AI AS SCIENCE

- Artificial Intelligence is the study of the computational basis of intelligent behavior.

AI AS ENGINEERING

AI seeks to make computer-based systems more intelligent.

AREAS OF ARTIFICIAL INTELLIGENCE

- Perception
  - Machine vision
  - Speech understanding
  - Tactile sensation
- Robotics
- Natural Language Understanding
- Planning
- Expert Systems
  - Diagnosis, Identification
  - Problem Solving and Design
- Machine Learning
- Theorem Proving
- Symbolic Mathematics

WHAT IS AN EXPERT SYSTEM?

- 'One which addresses problems normally thought to require human expertise for their solution.' (Duda & Shortliffe, 1982)

DEFINITION OF AN EXPERT SYSTEM

- A computer program that relies on knowledge and reasoning to perform a difficult task usually performed only by a human expert.

KNOWLEDGE-BASED STRATEGY

"In the Knowledge Lies the Power"

- The knowledge-based strategy is to include within the program a great deal of knowledge to cover particular cases.

- The somewhat surprising finding:
  A thousand rules can provide significant performance within a limited domain.

EVOLUTION OF THE KNOWLEDGE INDUSTRY

- Data Processing
- Databases
- Knowledge-Based Systems
- Merging Data, Text, and Knowledge

TYPES OF PROBLEM-SOLVING SYSTEMS

- ANALYSIS
- DIAGNOSIS
- CLASSIFICATION
- SYNTHESIS
- CONSTRAINT SATISFACTION
- PLANNING

TYPES OF PROBLEM-SOLVING SYSTEMS

- Analysis
  - Given a description of an object, draw conclusions about it.
- Diagnosis
  - Given a description of an object and symptoms of faulty behavior, explain the causes of the behavior.
- Classification
  - Given a set of characteristics of an object, determine the abstract category that best fits the object.

DIFFERENCES BETWEEN EXPERT SYSTEMS AND CONVENTIONAL PROGRAMS

CONVENTIONAL PROGRAMS	EXPERT SYSTEMS
"Data Processing"	"Knowledge Engineering"
Data representation and use	Knowledge representation
Algorithms	Heuristic
Repetitive	Inferential
Large data bases	Large knowledge bases

PROCEDURAL VS DECLARATIVE REPRESENTATION

Traditional programs represent knowledge with:

- procedures
- (principally numeric) data structures

This is inappropriate for AI programs because:

- knowledge is symbolic
- knowledge is heuristic

AI programs primarily use symbolic representation collections of symbols that represent:

- objects
- properties of objects
- relationships among objects
- rules about classes of objects

DATA DRIVEN COMPUTATION VS INSTRUCTION DRIVEN COMPUTATION

- Rules communicate with one another ONLY by way of the data
- There is NO explicit transfer of control between rules as there is in the procedural model
- Rules can not be referenced by other rules in any sort of subroutine call
- Unlike instructions, rules are not executed sequentially, and is not always possible to determine through inspection of a set of rules which rule will executed first or which rule could cause the program to terminate

DATA DRIVEN COMPUTATION vs INSTRUCTION DRIVEN COMPUTATION

- **Procedural computation:**
  knowledge and flow of control are mixed
- **Production system:**
  complete separation of the knowledge (in rules) from the control (provided by the executer, IE).
- Control in a PS is based on frequent reevaluation of the data states

HOW DO EXPERT SYSTEMS SOLVE THESE PROBLEMS?

- Provide for incremental evolution of knowledge base
- Provide for uncertainty handling
- Enable use of heuristics through rules
- Provide for organizations of knowledge by using taxonomical structures

KNOWLEDGE

- What is Knowledge?
- Levels of Knowledge
- Components of Knowledge
- Knowledge Representation
- What to Look for in Knowledge Representation

COMPONENTS OF KNOWLEDGE

- Naming
- Describing
- Organizing
- Relating
- Constraining

KNOWLEDGE REPRESENTATION

- Facts
- Logic
- Production Rules
- Semantic Nets
- Scripts
- Frames
- Objects
- Blackboards

