CHAPTER 3

EXPERT SYSTEM THEORY

3.1 Expert System

3.1.1 Expert System Definition

The expert system is a branch of artificial intelligence, the definition of expert system is a computer programming system using computer technology to solve difficult and complex problems by using stored knowledge and inference process of specific knowledge gathered from experiences and skills of expert in the field, text books, theory, and etc. as knowledge base and inference engine of a specific field of science.

The way process or problem solving process cannot be established in a straight forward way like other procedural programming language but it needs knowledge, experiences and problem condition in corporation together to find the solution.

3.1.2 Characteristics of an Expert System

The characteristics of expert system are :

3.1.2.1 Capability to keep an amount of knowledge.

3.1.2.2 Capability to improve and enlarge system knowledge continuously.

3.1.2.3 Capability to search the facts needed from stored knowledge.

3.1.2.4 Using computer technology in both hardware and software.

3.1.2.5 The specific field of knowledge in a system.

3.1.3 The Procedures for Developing an Expert System

The Procedures for developing an expert system are as shown in Figure 3.1 and described as follows :

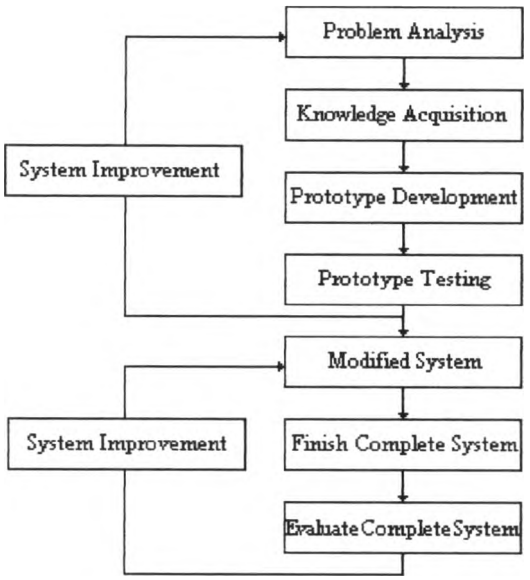

Figure 3.1 The Procedures for Developing an Expert System

3.1.3.1 Setup statement of problems, objectives and areas of expert system requirements.

3.1.3.2 Implementing knowledge acquisition and selection of the acquisition types.

3.1.3.3 Knowledge Analysis and representation from captured data.

3.1.3.4 Knowledge base arrangement into appropriate structure and paradigm such as rules, frame, and etc. by organising analysed data from the analysis of captured data.

3.1.3.5 Knowledge coding in selected tools.

3.1.3.6 Testing and correcting the problems and weakness of the expert system through validation which is the procedures and guidelines by which one may determine the integrity and evaluate the performance of expert system.

3.1.3.7 Implementation of Developed expert system. The expert system implementation should have the guidelines for implementation, control, monitoring, and maintenance of a completed expert system.

In order to be successful in expert system implementation, the problems should be selected appropriately and knowledge engineers as developer should well understand the operation of expert system appreciatively, the experts and related people must cooperate, especially the support must be given from top management levels in both system development and improvement by maintaining and modifying knowledge base continuously.

3.1.4 Benefits of Expert System

3.1.4.1 Act as Knowledge keeper which can store knowledge permanently in computer system, while human experts could resign, retire, be retrenched unintentionally, abandon works, loss of memory, and even death.

3.1.4.2 Extend determination capability of a developed expert system to more people in order to save expert usage for distributing benefits of them to many people in the other related works.

3.1.4.3 The emotion and feelings can be neglected from affected determining factors such as love, hate, angry, tire, confuse, and etc.

3.1.4.4 Repetitive works such as monitoring jobs can be eliminated by implementing expert system

3.1.4.5 Improve reliability of works by the all time functioning system instead of staying or leaving of human experts.

3.1.4.6 Improve certainty of determination results from the right knowledge database of expert system.

3.1.4.7 Act as a fine training tools for other employees.

3.1.4.8 Increase performance of working from reduction of operating time and determination time.

3.1.4.9 Implement expert system as the important parts of automated work for improving it to be used with the other parts in the environment as complete automation system in the future.

