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Expert Systems: Working Systems and the Research Literature

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EXPERT SYSTEMS: WORKING SYSTEMS AND THE RESEARCH LITERATURE

Bruce G. Buchanan

1. INTRODUCTION

Expert systems are the subject of considerable interest among persons in AI research or applications. There is no single definition of an expert system, and thus no precisely defined set of programs or set of literature references that represent work on expert systems. Nevertheless, I have attempted to put together such lists in an effort to further research and technology transfer.

The major dimensions along which I like to define expert systems are the following:

1. AI METHODOLOGY -- Expert systems are AI programs. That is, they are programs that reason with symbolic information and use heuristic (non-algorithmic) inference procedures.
2. HIGH PERFORMANCE -- Expert-level performance is what the designers are attempting to achieve, but this, too, is not always well defined. In narrow problem areas, it is possible to construct systems that reason as well as the specialists in those areas. In some areas, it is beneficial to construct systems that solve only a fraction of the problems that an expert can solve -- but solve them correctly -- if, for instance, those systems can free an expert's time for the more difficult problems.
3. FLEXIBILITY -- AI programs, generally, are more flexibly designed than algorithmic programs, partly because they have to be in order to allow modification as problems become better defined. In addition to the flexibility needed at design time, it is desirable for expert systems to exhibit flexibility at run time. In particular, the more tolerant they are of unanticipated input, new contexts of application, and different kinds of users, the more "expert" they would seem to be.
4. UNDERSTANDABILITY -- Just as an expert can explain his/her reasoning[1] an expert system should be able to explain its line of reasoning and the contents of its knowledge base. This, too, is important both at development time, for debugging, and at run time, for accepting the reasonableness of the system's conclusions.

One of the key elements of an expert system that makes possible this degree of flexibility and understandability is the separation of the knowledge base from the inference engine. McCarthy* noted years ago that a straightforward, modular, declarative representation of knowledge was a prerequisite for a system that could be told new facts and relations. Because AI systems are often used to help define ill-structured problems, they are constructed incrementally. Thus representing the knowledge base in a form outside of the main body of code will make it easier to modify and explain.

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[1] Plato [Theaetetus] used the ability to explain the underlying reasons for a belief as one of the essential differences between a person's *knowing* something and merely *believing* it. Similarly, it seems odd to say that a person has expertise in a reasoning task if s/he cannot explain the line of reasoning.

*"Programs with Common Sense", *Proceedings of the Symposium* on *the Mechanisation of Thought Processes, 1958,* pg. 77-84. also reprinted in *"Semantic Information Processing",* M. Minsky, ed., Massachusetts Institute Technology Press, 1968.

2. EXPERT SYSTEMS IN ROUTINE USE OR FIELD TESTING

The following systems do not necessarily exhibit *all* of the above characteristics, nor exhibit them to the degree we would like to see in the best systems. Nevertheless, they are listed because they match enough of the criteria well enough that most of us would agree they should be called expert systems. Moreover, I have chosen to include only systems that are out of the hands of developers -- either in routine use or in a field-test environment that is close to that of routine use. For this reason some well-known expert systems such as MYCIN are not listed. And I have chosen to include only systems that are public and thus that can be discussed in specific terms.

This list was based on information supplied largely by reliable sources among the developers. Additional proprietary systems were mentioned by Teknowledge, Intellicorp, Texas Instruments, Syntelligence, AI&DS, and APEX. Many others have been reported in the literature without a clear indication of status.

SITE	PROGRAM
DEC -- Configuring VAX orders, Order checking	XCON,XSEL,XSITE
Schlumberger -- Analysis of oil well logging data	Dipmeter Advisor
Elf-Aquitaine -- Advising on drill-bit sticking problems in oil wells [training tool]	SECOFOR
Stanford Oncology Clinic -- Cancer management	ONCOCTN
NL Tndus. -- Diagnosing mud-drilling problems	MUDMAN
H-P -- Troubleshooting photolithography steps in circuit fabrication	
Westinghouse -- Nuclear fuel enhancement	
NCR -- Order checking & configuration	OCEAN
Helena Labs -- Serum protein analysis	
Hughes Electo-Optical & Data Sys -- Sequencing steps in pc board assembly	Hi Class
Lockheed -- Troubleshooting communications hardware	BDS
Shell Petroleum -- Intelligent front-end for complex software	
Pacific Medical Center -- Interpreting pulmonary function tests	PUFF

Westinghouse
-- Job shop scheduling

Molecular Design Ltd — DENDRAL
-- Substructure searching [not data interpretation]

S.W. Bell — ACE
-- Troubleshooting telephone lines

Texas Instr./Boeing — Infomart Advisor
-- Advising shoppers on computer purchases

British Gas
-- Herbicide advisor

ITT
-- Diagnosis of faults on printed circuit boards

IBM — YES/MVS
-- Monitoring MVS operating system

GE — CATS
-- Diagnosis of problems in diesel-electric locomotive

XEROX — BUGGY
-- Debugging students' subtraction errors [field tested, now dormant]

Babcock & Wilcox
-- Advising on types of welds and materials based on engineering specs

Yale Univ. — PROUST
-- Debugging students' PASCAL pgms

. Delco Products
-- Checking fan motor design

Westinghouse
-- Elevator maintenance

SUNY-Stonybrook — SYNCHEM
-- Chemical synthesis planning

Travelers Insurance — DIAG8100
-- Diagnosing failures in DP equipment

SHELL INST.
-- Screening new chemicals for herbicidal properties

DEC — SPEAR
-- Diagnosing failures in tape drives

St. Vincent's Hospital, Sydney
-- Interpretation of Hormone Assay

I.C.L.
-- Configuring Series 39 computers

DEC ISA
-- Scheduling orders for manufacturing and delivery

Lawrence Livermore Labs TQMSTUNE
-- Tuning triple quadrapole mass spectrometer

Campbell Soups
-- Troubleshooting cookers, anticipating failures

ICI WHEAT COUNSELLOR
-- Advising on control of disease in winter wheat crops

EPA EDDAS
-- Advising on disclosure of confidential business information

AIG [American International Group]
-- Advising & supporting commercial insurance underwriters (e.g. on risks)

St.Paul Insurance Co.
-- Assessing a variety of commercial ins. risks

Nixdorf
-- Order entry checking and configuration

IBM
-- Advising on cost of moving mainframes from site to site

Hitachi
-- Controlling RR train braking for accuracy and comfort

Hitachi
-- Configuring machine room floor for computer system and peripherals

Kawasaki Steel (Mizushina Works)
-- Detecting cracks in billets & directing grinding

U.S. Army AALPS
-- Planning optimal loading of equipment on aircraft

NASA GEOX
-- Identifying earth surface minerals from remotely sensed hyperspectral image data

3. BIBLIOGRAPHY OF EXPERT SYSTEMS

All of AI research is relevant for building expert systems. Some articles, technical reports, and conference papers, however, are explicit reports of specific systems or of methods underlying the construction of expert systems. I have attempted to list those here. I have not included articles in the popular press and trade magazines unless they seemed to offer relevant specifics not found elsewhere. Please send additions and corrections online to Buchanan@Sumex, in SCRIBE format if possible.

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