BASIC ARCHITECTURE OF AN EXPERT SYSTEM

- User Interface
- Knowledge Base
- Inference Engine

THE STRUCTURE OF AN EXPERT SYSTEM

- The knowledge base
- The inference engine
- The user interface
- Explanation and acceptability
- The absence of learning

DATA OR WORKING MEMORY

- Global data base of symbols
- Symbols represent facts and assertions about the problem
- Data are instances of objects:
  - Physical objects
  - Facts related to the domain of application
  - Conceptual objects such as goals

PROGRAM
PRODUCTION RULE MEMORY

Set of rules that constitute the program

IF conditions ----> THEN actions

or

IF (data configuration for which rule applies)

--------->

THEN (instructions for changing the data configuration)

EXAMPLE RULES

- If
  The salt intake is high
  Then
  Blood pressures are high;
- If
  A hazard is present
  Then
  Injury or death may occur

INFERENCE

- Goal-Directed Inference
- And/Or Goal Trees
- Data Driven Inference
- Backward chaining inference
- Forward chaining inference
- Inexact inference

CONTROL STRATEGY

- Policy for guiding the application of knowledge

Forward vs. Backward chaining of rules:

-forward chaining (data driven) control-

A B
} rules
B C

A - data

C (conclusion-added to database)

-backward chaining (goal-directed) control-

Is C true? (goal)

A B
} rules
B C

A C (implicit rule)

Is A true? (match A with database)

THE FORWARD CHAINING CYCLE

1. Match
2. Resolve Conflicts
3. Act

INFERENCE ENGINE

SELECT-RULES

Applies some selection strategy
to determine which rules
will be executed

EXECUTE-RULES

Executes the rules selected

RECOGNIZE-ACT CYCLE

Then cycles back to the fist state and starts over

Since the rules change data memory elements,
a different set of rules will match
after the actions performed during rule firing

FRAME DEFINITION

When one encounters a new situation or makes a substantial change in one's view of a problem one selects from memory a structure called a frame.

This is a remembered framework to be adapted to fit reality by changing details as necessary.

Minsky 1975

FRAMES

- Packaging of Knowledge
- From Data Structures to Knowledge Structures
- Storage and Retrieval
- Inheritance Hierarchies
- Attached Procedures

THE BASIC STRUCTURE OF A FRAME

- The name of the frame.
- The parents of the frame.
- The slots (if any) of the frame and their values.
- The attached predicates (if any) for each slot.

THE COMPONENTS OF A FRAME SLOT

- Slot Name.
- Slot Value.
- If-Needed Predicate.
- If-Added Predicate.
- Other attached predicates.

