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Knowledge Based Approach For Fault Diagnosis In Electronic Circuit Boards

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Abstract

Today, Knowledge based systems are used for complex problem solving and are having number of successful applications. Fault diagnosis methodology is based on failure behavior and hardware of the unit under test. This methodology is considered for the present work. Fault diagnosis in a microprocessor based electronic circuit boards needs lot of empirical knowledge and expertise and is a true artificial intelligence problem. Present research work relates to artificial intelligence systems and more particularly to a fault diagnostic knowledge based system that infers a cause of failure in electronics circuit board. The basic components of systems are knowledge base, inference engine and user interface. The knowledge is represented using object-rule structures and inference mechanism is implemented using classes. Performance of object oriented approach and rule based approach is compared and diagnosed faults were validated by industrial experts.

Keywords: *fault, knowledge, microprocessor, memory*

1. Introduction

The goal of Artificial Intelligence (AI) is to design and generate computer programs which exhibit some features of human intelligence. Artificial intelligence is defined as the ability to acquire, understand and apply knowledge. AI has number of important sub areas like expert systems, natural language processing, Computer Vision, Theorem proving, understanding spoken dialogues, game playing, robotics etc. In 1950, Alan Turing [1] proposed the method for a machine to think.

AI systems give lot of emphasis on problem solving approaches. In artificial intelligence, the problem solving is based on science of reasoning, search strategies which systematically examine alternate steps, mean-end analysis, depth first search, breadth first search etc. are some of the widely used search strategies used in problem solving. The concept of tree search is successful in many AI applications. For instance, for path tracing robot application, tree search is used to find out next move optimally. Artificial intelligence systems are also called as advanced algorithmic systems. In algorithmic approach the designed algorithms are used to complete the assigned task in finite time and provides deterministic output. It is a computational procedure and its solution is guaranteed to be accurate. Human brain solves many problems in non algorithmic way with no guarantee about accuracy. For instance, a doctor does not diagnose the disease using any algorithms, he diagnoses it based on his knowledge, experience and static data about the patient. Hence this is a limitation of algorithmic approach that it is difficult to solve the complex decision making problems which are based on heuristics.

The area of AI has concentrated on the construction of high performance programs in specialized professional domains. The area of knowledge based systems investigates the

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methods and the techniques for constructing man-machine systems with specialized problem solving expertise. Expertise is related with knowledge about a particular domain, understanding of domain problems and skill of solving some of these problems.

2. Literature Survey

There are many approaches for fault diagnosis in all sectors, in the literature survey some related approaches were considered. Petri Nets are used for multiprocessing and the on line system modeling. Antonio Ramfrez Trevifio *et. al.*, [2] proposed an online model-based for fault diagnosis of is create 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. Chunlai Zhou, *et al.*, [3] devised a fault diagnosis approach for TV transmitters based on Fuzzy Petri Nets. 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. A fuzzy Petri-nets approach for fault diagnosis for electro mechanical equipment is discussed by Qunming Li, *et al.*, [4]. The information Flow in Fuzzy Petri Net model (FFDPN) is driven inversely, and the production rules are defined in a backward manner. The author has demonstrated the use of proposed model for other domains as well.

Wei Dan[5] devised a web based expert system solution for electronic control engine fault diagnosis. Author used ASP and SQL Server for web based support for expert system. The proposed system provides guidance to automobile technician for locating faults, finds out the causes of the faults and gives maintenance proposal on line. The expert system is developed using neural networks. Lie Chen, et al. [6] built a web based fault diagnosis instrument system. The system collects data based on vibrations, temperature, image, radio frequency identification for fault diagnosis. Authors proposed a portable instrument based on SC 32442B ARM processor for fault diagnosis. The Instrument uses embedded Linux platform. The instrument down loads fault identification task from the server and diagnoses the fault.

Be Van Ngo, et al. [7] discussed the use of JTAG (Joint Action Group) boundary-scan technology for testing complex Printed Circuit Board (PCB). However, there are some problems with the boundary scan architecture such as, many TTL 7400 series components on PCB may not support boundary scan facility. Li Jimin[38] discussed data fuse technique to handle uncertainty in electronic circuits fault diagnosis. The method deals with the results of the k-node analysis, direct current analysis and alternating current impedance characteristics. Dempster and Shafer evidence theory is introduced for fault diagnosis of analog circuits. Jiang Brandon Liu, *et al.*, [9] proposed an incremental fault diagnosis strategy. This method captures faulty lines one at a time using linear time single fault analysis algorithm. The applicability of the proposed method is demonstrated on multiple stuck-at faults, open interconnects and bridging faults. Zhu Yongli, *et al.*, [11] proposed a three element models based on simplified Bayesian network with noisy OR and noisy AND nodes to estimate the faulty section of a transmission power system. The three models are used to test any transmission line, transformer or bus bar within a blackout area. Domain expert knowledge is used for structures and for initial parameters of the Bayesian networks. The Bayesian network developed is universal and is applied for any power network. Authors pointed out the effectiveness of Bayesian network approach using practical tests on power systems. Wang B. Wang L [13] discussed intelligent fault diagnosis system based on UML. The diagnostic reasoning adopts the technique of uncertainty reasoning in expert systems. Authors simulated the approach using fault diagnosis in power system network.

