Expert Systems

To be covered

- Describe the concept and evolution of rule-based expert systems (ES)
- Understand the architecture of rule-based ES
- Learn the knowledge engineering process used to build ES
- Identify proper applications of ES

What is an expert system?

Expert Systems (ES)

- a computer program that attempts to imitate expert's reasoning processes and knowledge in solving specific problems
- Most Popular Applied AI Technology
  - Enhance Productivity
  - Augment Work Forces
- Works best with narrow problem areas/tasks
- Expert systems do not replace experts, but
  - Make their knowledge and experience more widely available, and thus
  - Permit non-experts to work better

Important Concepts in ES

- **Expert**

  A human being who has developed a high level of proficiency in making judgments in a specific domain

- **Expertise**

  The set of capabilities that underlines the performance of human experts, including

  - ✓ extensive domain knowledge,
  - ✓ heuristic rules that simplify and improve approaches to problem solving,
  - ✓ meta-knowledge and meta-cognition, and
  - ✓ compiled forms of behavior that afford great economy in a skilled performance

Features and Concepts in ES

- Experts / Expertise
  - Degrees or levels of expertise
  - Ratio of non-experts to experts → 100 to 1
- Transferring Expertise
  - From expert to computer to non-experts via acquisition, representation, inferencing, transfer

- Symbolic Reasoning / Inferencing
- Deep Knowledge / Self Knowledge

Conventional vs. Expert Systems

TABLE 11.1 Comparison of Conventional Systems and Expert Systems

Conventional Systems	Expert Systems
Information and its processing are usually combined in one sequential program.	The knowledge base is clearly separated from the processing (inference) mechanism (i.e.,knowledge rules are separated from the control).
The program does not make mistakes (programmers or users do).	The program may make mistakes.
Conventional systems do not (usually) explain why input data are needed or how conclusions are drawn.	Explanation is a part of most ES.
Conventional systems require all input data. They may not function properly with missing data unless planned for.	ES do not require all initial facts. ES can typically arrive at reasonable conclusions with missing facts.
Changes in the program are tedious (except in DSS).	Changes in the rules are easy to make.
The system operates only when it is completed.	The system can operate with only a few rules (as the first prototype).

Continued…

Conventional vs. Expert Systems

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Execution is done on a step-by-step (algorithmic) basis.	Execution is done by using heuristics and logic.
Large databases can be effectively manipulated.	Large knowledge bases can be effectively manipulated.
Conventional systems represent and use data.	ES represent and use knowledge.
Efficiency is usually a major goal.	
Effectiveness is important only for DSS.	Effectiveness is the major goal.
Conventional systems easily deal with quantitative data.	ES easily deal with qualitative data.
Conventional systems use numeric data representations.	ES use symbolic and numeric knowledge representations.
Conventional systems capture, magnify, and distribute access to numeric data or information.	ES capture, magnify, and distribute access to judgment and knowledge.

Applications of Expert Systems

- Classical Applications
  - DENDRAL
    - Applied knowledge (i.e., rule-based reasoning)
    - Deduced likely molecular structure of compounds
  - MYCIN
    - A rule-based expert system
    - Used for diagnosing and treating bacterial infections
  - XCON
    - A rule-based expert system
    - Used to determine the optimal information systems configuration
- New applications: Credit analysis, Marketing, Finance, Manufacturing, Human resources, Science and Engineering, Education, ...

