QUEEN
QA
76.76
.E95
E432
1989

Gouvernement du Canada
Ministère des Communications

Government of Canada
Department of Communications

Le Centre canadien de recherche sur l'informatisation du travail

Canadian Workplace Automation Research Centre

The Expert Systems Group

Elements for Building Expert Systems

Canada

Queen
QA
76.76
E95
E432
1989

Government of Canada
Department of Communications
Canadian Workplace Automation
Research Centre

The Expert Systems Group

Industry Canada
Library Queen
AVR
APR 24 1998
Industrie Canada
Bibliothèque Queen

Elements for Building Expert Systems

December 1989

COMMUNICATIONS CANADA
AUG 7 1991
LIBRARY – BIBLIOTHÈQUE

Joël Muzard
Kimiz Dalkir
Patrick Aboussouan
Ron Ferguson
Christine Gariépy
Lyne Champagne

DD 9382481
DL 10665299

QA
76.76
E95
E43?
1989

No de cat. Co 28-1/44-1989E
ISBN 0-662-17458-5

The opinions expressed in this document are those of the authors only.

* Une version française de ce document est aussi disponible.

Table of contents

Note: use of the masculine is in no way discriminatory and is intended only to make the text less awkward.

Tables and figures

List of tables

List of figures

INTRODUCTION

Some concrete solutions to the perfectly legitimate desire of organizations to be more productive and more competitive have appeared in recent years with the development of computer systems. Management systems, data bases, word processing are all tools designed to support organizations in the accomplishment of their daily work.

Today, new and even more efficient tools are available: knowledge-based systems, and more specifically, expert systems.

Dedicated to management of the expertise of an organization in a particular domain, expert systems offer many advantages:

- They organize and preserve the knowledge of experts in the organization.

- They give less experienced workers access to the knowledge of others.

- They prevent knowledge from being lost when experts leave.

- They support and improve decision-making by experts and managers.

Many years of research and considerable effort have been spent in developing artificial intelligence systems. It is essential that we continue this work, which opens up new horizons for organizations.

The document presented here, Elements for Building Expert Systems, reviews the theoretical basis of expert systems and their architecture, and describes the building stages and tools - computer hardware and software - used in these systems and the role of those involved in the process.

In short, this document is intended as a first step towards an understanding of expert systems and the potential they offer for your organization.

1. PRELIMINARY NOTIONS

a) Knowledge engineering in organizations

During the 1970', organizations became aware that data was a resource that had to be managed in the same way as human or material resources.

Today, "after having acquired control over their data, organizations are faced with a new necessity... gaining control over the knowledge at work within the organization. A number of facts demonstrate that this problem, which has generally gone unnoticed up to now, is taking on ever-greater importance. The increasing sophistication of the technology used in all sectors of organizational activity has brought about an increase in employee training time, while increasing their degree of specialization. More and more time is thus needed to train skilled workers, whose degree of specialization is then difficult to adapt to other areas of activity (emphasis is ours)."(1)

We are in fact moving towards a new approach to computers in organizations: knowledge engineering, or the development of systems that process the knowledge of a given domain to resolve complex problems. This new discipline makes use of contributions from the fields of artificial intelligence and cognitive sciene.

(1) Bernard Moulin et Marie-Michèle Boulet. De la gestion des données à la gestion des connaissances dans l'organisation, pp.277.

b) Artificial intelligence and cognitive science - theoretical basis

Artificial intelligence is defined as "the area of study in computer science concerned with the development of a machine that can engage in humanlike thought processes such as reasoning, learning and self-correction".[2]

Contrary to classical programs, where the computer needs <u>all</u> the necessary data and a precise problem-solving procedure to function, artificial intelligence programs can cope quite well with vague and incomplete data.

Table I gives a brief résumé of their characteristics.

Cognitive science draws on the most recent discoveries in psychology, computer science, linguistics, philosophy, the neurosciences and many other fields. Although this new discipline is closely linked to artificial intelligence, it does differ slightly: whereas artificial intelligence creates systems taking into account the limitations of machines currently available (or to come), cognitive science instead uses the «architecture» of human intelligence as its model.[3]

TABLE 1
ARTIFICIAL INTELLIGENCE PROGRAMS CHARACTERISTICS

CHARACTERISTICS	*DEFINITION*	*REMARKS*
1. Heuristic-approach	Problem-solving method using several variables and working by "successive approximations" towards a solution. Opposite of algorithmic method.	See "Heuristics" in Silvya Pavel, Artificial Intelligence Vocabulary
2. Knowledge representation	Correspondence between outside world and symbolic system makes reasoning possible.	
3. Ability to reason with incomplete data		E.g.: knowledge-based systems and expert systems (see Chapter Ic)
4. Learning capacity		Based on new data entered, the system uses its reasoning mechanisms to add new conclusions which increase its "intelligence".

(2) "Intelligence artificielle" as defined in the <u>Grand dictionnaire encyclopédique Larousse</u>, vol. 6, p. 5624.

(3) See "Cognitive science" in: Stuart C. Shapiro, David Eckroth et George A. Vallasi, <u>Encyclopedia of artificial intelligence</u>, vol.1, pp. 120-121.

c) Knowledge-based systems and expert systems

Knowledge-based systems are artificial intelligence programs that use specialized knowledge to solve problems. An expert system is a particular type, using the knowledge and expertise of an expert in a specific field.[4]

An expert system is in fact a program containing a large amount of knowledge in a specialized field (this knowledge is normally obtained from a highly competent human expert); it is capable of achieving expert performance in this field.[5] The user consults the expert system just as if it were a human expert, explaining the problem, making suggested tests, requesting explanations about proposed solutions, etc.

