Chapter Overview

Knowledge-Based Systems

Knowledge-Based Systems Structure
User's / Developer's / Tool Builder's View

Knowledge-Based Tools
Shells

Productions
Production Rules, Grammars, Languages

Semantic Nets
Nodes / Objects, Arcs / Relationships

Frames
Slots, Fillers

Logic
Propositional and Predicate Logic

Chapter Review
Important Issues

Structure

of Knowledge-Based Systems

internal structure
components and their interaction

perspectives
different points of view

End User's View

individual using the final product

intelligent program
frequently black box, no comprehension of its internal functioning

user interface

- allows questions about the problem to be solved
- queries about particular decisions
- provides explanations of decisions
- displays the derived results, possibly graphically
- saves or prints the results
- usually based on menus, graphic displays, natural language

must be carefully matched to the target end users

data / knowledge base

- contains relevant problem-specific information
- describes all currently known facts
- some facts may have been derived internally

Knowledge Engineer's View

interaction with the domain expert

intelligent program

- knowledge base
  contains relevant, domain-specific problem solving knowledge
  may be of heuristic or algorithmic nature
  internal representation format (rules, semantic nets, frames, objects, ...)
- inference engine
  derives additional knowledge from existing rules and facts
  must be suited for the chosen representation scheme and the nature of the problem

constitutes the final product for the end user

development shell

- knowledge acquisition tool
  construction of the knowledge base editor, syntax check, consistency check, ...
- test case data base collection of data from sample problems
  verifies the knowledge base after modifications
- developer's interface similar to the end user's interface, but with additional features
  display of intermediate steps, breakpoints, traces, access to test procedures, ...

Tool Builder's View

set of tools for the knowledge engineer

intelligent program

- knowledge base
  choice of internal representation formats (rules, semantic nets, frames, objects, ...)
- inference engine
  various inference mechanisms for the supported representation formats (forward / backward / bidirectional chaining, inexact reasoning, single / multiple solutions, correctness vs. performance, ldots)

constitutes the final product for the end user

development shell

- knowledge acquisition tool
  tools for the construction of the knowledge base editor, syntax check, consistency check, ...
- test case data base tools for constructing and using test cass
- developer's interface enhancements for development purposes
  display of intermediate steps, breakpoints, traces, access to test procedures, ...

similar to the knowledge engineer's view

Knowledge-Based Tools

shells: everything but domain knowledge

inductive shells
decision trees or rule sets
derived from example cases

rule-based shells
knowledge is expressed as If-Then rules
tools for editing, structuring, checking rules
Examples: CLIPS, Personal Consultant Plus

hybrid shells
integrate multiple knowledge representation
paradigms and various reasoning methods
very powerful, but also quite complex

special purpose shells
designed for particular problem classes
dedicated representation and reasoning
methods
Examples: G2, RTworks (real-time processes)

Knowledge

and its meaning

epistemology
study of knowledge:
nature, structure, origins

a priori knowledge
known to be true in advance of experience
does not require evidence for its validation

a posteriori knowledge
empirical, open to revision
requires evidence for its validation

Types of Knowledge

procedural
knowing how to do something
algorithm

declarative
statements that can be true or false
specification

tacit also: unconscious
can't be expressed in language
skills

also other classifications of knowledge

Knowledge

and Expert Systems

knowledge + inference = expert system
analogous to N. Wirth's expression

algorithms + data structures = program

Knowledge Hierarchy

meta-knowledge
: knowledge about knowledge
: selects applicable knowledge

knowledge
: information items and their relationships
: usually loosely structured

information
: processed data

data
: items of potential interest
: usually rigidly structured

noise
: irrelevant items, of no interest
: often obscure data

Productions

and rewrite rules

basic idea
: set of rules specifying how to change one string of symbols into another string of symbols

symbol manipulation
: purely syntactic transformations
: no meaning attached to strings (semantics, understanding)

modularity
: encapsulation of related knowledge
: incremental development

control
: in the initial version, no control strategy is given, allowing arbitrary application of rules

relatively old knowledge representation formalism [Post, 1943]

Backus-Naur Form

formal notation for specifying productions

meta-language
: defines the syntax of a language
: does not say anything about semantics (meaning)

grammar
: complete set of production rules defining a language unambiguously

parse tree also: derivation tree
: graphic representation of a sentence and its derivation

very popular for the specification of the syntax of (computer) languages

Example:

```
<sentence> ::= <subject> <verb> <end-mark>
```

Semantic Nets

also: propositional net, associative nets

labeled, directed graph

nodes
stand for physical objects, concepts, situations

arcs (links, edges)
represent relationships between nodes

classic AI representation technique
originally proposed by [Quillian, 1968] for the description of human memory and language understanding

Links

in semantic nets

purpose
basic structure for organizing knowledge
formal basis for inferences

format
basically unrestricted, any type of link can be defined

common types

- `is-a` an individual is an instance of a class
- `a-kind-of` relates an individual class to a parent class
- `is` defines the value of an attribute
- `cause` expresses causal knowledge

inheritance
characteristics of a node are duplicated in a descendent

Frames

structure for representing typical knowledge about objects

extension of semantic nets
nodes can have an internal structure

purpose
a frame represents related knowledge for a narrow topic

slots and fillers
slots define attributes, fillers contain values

procedural attachments to slots
procedures invoked in certain situations
`if-needed, if-added, if-removal`

commonsense knowledge
frames are very useful for causal and commonsense knowledge

very powerful and flexible, but sometimes inefficient and incorrect

Logic

and knowledge

knowledge representation
formal method to describe knowledge via logical sentences

inference mechanism
generally accepted rules of reasoning
often with strict formal properties,
e.g. correctness, completeness

Propositional Logic

manipulation of propositions

knowledge representation
logical variables represent propositions
propositions can be either true or false logical connectives for constructing compound sentences

inference
specified by a calculus
allows the evaluation of a sentence to true or false

limited ability to express knowledge
not adequate for many statements about the world

Predicate Logic

manipulation of predicates and terms

predicates
express relationships between objects

terms
used for the specification of objects

- constants stand for one specific object
- variables represent currently unspecified objects
- functions map arguments (terms) from one domain to another

quantifiers
restrict the scope of variables

unification
computes proper substitutions for matching predicate logic expressions

much more powerful than propositional logic
still some restrictions in its basic form (first order predicate logic)

Chapter Review

Knowledge-Based Systems

Knowledge-Based Systems Structure
User's / Developer's / Tool Builder's View

Knowledge-Based Tools
Shells: everything but domain knowledge

Productions
Production Rules, Grammars, Languages

Semantic Nets
Nodes / Objects, Arcs / Relationships

Frames
Slots, Fillers, Commonsense Knowledge

Logic
Propositional and Predicate Logic