Bailin Liu [16] devised an object oriented frame knowledge representation approach for fault diagnostic expert system based on hierarchical model. The domain specific knowledge is expressed by combination of object frames. An object frame is composed of relevant state-object, test object and rule object or repair object. Production rules are used to connect relevant objects states. The inference engine uses forward chaining mechanism. The fault diagnosis strategy is illustrated with example.

3. Motivation

Knowledge based systems are traditionally built using large collection of rules based on empirical associations. It is felt that the use of Artificial Intelligence that reasons from first principles i.e. from an understanding of causality of the device being diagnosed may be appropriate for fault diagnosis. In most of the cases fault diagnosis methodology operates on failure behavior and hardware. The erroneous behavior consists of responses of different components on the output lines on applying specific input values. Development of a new methodology which determines the possible source of causes in less diagnostic tests for a specified fault is the basic aim of the research. After understanding AI concepts it is felt that the scheme may be proposed to develop a system capable of reasoning in a fashion similar to an experienced electronic engineer for fault diagnosis in electronic circuit board. The system may be built by capturing the skills exhibited by an engineer who can diagnose the faults from the schematic without even using the particular unit beforehand. The unit under test exhibits some form of incorrect behavior and the diagnosis test must infer the faulty component that is producing the fault. Diagnosing a faulty component from an electronic circuit board is a challenging problem. Applying artificial intelligence approach to solve this problem is a true motivation behind this research. Fault diagnosis requires expertise and knowledge in the specific domain. The 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 approach. A unit under test fails when its observed behavior is different from its expected behavior. Development of a new methodology to determine possible sources of causes of failures by carrying out less diagnostic tests is basic aim of the research. The proposed work uses top down approach for fault diagnosis.

As per literature survey the logical and rule based expert systems are not found to be adequate for complex problem solving tasks with large database. There is consequently a search for alternative symbolic paradigm. The proposed diagnostic system uses integration of object-oriented paradigm and rule based system. The class and inheritance feature of object oriented paradigm describes entities more naturally and hence the system becomes more user oriented than system oriented. The development of proposed frame work is an attempt to integrate objects oriented and logical programming concepts to provide an extremely flexible and powerful environment for fault diagnosis process. The problems associated with rule based approach and need of integration is discussed.

Problem 1: The encapsulation of relevant information of a single entity is difficult in rules based systems while classes in object oriented paradigm bind data structures and operations easily.

Problem 2: For handling large scale database the rules lack software engineering tools like modules, information hiding and reusability while in object oriented paradigm inheritance specifies the common attributes and services in objects and utilizes the classes as per requirements to provide modularity.

Problem 3: Simultaneous execution of two rules is not possible in rule based approach.

Problem 4: The state of the system is determined by the data in working memory in rule based systems while in object oriented approach state is characterized by object data items.

Problem 5: The object orientation paradigm is weak in inference process for handling symbolic and logical computations while rules handle inference process more appropriately.

Problem 6: There is no universal fault diagnostic tool for fault diagnosis in any processor based system after updating knowledge base.

All these issues are handled in the present research work.

4. Rule based Knowledge Based System

The basic architecture of rule based System is as shown in Figure 1.It consist of knowledge base, inference engine and user interface.

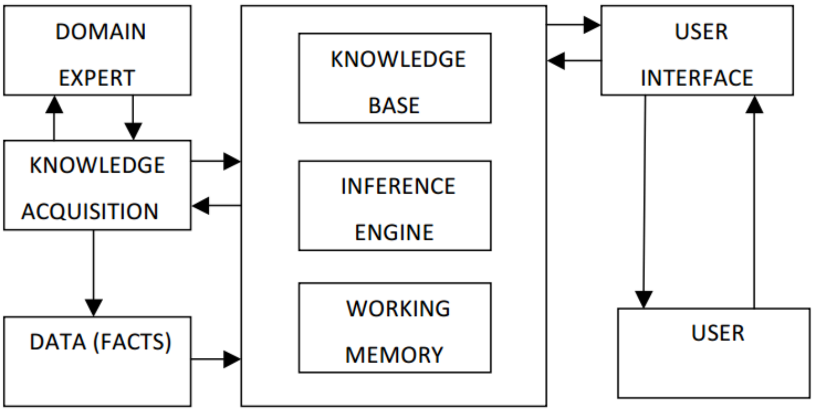

Figure 1. Rule Based Knowledge based System

4.1 Fuzzy Knowledge Base

The knowledge base stores all fault diagnostic information related to 8085 microprocessor board. For the present system rules are used for knowledge representation The uncertain diagnostic knowledge is represented using fuzzy quantifier values. The fuzzy quantifier values for different linguistic terms is as shown in Table 1. As per expert judgment the fuzzy values are assigned to rules. Here rule is considered as a set of different antecedents connected by AND operator. The membership of each antecedent is described by fuzzy values (fv). Typical structure of rule is of the form If < x is true > then <y is true>. Typical diagnostic fuzzy rules in English sentences and their implementation in visual prolog is shown in following two examples