2. INDIVIDUALS INVOLVED IN CARRYING OUT A PROJECT

2.1 Knowledge engineer

The knowledge engineer[6] acquires the knowledge and expertise of the expert and then translates it into a language the computer can use. With his knowledge of computer hardware and software, the knowledge engineer is well placed to advise the organization on the best possible choice.

2.2 User

The raison d'être of the project is the user, since he will be using the system in his work. From this point of view, the expert system must adapt to the user and not the reverse, and the knowledge engineer must accordingly ensure that:

- the system meets the user's needs;
- the user considers it useful for his work;
- the user has been consulted and his suggestions incorporated into the system.

2.3 Expert

The expert possesses the knowledge and expertise needed to solve problems. This knowledge is transformed into a program that can then simulate the procedures used by the expert.

2.4 Project manager

The project manager negotiates the project, manages it and directs the building team (knowledge engineer, expert, user). Before the start-up of the project, he discusses with these individuals the relevance of using the technology envisaged.[7] During the negotiation period, the project manager acts as the liaison between the requirements expressed by the various parties involved and the resources available.

3. THE ARCHITECTURE OF EXPERT SYSTEMS

Since human expertise uses methods such as intuition and rules of thumb (and not exclusively upon logical reasoning), the specific knowledge of a domain and the mechanisms for interpreting it are represented separately. If the situation changes, it is much easier to modify the system. Expert systems are generally composed of the following modules:[8]

3.1 Facts base

This includes the facts of the domain and the specific facts of the problem to be solved (data). In a domain such

(4) See "Knowledge-based system" in: V. Daniel Hunt, Artificial Intelligence and Expert Systems Sourcebook. pp. 147-148. For Knowledge-based systems various applications, see Appendix I.
(5) Alain Bonnet: Systèmes experts: vers la maîtrise technique, p. 44.
(6)Knowledge engineer: Person who acquires knowledge from experts, organizes and tramperts it into a compularized program. Can be of different background: computer science, psychology, etc. For more information of its role in the building process, consult Appendix II.
(7) See Appendix III : When to Use Expert System technology
(8) See Appendix III.

as accounting, the facts would be: current expenses, assets, liabilities, etc. The facts base is thus the working memory of an expert system.

3.2 Knowledge base

The knowledge base is made up of knowledge organized into various forms[9], some of which are:

- first-order logic

This category includes simple reasoning such as syllogisms[10]. A well-known example is:

«All men are mortal»
(Proposition 1)
«Socrates is a man»
(Proposition 2)
«Therefore, Socrates is mortal»
(Proposition 3).

- production rules

These are «if-then» rules. A medical diagnostic system might contain the following rule:

IF the patient is feverish AND the patient's nose is running, THEN it is very likely the patient has a cold.

- semantic networks

It is often convenient to represent knowledge in the form of semantic networks. A semantic network is a way of organizing knowledge in which concepts are arranged in an interconnecting hierarchy. Figure 1 provides an example.

- frames

In many cases, it is very useful to collect several pieces of knowledge into an overall information unit, the frame. In the system below, each bit of information on an electrical component will be considered as a drawer in a frame called "electrical component", as shown in Figure 2.

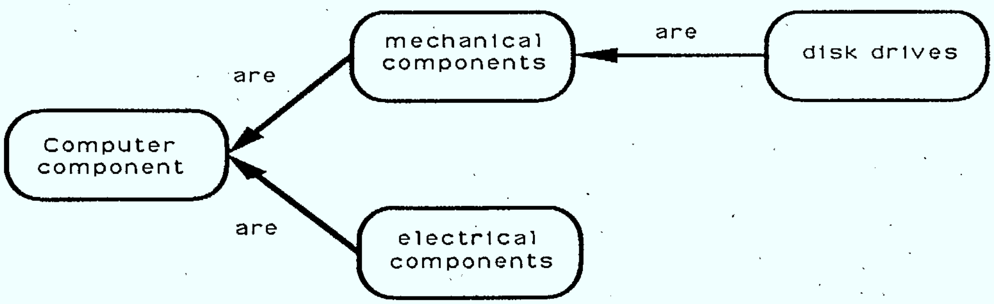


FIGURE 1 EXAMPLE OF A SEMANTIC NETWORKS

Electrical component	
Part no.	
Length	
Width	
Height	
Voltage	

FIGURE 2 FRAME EXAMPLE

(9) Examples are in large part extract from Fred L. Luconi and al. Expert Systems and Expert Support Systems : The Next Challenge for Management.
(10) Syllogism: an argument with two premises [major and minor] and a conclusionwhich is a deductive reasoning (Petit Larousse en couleurs, 1980, p. 892. In production rules, the order of the premises does not necessarily have influence on the conclusion.

This means of organizing knowledge makes it unnecessary to enter superfluous data. If the implicit voltage of Component X is 110V, the system will automatically deduce that, unless otherwise stated, all new components operate at a similar voltage. As well, if one of the variables (length, width, etc.) were to change, it would adapt all the others to maintain a balance.

3.3 Inference engine [11]

This component uses the knowledge base to draw conclusions about the problem. It contains inference methods for solving the problems submitted to it: forward chaining and backward chaining. The method chosen depends on the nature of the problem and the forms of knowledge used.[12]

Figure 3 gives an example of each method. The situation is as follows: an investor wants to avoid paying too much income tax. He has $100,000 and is prepared to take considerable risks. He asks the system which investment (A or B) is the better.

