CHAPTER 3

Overview of Expert Systems

- Introduction
- History of expert systems
- Architecture of an expert system
- Applications of expert systems
- Application of expert systems in LIS work
- Applications of expert systems in cataloguing
- References

3.1 Introduction

Expert systems are a part of Artificial Intelligence (AI). *Artificial Intelligence is that field concerned with the computations that connect situations to complex, human-like actions*[1]. AI can help or to some extent replace human experts in problem-solving. Though much of the research in AI started in early 20th century, it was the British mathematician Alan Turing who brought AI into the centre stage of computer science. He is considered as the father of AI. Turing is better known for his "Turing Test" experiment which was described in his classical paper[2] "*Computing machinery and intelligence*" published in 1950.

The term Artificial Intelligence was coined by John McCarthy during a Conference held at Dartmouth College in Hanover, New Hampshire in 1956. Two years later McCarthy invented the programming language *LISP* for developing AI applications.

In 1967, Richard Greenblatt at MIT built a knowledge-based chess-playing program, MacHack, that was good enough to achieve a class C rating in tournament play.

AI is concerned with developing computer systems which reason and behave in ways a neutral observer would consider "human". The areas in AI include: Problem solving, Knowledge Based Systems, Learning, Natural Language Processing, Vision, Speech, and Game playing, etc[3].

Some branches of AI have moved beyond pure research. They seek to apply what is known as AI science; they produce marketable AI technologies. One such branch is robotics, which seeks to give computers human mobility and sensory capabilities. Another is, knowledge based systems.

Winston[4] gives some of the key AI areas:

- **Computational robotics**, which includes vision, manipulation, locomotion, reasoning about space, and reasoning about object interaction

- **Sensor interpretation**, which includes visual sensors, acoustic sensors, and signal-to-symbol conversation

- **Expert systems**, which includes rule-based reasoning, constraint-based reasoning and analogy-based reasoning

- **Language understanding**, which includes speech, syntactic analysis, question understanding and discourse understanding

- **Learning**, which includes learning by noting patterns, and learning by exploiting precedents

- **Common-sense reasoning**, which includes variable-precision reasoning and qualitative reasoning about quantities

- **Supercomputing hardware and software**, which includes massively parallel architecture and very high-level languages

The present work deals with Expert Systems (ES) only and hence it is explained in detail.

Expert systems are considered to be the most important contribution of AI. Terms such as "expert systems," "knowledge-based systems," and "decision support systems" are used more or less synonymously by some writers, while others emphasize the subtle differences between such systems[5]. An expert system may be defined as *a computer program that exhibits, within a specific domain, a degree of expertise in problem solving that is comparable to that of a human expert*[6]. Expert systems are meant to support the domain experts in quick decision making and thereby problem solving.

Expert systems are computer systems designed to simulate the behaviour of human experts in a narrow domain of knowledge. They are relatively new and growing branch of AI. Expert systems are based on the idea that humans commonly use many types of knowledge when solving problems. Knowledge is an integrated collection of information which, when used, produces a competent level of performance. Two of the most important forms of knowledge are factual knowledge and heuristic knowledge.

The factual knowledge is the type of learning a person usually gains from reading books and attending school. Factual knowledge provides a set of general theories. It can suggest highly structured solution processes called algorithms, for solving problems in a finite number of steps.

Heuristic knowledge is the type of learning a person gains from experience. Heuristics are rules of thumb or situation-specific theories. Since each person's experiences are unique, heuristics knowledge is personal and private. People use heuristic knowledge every day to solve problems.

Expert systems differ in important ways from both conventional data processing systems and systems developed in other branches of AI. Firstly, they perform different tasks at expert levels of performance. Secondly, they emphasize domain-specific problem-solving strategies over the more general "weaker methods" of AI. Thirdly they employ self knowledge to reason about their own inference processes and provide explanations for conclusions reached[7]. In other words, an expert system can be compared with a computer based system that achieves a high level of performance in the task areas for which humans require years of special education and training.

The usefulness of an expert system is best explained by Waterman[8] in the following paragraph:

> *The most useful feature of an expert system is the high-level expertise it provides to aid in problem solving. This expertise can represent the best thinking of the top experts in the field, leading to problem solutions that are imaginative, accurate, and efficient. It's the high-level expertise together with skill at applying it that makes the system cost-effective, able to earn its own way in the commercial market place.*

Ignizio[9] credits experts systems with following advantages over human experts:

- Expert systems are always and instantly available, and always perform at the same level of expertise.
- Expert system has direct and instantaneous access to the necessary databases (ideally) and is not bound by limited, biased, and imperfect recollections of the human.
- It is logical, objective, and consistent – and thus unswayed by emotional arguments that might influence a human
- Expert systems do not forget or make mathematical errors

- The expert system is in a constant state of awareness (i.e. it will not overlook any critical events that it has been assigned, and has the means to monitor

- It makes its decisions with regard to the goals of the firm, rather than with regard to how such decisions might influence its personal promotions or pay raises

- The expert system multiplies the expertise of the firm, that is, it is directly accessible by all other divisions of the firm whereas the human expert's access is limited by physical and geographical considerations.