Table 1. Fuzzy Qualification Values

Fuzzy Quantifier	Most Sure	Probably	Some what	Possible	Maybe	Impossible
Values	1	0.8	0.6	0.4	0.2	0

Example 1
IF +5v present at pin 40_ U4 (f v =0.8)
AND pin 30 of U4 is low continuously(fv=0.7)
AND no system clock at pin 37 of U4(fv=0.8)
AND pin 35 is stuck to high (fv=0.7)
THEN IC_8085_faulty (fv =0.8)
Implementation in Visual Prolog
Diagnosed(IC_8085_faulty,0.8):-
Check(pin_40_U4,0.8);

Check(pin_30_U4,0.7);
Check(pin_37_U4,0.8),
Check(pin_35_U4,0.7).

Example 2

IF pin 8 of U9 is stuck to +5v (fv= 0.7)
AND pin 14 U7 +5v continuously (fv =0.8)
AND pin 6 U7 is stuck to +5v (0.7)
THEN IC_8155 faulty. (fv=0.7)

Visual Prolog Implementation

diagnosed(8155_faulty,0.7):-
check(pin_8_U9,0.7),
check(pin_14_U7,0.8),
check(pin_6_U7,0.7)

4.2 Fuzzy Inference Engine

Inference engine tries to derive new information about the problem domain using rules. Inference engine applies search strategy to find causes of the faults from a knowledge base. The strategy applied is backward chaining (faults→ causes). After the fault query is selected the inference engine applies first fuzzy rule form the rule base based on conflict resolution strategy, rule which is first in the rule base gets applied first. The inference engine uses goal driven back ward chaining search strategy. The main goal is decomposed into sub goals and sub goals further decomposed into sub goals and then step by step each goal is executed. A new fuzzy backward chaining algorithm is developed for reasoning. The algorithm can be stated as follows,

1. Assume the goal is 'X is faulty'. Set current goal state to X.
2. Find the rules which infers X by unification in the rule base. If there is no matching rule then go to step 6.
3. The main goal divides in to sub goals. Treat sub goal as a new goal and repeat step 2 and 3.
4. Compute Confidence Value (CV) using equation CV = min (fv of all antecedents) * fv of consequent, where fv is fuzzy value
5. If all sub goals in the rule are succeed then add the conclusion with Confidence Value to working memory.
6. Repeat for the next fault goal.

5. Object Oriented Approach

In object orientation, the most important concepts are object, class, instance, generalization, specialization, message passing and polymorphism. Object oriented design is a method which decomposes the complex problem in hierarchical manner. Object represents an instance of some class. Object oriented design (OOD) is based on many small concepts like, object, classes, operations and relationship etc. There are many important features of OOD some features used for the proposed system are inheritance, message passing and encapsulation. The OOD concepts are discussed briefly in sub sections below and its practical implications and analogies are discussed in later sections.

Objects:

It is an abstraction of something in a problem domain, reflecting the capabilities of the system to keep interaction with it. Booch [46] in his statement summarized that object has state behavior and identity. An object is a location in memory referenced by an identifier. It can be a variable, function or data structure. Objects are considered as instantiations of classes. Objects are basic foundation elements of object oriented paradigm and are a fundamental data type. In the present thesis use of objects to represent different circuit components is discussed.

Classes :

A class is a description of a group of similar instance objects and it determines the behavior of its instance. The class has a single name and set of different attributes which define the class properties. A class may be a sub class of another class and forms hierarchical structure and inherits properties from its parent class. A class contains attributes like name, super class, class variables, instance variables, class attributes.

Attributes:

An attribute is a characteristic of an object associated with value within the context of the system. The type of the attribute is defined by its class.

Methods :

These are a kind of attributes to objects and are defined in classes. Methods represent the capabilities of the classes.

Encapsulation :

This technique reduces interdependence among different modules by providing external interfaces. A method is encapsulated if access by other classes is restricted to predefined interfaces.

Inheritance :

Inheritance brings common properties across several classes into one general class called as parent class. This feature permits factoring knowledge into a class hierarchy and encourages modular development of knowledge. The expert system adopts the inheritance as follows,

If class A inherits from class C, then the objects of class A will support all operations supported by objects of class C.

Message Passing :

It is the only means of communication between objects. The system's behavior is determined by message passing mechanism. Message activates the methods in objects and consists of components like sender, receiver, selector and arguments related with message passing.

6. Architecture of Object Oriented Knowledge Based Expert System

The typical architecture of object oriented fault diagnosis systems is shown in Figure 2. It consists of main controller, knowledge base, inference mechanism, working memory, object space and 8085 Microprocessor Board as unit under test. Test Bench /Logic analyzer interface is used to test address bus, data bus.