Applications of Expert Systems

TABLE 11.2 Sample Applications of Expert Systems

Expert System	Organization	Application Domain
Classical Applications		
MYCIN	Stanford University	Medical diagnosis
XCON	DEC	System configuration
Expert Tax	Coopers & Lybrand	Tax planning
Loan Probe	Peat Marwick	Loan evaluation
La-Courtier	Cognitive Systems	Financial planning
LMOS	Pacific Bell	Network management
PROSPECTOR	Stanford Research Institute	Discovery of new mineral deposits
Reported Applications		
Fish-Expert	North China	Disease diagnosis in fish
HelpDeskIQ	BMC Remedy	Help desk management
Authorete	Haley	Business rule automation
eCare	CIGNA	Insurance claims
SONAR	NSAD	Stock market monitoring

Application Case 1

Expert System Aids in Identification of Chemical, Biological, and Radiological Agents

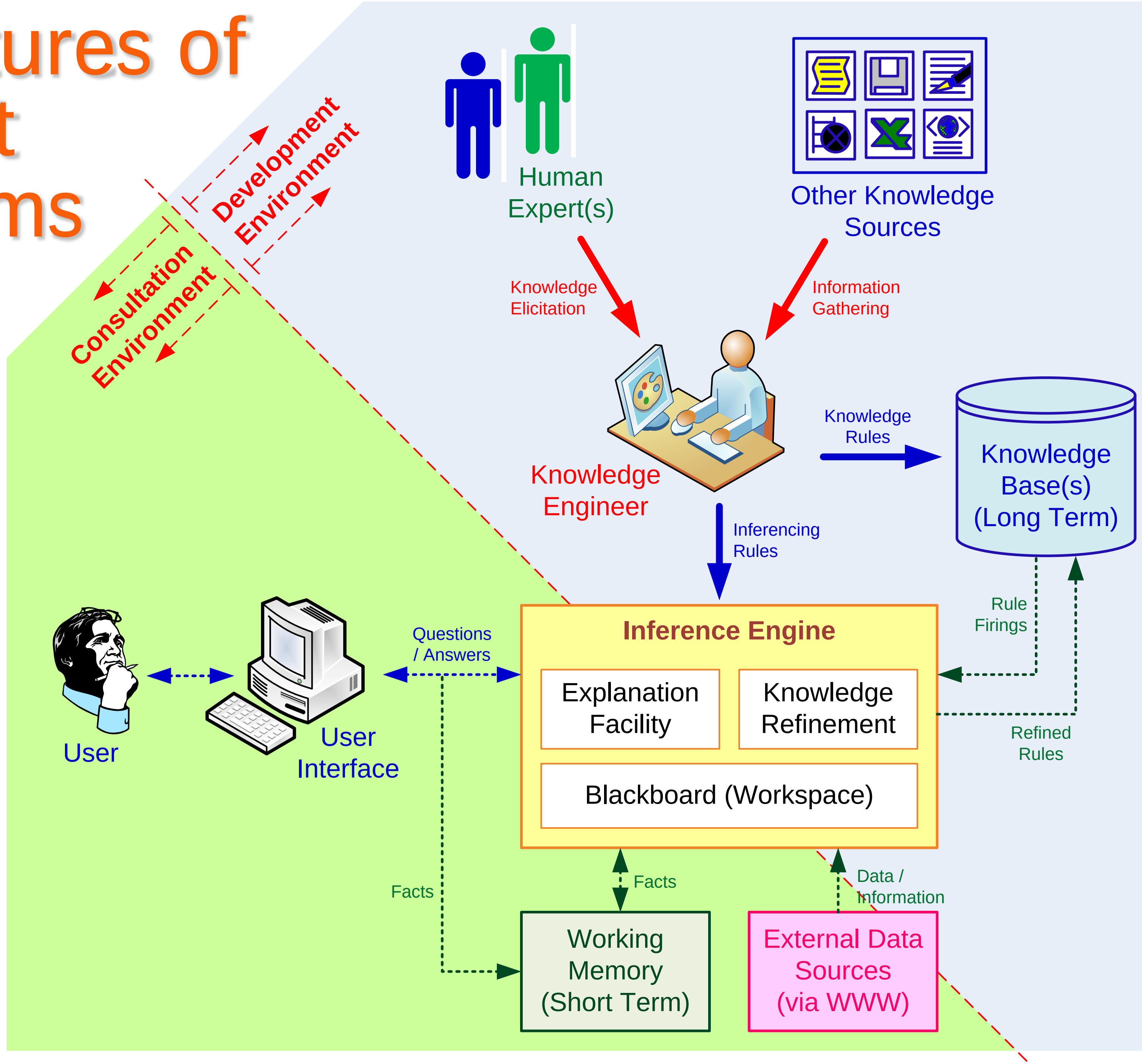
Questions for Discussion

1. How can CBR Advisor assist in making quick decisions?
2. What characteristics of CBR Advisor make it an expert system?
3. What could be other situations where such expert systems can be employed?