- The expert system is, itself, a repository for the storage of the knowledge of those experts from whose input it was developed; it is a knowledge bank of considerable value and is thus a tangible, and permanent asset of the firm.

3.2 History of Expert systems

The technology represented by current expert systems is an outgrowth of the AI techniques that have been the subject of intensive research since the late 1950s.

Alberico and Micco[10] summarize the major milestones in the history of expert systems developments in the following manner.

First Generation, Pre-1956

Warren McCulloch is considered to be one of the founding fathers of AI. At the University of Illinois, he had developed a neural net model of the brain. Though this model, later proved fundamentally flawed on various aspects, its influence was substantial.

Turing was the first one to visualize the 'think machines.' He is remembered in the AI circles for his famous 'Turing Test.' In this test, an operator interacts with two parties, one a human and the other a computer. If the operator fails to understand whether he is interacting with a computer or the human at any given time, it is assumed that the computer possess human reasoning.

Second Generation, 1956-1970

John McCarthy of Dartmouth College and his friend Marvin Minsky of MIT organized for the first time, a ten-man study of AI in 1956 at Dartmouth. This also facilitated the term "Artificial Intelligence" to appear in print for the first time. This conference is a milestone in the history of AI. Alan Newell and Herbert Simon from the Carnegie Institute of Technology, around the same time, were working on the 'Logic Theorist', which later evolved into the 'General Problem Solver.'

During this period some early expert systems with limited capabilities were also developed by AI researchers. BAGGER – a rule based system designed to pack groceries in bags and ANALOGY – an expert system to perform the I.Q. test were some of them. One of the major systems to be built in this period was the MACSYMA by two MIT researchers. MACSYMA was a powerful problem-solving system with the capability of performing over 600 distinct mathematical operations.

DENDRAL, one of the most known expert systems even today was built by Edward Feigenbaun in 1968. The system helps in identifying the structure of a parent compound from an input formula.

1970 – 1982

Many large systems were developed during this period. The approach was slowly shifted from problem solving to modelling of human expertise. Some of the well known systems like PROSPECTOR, MYCIN and XCON were developed in this period.

1982 – onwards

This is considered to be the golden period for expert systems research. Countries like the U.S. and Japan had veiled various new programmes with large funding. A number of computer vendors jumped into this area and many commercial expert system shells were made available. A large number of expert systems have been developed in various fields performing a range of different tasks.

3.3 Architecture of an expert system

Figure 3.1 explains the basic architecture of an expert system. The user interacts with the system through a *user interface* which may use menus, natural language or any other style of interaction. Then an *inference engine* is used to reason with both the *expert knowledge* (extracted from an expert) and data specific to the particular problem being solved. The expert knowledge will typically be in the form of a set of IF-THEN rules. The *case specific data* includes both data provided by the user and partial conclusions (along with certainty measures) based on this data. In a simple forward chaining rule-based system the case specific data will be the elements in *working memory*.