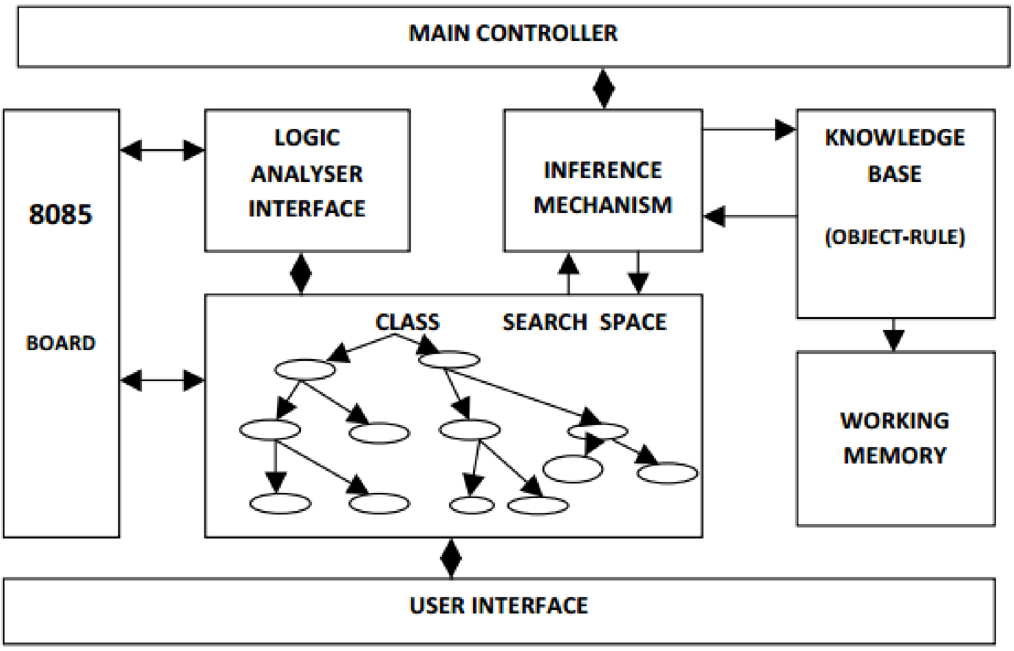

Figure 2. Architecture of Object Oriented Knowledge based System

The system is controlled by main controller. The diagnostic model is formed by interconnection of objects in the object space. The object space is the part of the working memory where objects are fired at run time. Every component on board is treated as independent object. The diagnostic information about the ICs is written in respective concrete classes. The status of the pins of ICs is detected by passing arguments to the maintenance technician and getting the argument values in Boolean type. The obtained status is stored in the working memory. As shown in the Fig 2, the interconnection of objects is shown by arrows; the inference engine uses message passing mechanism within the objects. The messages are passed sequentially. The inference mechanism is explained in next subsection. The knowledge base consists of procedural knowledge (diagnostic knowledge) and declarative knowledge. The maintenance technician can interact with the system using user interface. External logic analyzer interface is provided for testing address bus and data bus.

6.1 Knowledge Base

The fault diagnostic knowledge procedures are written using object structures and circuit board were described using frames. For categorization of faults fault classification knowledge is implemented using classes. Fault diagnose class contains CComp object as a member. CComp is a base class for all components on board. Similarly all procedural knowledge is represented for all the components available on the board. The declarative knowledge is used to describe the interconnections of components. A typical code fragment for its implementation using frames is shown in Fig.3 The frame describes the connectivity of IC 8085 with connector. This knowledge is used in inference process.

assertz(frame("8085_U4",[slot("PIN_03",[facet("NAME","reset_out"),facet("CONNECT_TO","47FRC1")]), slot("PIN_07",[facet("NAME","RST7.5"),facet("CONNECT_TO","50FRC1")]), slot("PIN_08",[facet("NAME","RST6.5"),facet("CONNECT_TO","46FRC1")]), slot("PIN_09",[facet("NAME","RST5.5"),facet("CONNECT_TO","49FRC1")

]), slot("PIN_11",[facet(NAME","INTA"),facet("CONNECT_TO","43FRC1")]), slot("PIN_35",[facet("NAME",”READY"),facet("CONNECT_TO","05FRC1")]), slot("PIN_38",[facet("NAME","HLDA"),facet("CONNECT_TO","41FRC1")]),

Figure 3. Code Fragment for declarative knowledge representation

6.2 Inference Mechanism

Inference mechanism uses classes & backward chaining. The classes and their methods form a hierarchical tree like structure. The inference mechanism starts the search from fault query and diagnoses the cause of failure.

6.3 User Interface

The inexperienced maintenance technician interacts with the system using user interface. To understand the behavior of the components, framework passes arguments to the maintenance technician and receives “yes” or “No” type messages.

7.Fault Diagnosis Strategy

The strategy applied by the system is like a human expert troubleshooter. The novice maintenance technician selects the fault query from the list. After the fault is identified, the controller passes the control to diagnostic module. The fault isolate-constructer initializes all flags and invokes the primary check methods. The methods pass arguments to novice maintenance technician and get argument values in Boolean form and return the suspected faulty component to the constructor. Constructor updates the member variable associated with it and calls diagnose method under identified component subclass. The specified component class calls diagnostic methods and passes arguments to novice maintenance technician and gets the required status of pins of ICs. Depending on the status entered, the faulty components are diagnosed as cause of the failure for the selected fault query and displayed in diagnosed faulty component menu.