3.1.4.10 Expert system can be traded to other firms in the markets as the innovative automated products and services.

3.1.5 Expert System Implementation

The expert system can be implemented broadly in application on various fields of knowledge and technologies such as Engineering, Management, Financial planning, assisting in stock market advisors, commodity trading., and etc.

The application of expert system can be categorised as follows :

3.1.5.1 Diagnostics

3.1.5.2 Design

3.1.5.3 Predicting and Planning

3.1.5.4 Interpretation

3.1.5.5 Checking, Monitoring, and Controlling

3.1.5.6 Determination

3.1.5.7 Training and education

3.1.5.8 Simulation, modeling, and prototyping

The examples of developed expert system in various fields as implemented application can be described respectively to the problems related as shown in Table 3.1 :

Table 3.1 Examples of Expert System Implementation

Types of problem	Name of Expert System	Developer	Description
Data Translation and Interpretation	DENDRAL	Stanford Univ.	Translate spectroscopic data by analysing mass spectrography data, nuclear magnetic resonance data, and other chemical data to represent unknown chemical molecule structure.
	GENESIS	IntelliCorp	Used in genetic engineering for analysing DNA of molecules.
	MACSYMA	MIT	(Developed from SAINT) Solve mathematical equation on differentiation and integration.
	HEARSAY I-II	CMU	Assist speech recognition acknowledgment.
	FXAA	Chemical Bank	Assist by audit the recognition of irregular transactions of foreign exchanges.
Diagnosis	INTERNIST/ CADUCEUS	U. of Pittsburgh	Diagnose the majority of diseases associated with internal medicine.
	MYCIN	Stanford Univ.	Give instruction on diagnose and treatment on diseases from bacteria infections of blood (meningitis and bacteremia infections), consisting of about 400 rules.
	PUFF	Stanford Univ.	Interpret measurements related to respiratory tests and identify pulmonary disorders.
	QMR	U. of Pittsburgh	Diagnose of illness based upon the patient's symptoms, examination findings, and laboratory tests.
	DELTA/CATS	GE	or Diesel-Electric Locomotive Troubleshooting Aid/ Computer aided Troubleshooting System Give instruction to repairing diesel locomotion by using visual support systems.

Types of problem	Name of Expert System	Developer	Description
Diagnosis	PROSPECTOR	SRI	Give instruction to geologist to explore mineral sources.
	TOAST	CMU	Give instruction for power system analysis.
	SACON	CMU	Give instruction for setting procedures on structural analysis.
Design	XCON (R1, OPS5)	DEC & CMU	Set VAX computer system configurations by customer orders.
	TALIB	CMU	Synthesise IC for nMos cell.
	PRIDE	XEROX	Give instruction for paper and copier transportation design.
	CODES	Univ. Southern California	Assist IDEFI database design.
Planning	GATE	TWA	Assist ground controllers in the assessment of gates to arriving and departing flights.
	Poultry Farming	Georgia Tech.	Analyse data from the poultry farm 's environmental control system and use it on feed and water consumption, temperature, humidity, and ammonia levels to alert for any diseases the chicken have or may get.
	KNOBS	MITRE	Help operation planning by military demand.
	PEP38	IBM	Used for planning computer size of IBM system/38.
	HESS	U. of Houston	(or Hybrid Expert or Hybrid Expert System Scheduler) Used for supporting petrochemical product and process scheduling.
	EDISON	UCLA	Used for planning the machine design.
	Fast Food Operation	N/A	Used by many companies in fast food market as expert system for reducing inventory, speeding up service, and training assistants.
	PlanPower	N/A	Assist planning on financial accounts and management

