Knowledge Acquisition and Validation

Knowledge Acquisition and Validation

Knowledge Engineering

Knowledge Engineering

- **Art of bringing the principles and tools of AI research to bear on difficult applications problems requiring experts' knowledge for their solutions**
- **Technical issues of acquiring, representing and using knowledge appropriately to construct and explain lines-of-reasoning**
- **Art of building complex computer programs that represent and reason with knowledge of the world**

- ***Narrow perspective:*** **knowledge engineering deals with knowledge acquisition, representation, validation, inferencing, explanation and maintenance**

- ***Wide perspective:*** **KE describes the *entire process* of developing and maintaining AI systems**

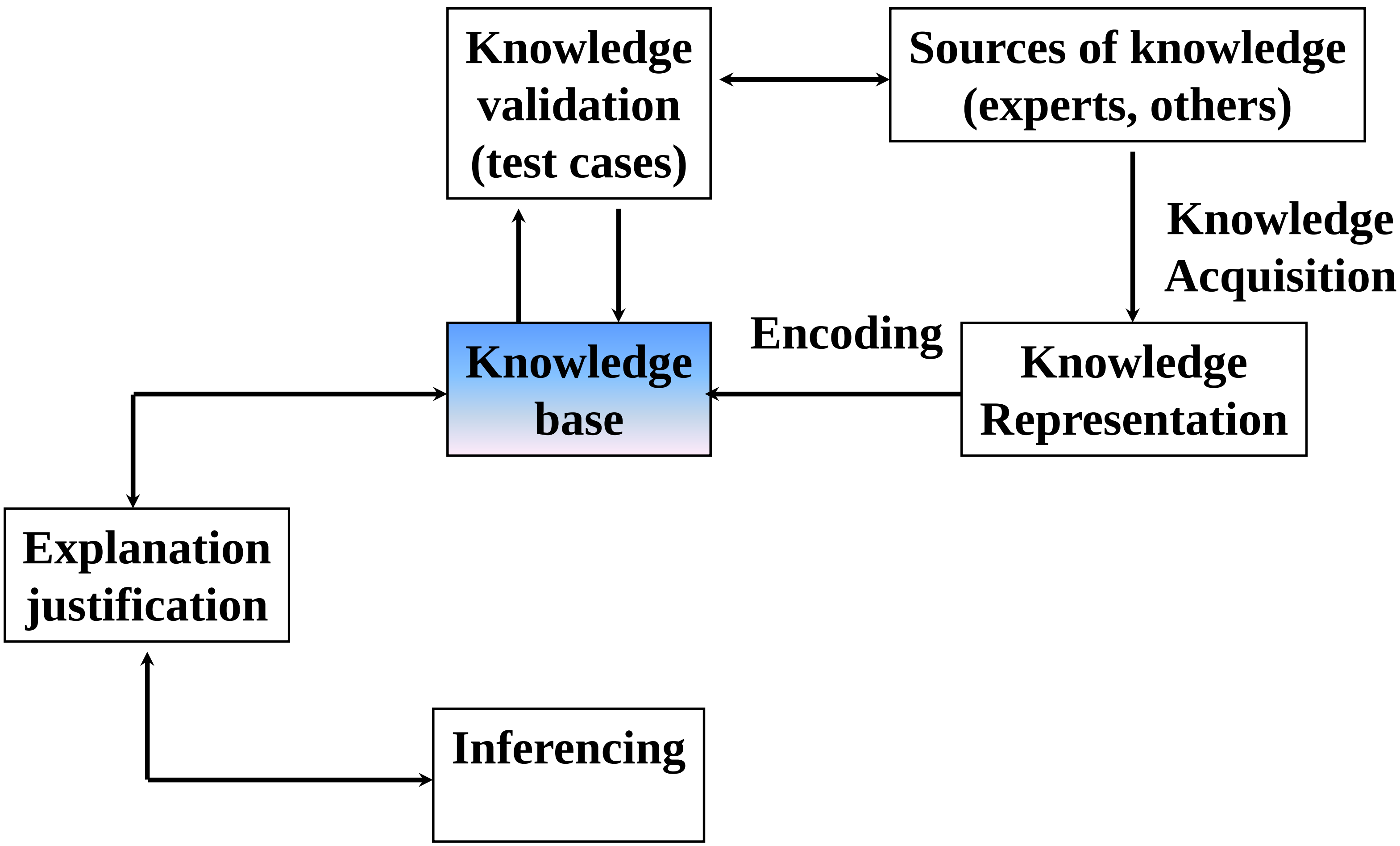
- **We use the Narrow Definition**
  - **Involves the cooperation of human experts**
  - **Synergistic effect**