Structure of Expert Systems

- Development Environment
- Consultation Environment
- Major Components
    - Knowledge acquisition subsystem
        - Knowledge Engineer
    - Knowledge Base
    - Inference Engine
    - User Interface
    - Blackboard (workplace)
    - Explanation subsystem (justifier)
    - Knowledge-refining system

Structures of Expert Systems



Application Case 2

Diagnosing Heart Diseases by Signal Processing – *to analyze digitally processed heart sound*

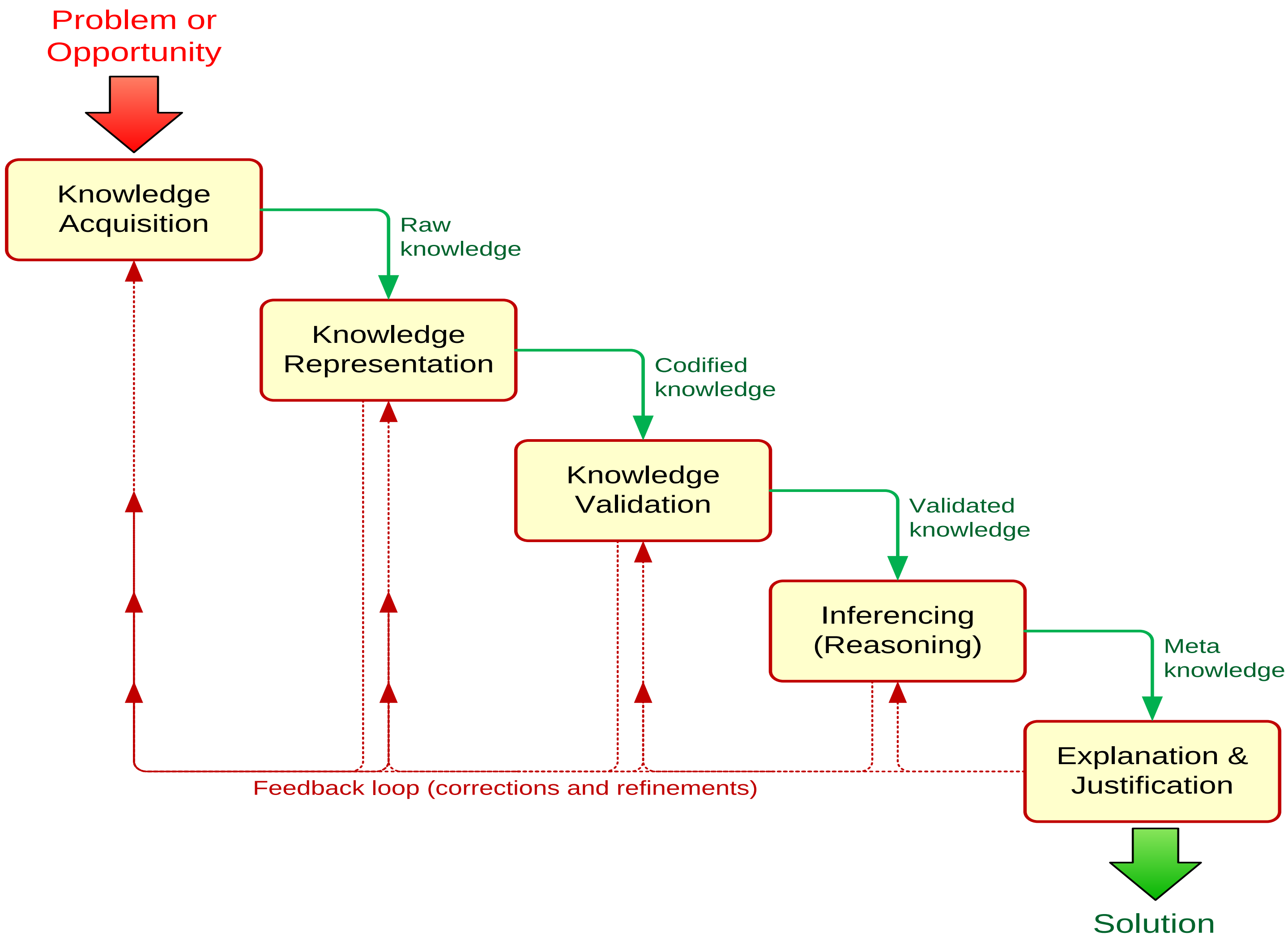
Questions for Discussion

1. List the major components involved in building SIPMES (Signal Processing Module Integrating Expert Systems) and briefly comment on them.
2. Do expert systems like SIPMES eliminate the need for human decision making?
3. How often do you think that the existing expert systems, once built, should be changed?

Knowledge Engineering (KE)

- A set of intensive activities encompassing the acquisition of knowledge from human experts (and other information sources) and converting this knowledge into a repository (commonly called a knowledge base)
- The primary goal of KE is to
  - help experts articulate *how they do what they do,* and
  - to document this knowledge in a reusable form
- Narrow versus Broad definition of KE?

The Knowledge Engineering Process



Difficulties in KE

TECHNOLOGY INSIGHTS 11.1 Difficulties in Knowledge Acquisition

Acquiring knowledge from experts is not an easy task. The following are some factors that add to the complexity of knowledge acquisition from experts and its transfer to a computer:

- Experts may not know how to articulate their knowledge or may be unable to do so.
- Experts may lack time or may be unwilling to cooperate.
- Testing and refining knowledge are complicated.
- Methods for knowledge elicitation may be poorly defined.
- System builders tend to collect knowledge from one source, but the relevant knowledge may be scattered across several sources.
- System builders may attempt to collect documented knowledge rather than use experts. The knowledge collected may be incomplete.