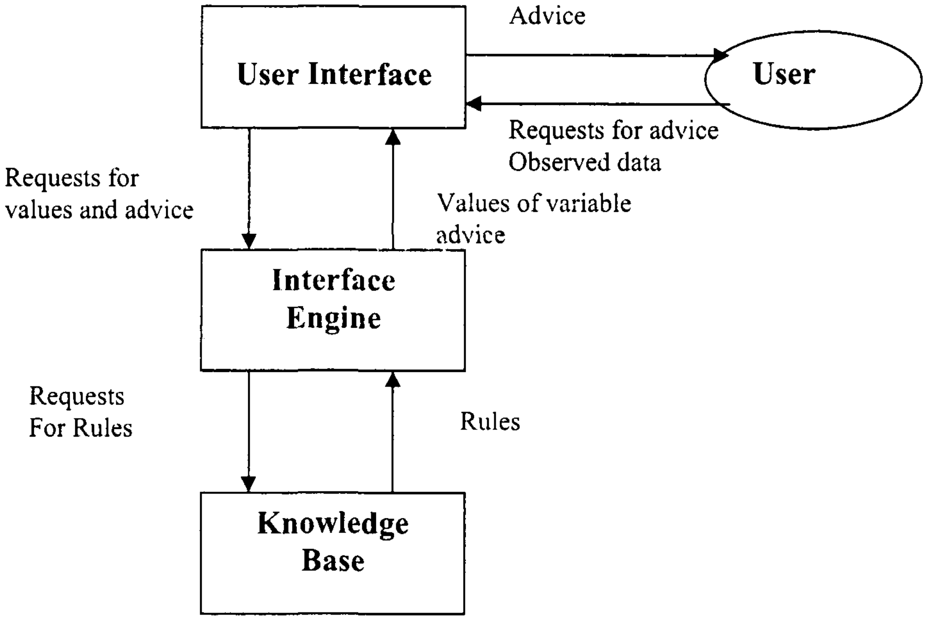

Figure 3.1 Architecture of an Expert System (adapted from *Yazdani, Masoud*[11], *1984*)

The main components[12] of an expert system are:

1. the knowledge base
2. the inference engine
3. a knowledge-acquisition module
4. an explanatory interface.

Each of these is discussed in detail in the following sections.

3.3.1 Knowledge base

The knowledge base stores information about the subject domain. Knowledge is stored in a logical manner so that the inference engine can perform deductions upon it. The specification knowledge base contains information about particular applications not necessarily disjoint, especially if these applications are related to different aspects of the same management environment. This information is covered by clusters of connected frames and captures the presence or absence of contradictions in the ground knowledge. Each application models information about a system or part of it[13].

There are various methods to represent knowledge in an expert system. Following are the major knowledge representation methods[14]:

Rules in IF-THEN format

The condition specifies some pattern and the conclusion may be an action or assertion. In such a system, the domain knowledge is represented as a set of rules that are checked against a collection of facts or knowledge about the current situation. When the IF portion of the rule is satisfied by the facts, the action specified by the THEN portion is performed. When the condition is satisfied the rule is said to 'fire' or 'execute'. A rule interpreter is used to compare the IF portions of rules with the facts and execute the rule whose IF portion matches the facts. The rule's action may modify the set of facts in the knowledge base.

Semantic nets

These represent relationships among objects in the domain by links between nodes. A semantic network is a method of knowledge representation based on a network structure. A semantic net contains points called *nodes* connected by links called *arcs*. The nodes represent objects, concepts or events. The arcs are used to represent the relations between the nodes. Arcs may be employed for varied purposes. The most common arcs represent the knowledge in hierarchies.

Frames

These are generalized record structures which are more flexible than is usual in traditional data-processing in that they may have default values or procedural entries as the values of certain fields or slots. Frames are in a way abstractions on groups of facts. Frames play an important role in dealings with potentially large number of facts, because they help organize facts. Frames are something called classes or prototype or structured object descriptions. The objective of a frame system is to partition data, just as modular programming partitions programs. The usual way is to group together facts about the same thing or object, or grouping facts with the same argument values.

Horn clauses

These are expressions in a form of predicate logic on which *Prolog* is based and with which the *prolog* system can perform inferences.

In the present work, we have used a rule-based approach for knowledge acquisition. Rules are the most predominant form for knowledge representation. MYCIN, one of the first expert systems to be built was based on this method. The rule based systems start with a set of rules, which contains all the necessary knowledge encoded in the IF-THEN format and a working memory. The system will examine all the rule conditions (IF), and determines a subset, the conflict set, of rules whose conditions are satisfied based on the working memory. Of this conflict set, one of those rules is triggered. Which one is chosen is based on a conflict resolution strategy. When the rule is fired, any actions specified in its THEN clause are carried out.

Following is an example of rule-based knowledge representation model[10]:

IF *1. the infection is meningitis, and*

2. the sub-type of meningitis is bacterial, and

3. only circumstantial evidence is available, and

4. the patient is atleast 17 years old, and

5. the patient is alcoholic

THEN

there is suggestive evidence that Diplococcus pneumoniae is an organism causing the meningitis

As already mentioned, for the present work, we have adopted a rule-based knowledge representation model. The knowledge base contains the AACR2 rules in an IF-THEN format.

3.3.2 The inference engine

An inference engine tries to reach conclusions or inferences based on the data available in the knowledge base. It is the most important part of the expert system. Most of the inference engines use one of the two reasoning strategies – forward chaining or backward chaining.

Forward chaining starts with the data available and uses the inference rules to conclude more data until a desired goal is reached. An inference engine using forward chaining searches the inference rules until it finds one in which the IF-clause is known to be true. It then concludes the THEN-clause and adds this information to its data. It would continue to do this until a goal is reached. Because the data available determines which inference rules are used, this method is also called 'data driven.' The famous *CLIPS* expert system developed by

Charles Forgy for the NASA-Johnson Space Centre used this method. Also, *Jess,* the expert system for the java platform developed by Ernest Friedman-Hill of Sandia National Labs used this method.