Knowledge Engineering Process Activities

- Knowledge Acquisition
- Knowledge Validation
- Knowledge Representation
- Inferencing
- Explanation and Justification

Knowledge Engineering Process

(Figure 11.1)



Scope of Knowledge

- ***Knowledge acquisition*** **is the extraction of knowledge from sources of expertise and its transfer to the knowledge base and sometimes to the inference engine**

- ***Knowledge*** **is a collection of specialized facts, procedures and judgment rules**

Knowledge Sources

- Documented (books, manuals, etc.)
- Undocumented (in people's minds)
  - From people, from machines
- Knowledge Acquisition from Databases
- Knowledge Acquisition Via the Internet

Knowledge Levels

- ***Shallow* knowledge (surface)**
- ***Deep* knowledge**

- **Can implement a computerized representation that is *deeper* than shallow knowledge**
- **Special knowledge representation methods (semantic networks and frames) to allow the implementation of deeper-level reasoning (abstraction and analogy): important expert activity**
- **Represent objects and processes of the domain of expertise at this level**
- **Relationships among objects are important**

Major Categories of Knowledge

- Declarative Knowledge
- Procedural Knowledge
- Metaknowledge

Declarative Knowledge

Descriptive Representation of Knowledge

- **Expressed in a factual statement**
- **Shallow**
- **Important in the initial stage of knowledge acquisition**

Procedural Knowledge

- Considers the manner in which things work under different sets of circumstances
  - Includes step-by-step sequences and how-to types of instructions
  - May also include explanations
  - Involves automatic response to stimuli
  - May tell how to use declarative knowledge and how to make inferences

- **Descriptive knowledge** relates to a specific object. Includes information about the meaning, roles, environment, resources, activities, associations and outcomes of the object
- **Procedural knowledge** relates to the procedures employed in the problem-solving process

Metaknowledge

Knowledge about Knowledge

- **In ES, *Metaknowledge* refers to knowledge about the operation of knowledge-based systems**
- **Its reasoning capabilities**

Knowledge Acquisition Difficulties

Problems in Transferring Knowledge

- Expressing Knowledge
- Transfer to a Machine
- Number of Participants
- Structuring Knowledge

Other Reasons

- Experts may lack time or not cooperate
- Testing and refining knowledge is complicated
- Poorly defined methods for knowledge elicitation
- System builders may collect knowledge from one source, but the relevant knowledge may be scattered across several sources
- May collect documented knowledge rather than use experts
- The knowledge collected may be incomplete
- Difficult to recognize specific knowledge when mixed with irrelevant data
- Experts may change their behavior when observed and/or interviewed
- Problematic interpersonal communication between the knowledge engineer and the expert

Overcoming the Difficulties

- Knowledge acquisition tools with ways to decrease the representation mismatch between the human expert and the program ("learning by being told")
- Simplified rule syntax
- Natural language processor to translate knowledge to a specific representation
- Impacted by the role of the three major participants
  - Knowledge Engineer
  - Expert
  - End user

- Critical
  - – The ability and personality of the knowledge engineer
  - – Must develop a positive relationship with the expert
  - – The knowledge engineer must create the right impression
- Computer-aided knowledge acquisition tools
- Extensive integration of the acquisition efforts

Required Knowledge Engineer Skills

- **Computer skills**
- **Tolerance and ambivalence**
- **Effective communication abilities**
- **Broad educational background**
- **Advanced, socially sophisticated verbal skills**
- **Fast-learning capabilities (of different domains)**
- **Must understand organizations and individuals**
- **Wide experience in knowledge engineering**
- **Intelligence**
- **Empathy and patience**
- **Persistence**
- **Logical thinking**
- **Versatility and inventiveness**
- **Self-confidence**