- It is difficult to recognize specific knowledge when it is mixed up with irrelevant data.
- Experts may change their behavior when they are observed or interviewed.
- Problematic interpersonal communication factors may affect the knowledge engineer and the expert.

Knowledge

Validation VS Verification??

Knowledge Engineering
Knowledge Validation/Verification

- Evaluation is a broad concept - its objective is to assess an ES's overall value

Validation versus Verification

- Validation is the part of evaluation that deals with the performance of the system
- Verification is building the system right or substantiating that the system is correctly implemented to its specifications

Knowledge Representation in ES

- Expert knowledge must be represented in a computer-understandable format and organized properly in the *knowledge base*
- The most common/popular way to represent human knowledge:
  - Production rules
    - Condition-Action pairs
    - IF ... THEN ... ELSE ...

Forms of Production Rules

- IF premise, THEN conclusion
  - IF your income is high, THEN your chance of being audited by the IRS is high
- Conclusion, IF premise
  - Your chance of being audited is high, IF your income is high
- Inclusion of ELSE
  - IF your income is high, OR your deductions are unusual, THEN your chance of being audited by the IRS is high,   ELSE your chance of being audited is low
- *More complex rules…*

Knowledge and Inference Rules

- Knowledge rules (declarative rules), state all the facts and relationships about a problem
  - Knowledge rules are stored in the knowledge base
- Inference rules (procedural rules), advise on how to solve a problem, given that certain facts are known
  - Inference rules contain rules about rules (metarules)
  - Inference rules become part of the inference engine
  - Example:
    - IF needed data is not known THEN ask the user
    - IF more than one rule applies THEN fire the one with the highest priority value first

Inferencing in ES

Inference is the process of chaining multiple rules together based on available data

- Forward chaining

  A data-driven search in a rule-based system.

