzechca,Jerzy Rutkowski," Use of Neuro-Fuzzy System to Time Domain Electronic Circuit Fault Diagnosis", Proc. Of IEEE International Conference on Test and Automation, 2005. PP 1-4.

[19] Antonio Ramfrez et al. "Online Fault Diagnosis of Discrete Event Systems. A Petri Net- Based Approach", IEEE *Transaction on Automation Science and Engineering,* Vol.4.No.1. Jan 2007.pp 31

[20] Qunming Li,Ling Zhu,Zhen Xu," Fuzzy Petri-Nets based Fault Diangosis for Mechanical –electrical Equipment" Procc. of 2007 IEEE International Conference on Control and Automation, 2007 PP 2539 -2543.

[21] Chunlai Zhou and Zhongcheng Jiang, " Fault Diagnosis of TV Transmitters Based on Fuzzy Petri Nets" Procc. of IMACS Multiconference on " Computational Engineering in Systems Applications , 2006. PP 2003-2007.

[22] Yan Qu et al. "A Fuzzy Expert System Framework Using

a. ObjectOriented Technique" *Proceeding of 2008 IEEE Pacific –*

b. Asia workshop on Computational Intelligence and Industrial

c. *Applications* .PP474-478.

[23] M. Karakose, I.Aydin, ,E Akin "The Intelligent Fault Diagnosis Framework Based on Fuzzy Integral" *SPEEDAM 2010 international Symposium on Power Electronics, Electrical Drives, Automation and Motion.* PP 1634-1639.

[24] Liang Xiao-lin, Zhao Yan-xia .et al. "Research on Applications of Fuzzy Fault Analysis in the Electronics Equipment Fault Diagnosis" IEEE System Engineering & Electronics,Vol 2, 2010.

[25] Hruday: A Heart Disease Advisor Expert System, Vidwan- An Expert System Shell: User Manual", *National Centre for Software Technology,Mumbai*, 1993.PP18519

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