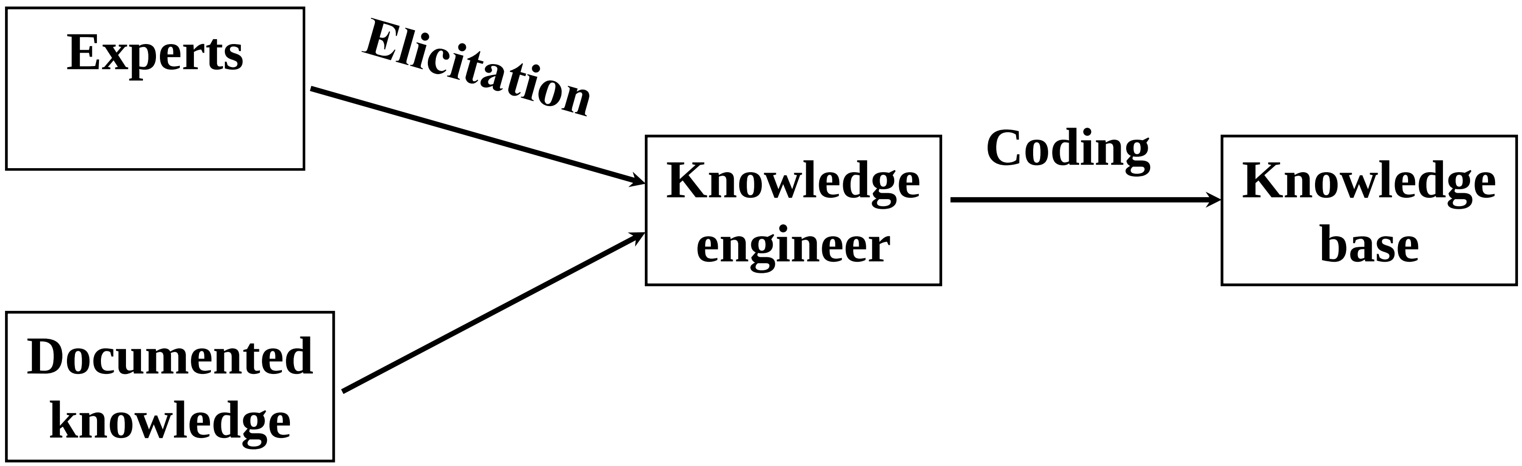
Knowledge Acquisition Methods: An Overview

- Manual
- Semiautomatic
- Automatic (Computer Aided)

Manual Methods - Structured Around Interviews

- **Process (Figure 11.4)**
- **Interviewing**
- **Tracking the Reasoning Process**
- **Observing**
- **Manual methods: slow, expensive and sometimes inaccurate**