3.4 Interfaces

An interface is defined as "the means of interaction between two... systems that handle data in different ways, such as different codes or formats".[13] In an interface, we give the specific nature and form of the data and commands to be exchanged.

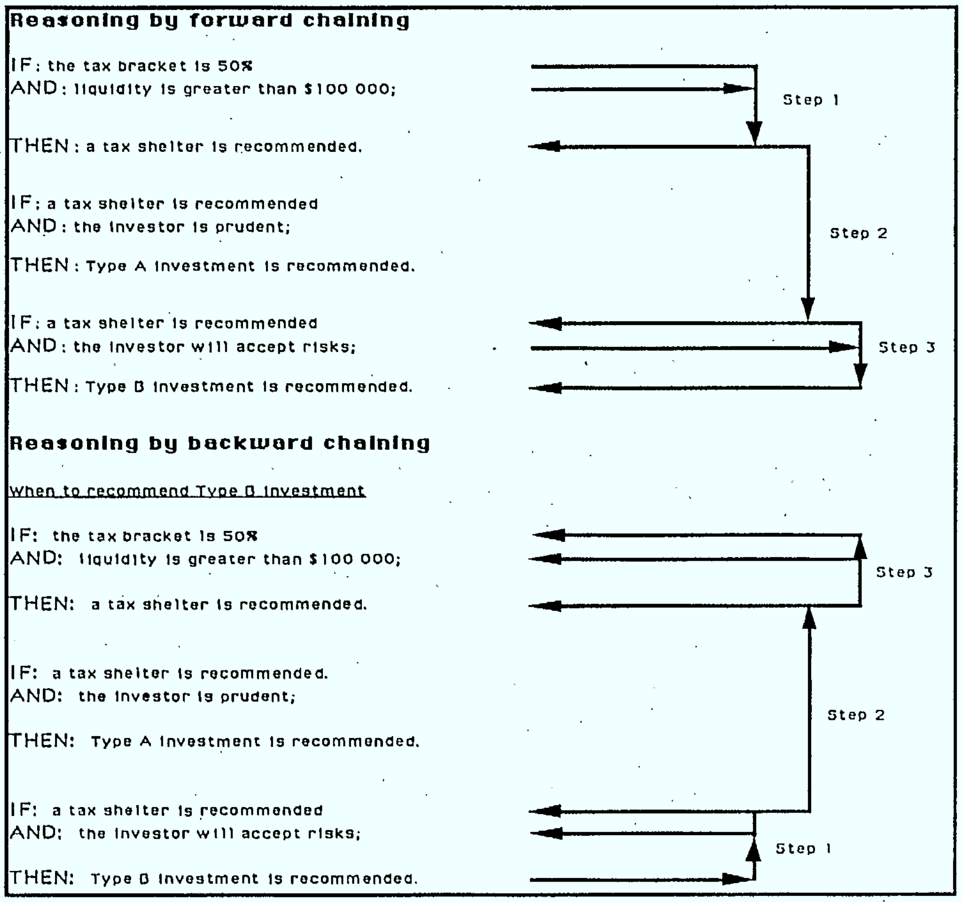


Figure 3 REASONING ACCORDING TO EACH INFERENCE METHOD

(11)**Inference** : logical reasoning by wich a premise is assumed by its link to other premises already claimed to be true (Petit Robert, 1977, p.998).
Inference process : the process of arriving at some conclusion which, though it is not logically derivable from the assumed premises, possesses some degree of problbility relative to the premises (The American College Dictionary Ramdon House New York , p. 622)."
(12) See chapter 3.2.
(13) "Interface" in: Pierre Morvan, Dictionnaire de l'informatique, p. 162.

As mentioned, there are two types of interface: the interface with other systems (expert or other) and the user interface, which should allow for easy data entry. In most cases, this consists of answering questions posed by the system. In this area, there is an increasing trend to user- friendliness, i.e., ease of access and use of the computer system.

4. STAGES IN BUILDING EXPERT SYSTEMS

Researchers have proposed several methods.

One of these methods, by Hayes-Roth et al.[14] is shown in Figure 4.

The method used by the Expert Systems Group can be adapted to the project partners, their limitations and their objectives. This is why we have added negotiation and approval stages. Each stage is approached using the problem-solving method[15].

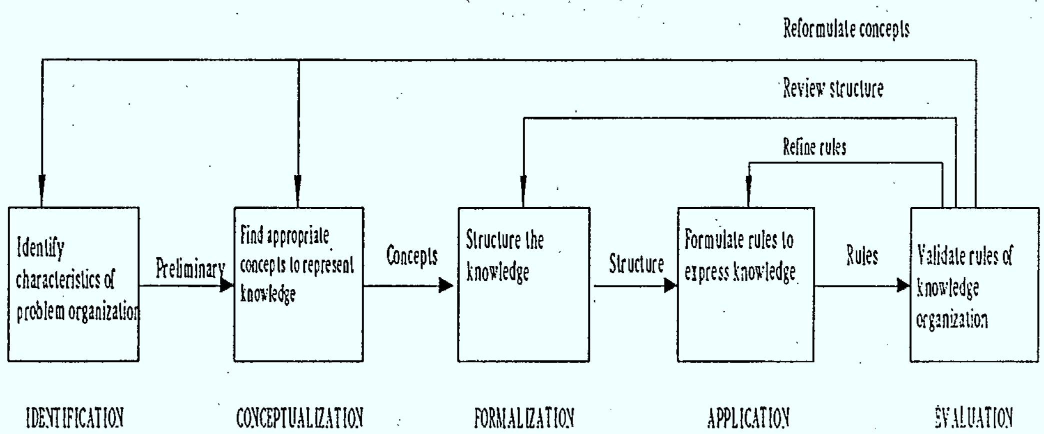


Figure 4 HAYES-ROTH METHOD

(14) Frederick Hayes-Roth and al. Building expert systems, p. 139.