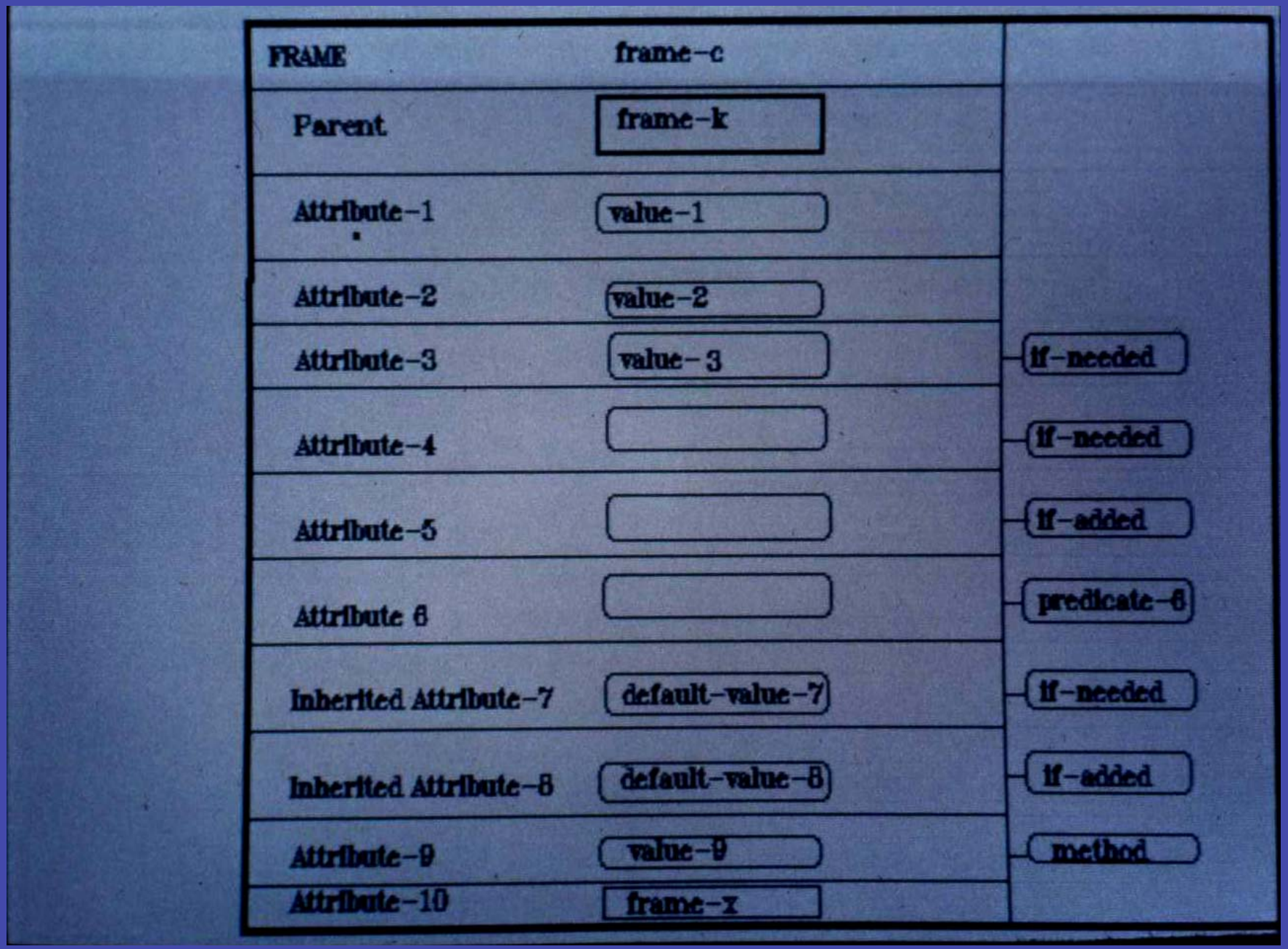
ATTACHED PROCEDURES

Types of Demon:

- If-Needed
- If-Added
- If-Replaced
- If-Removed

INHERITANCE

1. Allows sharing of information among set of elements
2. Frames may be organized into inheritance hierarchies
3. Properties may be inherited:
   - Slots
   - Values
   - Procedures
   - Demons


FRAME
frame-c
Parent
frame-k
Attribute-1
value-1
Attribute-2
value-2
Attribute-3
value-3
if-needed
Attribute-4
if-needed
Attribute-5
if-added
Attribute 6
predicate-6
Inherited Attribute-7
default-value-7
if-needed
Inherited Attribute-8
default-value-8
if-added
Attribute-9
value-9
method
Attribute-10
frame-x

OBJECTS

- Objects are Organized in a Network Hierarchy
- Objects Inherit Properties and Information
- Objects Communicate by Sending and Receiving Messages
- Objects are Created by Copying and Editing