7.1 Fault Diagnosis in 8085 Microprocessor Based Circuit Board

Experiment No.1: Fault Query: *No data get written form C100 H onwards*

On selection of this fault query from the menu, system generates an object instance. After pressing start diagnosis button from the menu the controller calls the CFault_diagnose class. For initialization and primary checks constructor is used. The constructor calls diagnose method form the generated object instance. The diagnose method passes arguments “Does pin 20 U1 high?” & “clock present between 1_2?” respectively to the technician. The technician responds “yes” to both arguments. The diagnose method returns U6-74ls138 and U1_8085 to the fault diagnose class as suspected faulty components. The fault diagnose class invokes CComp_74ls138_U6 class. The CComp_74ls138_U6 class calls respective diagnose methods. The diagnose method skips “Does pin 20 U1 6161 high?” argument from passing to technician since it is already available in data base. The next argument is Pin_ 6 _U18 B 74HC 32 high? is passed, it also gets passed. The method then passes the next argument, Pin 12 U6 74ls138 low? & Pin 5 U18 B 74HC 32 low? for the present fault and gets succeeded. Based on all arguments success, the CCompo_74LS138 class returns 74HC32_U18b component as faulty component to Fault diagnose class. The strategy is illustrated in Figure 4 P indicates test passed and F indicates test failed. Since 74HC32_U18 b is faulty for the present fault it is indicated by high lighter.

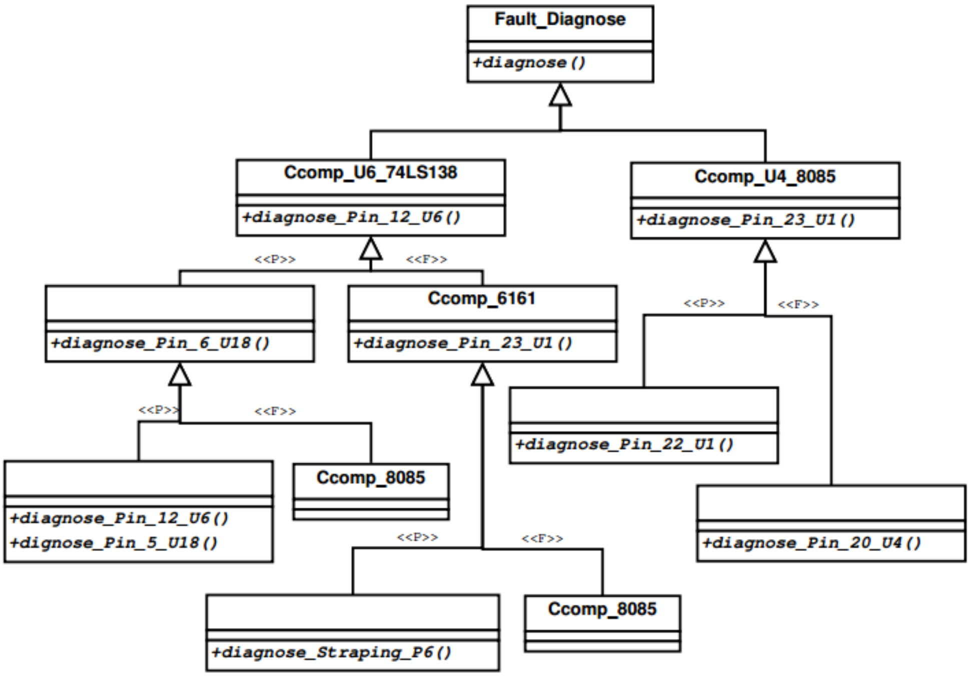

Figure 4. Diagnosing Memory Related Fault

Experiment No. 2: ***System not getting TURN ON***

On selection of this fault query from the menu, system generates an object instance. After pressing start diagnosis button from the menu the controller calls the CFault_dia class. For initialization and primary checks constructor is used. The constructor calls diagnose method form the generated object instance. The diagnose method passes arguments +5v not present at pin 40 of 8085? And “is power cable connection proper?” to the technician. The technician responds “yes” to both arguments. The diagnose methods returns supply power and connector to the fault diagnose class as suspected faulty components. The Fault diagnose class invokes CComp_power class. The CComp_power class calls diagnose method. The diagnose method skips pin 40 U4 8085 “+5v present?” argument when passing to technician since it is already checked.. The next argument from Ccomp_connector class, +5v present at output of power supply present? is passed and get succeeded. The method then passes next argument from connector class, Is power connector properly connected? for the present fault and it is also got succeeded. The decision is taken based on success for all arguments. The CCompo_connector class returns “connector” as a faulty component to Fault diagnoses class. The strategy is illustrated in Figure 5. P indicates test passed and F indicates test failed. Since power connector is faulty for the present fault it is indicated by high lighter.