(15)This method is described by Georges Polya in his book called How to solve it and summarized as such:

Problem solving:

1. Understand the problem;
2. Prepare a plan;
3. Execute the plan;
4. Estimate the solution;

TABLE II
STAGES IN BUILDING EXPERT SYSTEMS: DESCRIPTION

STAGES	OBJECTIVES	ACTION	RESULTS
Negociation	- agree with partners - identify problem(s) the organization wants to solve - note needs - identify human, material and financial resources	- meet with partners to identify problems to be solved - analyse development context -see Appendix VI for a summary or consult Negotiation of Expert System projects	- agreement between partners - planning document - definition of each party's contribution
Definition	- identify potential user characteristics - determine domain and experts	- meet with potential users of system and experts - identify duties and constraints - define performance criteria	- description of domain - identification of users, their needs and characteristics of system
Design	- define prototype architecture	- find concepts to represent expert knowledge and expertise - identify inference methods - define system modules - choose software	- conceptual definition of prototype
Developement	- develop prototype 1. acquisition of knowledge and expertise 2. knowledge representation 3. system validation	- meet with experts - set up software tools to favour acquisition of knowledge - transfer and representation in knowledge base of system	EXPERIMENTAL PROTOTYPE
Approval	- Evaluate system and validate its behaviour	- see Appendix V	- prototype to be revised based on results observed; recommence past stages if needed - final report

Table II describes the objectives, actions and results of each stage.

5. EXPERT SYSTEM DEVELOPMENT TOOLS

5.1 Available tools

To put together an expert system, knowledge engineers use either conventional programming languages, or expert system shells, specialized software that provides reasoning mechanisms. The choice of one type of tool rather than another is based on the nature of the problem or the situation to be improved. This is a point to be discussed with the knowledge engineer.

5.2 Desirable tools

Other tools might make research and development work easier. These tools would take into account:
- all phases in the life cycle of an expert system;
- factors such as productivity, quality and reliability in the development of systems;

- giving as much importance to design and development methods as to performance (knowledge base capacity, response time);
- communications problems between expert systems and existing information systems.[16]

These tools and the purpose they would accomplish are described in Table III.

TABLE III
DEVELOPMENT TOOLS AND PURPOSE THEY WOULD ACCOMPLISH

DEVELOPMENT TOOLS	
Preliminary study	Give opinion on: - feasibility of system - overall planning - cost - time frame, etc.
Knowledge acquisition support	Structure knowledge. Tools such as KSS (Knowledge Support System) will be studied in the near future.
Knowledge representation support	Choose the best method for representing knowledge and the best inference engine for the problem posed.
Support for construction and management of knowledge base	- analyse knowledge bases - enter, document and edit knowledge (rules, frames, etc.).
Test and validation	Develop a series of tests to validate prototype and final version
Support for management of expert system development	Plan and monitor development of expert systems.

CONCLUSION

Artificial intelligence today offers new tools for improving organizational productivity: expert systems. Designed to deal with specific problems, they use resources as yet not fully exploited: the knowledge and expertise of the experts in the organization.

Use of an expert system makes it possible to preserve, organize and make accessible the invaluable expertise that is the hallmark of organizations. Increased production and more successful goal fulfilment are only two of the many advantages your organization may derive from the use of an expert system.

Much research is still needed to render expert system technology more accessible to organizations, both business and private. Projects underway at the Canadian Workplace Automation Research Centre contribute to this important undertaking.

(16) Alain Bonnet. Expert systems: Towards technical control.

APPENDIX I

SOME APPLICATIONS OF KNOWLEDGE-BASED SYSTEMS

1. DESIGN SYSTEMS

Applied to design of printed circuits, building design, budget preparation, etc.

2. PLANNING SYSTEMS

Used for project planning, resource distribution, communications, military engineering, etc.

3. MAINTENANCE SYSTEMS

Applied to domains such as automobiles, aviation, communications networks, computer maintenance.

4. MONITORING SYSTEMS

Used for monitoring nuclear power plants, air traffic, hospital patients, financial management, etc.

5. INTELLIGENT TUTORING SYSTEMS

Can instruct, diagnose student problems and provide feedback.

6. INTERPRETATION SYSTEMS

Used for supervision, understanding discourse, analysing images, interpreting signals.