The backward chaining starts with a list of goals and works backwards to see if there is any data which will allow it to conclude any of these goals. An inference engine using backward chaining would search the inference rules until it finds one which has a THEN-clause that matches a desired goal. If the IF-clause of that inference rule is not known to be true, then it is added to the list of goals. *Prolog*, the programming language supports this method. One of the the famous expert systems, MYCIN was built based on this method of inferencing.

3.3.3 Knowledge acquisition

Acquiring expert knowledge is considered to be one of the difficult tasks in developing expert systems. The main reason is that the experts are usually very poor in describing their reasoning process for a particular problem. Forsyth[15] says it is difficult to get the knowledge out of the experts for any of the three reasons – (a) deliberate resistance, (b) inarticulacy, or (c) cognitive mismatch between brains and programs.

Many techniques have been developed to help elicit knowledge from an expert. These are referred to as knowledge elicitation or knowledge acquisition (KA) techniques. The term "KA techniques" is commonly used in this context. Scientists have also tried automating the entire knowledge acquisition process since it is very difficult to acquire knowledge from the experts[16].

Ontologies are used these days for the knowledge acquisition process. Although there is a lack of unanimity in the exact definition of the term ontology, it is generally regarded as a formalized representation of the knowledge in a domain taken from a particular perspective or conceptualization. The main use of an ontology is to share and communicate knowledge, both between people and between computer systems. A number of generic ontologies have been constructed, each having application across a number of domains which enables the re-use of knowledge.

3.3.4 The interface

The interface is meant for communication with the user. The user interface is generally not a part of the ES technology, and was not given much attention in the past. However, it is now widely accepted that the user interface can make a critical difference in the perceived utility of a system regardless of the system's performance. The user interface checks all responses to ensure that they are of the correct data type. Any responses that are restricted to a legal set of answers are compared against these legal answers. Whenever the user enters an illegal answer, the user interface informs the user that his/her answer was invalid and prompts him/her to correct it.

Modern day expert systems incorporate concepts from human-computer interaction research to design better interfaces.

3.4 Applications of expert systems

Expert systems are used in diverse fields like manufacturing, medical diagnosis, software engineering, library and information services, military applications, etc. DENDRAL, considered to be the very first expert system was used for the identification of chemicals. It was built in the mid-1960s at the Stanford University[17]. In 1969, Carnegie-Mellon University had developed HEARSAY-I in an attempt to demonstrate the possibility of speech recognition systems. An advanced version HEARSAY-II was developed in 1971.

MYCIN an expert system in blood infections, is one of the most widely known expert system, was built 1976. The knowledge base of MYCIN contains the heuristic rules used by physicians in the identification of certain infections[18].

General Electric Company had developed an expert system, known as DELTA/CATS-1, in the 1980s to aid the maintenance of diesel-electric locomotives[19].

AT&T Bell Laboratories had developed a LaSSIE, an expert system that uses a frame-based description language and classification interference to facilitate a programmer's discovery of the structure of a complex system[20]. The system is designed to be used in a formulate-retrieve-reformulate cycle. If the answer to an initial query is unsatisfactory, the user can reformulate the query in a variety of ways and try again.

John V. Thomason[21] at the Commonwealth Scientific and Industrial Research Organization, Australia had developed an expert system which analyses possible ways of water leakage through window frames. This system broke new ground in the sense that it has heavily used graphics. The most interesting part of the system is that the knowledge is mostly represented in the form of objects instead of data.

SAL (System for Asbestos Litigation) was meant for the legal decision making. It is a rule-based expert system. It is supposed to be most widely used expert system in the area of law[22].

Now a days, expert system shells are being offered by commercial vendors for various applications. One could you use these shells for developing expert systems without having to apply much programming skills.

3.4.1 Applications of expert systems in Library and Information (LIS) work

Similar to its applications in other fields, expert systems are developed for various library and information related activities. Expert systems have a variety of applications in the area of Library and Information Science. Expert systems are rapidly becoming part of the Librarian's vocabulary. They offer a level of technology sophistication that has never been experienced in the library world. Already work is in progress in areas such as reference work, cataloguing, classification, indexing and intelligent information retrieval. Alberico and Micco[23] observe that:

> *In libraries there are a number of possible applications, such as the provision of reference assistance to users as well as a variety of other information management tasks, including acquisitions, cataloguing, indexing, database searching, interlibrary loan, and automated information retrieval.*

According to Gibb and Sharif[24], the main areas of expert system applications to library and information science can be in the following areas:

- Classification
- Cataloguing
- Intelligent front-ends to databases
- Referral assistance
- Abstracting and summary systems
- Archives

Although expert systems can and have been applied to many areas within Library and Information Science, the most popular areas have been online retrieval, reference and referral services[25].