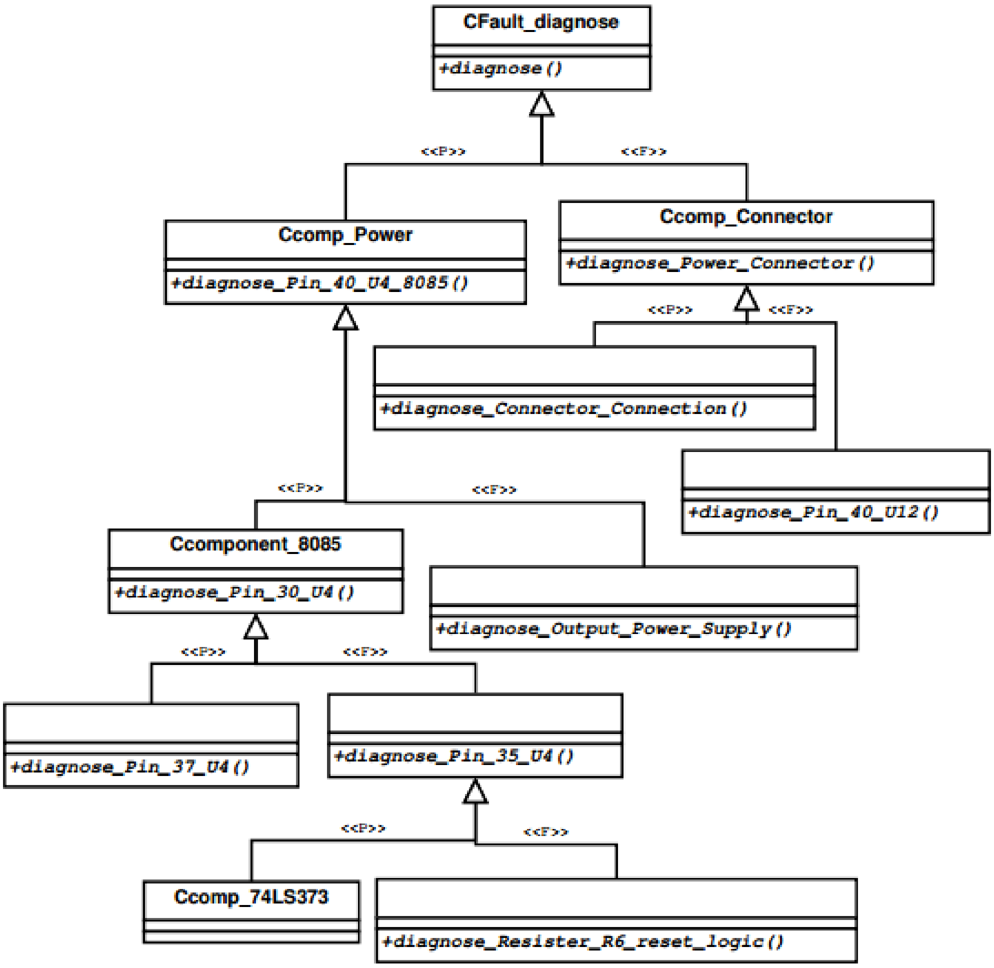

Figure 5. Diagnosing System Related Fault

Experiment No. 3: *Wrong data output on port A of 8255*

On selection of this fault query from the menu, framework generates an object instance. On pressing start diagnosis button from the menu the controller calls the CFault_diagnoses class. For initialization and primary checks constructor is used. The constructor calls diagnose method form the generated object instance. The diagnose method passes arguments pin 6_U10 8255 low? & Pin 10_U10_8255 high**?** to the technician. The technician responds “yes” to both arguments. The diagnose method sends U4_8085 and U10_8255 to the fault diagnose class as suspected faulty components. The fault diagnose class invokes CComp_U4_8085 class. The CComp_U4_8085 class calls diagnose method. The diagnose method pass pin 30_U4_8085 high? Argument to technician, technician responds by pressing “yes”. The next argument pin 6 U10 8255 is low? from CComp_8255 is skipped since is inherited and next argument pin 35_U10_8255 low? is passed. The technician answers it by pressing “y”. Since all arguments succeeded the CCompo_8255 class returns U10_ 8255 as faulty component to Fault diagnose class. The strategy is illustrated in Figure 6 below. P indicates test passed and F indicates test failed.. Since 8255 is faulty for the present fault it is indicated by high lighter.

