Chapter Overview

Alternatives to Rule-Based Reasoning

Introduction

Semantic Networks

Frames

Blackboard Architectures

Chapter Review

Introduction

alternatives to rule-based reasoning

adequacy
rules are not suitable for all types of knowledge-based systems

structured knowledge
about physical objects or concepts

composition
of objects from components

relationships
between objects and components

reasoning method
opportunistic reasoning

cooperation
between relatively independent modules

Rules

Advantages

- modularity
  rules are separate units of knowledge can be added, modified, removed independently (with limitations)
- uniformity
  all knowledge is represented in the same format can also be a limitation
- naturalness
  similar to the way experts think not necessarily for all applications

Problems

- cyclic rules lead to infinite chaining
- introduction of contradictions
- modification of rules

Semantic Nets

also: propositional nets, associative nets

labeled, directed graph

nodes
stand for physical objects, concepts, situations or
properties and their values

arcs (links, edges)
represent relationships between nodes

labels
describe associated objects / relationships

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

see [Giarratano and Riley, 1994], p. 69-73

Examples:

1) Airline routes [Gonzalez and Dankel, 1993] Fig. 6.1, p. 161, [Giarratano and Riley, 1994] p. 71

2) Quillian's Food network [Gonzalez and Dankel, 1993] Fig. 6.2, 6.3, p. 162-3

3) TR-7 ignition system [Gonzalez and Dankel, 1993] Fig. 6.4,

4) Toilet [Gonzalez and Dankel, 1993] Fig. 6.6, 6.7,

5) Family relationships [Giarratano and Riley, 1994] p. 71

6) Aircraft types [Giarratano and Riley, 1994] p. 72

7) Tweety [?] Fig. 3.10, p.70

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

see [Giarratano and Riley, 1994], p. 79 Examples:

1) is-a links and transitivity [Gonzalez and Dankel, 1993] Fig. 6.5, p. 164, [Giarratano and Riley, 1994] p. 71

2) Toilet [Gonzalez and Dankel, 1993] Fig. 6.6, 6.7,

3) Aircraft types [Giarratano and Riley, 1994] p. 72

Inheritance

in semantic networks

object properties

properties of the parent node are duplicated for the descendent node

representation

usually through is-a links
eliminates the need to replicate information

operation

queries about properties of a node can be passed to its parent node

exception handling

in some cases, the properties of ancestor nodes must be overridden
the respective property is represented locally

Examples:
7) Tweety query [?] Fig. 3.11, p.72

Semantic Nets

Advantages

- visual representation
- explicit relationships between concepts
- flexible

Problems

- logical inadequacy
  restricted to propositional logic
- heuristic search
  no heuristics for efficient search
- semantics
  properties of relationships (transitive, commutative, ...)
- interpretation
  varies between programs, and human users

- variety of links
  types, names, treatment for inferencing
- combinatorial explosion
  many possible relationships
  especially a problem for negative queries (all of the links may have to be searched)
- invalid inferences
  inappropriate interpretation of links, unforeseen chains

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

commonsense knowledge
frames are very useful for causal and commonsense knowledge

very powerful and flexible, but sometimes inefficient and incorrect

see [Giarratano and Riley, 1994], p. 82-86

Structure

of frames

name
designates the object to be represented

slots and fillers
slots define attributes, fillers contain values

facets associated with slots
additional control over property values
(e.g. range, data type)

procedural attachments special type of facets
procedures (or *methods* invoked in certain situations `if-needed, if-added, if-removal`

frames are somewhat similar to databases; the difference lies in the contents of the slots / fields, and the operations performed on them

Types

of frames

class frame (*generic frame*)
represents general characteristics of a set of objects;
an object with the properties of a generic frame is a *prototype*

instance frame (*specific frame*)
specific object within a class
inherits properties and property values from a class

situational frame
contains knowledge about situations

action frame
slots specify actions to be performed

causal knowledge frame
describes cause-and-effect relationship[s

Frames

advantages and disadvantages

Advantages

- very flexible
- useful for representing commonsense knowledge
- well suited for causal knowledge
- organized representation of knowledge
- can incorporate hierarchies and inheritance
- rule-based and procedural components can be integrated
- differentiates between generic and specific knowledge

Problems

- semantics and interpretation of slots
- handling of atypical and new situations
- modifications may have unforeseen consequences in other frames
- heuristic knowledge may be specified more easily via rules

Opportunistic Reasoning

flexible evaluation strategy

reasoning method
determined dynamically depending on the current status

architecture
independent modules cooperate in solving a problem

applications
complex problems requiring expertise from different domains

Blackboard Architectures usually employ opportunistic reasoning

Blackboard Architectures

several ES modules share information

distributed knowledge
different human experts,
different domains, different representations

distributed problem solving
cooperation among different systems

communication
exchange of information between rule sets

ES modules
for different tasks / subproblems

blackboard
forum for the exchange of information
accessible for all components

scheduler
controls modules
determines overall reasoning strategy

Slide [Gonzalez and Dankel, 1993] Figure 7.1, p.210
Definition [?] p. 68 Example:
1) Automobile Diagnostic System [?] p. 202-213
2) HEARSAY-II [Gonzalez and Dankel, 1993] Fig. 7.3 - 7.4, Table 7.1, pp. 215 - 220

Knowledge Sources

individual ES units

domain knowledge
each source contains knowledge about a specific area

representation
may be different for each unit
e.g. frames, rules, procedures

preconditions
may have to be satisfied for a unit

independence
each unit decides if it can contribute knowledge, and what the contributions are

Blackboard

central communication mechanism

information sharing
central location for common information

problem description
data describing the initial problem to be solved
often organized hierarchically, with different representation mechanisms on different levels

problem state
contains relevant data for the current status

modifications
by knowledge sources as they work on their specific subtask

panels
the blackboard can be hierarchically structured and subdivided into *panels*

Scheduler

control and coordination unit

coordination
synchronization between knowledge sources
execution of actions
modifications of the problem description and solution

focus of attention
selection of the active knowledge source
selection of the current blackboard object

heuristics
granularity
attributes / side-effects of actions
changes in problem characteristics

strategy
emphasis on global issues instead of local subproblems

Operation

change of a blackboard object
knowledge source makes a change
recorded in the control data area

examination of changes
each knowledge source examines the change
determines possible actions
reports them to the scheduler

focus of attention
the scheduler examines the possible contributions, and determines the focus of attention (knowledge source, blackboard object)

execution
the selected knowledge source applies its actions to the chosen blackboard objects

How does the system know when to stop?

Blackboard Systems

advantages and disadvantages

+ flexibility: suitable for a diversity of problems
  diverse forms of input data
  large solution spaces
  pieces of knowledge from different sources must be coordinated
  goals may not be clearly defined, resulting in multiple lines of reasoning
+ distributed operation: very well suited for parallel and distributed systems
+ hierarchical organization
+ data abstraction
+ postponement of decisions
+ loose coupling: all knowledge is accessible through the blackboard

- very expensive: usually custom-built for each application
- partitioning of knowledge difficult
- complex development

Chapter Review

Alternatives to Rule-Based Reasoning

Introduction
inadequacy of rule-based systems

Semantic Networks
graph specifying relationships between objects

Frames
internal structure of objects

Blackboard Architectures
opportunistic reasoning, distributed systems

Chapter Review