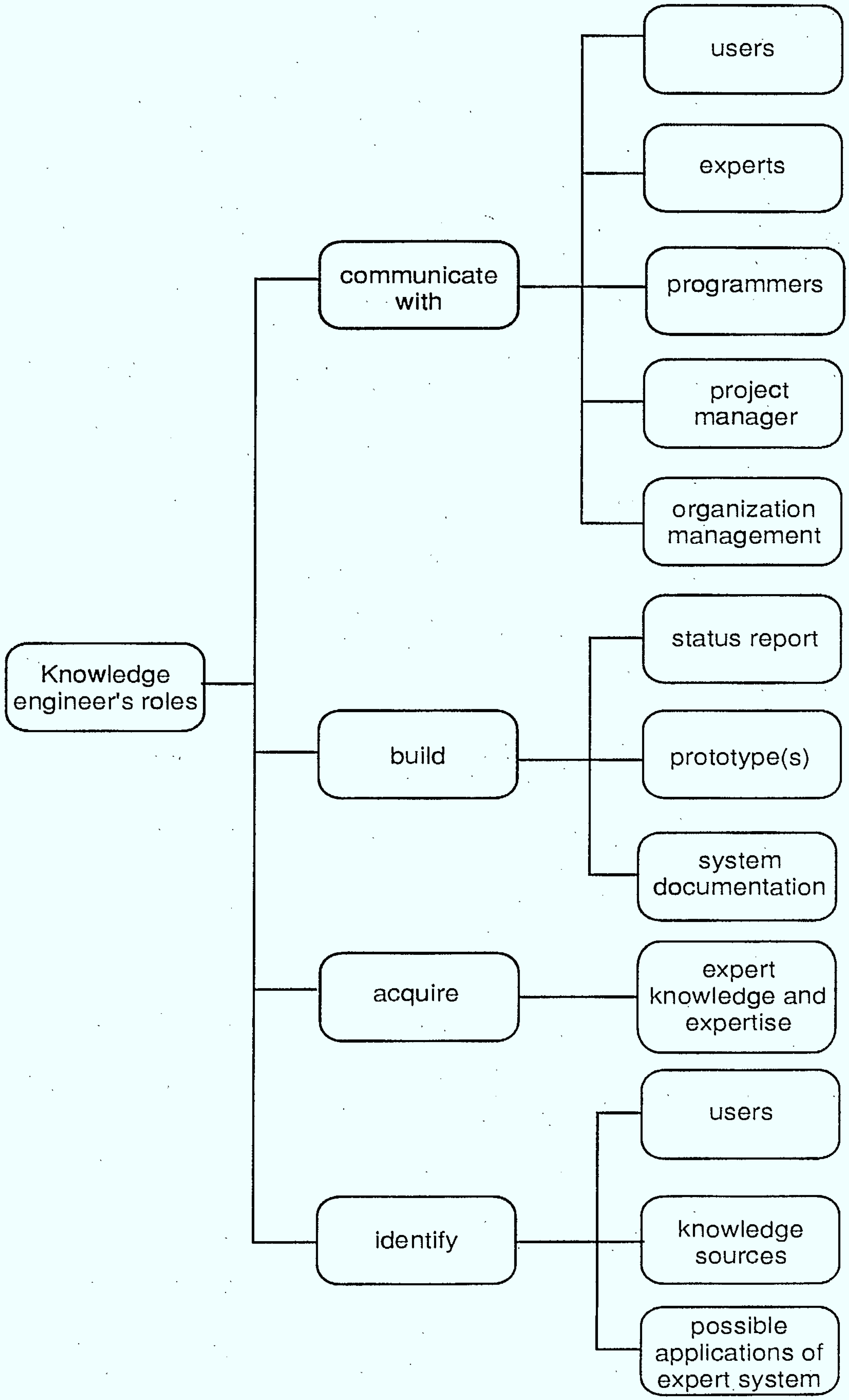
7. FORECASTING SYSTEMS

Used for weather and demographic forecasting, forecasting traffic on networks, estimating agricultural production, military forecasting, etc.

8. MANAGEMENT SUPPORT SYSTEMS

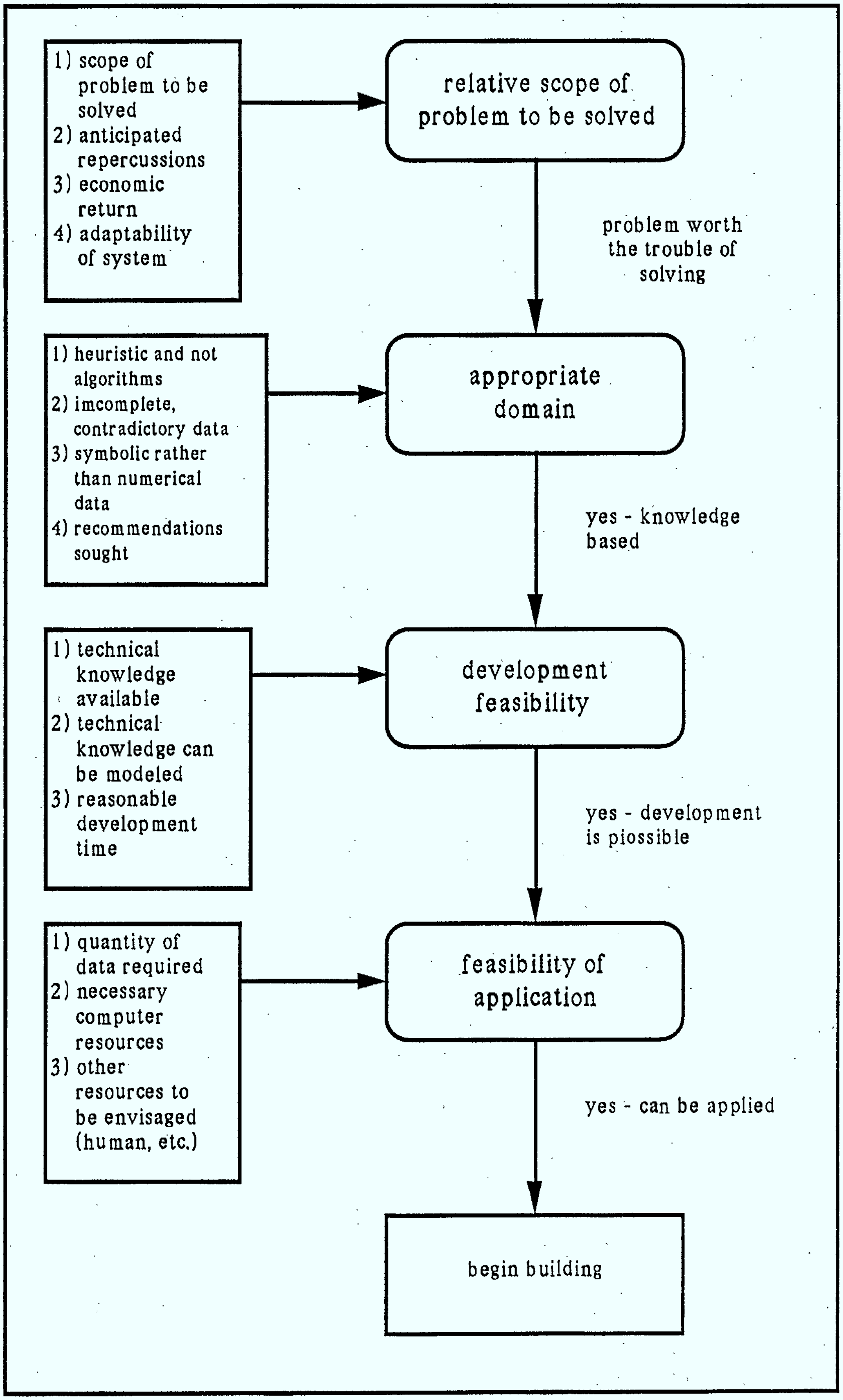
These systems help the user with tasks normally encountered in an office.

