CHAPTER I

1. INTRODUCTION

1.1 BACKGROUND

The latest developments in the area of Artificial Intelligence are revolutionising the field of Fault_Diagnosis. Much current research in artificial intelligence focusses on computer programs that help people with complex reasoning tasks. One way to create intelligent systems is to incorporate large amounts of task-specific knowledge.

Expert Systems, which incorporate a knowledge base of facts regarding the problem domain and domain-specific heuristics for faster processing of the knowledge to arrive at results, are becoming popular as applications of artificial intelligence techniques. Expert systems are to perform several problem-solving activities, for example in MYCIN these include: identifying the problem, processing data, generating questions, collecting information, establishing hypothesis space, pursuing and testing hypotheses, exploring and refining, asking questions and making a decision.

1.2 FAULT-DIAGNOSIS

Traditionally Fault Trees have been extensively employed for the activity of fault-diagnosis. FMECA (Failure Modes, Effects and Criticality Analysis) is an exhaustive approach for locating faults in systems and is a qualitative technique. For simple systems fault trees may be an easy solution and FMECA can afford to be exhaustive. But for complex systems such as flight control systems with hundreds of components with multiple failure modes, these techniques assume a high complexity increasing the chances of errors besides requiring large processing times. Automated Fault Tree Analysis and FMECA suffer from the same problems in addition to being rigid and most uncommunicative owing to the nature of the computer languages employed.

Expert systems based on artificial intelligence techniques developed in highly flexible and user-interactive programming environments (such as LISP or PROLOG) are capable of providing many advantages for better implementation of the diagnosis task as proved by the example of the MYCIN (it is used for the medical diagnosis of diseases due to bacterial infections). These include:

* explicit representation of knowledge regarding the cause effect relatioships of the various subsystems in any complex system;

* a structured representation of the various subsystems, their failure modes, the symptoms exhibited in these failure modes and the possible causes and the applicable remedies;

* applying their expertise to the solution of problems in an efficient manner. They are able to employ plausible inference and reasoning from incomplete or uncertain data;

* explaining and justifying what they do

* communicating well with other experts and acquiring new

knowledge;

* restructuring and reorganizing knowledge;

* determining relevance so as to know when a problem is outside their expertise; and

* a highly interactive user interface leading to considerable ease in presenting, modifying and retrieving the knowledge in the knowledge base.

1.3 A.I. AND EXPERT SYSTEMS

Artificial Intelligence refers to area of computer science which is concerned with making computers perform intelligent tasks based on knowledge about the problem. The knowledge required for A.I. applications should be represented in such a way that: (a) it captures generalizations, (b) it is understood by people who provide it, (c) it can be easily modified to correct errors and reflect changes in the world, and (d) it can be used in situations where it is not totally accurate or complete. Lists, semantic nets, frames, predicate logic, conceptual dependencies and scripts are some of the various structures used for knowldge reprsentation. A,I, techniques such as forward and backward reasoning, graph reduction, matching, indexing, generate-and-test, hill climbing, breadth-first search, best-first search, constraint propagation, means-end analysis etc. use this knowledge to arrive at intelligent solutions to problems pertaining to their knowledge domains. Some of the problems that fall within the scope of A.I. include: game playing, theorem proving, general problem solving, vision processing, speech processing, natural language understanding and expert problem solving.