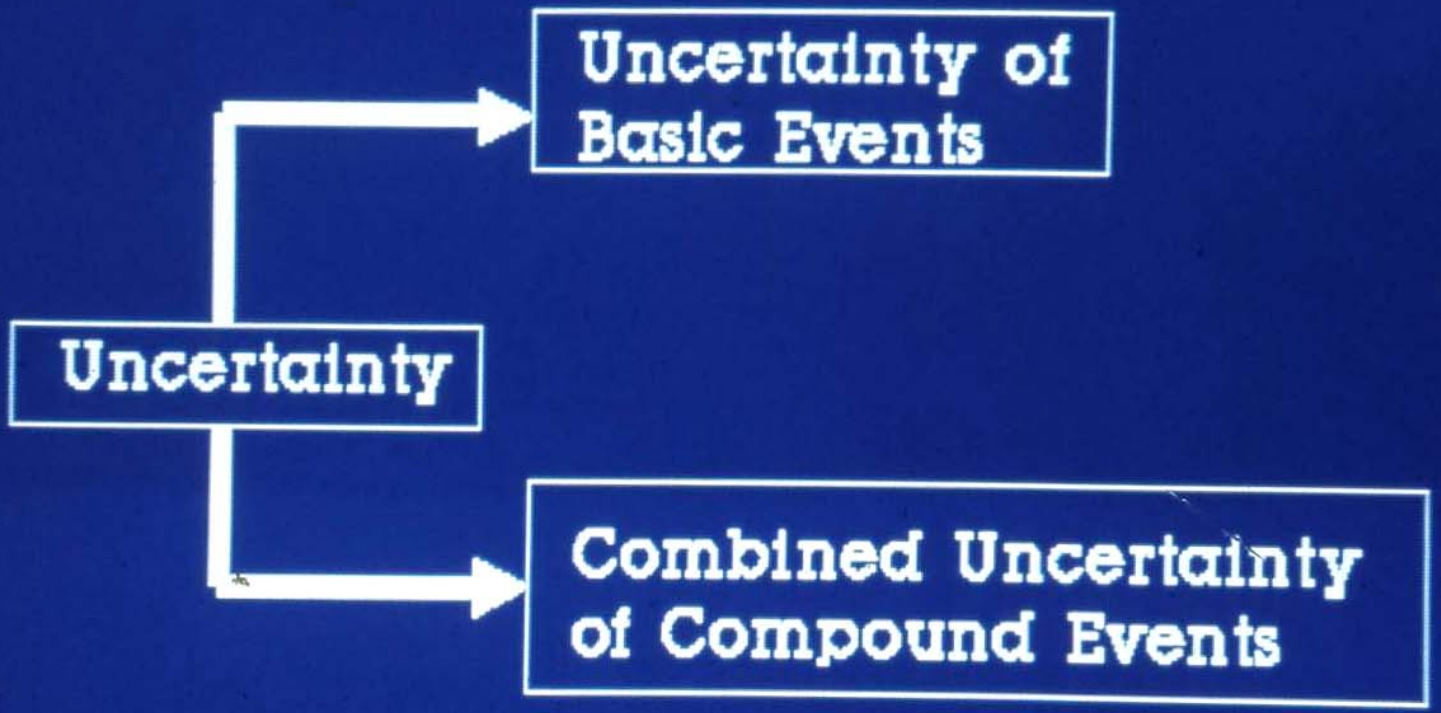
BLACKBOARDS

A blackboard allows different knowledge sources to share hypotheses and information.

Components:

1. Global Database (Blackboard)
2. Knowledge Sources
3. Scheduler to Control Knowledge Source Activity

ISSUES IN DEALING WITH UNCERTAINTY



THE NEED FOR INEXACT INFERENCE

1. We need to be able to reason about uncertain information.
2. Some rules and facts are uncertain.
3. Inexact inference uses a multi-valued form of logic.

APPROACHES TO INEXACTNESS

- Probability - Bayesian Theory
- Fuzzy Logic (Zadeh)
- Certainty Theory
- Dempster/Shafer - Evidential Reasoning
- Nonmonotonic Reasoning

INEXACT REASONING

Hypothesis (H): Landforms and Associated Certainties

Evidences (H): Pattern Element Values and their Certainty Values

Update Certainties of Hypothesis Using

IF E then H (to degrees) LS, LN

where

LS a measure of how encouraging it is for H to find E present

LN a measure of how discouraging it is for H to find E absent

FUNCTIONS OF AN EXPERT SYSTEM SHELL

- Assists in building the knowledge-base
- Provides methods of inference or deduction
- Provides a user interface
- A good shell should perform each of these tasks well

EXPERT SYSTEM TOOLS

Many expert system tools are available.

- University Tools: Cheap, but no support.
- Big Commercial Tools: Good, supported, expensive.
- Small Commercial Tools: Lots of them; some are good; most are cheap.

Recommendation:

Get your feet wet first with something cheap. Then you can make an informed choice among more expensive tools. Or, if you have lots of money, get one of the big tools with the associated training.