Types of problem	Name of Expert System	Developer	Description
Planning	Syntelligence	N/A	Assist insurance company analysing business risks and evaluation of properties for loan approval.
	Insurance Expert Tax	Coopers and Lybrand	Assist the identification of tax planning and accrual issues.
Monitoring	DustPro	US. Bureau of Mines.	Assess air quality of mining operations by monitoring amount of methane, coal and silica dust in the air.
	YES/MVS	IBM	Used for monitoring and controlling IBM MVS operating system.
	REACTOR	EG & G	Used for warning accident which might be occurred from nuclear reactor by monitoring signals from instrument inside reactor.
	VM	Stanford Univ.	Assist monitoring patients in ICU after operation.
Training	SOPHIE	BBN	Used for training students to analysis on causes of abnormal events in electronic circuit.
	GUIDON	Stanford Univ.	Instruct students for bacteria infecting therapy case study.
	PROUST	Yale Univ.	Correct bug or assist debugging in Pascal/Lips programming.
Classification	Codecheck	Abraxas	Check and evaluate C-Language source codes for complexity, formatting, and adherence to standards.
	TOP SECRET	US Department of Energy	Classify guides to nuclear weapon security data by classes such as confidential, secret, top secret and determine the permitted people to view the document.
	Jonathan's Wave	Michael Archer	Assist stock and commodity trading for commodities futures and commodities future options trading.

Types of problem	Name of Expert System	Developer	Description
Reporting	ACE	AT&T	Provide reports for solving and analysing the complexities of jobs and large information on telephone line maintenance arrangement.
	COMPASS	GTE	

3.2 Fundamental Structure of Expert System

Fundamental structure of expert system can be illustrated as follows in Figure 3.2 :

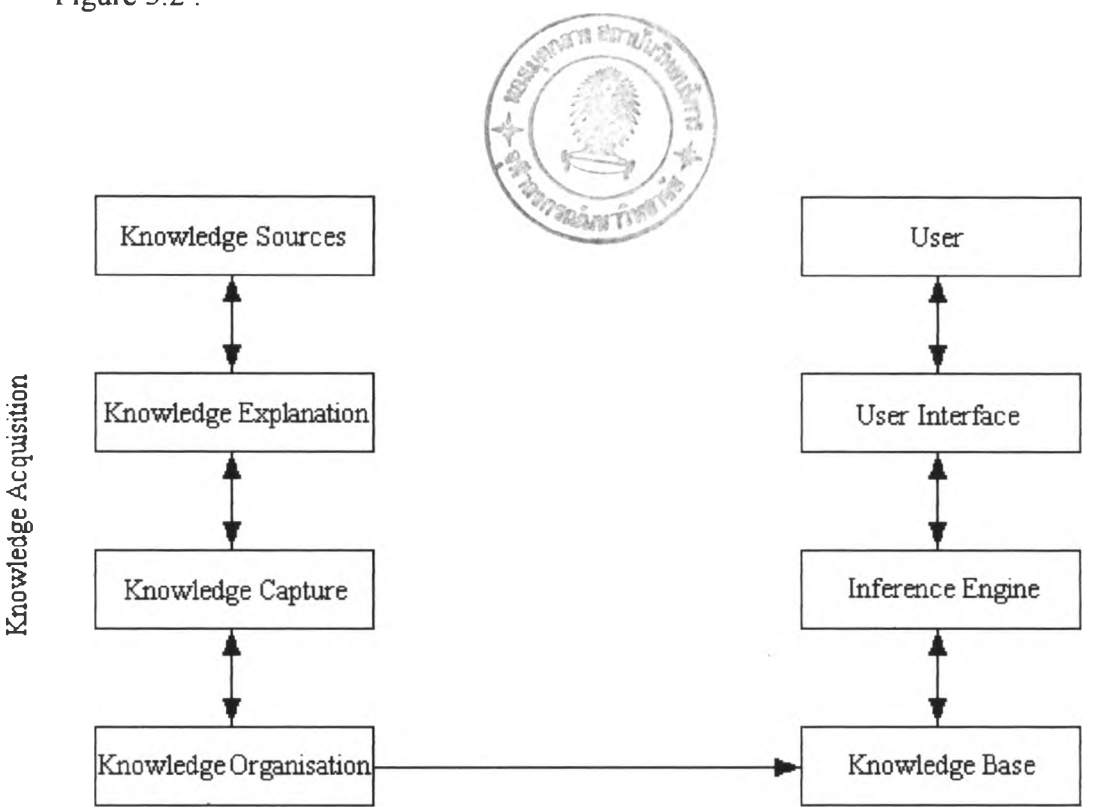

Figure 3.2 Expert System Structure

3.2.1 Knowledge Sources

Knowledge can be collected from various sources and various methodology. There are many sources of data to make knowledge acquisition as follows :

3.2.2.1 Documentary Sources : Collecting from documentary sources which consist of theory, research literature, text books, equipment manual, training document, operating memo, case study notes, specific characteristic requirement, and related research.