Prasad and Rath[26] have developed an expert system to capture bibliographic data from the title pages and verso of the title pages of documents. The system uses a heuristics methodology which can help in developing a program to automatically identify the various bibliographic data elements. The title pages and back of the title pages are scanned and stored as HTML pages using optical recognition software. The heuristics are then applied on the HTML pages.

Clarke and Cronin[27] discusses about certain early expert systems developed for bibliographic searches. National Library of Medicine, USA has developed an expert system for searching the MEDLINE database in 1981. A hospital in Boston, Massachusetts has developed an expert system called PAPERCHASE for searching the medical literature. Crystal and Jacobson[28] describe a system called FRED developed for searching large databases. The FRED system helps the user to select the target database based on the information provided in the user query.

The Defence Metallurgical Research Laboratory, Hyderabad, India had developed an expert system for the classification of technical documents using the UDC scheme[29]. The system uses the UDC rules as its knowledge base. In order to suit the automated system, the rules have taken an enumerative structure instead of analytico-synthetic structure. The system interacts with the classifier making him/her conform to the route suggested by the classification scheme and alerts the classifier whenever some minor variations are found. In this way the system tries to bring consistency in the classification process.

In 1986, the National Agricultural Library of the United States' Department of Agriculture (USDA) developed a system called ANSWERMAN for assisting in answering questions related to a wide variety of reference books and other reference materials in the area of agriculture[30]. The shortcomings in ANSWERMAN were removed and modified version known as AQUAREF was developed. This new model allowed the users to build links between knowledge bases representing their own collections and expertise which could be chained to other knowledge bases. It used a concept called "distributed expertise" to help the user in finding correct answers to their queries[31].

McDonald and Weckert[32] discuss a system called DISTREF developed for referral services at the Charles Sturt University in Australia. The main components of the system include a "knowledge editor" module for creating and maintaining concept hierarchies and a "knowledge integrator" module for building structural relationships among concepts.

Ohio State University has developed an expert system called SOURCEFINDER[33] to support the reference services at the main Library. Reference librarians use SOURCEFINDER as a training aid, in unfamiliar subject areas and same is also used when trained librarians are unavailable. The system provides direct access to reference knowledge by means of a series of questions known as 'Question Units' on a variety of subjects, where instructions and sources area are arranged in the form of types of reference questions. The system has an inference mechanism which converts reference questions into the subjects already represented in the library catalogue and then matches the same with the resources available in the library.

Madalli[34] has developed VYASA, an expert system for automatic updation of colon classification schedule. The system had used a frame based knowledge representation model.

Wei and Cole[35] have developed a prototype web-based electronic database selection expert system. The prototype system is designed to assist users in selecting from among the article databases, directories, statistical and government document electronic resources (including Web and CD-ROM bibliographic/fulltext resource databases, but excluding the online catalogs, electronic books, encyclopaedias, and dictionaries). Users were able to select resources by any of three methods:

(1) searching for relevant resources using free-text keywords and phrases;

(2) browsing available databases by subject categories; or

3) choosing desired database characteristics from menus (e.g. material types indexed, chronological coverage).

MacLennan[36] describes a system called BROWSER, designed for aiding the librarians in literature selection in libraries. The system displays the features of an expert, or knowledge-based system, in that it implements a set of rules, or heuristics, which are obtainable with relative ease from a human "expert", or which may at least be derived by a process of trial and error from a series of postulated rules which can be refined, by the adjustment of weightings, to reproduce the operation of such rules. It was developed using the *Prolog* programming language.

Gopinath and Prasad[37] discuss an expert system called PROLOGOMENA, developed to automatically generate surface structure of subject indexing strings based on deep structure derived according to POPSI.

Panigrahi[38] discusses VISWAMITRA, an expert system for generating automatic classification numbers based on the Colon Classification scheme. The system uses a frame-based knowledge representation model.

3.4.2 Application of expert systems in cataloguing

Cataloguing is certainly one of the most complex activities in the library. A cataloguer is supposed to know many rules, whatsoever the codes he/she uses, interpret them right in various situations to make correct entries. Since cataloguing is an intellectual exercise it requires the involvement of professional staff. So this makes the entire process an expensive affair for any library. Hence there is a great demand for atleast partially, if not fully, automating the cataloguing process.

Cataloguing is again one of the oldest library techniques. Catalogues were earlier prepared only on the basis or rules of thumb without taking into consideration the functions to be performed by a catalogue. The present day codes such as AACR2 contain rules formulated in a systematic manner based on normative principles. A cataloguer prepares catalogues of documents for the purpose of recording and interpreting them for its potential users. He/she prepares the catalogue based on the rules given in cataloguing code. Cataloguing consists of various processes involved in the preparation of entries and maintenance of a catalogue. Each entry is designed for satisfying a particular approach of a user.