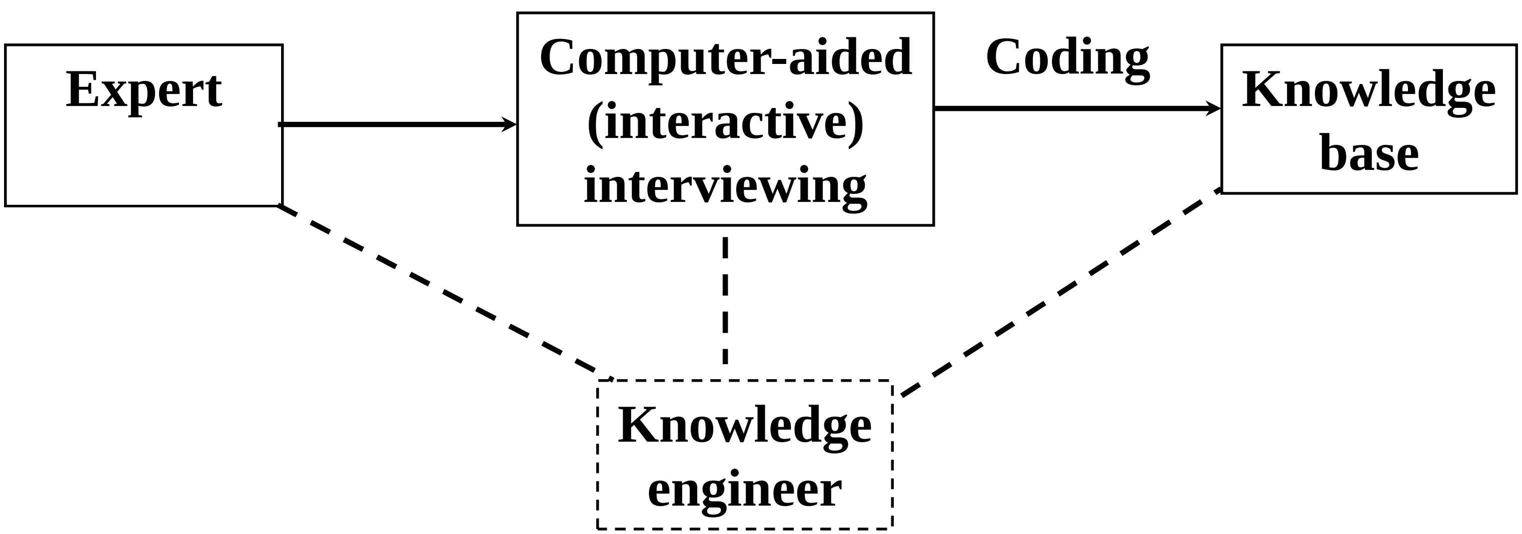
Manual Methods of Knowledge Acquisition



Semiautomatic Methods

- **Support Experts Directly (Figure 11.5)**
- **Help Knowledge Engineers**

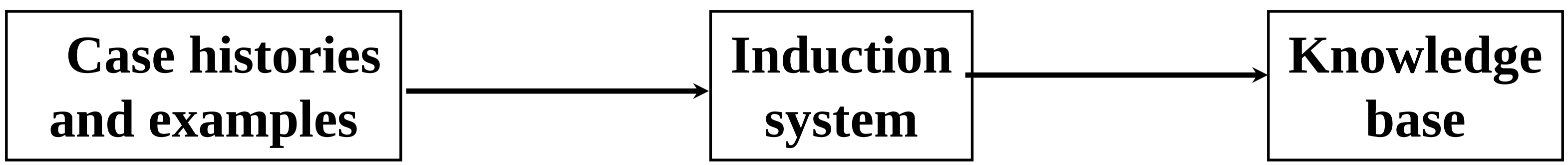
Expert-Driven Knowledge Acquisition



Automatic Methods

- **Expert's and/or the knowledge engineer's roles are minimized (or eliminated)**
- **Induction Method (Figure 11.6)**

Induction-Driven Knowledge Acquisition



Knowledge Modeling

- **The *knowledge model* views knowledge acquisition as the construction of a model of problem-solving behavior-- a model in terms of knowledge instead of representations**
- **Can *<u>reuse models</u>* across applications**

Interviews

- <u>Most Common</u> Knowledge Acquisition: Face-to-face interviews
- Interview Types
  - Unstructured (informal)
  - Semi-structured
  - Structured

Unstructured Interviews

- Most Common Variations
  - Talkthrough
  - Teachthrough
  - Readthrough

- The knowledge engineer slowly learns about the problem
- Then can build a representation of the knowledge

- Knowledge acquisition involves
  - Uncovering important problem attributes
  - Making explicit the expert's thought process

Unstructured Interviews

- **Seldom provides complete or well-organized descriptions of cognitive processes because**
  - **The domains are generally complex**
  - **The experts usually find it very difficult to express some more important knowledge**
  - **Domain experts may interpret the lack of structure as requiring little preparation**
  - **Data acquired are often unrelated, exist at varying levels of complexity, and are difficult for the knowledge engineer to review, interpret and integrate**
  - **Few knowledge engineers can conduct an efficient unstructured interview**

Structured Interviews

- Systematic goal-oriented process
- Forces an organized communication between the knowledge engineer and the expert
- Procedural Issues in Structuring an Interview

- Interpersonal communication and analytical skills are important

Interviews - Summary

- Are important techniques
- Must be planned carefully
- Results *must* be verified and validated
- Are sometimes replaced by tracking methods
- Can supplement tracking or other knowledge acquisition methods

Recommendation

Before a knowledge engineer interviews *the* expert(s)