3.2.2.2 Human Experts : Interview from human experts in specific domain of knowledge, skills, and experiences for problem solutions and suggestion on specific techniques from domain experts.

Domain experts are the person who have specific knowledge and experience in knowledge field needed, provide knowledge, experience to be collected as data in expert system.

3.2.2 Knowledge engineers

Knowledge engineers are the person who makes related coordination between domain experts and computer system in order to transform knowledge into expert system format, in some case, domain experts can be actually the same person as knowledge engineer.

3.2.3 Knowledge Acquisition

Knowledge acquisition is the procedures of collecting, transferring, and converting problem solution methodology of domain experts from various

sources of knowledge in order to use the gathered knowledge as knowledge base data for computer .

The approach used to elicit the rules from the expert or from a set of representative examples of solution procedures.

There are various acquisitive methodology and many sources of knowledge for implementing knowledge acquisition which will be described as follows :

3.2.3.1 Interview

Knowledge of domain experts can be drawn directly by interview or can be drawn by using specific form of questionnaire sheets which can be categorised into uniform sheet, semiuniform sheet, and free-form sheet.

3.2.3.2 Discussion

The discussions between knowledge engineers and domain experts are needed to be done in appropriate time.

3.2.3.3 Observation of the Task Performance

Knowledge engineers should study the solution methodology and procedures of working experts on site seeing and observe the problem areas for better understanding.

3.2.3.4 Case Study

The continuous notation of related happening events and solution can enable knowledge engineers to collect and study for creating knowledge base as an important source of knowledge.

3.2.3.5 Text Books

The related text books are the most important sources for knowledge engineers for finding out the fundamental principles and theories of related knowledge which are about 70-80 percent.

3.2.4 Knowledge Base

Knowledge base is the systematic data as facts and rules of a domain knowledge including data gathered from interacting between system and users, stored in working memory of computer system which also stores temporary data happened between problem solving procedures.

The status of knowledge base can be categorised into static database which cannot be changed during processing and dynamic database which can be changed during processing.

The knowledge base is established from gathered knowledge and experiences as 'fact' in the form of natural-language sentence and etc., settled by functions of knowledge engineer.

The knowledge will be collected from domain experts and other sources of data and then it will be analysed to the form of organised data. After that,

the analysed data will be stored into computer system in the following forms which can be used by inference engine of the expert system :

3.2.4.1 Rule-Based Representation

Any rules can be divided into condition and conclusion. Knowledge in the form of rules can be settled as If-Then-Else sentence form as shown in Figure 3.3 below :

If <Condition>
Then <If True>
Do Action A

Else <If False>
Do Action B

Figure 3.3 Rules in Expert System

'If' command will check the condition. After passing 'If' condition, conclusion action will be considered which consists of 2 parts in a rule. The first part will be related to process after executing on the action following 'Then' when the logical condition is <if true> and the second part will be related to process after executing on action following 'Else' when the condition is rejected or logical condition is <if false>.

'Else' action can be linked to the external programmes or related to any other rules.

3.2.4.2 Object-Oriented Representation

Object-oriented or frame-based representation appropriates for more complex determination situation. Knowledge in the form of Object-Oriented data can be shown its relationships by using Class, Object, and Property as shown in Figure 3.4 which :

3.2.4.2.1 Class is the prototypes which will transfer Property down to the lower level members. The members of a Class are objects which normally have associated characteristics.

3.2.4.2.2 Object is the autonomous members under Class and inherited specific property from Class. Each object as information collector of database has it own initial values and properties.

3.2.4.2.3 Property is the characteristics and information inherited from Class to Object in the semantic network which may be consisting of any types of associated data stored in slots such as Boolean, Integer, Float, String, Date, Time, Special, and etc.