Recent attempts to automate cataloguing through expert systems have focussed on descriptive cataloguing because it is considered to be a rule-based activity. There are two approaches for applying artificial intelligence techniques to cataloguing[39], basically:

(a) A human-machine interface, where the intellectual effort is divided between the intermediary and the support system.

(b) An expert system with full cataloguing capability linked into electronic publishing system, so that as a text is generated online, it can be passed through a knowledge based cataloguing process without any intellectual input from an intermediary.

The motivation of decreasing cataloguing costs by minimizing the role of the professional cataloguer in the cataloguing has led to experiments in the application of expert systems to cataloguing[40]. The MITINET/MARC system developed in 1986 is considered to be one of the first expert systems for cataloguing. The system helps the user with instructions for entering bibliographic data and translates that information into the appropriate MARC format. The system had many loopholes and it was hardly better than the cataloguing modules in any standard integrated library systems.

MAPPER an expert system developed as part of a doctoral research was based on a rule-based expert system concept. The design of MAPPER was quite similar to the MYCIN expert system which was used for medical diagnosis. Using AACR2 cataloguing rules for maps and knowledge contributed by expert cataloguers, the system was envisioned to require a cataloguer enter specific information about the item being catalogued. The system interprets the data based on various rules in knowledge base and produces descriptive cataloguing entry with opportunity for the cataloguer to verify the information.

Roland Hjerppe and colleagues at the Linkoping University in Sweden had developed an expert system called ESSCAPE (Expert Systems for Simple Choice of Access Points for Entries). The system was developed for the cataloguing of books and primarily concentrated on Chapter 21 of AACR2[41]. ESSCAPE incorporated the rules in part 2 of AACR2 formulated as a series of IF-THEN rules and was also designed to interface with a human user through a series of prompts[42].

De Silva and Zainab[43] explain a system they have designed to educate novice cataloguers in creating bibliographic records for published conference proceedings as well as to improve conventional instruction in the cataloguing of conference proceedings. The system, *The Conference Proceeding Advisor System (CoPAS),* uses the relevant AACR2R rules that were identified based on the nine types of published conference proceedings. Private knowledge or heuristics was elicited from three human cataloguers though a multiple observation method. This elicited personal knowledge was then modelled into a mental map of their thought processes on how to provide a bibliographic description for published conference proceedings. Based on the mental mappings of the experts, the expert advisor system was developed. The development tool used was Asymetrix ToolBook-2.

CATALYST[44], an expert system designed to give assistance to cataloguers, was based on a frame-based model. The system had used the popular expert system shell, ESP-Advisor. It is a menu driven system where the burden on the user is relatively low. The number of options from which a user has to choose is rarely more than 6, and is often reduced to a simple yes/no response.

Davies and James[45] developed an expert system based on frame-based model. The system required a cataloguer to choose options from a menu about the type of publication under consideration and access points. After a series of questions about the publication, the system offers a template, called a frame, for the cataloguer to record the remaining data for bibliographic description.

Ling-Hwey Jeng had made immense contributions to the field of expert systems applications to cataloguing. In 1986, she has worked on an expert system model to the intellectual process involved in conceptual and logical levels for determining the title proper of monographs[46]. She further studied the general rules of AACR2R (1998) to identify the definition and functions of a rule[47]. For each of the rules required for cataloguing monographs, she created condition/action pairs for rules. One of the findings of her study is that it is difficult to implement all AACR2 rules in a single system. Hence she has suggested building multiple subsets of rules of AACR2 which can be integrated.

Following are some of the major concerns expressed by researchers who have tried building expert systems based on AACR2:

1. AACR2 code poses problems that seem to stem from inherent inconsistencies and structural deficiencies[48].

2. All of AACR2 is probably too large to set up as one knowledge base in a feasible expert system. Therefore, separate expert system modules could be implemented for different types of documents, to be called upon as needed[49].

3. Many of the AACR2 rules are not explicit and many a times require the developer to add additional rules to represent such implicit knowledge[50]

4. The information required to make cataloguing decisions is missing for many instances in AACR2. Rules are not particularly amenable for immediate computerization[51].

However, the optimism of researchers like Ann Clarke and Blaise Cronin are quite evident from their following statement[52]:

Cataloguing is a rule based activity. The Anglo-American Cataloguing Rules constitute the totality of guidance required in order to catalogue *successfully any given item..... cataloguing would therefore seem suitable for an AI application.*

3.5 REFERENCES

1. **Winston, Patrick H.** The commercial debut of Artificial Intelligence. In : Quinlan, J. Ross (ed.). Applications of Expert Systems. Sydney : Turing Institute Press, 1987, p.3

2. **Alan Turing**. Computing machinery and intelligence. In : *Mind.* LIX(236), October 1950, pp. 433-460. Available at http://turingtest.area51.ipupdater.com Browsed on September 2005.