1. Interview a less knowledgeable (minor) expert

- **Helps the knowledge engineer**
  - **Learn about the problem**
  - **Learn its significance**
  - **Learn about the expert(s)**
  - **Learn who the users will be**
  - **Understand the basic terminology**
  - **Identify readable sources**

2. Next read about the problem

3. Then, interview the expert(s) (much more effectively)

Tracking Methods

- **Techniques that attempt to *track* the reasoning process of an expert**
- **From cognitive psychology**
- **Most common formal method:**

  Protocol Analysis

Protocol Analysis

- ***Protocol*: a record or documentation of the expert's step-by-step information processing and decision-making behavior**
- **The expert performs a real task and verbalizes his/her thought process (think aloud)**

Observations and Other Manual Methods

- **Observations**
- **Observe the Expert Work**

Other Manual Methods

- Case analysis
- Critical incident analysis
- Discussions with the users
- Commentaries
- Conceptual graphs and models
- Brainstorming
- Prototyping
- Multidimensional scaling
- Johnson's hierarchical clustering
- Performance review

Expert-driven Methods

- **Knowledge Engineers Typically**
  - **Lack Knowledge About the Domain**
  - **Are Expensive**
  - **May Have Problems Communicating With Experts**
- **Knowledge Acquisition May be Slow, Expensive and Unreliable**
- **Can Experts Be Their Own Knowledge Engineers?**

Approaches to Expert-Driven Systems

- **Manual**
- **Computer-Aided (Semiautomatic)**

Manual Method: Expert's Self-reports

Problems with Experts' Reports and Questionnaires

1. Requires the expert to act as knowledge engineer
2. Reports are biased
3. Experts often describe new and untested ideas and strategies
4. Experts lose interest rapidly
5. Experts must be proficient in flowcharting
6. Experts may forget certain knowledge
7. Experts are likely to be vague

Benefits

- **May provide useful preliminary knowledge discovery and acquisition**
- **Computer support can eliminate some limitations**

Computer-aided Approaches

- To reduce or eliminate the potential problems
  - REFINER+ - case-based system
  - TIGON - to detect and diagnose faults in a gas turbine engine
- Other
  - Visual modeling techniques
  - New machine learning methods to induce decision trees and rules
  - Tools based on repertory grid analysis

Repertory Grid Analysis (RGA)

- Techniques, derived from psychology
- Use the classification interview
- Fairly structured
- Primary Method:

  Repertory Grid Analysis (RGA)

The Grid

- **Based on *Kelly*'s model of human thinking: Personal Construct Theory (PCT)**
- **Each person is a "personal scientist" seeking to predict and control events by**
  - **Forming Theories**
  - **Testing Hypotheses**
  - **Analyzing Results of Experiments**
- **Knowledge and perceptions about the world (a domain or problem) are classified and categorized by each individual as a personal, perceptual model**
- **Each individual anticipates and then acts**

How RGA Works

1. The expert identifies the *important objects* in the domain of expertise (interview)
2. The expert identifies the important *attributes*
3. For each attribute, the expert is asked to establish a bipolar scale with distinguishable characteristics (traits) and their opposites
4. The interviewer picks any three of the objects and asks: What attributes and traits distinguish any two of these objects from the third? Translate answers on a scale of 1-3 (or 1-5)

RGA Input for Selecting a Computer Language

Attributes	Trait	Opposite
Availability	Widely available	Not available
Ease of programming	High	Low
Training time	Low	High
Orientation	Symbolic	Numeric

- **Step 4 continues for several triplets of objects**
- **Answers recorded in a Grid**
- **Expert may change the ratings inside box**
- **Can use the grid for recommendations**

Example of a Grid

Attribute	Orientation	Ease of Program-ming	Training Time	Availa-bility
Trait Opposite	Symbolic (3) Numeric (1)	High (3) Low (1)	High (1) Low (3)	High (3) Low (1)
LISP	3	3	1	1
PROLOG	3	2	2	1
C^{++}	3	2	2	3
COBOL	1	2	1	3

RGA in Expert Systems - Tools

- **AQUINAS**
  - **Including the Expertise Transfer System (ETS)**
- **KRITON**

Other RGA Tools

- **PCGRID (PC-based)**
- **WebGrid**
- **Circumgrids**

Knowledge Engineer Support

- Knowledge Acquisition Aids
- Special Languages
- Editors and Interfaces
- Explanation Facility
- Revision of the Knowledge Base
- Pictorial Knowledge Acquisition (PIKA)