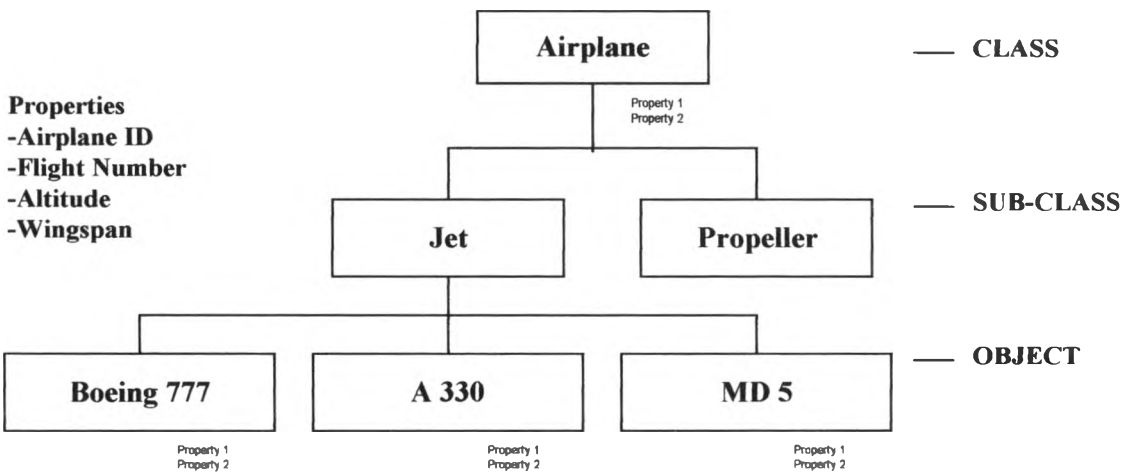

Figure 3.4 Relationships between Class, Object, and Property

3.2.5 Inference Engine

Inference engine is the most important strategies and procedures for deriving conclusions from analysing limited facts and rules on a knowledge base. The inference engine can be represented by the tools or expert shell programs served as the inference and control mechanism or knowledge processing element for finding and drawing a conclusion by means of a set of rule. The types of inference engine depend on the types of data representation.

The function of inference engine algorithm in the rule based condition is to compare asserted data or events with the clause of 'If' condition. When the comparison is the same or true, the execution on the condition of 'Then' will be conducted.

There are three parts of inference engine as follows :

3.2.5.1 Context block : Store present status of problems and problem solving methodology.

3.2.5.2 Inference (reasoning) mechanism : Search engine set of knowledge and related data working together with context block in order to find the conclusion or answer of condition.

Types of inference can be divided as follows :

3.2.5.2.1 Forward Chaining : Searching solution from the beginning to the end or called the data driven method.

The facts or supporting evidence will be established and then the goal or conclusion will be searched for being the conclusion or the consideration for next condition.

3.2.5.2.2 Backward Chaining : Searching solution from the end back to the beginning.

The goal or sample conclusion will be established and then the supporting data will be searched and tested. If the supporting data and condition of sample conclusion is true then the sample conclusion is the answer, but if not true then the new sample conclusion will be established and tested until getting answer.

3.2.5.2.3 Bi-directional Chaining or Rule-Value Method : The mix of both mentioned solution searching. The most important data will be asked first for entering the goals at the beginning and then the less important data will be asked respectively by its importance and so on which can make the expert system faster and more efficient.

However, the difficulties on large-amount data sorting and the different importance on weights of fact properties are the restriction of this inference types.

3.2.5.3 Description part : Provide description of the running procedures of system and information about the inference engine to users in the form of help topics, descriptive guidelines, wizards, and etc.

3.2.6 User Interface

From the fact that expert system needs to communicate comfortably and efficiently with users for easy understanding and interpreting, the inference engine must have user interface parts which use input and output devices for communicating with users in order to interact expert system naturally and nearly like the interacting with human experts when additional data is needed to be gathered,

when some information of analysed events is needed to be presented descriptively or summarised finally, assisting users to ensure and understand procedures as explanation facility which can explain the reasons of condition, problem solving methods, and etc.

So, the communication of expert system on specific condition of problem gathered from inference engine processes can be divided in 2 parts. The function of the first part as receiving medium is to show what additional information the expert system want or called data input. The second part as reporting medium is called reporting which indicates what analysed information and which solution the expert system try to demonstrate. The communication can be done by using the user interaction tools or backward knowledge acquisition facility of expert system which communicates with users as user interface that can be categorised into 2 types as described follows :

3.2.6.1 Text Mode : Representation as standard characters or plain texts displayed on terminal screen.

3.2.6.2 Graphic User Interface (GUI) : Displayed as interactive graphics which makes users understand interaction naturally and easily without requiring sophisticated users or extensive training for users to enable users to interact with the system in order to enable users to use expert system effectively.