3. **Prasad, A.R.D**. Introduction to Artificial Intelligence. In : Proceedings of the DRTC Refresher Workshop on Artificial Intelligence and its applications to Library and Information work. Documentation Research and Training Centre, Bangalore, 1993. Paper A.

4. **Winston, Patrick H**. The commercial debut of Artificial Intelligence. In : Applications of Expert Systems. Edited by J. Ross Quinlan. Sydney : Turing Institute Press, 1987, pp 4-5.

5. **Borko, Harold**. Getting started in library expert systems research. In : *Information Processing & Management.* 23(2), 1987, p.81

6. **Ignizio, James P**. Introduction to Expert Systems: The development and implementation of rule-based expert systems. New York : McGraw-Hill, 1991, p.11

7. **Hayes-Roth, Frederick, et al.** An overview of expert systems. In : Building Expert Systems. Ed. By Hayes-Roth, Frederick, et al. London : Addison-Wesley Publishing Company, 1983, p.5

8. **Waterman, Donald A**. A guide to expert systems. Harlow : Addison-Wesley, 1999, p.7

9. **Ignizio, James P**. Introduction to Expert Systems: The development and implementation of rule-based expert systems. New York : McGraw-Hill, 1991, p.9

10. **Alberico, Ralph** and **Micco Mary**. Expert systems for reference and information retrieval. London : Meckler, 1990, pp.22-30.

11. **Yazdani, Masoud**. Building an expert system. In : Forsyth, R. (ed.). Expert systems: Principles and case studies, 2nd edition. London : Chapman and Hall, 1984, p175.

12. **Forsyth, R**. (ed.). Expert systems: Principles and case studies, 2nd edition. London : Chapman and Hall, 1984, p.9.

13. **Prasad, A.R.D**. Applications of computer-based language processing tools and techniques in developing indexing languages. *Ph.D Thesis*. Karnataka University, 1993. (*Unpublished*).

14. **Forsyth, R.** (ed.). Expert systems: Principles and case studies, 2nd edition. London : Chapman and Hall, 1984, p.11.

15. ibid p.17

16. **Hart, A.E.** Experience in the use of an inductive system in knowledge engineering. In: Bramer, M. (ed.). Research and development in expert systems. Cambridge : Cambridge University Press, 1985, p.40

17. **Ignizio, James P**. Introduction to Expert Systems: The development and implementation of rule-based expert systems. New York : McGraw-Hill, 1991, pp. 51-52

18. ibid p.53

19. **Bonissone, P.P.** and **H.E. Johnson**. Expert system for diesel-electric locomotive repair. Knowledge-Based Systems Report, General Electric Company, New York, 1983.

20. **Devanbu, Premkumar, et al.** A knowledge-based software information system. In : *Proceedings of the Eleventh International Joint Conference on Artificial Intelligence*, 20-25 August 1989, sponsored by the International Joint Conference on Artificial Intelligence, Inc., Vol. 1, pp.110-115.

21. **Thomson, John V**. A water penetration expert system using PROLOG with graphics. In : Quinlan, J. Ross (ed.). Applications of Expert Systems. Sydney : Turing Institute Press, 1987, pp.48-65.

22. **Waterman, Donald A., et al.** Expert systems for legal decision making. In : Quinlan, J. Ross (ed.). Applications of Expert Systems. Sydney : Turing Institute Press, 1987, pp. 23-47

23. **Alberico, Ralph and Micco Mary**. Expert systems for reference and information retrieval. London : Meckler, 1990, p.3

24. **Gibb, Forbes** and **Sharif, Carolyn**. CATALYST: an expert assistant for cataloguing. In : *Program*. 22(1), January 1988, p.62

25. **Williams, James G.** and **Sochats, Ken**. Application of expert agents/assistants in Library and Information systems. http://ltl13.exp.sis.pitt.edu/Website/Webresume/ExpertAgentsPaper/Expert.htm
Browsed on August 2005

26. **Prasad, A.R.D.** and **Rath, Durga Sankar**. Heuristics for identification of bibliographic elements from verso of title pages. In : *Library Hi Tech*. 22(4), 2004, pp.397-403.

27. **Clarke, Ann and Cronin, Blaise**. Expert systems and library/information work. In : *Journal of Librarianship*. 15(4), 1983, p.286-7.

28. **Crystal, M.I.**, and **Jacobson, G.E**. FRED, a front end for databases. In : *Online*. September 1982, pp.27-30.