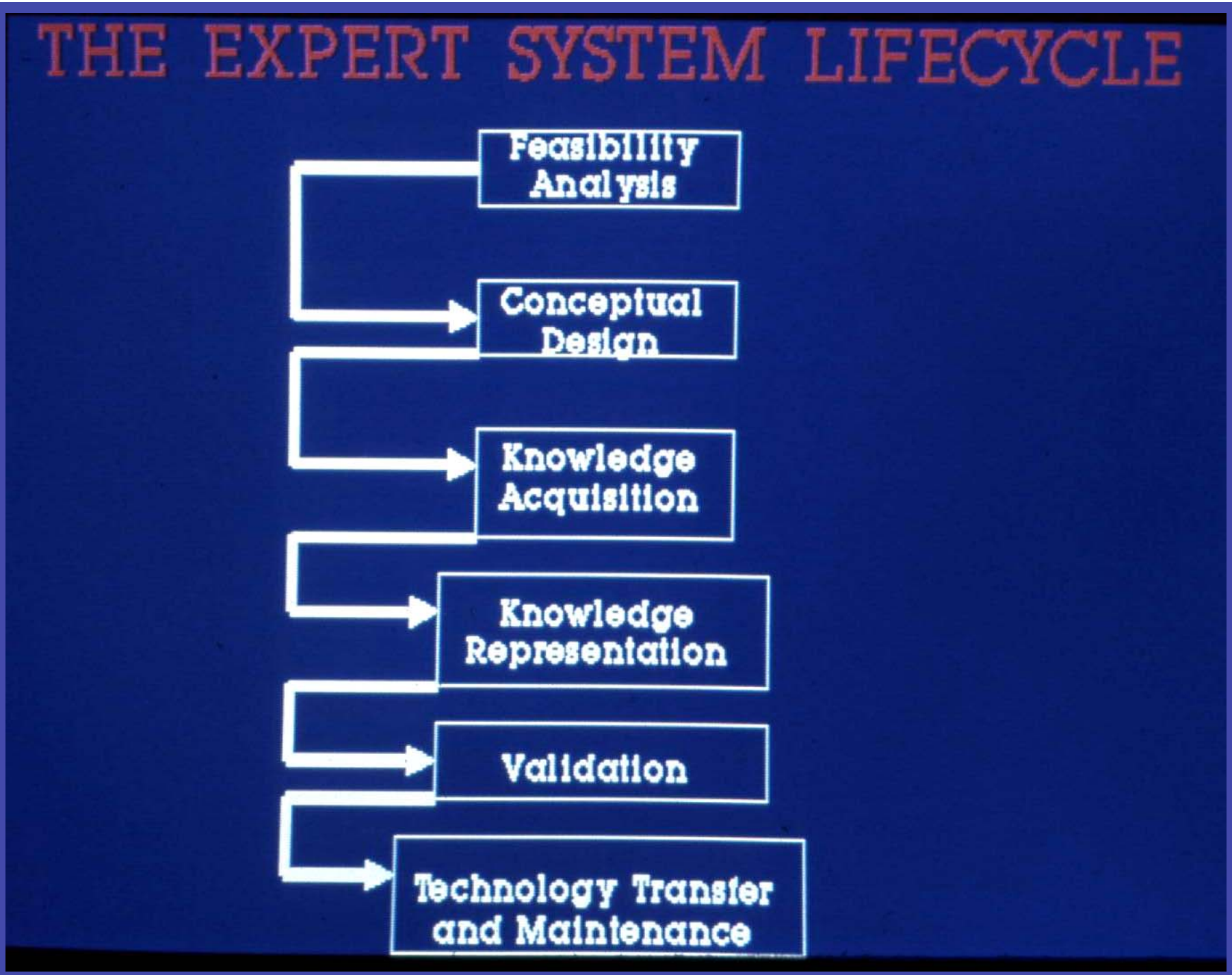
A MINIMUM SET OF FEATURES

- A Production Rule System
- A Method of Organizing Knowledge
- A Method for Reasoning With Uncertain Information

CAPABILITIES TO LOOK FOR IN A TOOL/SHELL

- Expression of Knowledge
- Organization and Display of Knowledge
- Reasoning with and Validation of Knowledge
- Efficiency of Knowledge Operations

THE EXPERT SYSTEM LIFECYCLE



THE VECTORS OF EXPERT SYSTEMS DEVELOPMENT