Chapter Overview

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Important Issues

Artificial Intelligence

Myths, hype, and the truth ...

Old adages
"It's an AI problem if it hasn't been solved yet."
"AI is like computers in movies (e.g. HAL)."
"AI is Advanced Informatics."

AI Applications

The truth (maybe).

Natural Language
parsers (games, data base front ends)

Programming
objects, expert systems, agents

Robotics
autonomous vehicles, sensors, planning

Vision
object recognition, feature detection

Knowledge
representation, acquisition, processing

Expert System

What is an Expert System?[1]

Basic concepts

- designer / user supplies facts and information
- user asks queries and receives expert advice
- limited to a problem domain (*knowledge domain*)

Components

- user interface
- knowledge base
- inference mechanism

Synonyms: knowledge-based system, knowledge-based expert system

[1][Jackson, 1999, Liebowitz and Letsky, 1998, Giarratano and Riley, 1994, Gonzalez and Dankel, 1993]

Terminology

Knowledge, Data and Information

Knowledge:

definition:[1] Information and understanding about a subject which a person has in his or her mind or which is shared by all human beings

similar terms:[2] *learning, lore, scholarship, wisdom, instruction, book-learning, enlightenment, expertise, intelligence, light, theory, science, principles, philosophy, awareness, insight, education, substance, store of learning, know-how*

important aspects: possibly complex structure (relations between items)

[1][Sinclair, 1987]
[2][Laird, 1982]

Data:

definition:[1] Information, usually in the form of facts or statistics that you can analyse, or that you use to do further calculations

similar terms:[2] *evidence, reports, details, results, notes, documents, abstracts, testimony, matters of direct observation, facts, raw materials, memorandums, statistics, figures, measurements, conclusions, information, circumstances, experiments*

important aspects: rigid, simple structure (tables)

[1][Sinclair, 1987]
[2][Laird, 1982]

Information:

definition:[1]

1. knowledge acquired through experience or study
2. knowledge of specific and timely events or situations; news
3. the act of informing or the condition of being informed
4. an office, agency, etc. providing information
5. a charge or complaint made before justice of the peace
6. the results derived from the processing of data according to programmed instructions
7. another word for data

similar terms:[2] *derived knowledge, acquired facts, evidence, knowledge, reports, details, results,*

[1][Hanks, 1979]
[2][Laird, 1982]

notes, documents, testimony, facts, figures, statistics, measurements, conclusions, deductions, plans, field or laboratory notes, learning, erudition; news, report, notice, message

important aspects:
: rather vague usage in common language, precise definition in information theory

Structured Knowledge

information items and their relationships

information items
: objects, concepts, features, attributes

relationships
: hierarchical, membership, component, similarity, location, ...

Knowledge Representation

formalisms to describe information items and their relationships

adequate
: are essential aspects captured?

comprehensible
: is the represented knowledge understandable?

transferable
: can the knowledge be communicated?

uniform
: is identical information consolidated?

composite
: can components be grouped into ensembles?

efficient
: usage of space
: execution time for basic operations

Knowledge Processing

knowledge representation formalism plus inference mechanism

algorithms
: knowledge as data structures, procedural processing

rules
: rule-based representation, forward/backward chaining

semantic nets
: network representation, activity propagation or specific reasoning methods

schemata
: frames, scripts as enhanced data structures; specific reasoning methods

objects

the essential aspects of all of these formalisms can be translated into propositional or predicate logic

Algorithms

structured sequence of steps to solve a problem

natural
relatively easy to formulate and understand

formal basis
Turing machines, computability

evaluation
good fit with the way computers work

Advantages

- modularity
  procedures, modules
- uniformity
  all knowledge is represented in the same
  format can also be a limitation
- naturalness
  similar to the way many programmers think
  not necessarily for all applications
- popularity

most popular method to program computers

Problems

- formal verification tedious to impossible
- not suitable for the representation of knowledge
- complex systems become difficult to handle
- re-use is limited in practice
- no satisfacory algorithms for "easy" problems

Rules

knowledge expressed in IF ... THEN format

natural
relatively easy to formulate and understand

formal basis
modus ponens as inference rule

nonmonotonic
assertions may be retracted to avoid contradictions

uncertainty
can be incorporated into the inference process

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

graph-based representation of knowledge

nodes
: represent objects or concepts

arcs
: represent relationships between concepts

semantic relationships
: constructed to provide an understanding of the represented information

inheritance
: propagation of attributes in hierarchies

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

Schemata

based on structures for representing knowledge
examples: frames, scripts

nodes can have internal structure
: a set of attribute-value pairs (slots, fillers)

stereotypes
: a frame represents a typical object or situation
: contains related knowledge about a situation

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

Objects

encapsulation of related information and manipulation methods

object
: data and methods corresponding to an entity in the real world

classes define general properties of objects
: instances specific individual objects

messages are used to exchange information between objects

Abstraction
: suppression of lower-level information not relevant for the current task

Encapsulation (information hiding)
: implementation details are hidden, only interface information is visible