  If the premise clauses match the situation, then the process attempts to assert the conclusion.

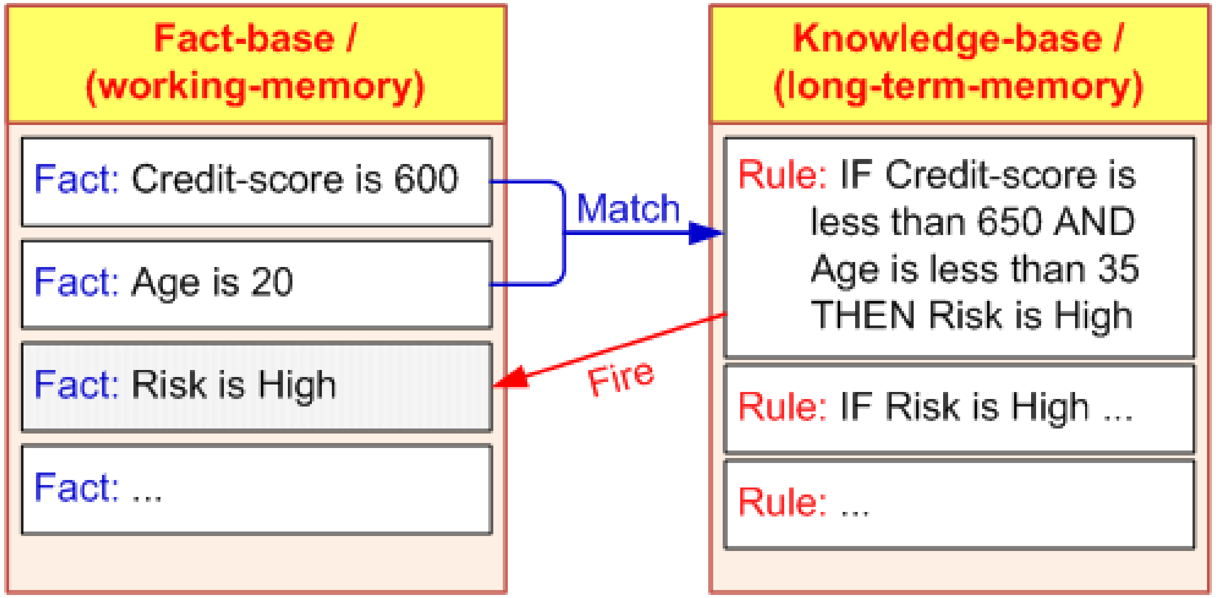
- Backward chaining

  A goal-driven search in a rule-based system.

  It begins with the action clause of a rule and works backward through a chain of rules in an attempt to find a verifiable set of condition clauses.

Inferencing with Rules: Forward and Backward Chaining

- Firing a rule
  - When all of the rule's hypotheses (the "if parts") are satisfied, a rule said to be FIRED
  - Inference engine checks every rule in the knowledge base in a forward or backward direction to find rules that can be FIRED
  - Continues until no more rules can fire, or until a goal is achieved



Explanation as a Metaknowledge

- Explanation
  - Human experts justify and explain their actions
    ... so should ES
  - Explanation: an attempt by an ES to clarify reasoning, recommendations, other actions (asking a question)
  - Explanation facility = Justifier

- Explanation Purposes...
  - Make the system more intelligible
  - Uncover shortcomings of the knowledge bases
  - Explain unanticipated situations
  - Satisfy users' psychological and/or social needs, ...