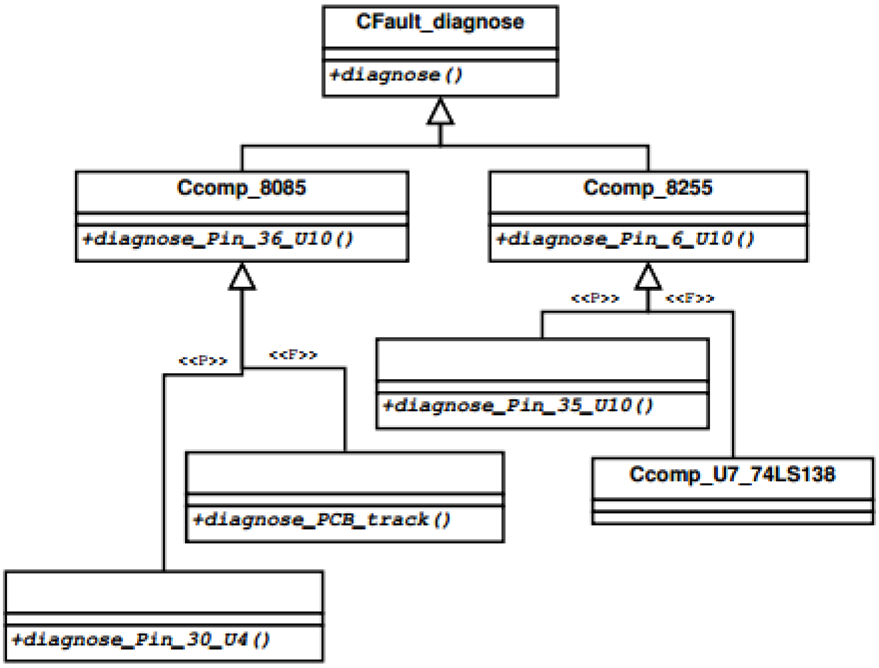

Figure 6. Diagnosing Input/Output Related Faults

Experiment No. 4: Display not working.

On selection of this fault query from the menu, controller in framework generates an object instance. After pressing start diagnosis button from the menu the controller calls the CFault_diagnose class. For initialization and primary checks constructor is used. The constructor calls fault_isolate() method form the generated object instance. The diagnose method passes argument Does pin 22 U12 low? & Does Pin 3 U12 8279 high**?** to technician. The technician responds "yes" to both arguments. The diagnose method sends U11_74ls145 and U4_8085 to the fault diagnose class as suspected faulty components. The fault diagnose class invokes CComp_U11_74ls145 class. The CComp_U11_74ls145 class calls diagnose method. The diagnose method pass Is "Does pin3_8279_U12_high?" argument to technician, technician responds by pressing "yes". The next argument Does pin 32 to 34_U12 is high it is responded as "yes" and gets stored in working memory as scan_lines_are_ok and Pin 37_U4_8085 high is checked concurrently using multithreading with scan lines status stored in working memory. It is very much essential to check status of both at a time for display driver IC. The two methods are called as threads predicates and declared under multithreading class. For both the response is "yes". Then next argument pin 23_U12_8279 low? is passed. The technician answers it by pressing "yes". Next, Pin 1 U11 74ls145 stuck low? Argument is passed. The technician answers "yes". Since all arguments succeeded under CCompo_74ls145 class, it returns U11_74ls145 as faulty component. U11_74ls14 faulty is displayed as faulty component in faulty component menu. The strategy is illustrated in Figure7 below. P indicates test passed and F indicates test failed. Since U11_74ls145 is faulty for the present fault it is indicated by high lighter.

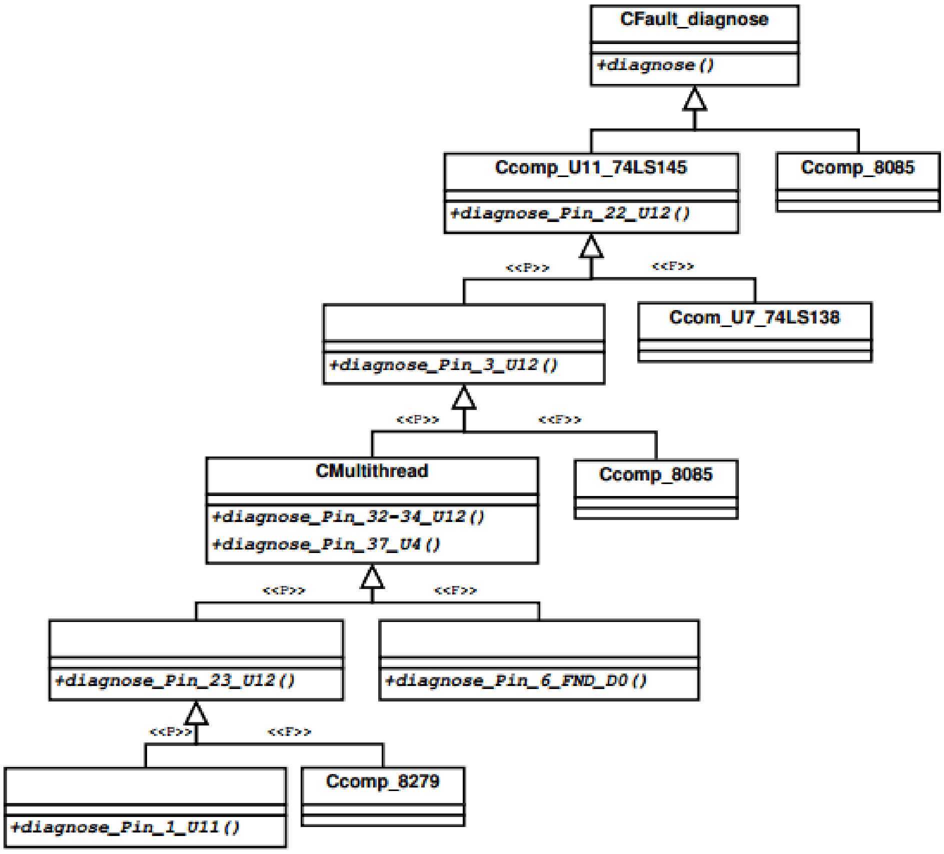

Figure 7. Diagnosing Display Related Faults

8. Results Obtained using Two Approaches

For typical faults in 8085 microprocessor circuit board faults diagnosed using two approaches are presented in table 1.