Expert systems are A.I. techniques which deal with expert problem solving. This is a major application area for A.I. Symbolic mathematics, medical diagnosis, chemical analysis, engineering design, management decision making etc. are some of the fields in which expert systems are being extensively used. Rule Based Systems (also known as Production Systems or RBSs) which are a special class of expert systems represent knowledge in the form of 'IF <condition> THEN <action>' rules. These RBSs constitute the best currently available means for codifying the problem solving knowledge of human experts. Some of the key features of any RBS include : (a) incorporation of practical human knowledge in conditional IF-THEN rules, (b) increase of skill at a rate proportional to the enlargement of the knowledge bases, (c) ability to solve a range of possibly complex problems by selecting relevant rules and then combining the results in appropriate ways, (d) determining adaptively the best sequence of rules to execute, and (f) ability to explain their conclusions by retracing their actual lines of reasoning. The fundamental structure of any expert system includes: (i) a knowledge base for storing knowledge in the form of facts and rules, (ii) an inference engine for utilising the knowledge base to arrive at solutions to problems, and (iii) a User Interface Module to enable the user to review/update the knowledge base, present the problem to the inference engine and obtaining the solution in the required format. Sometimes, a Knowledge Acquisition Module is seperately mentioned owing to : the importance of creating, modifying/updating and retrieving knowledge from the knowledge base as also the variety in the methods of acquiring knowledge such as by direct specification, by analogy, by example, by observation, discovery and experiment and by reasoning from deep structure. MYCIN (medical diagnosis), XCON (configuration of VAX computer systems), DENDRAL (identification of the structure of organic compounds), HICLASS (product classification and process planning) etc. are some examples of Rule-Based systems. The success of RBSs has led to the development of domain-independent systems such as EMYCIN, OPS5, KES etc. which have a generalised inference engine operating on specific knowledge domains.

In this thesis the author presents a detailed description of the structure and functioning of FAULT-ART a domain independent expert system for fault diagnosis of complex systems, developed by him. Some supplementary work on parameter search and reliability design and modelling carried out by the author during the course of his research are also described.

Chapter I presents an introduction to the problem under consideration and the contents of the thesis. Chapter II is detailed survey of the literature in the areas of artificial intelligence, expert systems, fault trees and FMECA for fault diagnosis and reliability modelling. It traces the evolution of these concepts and presents the state-of-art development in these fields.

Chapter III deals with representation issues for knowledge in the field of fault diagnosis. An analysis of the nature of the failure information used for fault diagnosis leading to choice of possible representation techniques for efficient performance follows.

Chapter IV examines the nature of diagnosis process in automated fault diagnosis. The design of the generalised inference engine capable of operating on different knowledge domains to arrive at a diagnosis are discussed.

A user-friendly interface is of prime necessity for input/output operations concerning complex information. To facilitate an easy method of presenting, updating/modifying and retreiving knowledge regarding the causes, failure patterns and their effects on systems, a highly interactive Knowledge Acquisition Module is presented. Other user interactions such as the explanation of the reasoning process etc. are handled by the user interface module. Chapter V presents these details.

Chapter VI presents a unified view of the functioning of the domain-independent expert system for fault diagnosis, FAULT-ART, along with the interactions between the knowledge base, the inference engine, the knowledge acquisition unit and the user interface module.

The application of FAULT-ART for the knowledge building and diagnosis activities for a travelling bridge crane system is examined in Chapter VII.

A proposed real-time expert system for condition monitoring and fault diagnosis as a natural extension to FAULT-ART is discussed in Chapter VIII. Issues relating to real-time operation and extensions to the knowledge base are presented.

Chapter IX deals with problems of parameter search, reliability design and modelling.

The inverse distributions are aimed at parameter search problems in mechanical reliability design. Tabular methodologies suffer from inaccuracies due to interpolation and unavailability of tables in narrow regions. This is of paramount importance specially at the design stage where every precaution needs to be taken to ensure desired reliability. Theoretical basis has been developed for the inversion of univariate distributions and has been successfully used to develop inverse-normal and log-normal distributions. A typical case in mechanical reliability design has been taken and the inverse-normal and log-normal distributions have been employed for searching parameters to meet the requirements of desired reliability. Inverse t-distribution has also been developed to be used for parameter search problems. An inverse problem of searching parameter is more natural in a reliability design problem and hence this problem of fixing up parameters has been undertaken.

A methodology has been developed for the inverse bivariate distributions as well.

A methodology has been developed for the evaluation of reliability of mechanical systems specially for cases where no basis exists for assuming any specific distribution, but where experimentation has been performed yielding sufficient empirical data.

A methodology for tackling an unconventional problem of synthesis of reliability networks based on available data has also been developed. The accuracy of the model developed based on the available data and component reliability has also been discussed. The case of a bridge network has been discussed and depending on the requirement of accuracy the models can be chosen. A generalization has also been developed for much more complex networks where components may have varying reliabilities.

The conclusions drawn from the application of the FAULT-ART system for the fault diagnosis of the crane system and the scope for future work form the subject matter of Chapter X.

The list of references follows in chapter XI.