Two Basic Explanations

- Why Explanations - Why is a fact requested?
- How Explanations - To determine how a certain conclusion or recommendation was reached
  - Some simple systems - only at the final conclusion
  - Most complex systems provide the chain of rules used to reach the conclusion

- Explanation is essential in ES
- Used for training and evaluation

Problem Areas Suitable For Expert Systems

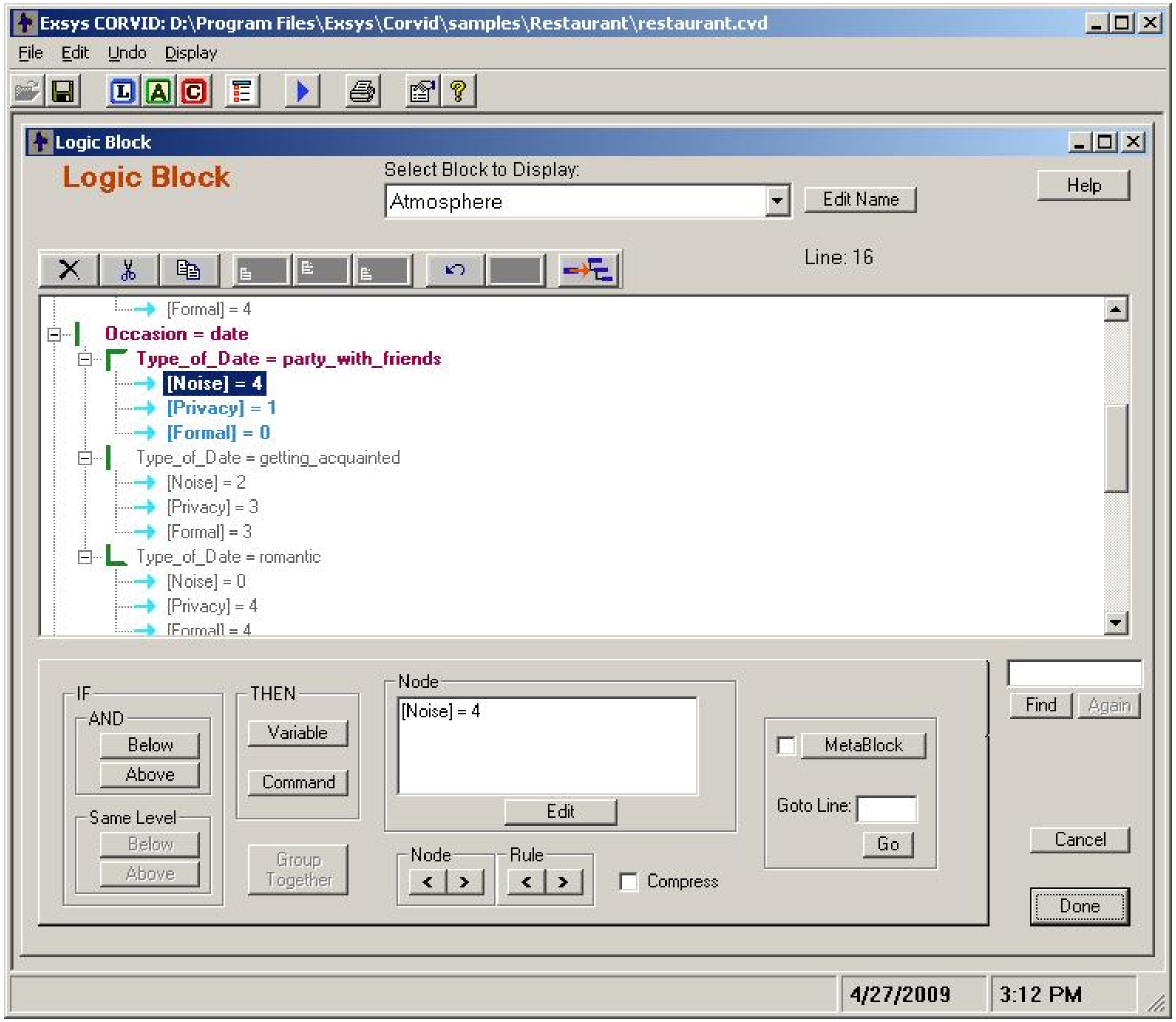
TABLE 11.3 Generic Categories of Expert Systems