Table 1. Results Obtained using Two Approaches

Sr. No.	**Fault Query**	**Using Fuzzy Expert System with Confidence Value (CV)**	**Using Concurrent Object Oriented Expert System.**
1.	No sign on Message on reset pressed	EPROM 2764 Faulty cv =0.8, EPROM 2764 Socket faulty 74ls373 faulty cv=0.5 Cv=0.7 No. of rules applied = 02	EPROM 2732 Faulty Reset Key failure No. of methods applied = 03
2	Display D1 not working	8279 faulty cv =0.8 74ls138_U7 faulty cv=0.6 74ls138_U7 socket faulty cv=0.5	74ls138_U7 faulty Display D1 Faulty No. of methods applied = 02

		No. of rules applied = 02	
3.	Interrupt RST 6.5 not working	8085 socket faulty cv =0.7, 8085 faulty cv=0.5 No. of rules applied=02	8085 faulty 74ls04_U14b faulty Strapping p2 open No. of methods applied = 02
4.	Memory read operation from C200H onwards not working	P6 Strapping open cv =0.9 6264 faulty cv=0.6 No. of rules applied =02	74HC32 U18B faulty 6264 faulty Strapping p17 open No. of methods applied = 02
5	System not getting started	Memory strapping p6 Open cv =0.7 8085 socket failure cv=0.5 No. of rules applied - 01	Power cable failure Power cable loose connections 8085 socket failure No. of methods applied = 02
6	After reset key pressed system is not get resetting	805 failure cv=0.7 Key in reset logic failure cv=0.4 Resistor R6 in reset logic failure cv=0.3	Key in reset logic failure Resistor R6 in reset logic failure 8085 failure No. of methods applied = 02
7	On TURN ON display show garbage information	8279 faulty cv=0.9 2764 faulty cv=0.6 74ls 145 faulty cv=0.2 N0. Of rules applied =02	8279 faulty 2764 faulty No. of methods applied = 02
8	After execution of instruction MOVA,40H no register get modified with data	INC key faulty cv=0.6 8279 faulty cv=0.5 8279 socket faulty cv=0.2 No. of rules applied =0.3	8279 faulty 8279 socket faulty No. of methods applied = 02
9	Program is not executed on pressing EXEC key	74156 faulty cv=0.8 8279 faulty cv=0.4 No. of rules applied=02	8279 faulty EXEC Key failure Track below EXEC key open. No. of methods applied = 01
10	Data is not get written from C100 onwards	6264 Faulty cv=0.8 8085 faulty cv=0.4 No. of rules applied=03	74HC32_U18B failure 6264Faulty 8085 faulty Strapping P6 open No. of methods applied = 02
11	TRAP pin not working	8085 faulty cv=0.9 Strapping P1 open cv=0.7 No. of rules applied	Strapping P1 open 8085 failure No. of methods applied = 01
12	Data is not get written from	6264 faulty cv=0.9 74ls373 faulty cv=0.6	6264 faulty 74ls373 faulty

	C200 onwards	No. of rules applied =03	No. of methods applied = 02
13	Interrupt RST 7.5 not working	8085 failure cv=0.7 8085 socket failure cv=0.8 No. of rules applied =02	8085 failure Resistor R8 open Key V1 failure No. of methods applied = 03
14	Interrupt RST 5.5 not working	74ls04 U14 failure cv=0.9 8085 failure cv=0.5 8085 socket failure cv=0.3 No. of rules applied =03	74ls04 U14 failure Strapping p2 open Pull up resistor R3 open No. of methods applied = 02
15	Interrupt TRAP not working	8085 failure cv =0.6 Strapping p1 open cv=0.6 No. of rules applied =03.	Strapping p1 open 8085 failure No. of methods applied = 01

9. Conclusion

As per the faults diagnosed by both approaches it is conclude that, in the second approach less methods are applies as compared to rule based approach. The Fault classification strategy in object oriented fault diagnosis system has minimized 50% efforts in identifying the fault area. The message passing and inter class communication has provided flexible inference mechanism. Using inheritance in object orientation, object orientation strategy diagnoses 20% faults using three methods, 50% faults using two methods and 30% faults using one method as against rule based approach . In rule based approach all rules were applied sequentially hence it took more time in diagnosing typical faults. In future web based approach can be developed for on line fault diagnosis.

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