APPENDIX II
KNOWLEDGE ENGINEER'S ROLES



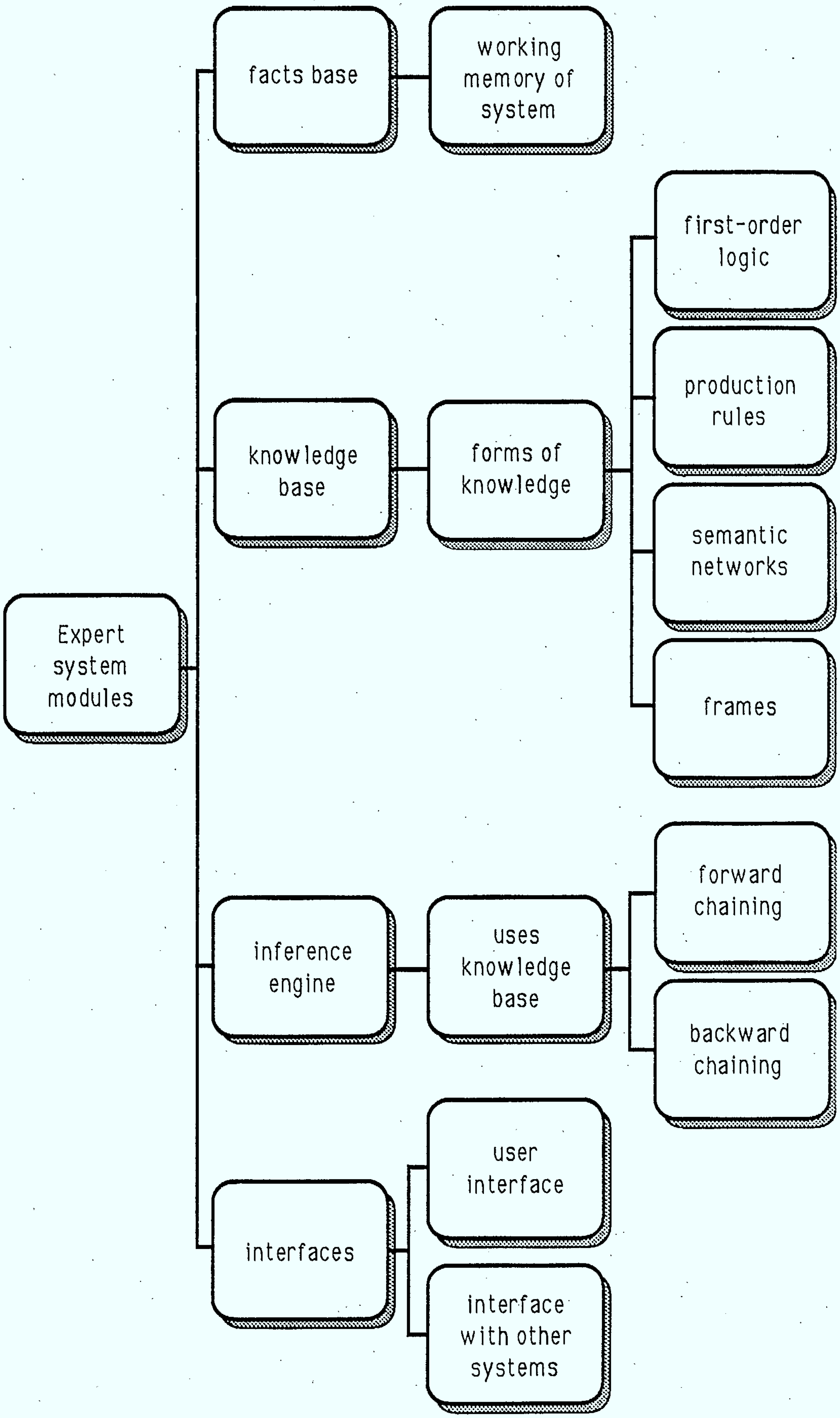
APPENDIX III

WHEN TO USE EXPERT SYSTEM TECHNOLOGY[17]



(17) Adapted from Louis R. Gieszl. <u>The Expert system Applicability Question.</u>

APPENDIX IV
ARCHITECTURE OF EXPERT SYSTEMS - SUMMARY



APPENDIX V

EXPERT SYSTEM EVALUATION CRITERIA (18)

(18) Adapted from Kimiz Dalkir. A Systems Approach to the Evaluation of Expert Systems. A more complete list of assessment criteria is included in the document.