29. **Gowtham, M.S.** and **Kamat, S.K**. An expert system as a tool to classification. In : *Library Science with a Slant to Documentation and Information Studies*. 32(2), June 1995, pp.57-63.

30. **Samuel T. Waters**. Answerman, the Expert Information Specialist: An Expert System for Retrieval of Information from Library Reference

Books. In : *Information Technology and Libraries*. September 1986, pp. 204-212

31. **Deborah Hanfman**. AquaRef: An Expert Advisory System for Reference Support. In : *The Reference Librarian*. No.23, 1989, pp. 113-133

32. **McDonald, Craig** and **Weckert, John**. Libraries and expert systems. London : Taylor Graham, 1991.

33. **Stalker, J.C.** and **Murfin, M.E**. Why reference librarians won't disappear: a study of success in identifying answering sources for reference questions. In : *RQ*. 35(4), Summer 1996, pp.489-503.

34. **Madalli, Devika P**. A knowledge representation model for management of analytico-synthetic scheme: a case study of Colon Classification. *Ph.D Thesis*. University of Mysore, 2000. (*Unpublished*).

35. **Ma, Wei** and **Cole, Timothy W**. Genesis of an electronic expert system. In : Emerald Fulltext database. http://www.emeraldinsight.com/Insight/html/Output/Published/EmeraldFullTextArticle/Articles/2400280301.html Browsed on April 2005

36. **MacLennan, Alan**. Fiction selection – an AT at work? In : *Emerald Fulltext database*. http://www.emeraldinsight.com/Insight/html/Output/Published/EmeraldFullTextArticle/Articles/0720970204.html Browsed on April 2005.

37. **Gopinath, M.A.** and **Prasad, A.R.D.** A knowledge representation model for analytico-synthetic classification. In : *Proceedings of the 3rd International Society for Knowledge Organization (ISKO) Conference*: Knowledge organization and quality management Copenhagen, Denmark, 20-24 Jun 94. Edited by Hanne Albrechtsen and Susan Oernager, Frankfurt/Main, INDEKS Verlag, 1994, p.320-7.

38. **Panigrahi, Pijushkanti**. Design and development of a knowledge representation model for analytico-synthetic classification. *Ph.D. Thesis*. Vidyasagar University, 1996. (*Unpublished*).

39. **Clarke, Ann** and **Cronin, Blaise**. Expert systems and library/information work. In : *Journal of Librarianship*. 15(4), 1983, p.289.

40. **Anderson, Barbara.** Expert systems for cataloguing: Will they accomplish tomorrow the cataloguing of today? In : *Cataloguing & Classification Quarterly*. 11(2), 1990, p.33

41. ibid p.38

42. **Hjerpe, Roland** and **Olander, Birgitta.** Cataloguing and expert systems: AACR2 as a Knowledge base. In : *Journal of American Society for Information Science*. 40(1), 1989, pp.27-44

43. **De Silva, Sharon Manel** and **Zainab, Awang Ngah**. An advisor for cataloguing conference proceedings: design and development of CoPAS. In : *Cataloguing and Classification Quarterly*. 29(3), 2000, pp.63-80.

44. **Gibb, Forbes** and **Sharif, Carolyn**. CATALYST: an expert assistant for cataloguing. In : *Program*. 22(1), January 1988, pp.62-71

45. **Davies, Roy** and **James, Brian**. Towards an expert system for cataloguing: some experiments based on AACR2. In : *Program*. Vol.18, 1984, pp.283-97

46. **Jeng, Ling-Hwey.** An expert system for determining title proper in descriptive cataloguing: a conceptual model. In : *Cataloguing and Classification Quarterly*. 7(2), 1986, pp.55-71.

47. **Jeng, Ling-Hwey**. The structure of knowledge base for cataloguing rules. In : *Information Processing & Management*. 27, 1991, pp.97-110.

48. **Hjerpe, Roland** and **Olander, Birgitta**. Cataloguing and expert systems: AACR2 as a Knowledge base. In : *Journal of American Society for Information Science*. 40(1), 1989, p.36

49. ibid p.38

50. **Davies, Roy** and **James, Brian**. Towards an expert system for cataloguing: some experiments based on AACR2. In : *Program*. Vol.18, 1984, p. 288

51. **Sauperl, Alenka** and **Saye, Jerry, D**. Pebbles for the mosaic of cataloguing expertise: what do problems in expert systems for cataloguing reveal about cataloguing expertise? In : *LRTS*. 43(2), 1998, pp.90-91

52. **Clarke, Ann** and **Cronin, Blaise**. Expert systems and library/information work. In : *Journal of Librarianship*. 15(4), 1983, p.289.