- Integrated Knowledge Acquisition Aids
  - PROTÉGÉ-II
  - KSM
  - ACQUIRE
  - KADS (Knowledge Acquisition and Documentation System)
- Front-end Tools
  - Knowledge Analysis Tool (KAT)
  - NEXTRA (in Nexpert Object)

Machine Learning: Rule Induction, Case-based Reasoning, Neural Computing, and Intelligent Agents

- **Manual and semiautomatic elicitation methods: slow and expensive**
- **Other Deficiencies**
  - **Frequently weak correlation between verbal reports and mental behavior**
  - **Sometimes experts cannot describe their decision making process**
  - **System quality depends too much on the quality of the expert and the knowledge engineer**
  - **The expert does not understand ES technology**
  - **The knowledge engineer may not understand the business problem**
  - **Can be difficult to <u>validate</u> acquired knowledge**

Computer-aided Knowledge Acquisition, or Automated Knowledge Acquisition Objectives

- **Increase the productivity of knowledge engineering**
- **Reduce the required knowledge engineer's skill level**
- **Eliminate (mostly) the need for an expert**
- **Eliminate (mostly) the need for a knowledge engineer**
- **Increase the quality of the acquired knowledge**

Automated Knowledge Acquisition (Machine Learning)

- Rule Induction
- Case-based Reasoning
- Neural Computing
- Intelligent Agents

Machine Learning

- **Knowledge Discovery and Data Mining**
- **Include Methods for Reading Documents and Inducing Knowledge (Rules)**
- **Other Knowledge Sources (Databases)**
- **Tools**
  - **KATE-Induction**
  - **CN-2**

Automated Rule Induction

- **Induction: Process of Reasoning from Specific to General**
- **In ES: Rules Generated by a Computer Program from Cases**
- **Interactive Induction**

TABLE 13.6 Case for Induction - A Knowledge Map

(Induction Table)

	Attributes				
Applicant	Annual Income ($)	Assets ($)	Age	Dependents	Decision
Mr. White	50,000	100,000	30	3	Yes
Ms. Green	70,000	None	35	1	Yes
Mr. Smith	40,000	None	33	2	No
Ms. Rich	30,000	250,000	42	0	Yes

Case-based Reasoning (CBR)

- **For Building ES by Accessing Problem-solving Experiences for Inferring Solutions for Solving Future Problems**
- **Cases and Resolutions Constitute a Knowledge Base**

Neural Computing

- Fairly Narrow Domains with Pattern Recognition
- Requires a Large Volume of Historical Cases

Intelligent Agents for Knowledge Acquisition

Led to

- **KQML (Knowledge Query and Manipulation Language) for Knowledge Sharing**
- **KIF, Knowledge Interchange Format (Among Disparate Programs)**

Selecting an Appropriate Knowledge Acquisition Method

- **Ideal Knowledge Acquisition System Objectives**
  - Direct interaction with the expert without a knowledge engineer
  - Applicability to virtually unlimited problem domains
  - Tutorial capabilities
  - Ability to analyze work in progress to detect inconsistencies and gaps in knowledge
  - Ability to incorporate multiple knowledge sources
  - A user friendly interface
  - Easy interface with different expert system tools
- **Hybrid Acquisition - Another Approach**

Knowledge Acquisition from Multiple Experts

- **Major Purposes of Using Multiple Experts**
  - **Better understand the knowledge domain**
  - **Improve knowledge base validity, consistency, completeness, accuracy and relevancy**
  - **Provide better productivity**
  - **Identify incorrect results more easily**
  - **Address broader domains**
  - **To handle more complex problems and combine the strengths of different reasoning approaches**
- **Benefits And Problems With Multiple Experts**

Handling Multiple Expertise

- **Blend several lines of reasoning through *consensus methods***
- **Use an *analytical approach* (group probability)**
- **Select one of several distinct lines of reasoning**
- **Automate the process**
- **Decompose the knowledge acquired into specialized knowledge sources**