TECHNICAL ASPECTS

- program easy to modify if initial situation changes or if improvements are desiared;

- program can be adapted to a number of systems (e.g. PC and compatibles);

- program is reliable.

KNOWLEDGE BASE

- it is valid (program arrives at same conclusions as expert);

- it is complete (handles all cases in the chosen domain);

- it follows a strict logical system;

- it gives the user any necessary assistance at all times and provides guidance (e.g. explanations, notes);

- it offers the user useful results (reports or tables rather than simply lists);

- it uses clear, unambiguous language; level of detail is appropriate (neither too much nor too little).

HUMAN FACTORS

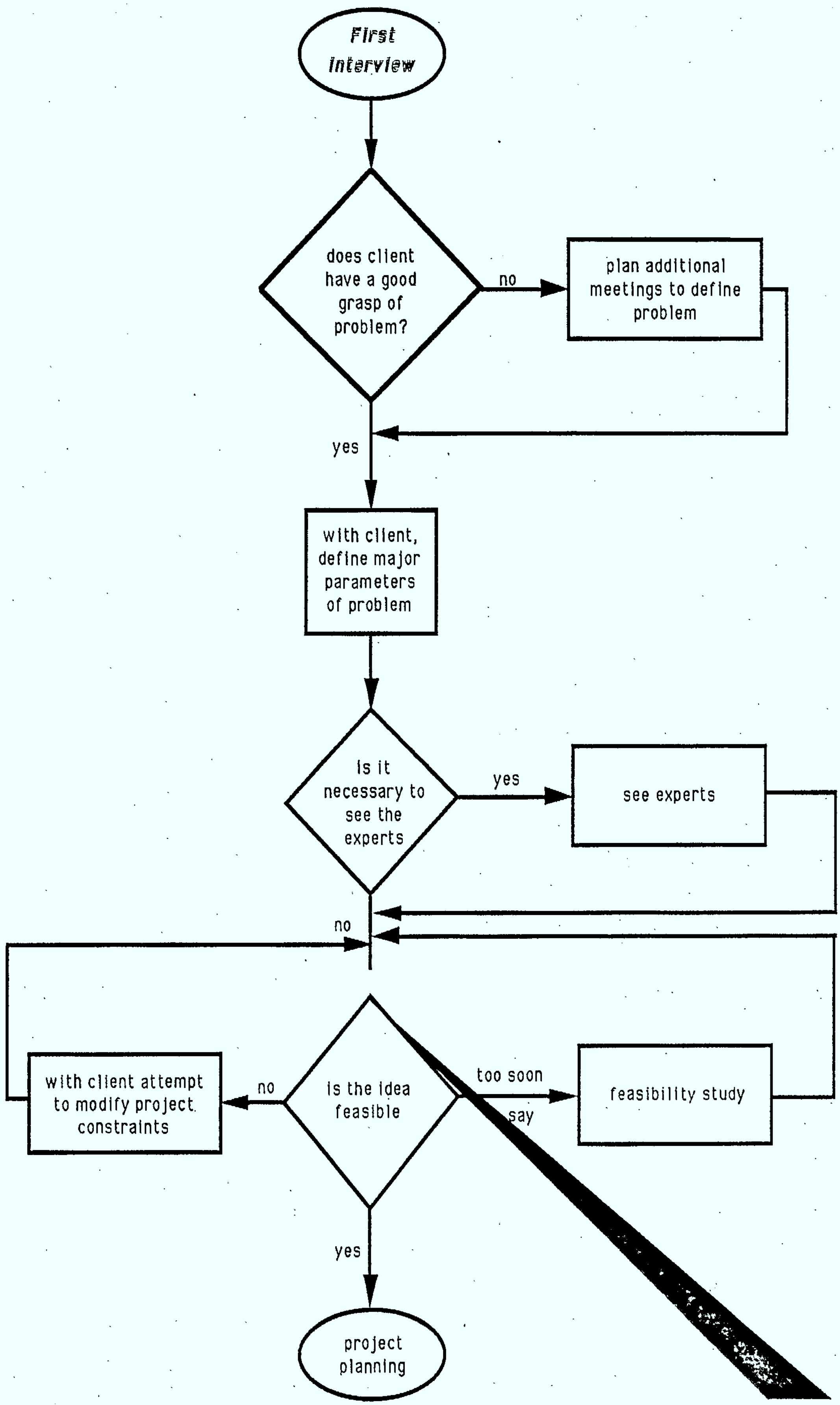
- program adapts to users rather than the contrary (level of knowledge, e.g. one for the expert and one for the novice);

- program provides benefits for users:

ogram helps users in their work;

- cost-benefit analysis favourable.