Category	Problem Addressed
Interpretation	Inferring situation descriptions from observations
Prediction	Inferring likely consequences of given situations
Diagnosis	Inferring system malfunctions from observations
Design	Configuring objects under constraints
Planning	Developing plans to achieve goals
Monitoring	Comparing observations to plans and flagging exceptions
Debugging	Prescribing remedies for malfunctions
Repair	Executing a plan to administer a prescribed remedy
Instruction	Diagnosing, debugging, and correcting student performance
Control	Interpreting, predicting, repairing, and monitoring system behaviors

Development of ES

- Defining nature and scope of problem
- Identifying proper experts
- Acquiring knowledge
  - Knowledge engineer
- Selecting the Building Tools
  - Shells versus Complete Development
- Coding the system
- Evaluating and Launching the System

A Popular Expert System Shell: Exsys



Application Case 3

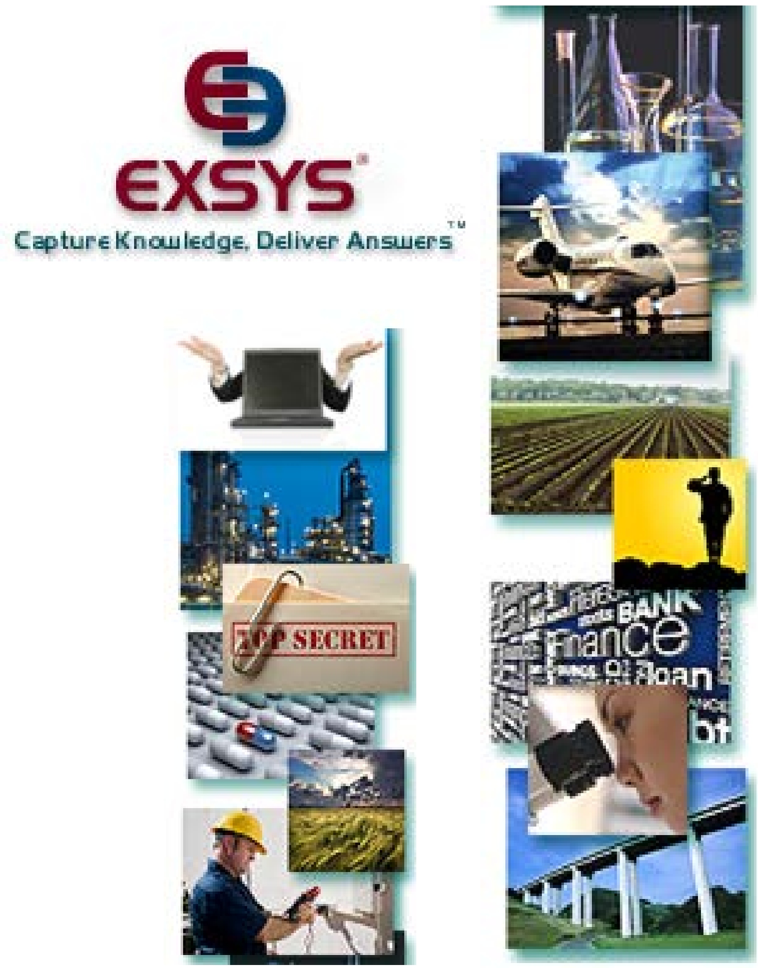
Clinical Expert System for Tendon Injuries

Questions for Discussion

1. Research other expert systems in other domains and list a few of them.
2. Why is important to evaluate the expert systems before they are put into use?

Problem Areas Addressed by ES

- Interpretation systems
- Prediction systems
- Diagnostic systems
- Repair systems
- Design systems
- Planning systems
- Monitoring systems
- Debugging systems
- Instruction systems
- Control systems, ...



How to develop an expert system to support loan approval decision??

- https://www.youtube.com/watch?v=P7yqH95lcqA