Validation and Verification of the Knowledge Base

- Quality Control
  - Evaluation
  - Validation
  - Verification

- **Evaluation**
  - **Assess an expert system's overall value**
  - **Analyze whether the system would be usable, efficient and cost-effective**
- **Validation**
  - **Deals with the *performance* of the system (compared to the expert's)**
  - **Was the "right" system built (acceptable level of accuracy?)**
- **Verification**
  - **Was the system built "right"?**
  - **Was the system correctly implemented to specifications?**

Dynamic Activities

- **Repeated each prototype update**
- **For the Knowledge Base**
  - **Must have the *right* knowledge base**
  - **Must be constructed properly (verification)**
- **Activities and Concepts In Performing These Quality Control Tasks**

To Validate an ES

- Test
  1. The extent to which the system and the expert decisions agree
  2. The inputs and processes used by an expert compared to the machine
  3. The difference between expert and novice decisions

(Sturman and Milkovich [1995])

Analyzing, Coding, Documenting, and Diagramming

Method of Acquisition and Representation

1. Transcription
2. Phrase Indexing
3. Knowledge Coding
4. Documentation

(Wolfram et al. [1987])

Knowledge Diagramming

- **Graphical, hierarchical, top-down description of the knowledge that describes facts and reasoning strategies in ES**
- **Types**
  - **Objects**
  - **Events**
  - **Performance**
  - **Metaknowledge**
- **Describes the linkages and interactions among knowledge types**
- **Supports the analysis and planning of subsequent acquisitions**
- **Called conceptual graphs (CG)**
- **Useful in analyzing acquired knowledge**

Numeric and Documented Knowledge Acquisition

- **Acquisition of Numeric Knowledge**
  - Special approach needed to capture numeric knowledge
- **Acquisition of Documented Knowledge**
  - Major Advantage: No Expert
  - To Handle a Large or Complex Amount of Information
  - New Field: New Methods That Interpret Meaning to Determine
    - Rules
    - Other Knowledge Forms (Frames for Case-Based Reasoning)

Knowledge Acquisition and the Internet/Intranet

- **Hypermedia (Web) to Represent Expertise Naturally**
- **Natural Links can be Created in the Knowledge**
- **CONCORDE: Hypertext-based Knowledge Acquisition System**
  - **Hypertext links are created as knowledge objects are acquired**

The Internet/Intranet for Knowledge Acquisition

- **Electronic Interviewing**
- **Experts can Validate and Maintain Knowledge Bases**
- **Documented Knowledge can be accessed**
- **The Problem: Identifying relevant knowledge (intelligent agents)**
- **Many Web Search Engines have intelligent agents**
- **Data Fusion Agent for multiple Web searches and organizing**
- **Automated Collaborative Filtering (ACF) statistically matches peoples' evaluations of a set of objects**

Also

- ***WebGrid*: Web-based Knowledge Elicitation Approaches**
- **Plus Information Structuring in Distributed Hypermedia Systems**

Induction Table Example

- **Induction tables (knowledge maps) focus the knowledge acquisition process**
- **Choosing a hospital clinic facility site**

Induction Table (Knowledge Map) Example

Population Density	Density over How Many Sq. mi	Number of Near (within 2 miles) Competitors	Average Family Income	Near Public Transportation?	Decision (Choices)
People / Square Mile	Numeric, Region Size	0, 1, 2, 3, ...	Numeric, $ / Year	Yes, No	Yes, No
>= 2000	>=4	0			Yes
>=3500	>=4	1			Yes
		>=2			No
			<30,000		No

- **Row 1: Factors**
- **Row 2: Valid Factor Values and Choices (last column)**

- **Table leads to the prototype ES**
- **Each row becomes a potential rule**
- **Induction tables can be used to encode *chains of knowledge***

Class Exercise: Animals

- Knowledge Acquisition
- Create Induction Table
  - I am thinking of an animal!
  - Question: Does it have a long neck? If yes, THEN Guess that it is a giraffe.
  - IF not a giraffe, then ask for a question to distinguish between the two. Is it YES or NO for a giraffe? Fill in the new Factor, Values and Rule.
  - IF no, THEN What is the animal? and fill in the new rule.
  - Continue with all questions
  - You will build a table very quickly