Some examples on user interface methods of GUI are as follows :

Text and Iconic Labels	Push Buttons	Check Boxes
Radio Buttons	Selection menus	Input Fields
Menus	Selection table	Input table

3.3 Related Literature Surveys

Several master thesis, books, and papers, including other related topics on the subject have been reviewed and summarised as follows :

Klangduen Pochana, 1991.

The thesis mentions about development of decision support systems for production planning in chicken processing plant implemented on microcomputer by using a database management system and a production planning system utilising data from database management system by using expert's planning criteria.

The system can reduce planner's skill requirement, planning time in accurate planning depended on company policy.

Phisan Pattanakooha, 1995.

The thesis mentions about development of a decision support system for overhauling power circuit breakers in electrical substations, developed under Ms. Access 2.0 by using MIS implementation.

Decision support system and database systems (DECCIB) collects substation record, substation equipment record and daily data, providing decision maker for circuit breaker replacement by using 3 criteria of equipment as follows :

1) A number of short circuit Interruptions.
2) The cumulated short circuit current.
3) The cumulative square of short circuit current.

Chavalit Jiaranuchart, 1994.

The thesis mentions about development of an expert system for the preliminary evaluation of telephone switching systems in economics and technical aspect in system capacity and service performance developed by using M1 expert system shell implemented on collecting data from specification, related theories and domain experts' opinion. Knowledge base used in the developed expert system can be categorised into :

1. Preliminary evaluation in economics and technical aspects.
2. Detailed technical evaluation for technical aspects in the system capacity and system performance.

Which can reduce evaluator's skill requirement and evaluation time.

Bandhit Vongderri, 1990.

The thesis shows an application of AI and expert system for diagnosis and maintenance on the operations of industrial fire tube boiler developed by using M1 shell, priority degree of trouble design, and user-friendly interface to create BODES (Boiler Operations Diagnosis Expert System), dealing with automatic combustion control, automatic feed water control, automatic fuel oil supply control and safety control system.

Danai Chindaratana, 1990.

The thesis mentions about development of an expert system for the scheduling of production in PCB industry based on rules and heuristics gathering from domain experts to provide an appropriate schedule for each operation, solve complex problems by breaking down them into controllable sub-problems for the jobs scheduling.

Vinai Sathtachotinun,1993.

The thesis presents a computer-programmed tool for creating expert system shell by using certainty percentage of factor for mechanical system diagnosis. The tool characteristics are a natural language interface, providing automatic linkage between multi-knowledge bases, and the other fundamental features, the developed expert system architecture was designed by using backward-chaining inference.

The outcome of the consultation has certainty factors in percentage to support each decision. The program facilities include the feature of create, update, edit and display the knowledge base with explanations for each step of the program.

Nartlada Chantharojwong,1989.

The thesis presents the effective selection and construction of an appropriate expert system shell by using developed guideline, the criteria and procedures which are used to evaluate existing expert system for selection other appropriate tools. The thesis also reviews the comparative analysis between the features of expert system shells.

Songwut Asuwapongpatana,1988.

The thesis mentions about the structure and development of an expert system for the selection of air conditioning system design for Thailand environment by using factors and constraint of building in the first part, the second part relates with air-conditioning system, cooling tower and water pump diagnosis, the other part describes about system selection.

Developed expert system in this thesis was designed by using backward-chaining inference engine with friendly user interface.

Petcharat Ubolriabroy, 1992.

The thesis mentions about development of an expert system for determining cost of ornamental rings by using C programming, modified from development of demonstration expert system shell prototype by using same forward reasoning and rule based representation and adding in some features.

Somdet Sue., 1995.

The thesis mentions about PLASA II which is an expert system for plastics processing methods selection, built on Smart Element version 1.0 by using 12 rules class comprising over 150 rule dealing with product shape, geometry of product, production rate, dimensional tolerance, mechanical strength, constraint relaxation providing less suitable solutions, rasin type, question handling which is a set of rule providing next appropriate questions based upon the entered information, and etc. The other information such as diagrams and Figures of the process, a list of typical products and resins, machine cost, and commercial information.