APPENDIX VI
SUMMARY TABLE
- NEGOTIATION -



REFERENCES

Bonnet, Alain et al. Systèmes experts: vers la maîtrise technique, Paris, InterEditions (coll. IIA informatique intelligence artificielle), 1986.

Dalkir, Kimiz. A Systems Approach to the Evaluation of Expert Systems, CCRIT, 1988.

Gieszl, Louis R. "The Expert System Applicability Question» in : Proceedings, *Conference on AI and Simulation*, San Diego, L.A., january 1987.

Hayes-Roth, Frederick,Lenat, Douglas B. and Donald A. Waterman. Building Expert Systems, Addisson-Wesley Publishing Company Inc., 1983.

Grand dictionnaire encyclopédique Larousse, 1980.

Hunt,V.Daniel. Artificial Intelligence and Expert Systems Sourcebook, New York, Chapman and Hall, 1986 (Coll. Chapman and Hall Advanced Industrial Technology Series).

Luconi, Fred L., Malone, Thomas W. and Michael S. Scott Morton. Expert Systems and Expert Support Systems : The New Challenge for Management, MIT, Sloan School of Management, 1984 (Coll. Management in the 1990's).

Morvan, Pierre (sous la direction de). Dictionnaire de l'informatique, 6e édition revue et mise à jour, Paris, Librairie Larousse (coll. Références Larousse), 1986.

Moulin, Bernard et Marie-Michèle Boulet. «De la gestion des données à la gestion des connaissances dans l'organisation» dans : Transformation-Information-Technology Evolving for the Future, Proceedings, Canadian Information Processing Society, 1986, p. 277-282.

Pavel, Sylvia. Vocabulaire de l'intelligence artificielle, Ottawa, Secrétariat d'Etat du Canada, Direction générale de la terminologie et des services linguistiques.

Petit Robert, 1977.

Polya, G. How to solve it. New York, Doubleday.

THEMATIC BIBLIOGRAPHY

Bibliographiy

Carande, Robert."Checking out AI sources" in : AI expert, 3 (6), june 1988, p.60-65.

Dictionaries an bilingual glossaries

AFNOR. Vocabulaire international de l'informatique : traitement de l'information, Paris: AFNOR, 1986.

CANADA. Glossary: Electronic Data Processing. Ottawa: Supply and Services Canada, c1985.

CANADA. Information Technology Vocabulary. Ottawa: Supply and Services Canada, 1984.

Ginguay, Michel et Annette Lauret. Dictionnaire d'informatique français-anglais, Paris: Masson, c1981.

OFFICE DE LA LANGUE FRANÇAISE. Terminologie de l'informatique : états terminologiques et bibliographies, Québec: Gouvernment of Quebec, c1983.

Artificial Intelligence: general works

Andriole, Stephen. Applications in artificial intelligence, Princeton, Petrocelli Books, c1985.

Firdman, Henry Eric. Putting artificial intelligence to work, Fallbrook, Henry Firdman and associates, c1988, 2 vol.

Generesereth, Michael R. et Nils J. Nilsson, Logical foundations of artificial intelligence, Los Altos, Morgan Kaufmann, c1987.

Johnson, George. Machinery of the mind : inside the new science of artificial intelligence, New York, Times Books, c1986.

Michie, Donald. On machine intelligence, Chichester, Toronto : Ellis Horwood, John Wiley and Sons (Ellis Horwood Series in Artificial Intelligence), c1987.

Mishkoff, Henry C. Understanding artificial intelligence, Indianapolis, Howard W. Sams and Co. (Sams Understanding Series), c1985.

Saridis, George N. «Artificial intelligence vs machine intelligence : facts and fiction» dans : The Second Conference on Artificial Intelligence Applications in the engineering of Knowledge-based Systems, Washington. D.C., IEEE, Computer Society Press, 1985, p. 144-145.

Scown, Susan J. The artificial intelligence experience : an introduction, Maynard, Digital Equipment Corporation, c1985.

THEMATIC BIBLIOGRAPHY

Artificial intelligence: economic aspects

Busch, Earlene Kingery. «Artificial intelligence : why on again, off again?» Teitell, Murray ed., dans : Proceedings of the Third Annual Artificial Intelligence and Advanced Computer Technology Conference, Wheaton, Tower Conference Management, 1987, p. 455-458.

Toda, Iwao. «On the future of AI» dans : ICOT journal, sept. 1987, p. 3-13.

Artificial intelligence: legal aspects

Frank, Steven J. «What AI practitioners should know about the law», AI magazine, 9 (2), summer 1988, p. 109-114.

Ethics/philosophy and artificial intelligence

McCarthy, John. «Epistemological problems of artificial intelligence» dans : Readings in Knowledge Representation, Los Altos, Morgan Kaufmann, c1985, p. 23-30.

McCarthy, John et P.J. Hayes, «Some philosophical problems form the standpoint of artificial intelligence» dans : Readings in Artificial Intelligence, Los Altos, Morgan Kaufmann, c1981, p. 431-450.

QUEEN QA 76.76 .E95 E432 198
Muzard, Joël
Elements for building expert

CACC / CCAC
95321

DATE DUE
DATE DE RETOUR

CARR McLEAN
38-296

Pour plus de détails, veuillez communiquer avec :

Le Centre canadien de recherche sur l'informatisation du travail
1575, boulevard Chomedey
Laval (Québec)
H7V 2X2
(514) 682-3400

For more information, please contact:

Canadian Workplace Automation Research Centre
1575 Chomedey Blvd.
Laval, Quebec
H7V 2X2
(514) 682-3400