Inheritance
: common characteristics are derived from ancestors

Polymorphism
: appropriate instances of classes and operators can be selected at runtime

Advantages

- very flexible
- suitable for large systems
- support reuse

Problems

- handling of new and atypical situations
- quite complex
- formal verification

Extreme Positions

about knowledge and its representation

formalistic assumption
: knowledge can be represented by finite structures composed of discrete atomic symbols in accordance with a finite number of syntactic relations [1]

relativistic assumption
: knowledge can only be described in a meaningful way with respect to a framework incorporating non-quantitative aspects like experience, belief, expectation, feelings, ... as a consequence, knowledge cannot be described in absolute terms [2]

Physical Symbol Systems Hypothesis
: A *Physical Symbol System* consists of symbols and structures that have to be realized physically; it has the necessary and sufficient

[1] [MacLennan, 1994]
[2] Joseph Weizenbaum

conditions for an intelligent system [3]

[3] [Newell and Simon, 1976]

Search

in Artificial Intelligence

search of a problem space

for a solution to a problem

not: search through data structures

basic idea:

find a path from the initial description of a problem to a description of the solved problem

problem space is created incrementally, not predefined and already in existence

problem-solving method

powerful technique for many different areas

Problem Space

Representation

Network

graph with nodes as states and arcs as possible steps

unique representations of states, multiple incoming arcs

Tree

multiple representations of states

Search

different ways to search

random search

next step is selected randomly from the possible ones

non-systematic; can't guarantee complete coverage of the search space; paths may be selected multiple times; may take infinite time

blind search

systematic approach; no knowledge about closeness to the solution; complete coverage; ineffective if closeness to solutions can be measured

directed search (also: informed search)

systematic approach; paths leading towards the solution are preferred

Search Methods

used in AI problems

depth-first

blind, systematic

expands each path to the end, backtracking when a dead end is encountered

breadth-first

blind, systematic

all nodes at one level are expanded

finds the shortest path

beam search

directed, heuristic variation of breadth-first

only a limited number of nodes are expanded

all successor nodes are evaluated, the best ones are selected for expansion

hill-climbing

directed variation of depth-first

successor node with the greatest progress towards the goal is selected *problems:* local maxima, plateaus, ridges

uniform-cost (lowest path-cost)
directed search
node with the shortest path so far is selected
finds the shortest path
problem: significant portion of the search tree must be expanded

best-first (greedy)
directed, heuristic search algorithm
requires estimate of the distance to the solution
selects the node with the smallest estimate
problem: does not take into account the length of already expanded parts of the paths

A⋆ (A-Star)
combination of best-first and uniform-cost
requires estimate of the distance to the solution
uses estimate and previous path length to calculate the cost

if estimates are always greater than zero but never greater than the actual cost, the lowest cost path will be found
reduces the number of nodes expanded by best-first

Knowledge and Expertise

representation of expert knowledge

general knowledge
central topic of many initial AI approaches
not sufficient for most practical applications

specific knowledge
different for each domain
corresponds to much of the knowledge of a human expert

heuristics
informal knowledge (rules of thumb, experience)
cause-and-effect relationships
often shortcuts to a satisfactory solution
not always optimal or even correct

salient features
important aspects of the problem

Heuristics

finding an acceptable solution

combinatorial explosion
too many possible paths

evaluation
it is difficult to decide which path is better
complex algorithmic evaluation function

approximation
the algorithmic evaluation function is unknown

Knowledge-Based Systems

Definition

computer-based system
implemented on a computer system

domain knowledge
must be available in the system

reasoning mechanism
to draw conclusions based on the domain knowledge

problem solving
must be able to find an equivalent solution to that of a human expert

Fundamental Concepts

of knowledge-based systems

separation of knowledge and its usage

specificity
highly specific domain knowledge

heuristic nature
solutions are often derived by heuristics rather than algorithms

Types of Knowledge

skills of experts

associational knowledge
heuristic ability to associate inputs with outputs
"black-box knowledge"

motor skills
usually learned by repetition
may be difficult for computers / robots

theoretical knowledge
formal knowledge about a domain
requires understanding of the underlying concepts

Features

of knowledge-based systems

Requirements

- performance: level of competency equal or higher than an expert
- response time: at least as fas as a human expert; critical for real-time expert systems
- reliability: crashes or malfunctions may be dangerous
- understandability: steps of reasoning must be explained on request

Advantages

- availability of expertise
- explicit representation of knowledge
- ease of modification
- consistency of answers
- accessibility
- incomplete / inexact data
- comprehensibility

Disadvantages

- incorrect answers
- limited knowledge
- lack of commonsense
- brittleness

Development

of knowledge-based systems

knowledge acquisition
extract knowledge from a human expert

knowledge representation
suitable for use by computers

maintenance
update of the knowledge base

Chapter Review

Computing Methods
algorithms, rules, semantic nets, ...

Search Methods
random, blind, directed search
depth-/breadth first, uniform-cost, best first, A$\star$

Knowledge-Based Systems
separation of knowledge and its use
evailability of expertise
performance and reliability
limited domain knowledge