Somkuarn Atiraklapvarodom,1995.

The thesis mentions about an expert system for practice and trouble shooting of the vertical solder coated leveling process of a printed circuit board, consisting of 21 hypotheseses, 4 sub-system shells as inference engine and collected tools for collecting knowledge base rules.

Pederson Ken, 1989.

The book 'Expert Systems Programming : Practical Techniques For Rule-Based Systems' presents developing methodology of building rule-based expert system (especially backward chaining) under commonly available shells by showing powerful approaching way for the very first project, particularly related with diagnostic, selection and classification of problems and the steps to accomplish problems mentioned are first; define the project, set proper goals, frame the problems and manage expectations. Second; acquire, organise, test, and maintain the knowledge destined for the expert system.

Bruce G. Buchanan and R.O. Duda, 1982.

The book discusses the design of expert systems, including the representation, inference, and uncertainty management. Examples from numerous specific systems, and discusses which problems are suitable for solving by rule-based systems.

James P. Ignizio 1991.

The book focuses on the building of knowledge-base model and its proper implementation from a decision-making point of view. The book covers knowledge acquisition, inference, and validation, especially appropriate for fields besides computer science, such as business, engineering, and etc.

Dennis Merritt, 1989.

The book explains about how to build various expert system shells in Prolog, including forward and backward chaining, rete-network, frames, solving the Rubik's cubic and more. The book contents also includes the complete source code listings.

Neuron Data, 1993.

Smart Elements is the Neuron Data's Nexpert Object development tool written in C, which supports objected-oriented development for rule-based application, and the uses of it appropriate for complex logic and business rules, application with the cross-platform Graphical User Interface (GUI) design element of the Neuron Data 4GL Open script element Interface which provides rapid application development in the forms system without compiling, and ability to be linked with any widget objects as knowledge acquisition tools for various actions such as : Suggest, Volunteer, Knowness, send a message, execute a routine, open a new window, and etc. So, developers can build rapid application easily across 35 platforms of operating system without recompilation.

Gensym Corporation, 1995.

Gensym's G2 offers a graphical, object-oriented environment for creating intelligent real-time applications that monitor, diagnose, and control dynamic events in on-line and simulated environments for diagnostic or training, especially system modeling and design for business process re-engineering. The characteristics of G2 Feature a structured natural language for creating rules, models, and procedures, G2 end-user applications under object-oriented system and Graphical User Interface (GUI). Gensym's application products include the G2 Diagnostic Assistant (GDA) which provides a visual programming environment for creating intelligent process management applications. NeurOn-Line allows users to create neural network applications easily. G2 includes concurrent execution of rules and procedures and the ability to reason about behavior over time. Telewindows provides the effective multi-user function for client/server environment which allows users to share G2 applications. G2 opens its products for connectivity to other programs (C and ADA) and real-time data systems including relational databases, distributed control systems, and Programmable Logic Controllers.

Borland Delphi 2.0.

The developer tool for establishing 32 bit rapid application development (15-50 times faster than other packages in market) on MS.Windows 95 and MS.Windows NT platform. It provides 32 bit native code compiler (compiles more than 350,000 command lines per minute), various tools, drag-and-drop feature for libraries of visual component in Object-Oriented Programming environment. It appropriates for applications which need frequent changing database size related to their environment.

Compiled expert system will work faster than uncompiled expert system but knowledge base of compiled expert system cannot be modified on-line between testing the system, it needs to be re-compiled before running again.

MS. Visual Basic 4.0

From the past, the applications for Microsoft Windows were developed by using C language and Software Development Kit (SDK) of Microsoft which developers need to understand on C programming and pointers appreciatively, especially on language principles. After that, Turbo Pascal for Windows and program generators such as toolbooks and windows maker became widely be used. MS Visual Basic is the new generation of developer tools.

Visual Basic provides extensive and efficient environment for software developers such as User Interface and menu designer, report writer, editor for developing 32 bit application for programming, debugger for correcting the mistake in programming, and etc., including the other commands and functions for objects and OLE, DDE, API, clipboard.