Vorlesung

Grundlagen der Künstlichen Intelligenz

Reinhard Lafrenz / Prof. A. Knoll

Robotics and Embedded Systems
Department of Informatics – I6
Technische Universität München

www6.in.tum.de
lafrenz@in.tum.de
089-289-18136
Room 03.07.055

Wintersemester 2012/13 8.2.2013
Recap + Q&A session
An agent is an entity that perceives and acts.
It consists of an architecture and a program.
A ideal rational agent is expected to maximize its performance measure, given the evidence provided by the percept sequence and the built-in knowledge.
There are different types of environments, some are more challenging than others:
  - E.g. partially observable, stochastic, sequential, dynamic, continuous.
There are different types of agents:
  - Reflex agents, only reacting to the percepts.
  - Goal-based agents, trying to achieve given goal(s).
  - Utility-based agents, maximizing their performance.
Search algorithms

- In order to search for a solution, an agent has to define its goal and based on this the agent has to define its problem.
- A problem consists of 5 parts: state space, initial state, operators, goal test and path costs. A path from the initial state to a goal state is a solution.
- There exists a general search algorithm that can be used to find solutions. Special variants of the algorithm make use of different search strategies.
- There are optimal and complete search algorithms which are “much better” than blind search.
- However, the state spaces and the complexity is still exponential.
Search algorithms

- Blind search:
  Depth-first, breadth-first, iterative deepening, ...

- Heuristic search:
  A* always leads to optimal solutions, but space ...
  Different heuristics, admissible, consistent ones
  Criteria for choosing “good“ heuristics

- All these search algorithms differ in the order in which the expanded nodes are inserted into the „open“ list
Search algorithms

- Local search and optimization
  - Useful if only the final state is of interest
  - Problem: local minima, plateaus, etc.
  - Several algorithms: hill-climbing, simulated annealing, local beam search, genetic algorithms, etc.

- Search with non-deterministic action results
  - Contingency plan instead of action sequence
  - AND-OR-trees
Constraint satisfaction problems (CSPs)

- CSPs: state represented by variable-value pairs
- Set of constraints on variables (unary, binary, and higher-order)
- Backtracking = depth first search + test
- Min-conflicts heuristics are very successful and easy
- Reduction of complexity by reduction to trees instead of graphs
Adversarial search

- Adversarial search needs to take all possible moves of the opponent into account
- Maximise your strategy based on the assumption that the opponent acts optimally
- Alpha-beta pruning can reduce the search space
- Incomplete real-time decisions need evaluation functions
Logical agents

- Knowledge-based agents with internal representation of knowledge
- Reasoning process to gain new knowledge and to draw conclusions
- Representation schemes (languages)
- A knowledge base is a collection of (formal) sentences
- Syntax and semantics
- Models (possible worlds)

- Two operators on the knowledge base:
  - \texttt{T ell}(KB, sentence)
  - \texttt{A sk}(KB, sentence)
Logic

- Logical agents apply inference to a knowledge base to derive new information and make decisions.

Basic concepts of logic:
- **syntax**: formal structure of sentences
- **semantics**: truth of sentences wrt models
- **entailment**: necessary truth of one sentence given another
- **inference**: deriving sentences from other sentences
- **soundness**: derivations produce only entailed sentences
- **completeness**: derivations can produce all entailed sentences

- Wumpus world requires the ability to represent partial and negated information, reason by cases, etc.
- Resolution is complete for propositional logic
- Forward, backward chaining are linear-time, complete for Horn clauses
- DPLL and WalkSAT algorithms
Logic

- First-order logic:
  - objects and relations are semantic primitives
  - syntax: constants, functions, predicates, equality, quantifiers
  - Increased expressive power: sufficient to define wumpus world including “hidden properties” such as “hasArrow”
  - Knowledge engineering scheme

- Most every-day sentences can be expressed in FOL
What is Planning

- Generate sequences of actions to perform tasks and achieve objectives.
  - States, actions and goals

- Search for solution over abstract space of plans.

- Assists humans in practical applications
  - design and manufacturing
  - games
  - space exploration
  - Rescue operation (see also RoboCup rescue league)
Planning

- Planning is an area of great interest within AI
- Biggest problem is the combinatorial explosion in states.

- Planning described as set of preconditions, actions, and postconditions
- Use of search strategies to create plans
- Use of theorem proving

- Consideration of limited resources and time

- Hierarchical planning approaches
Knowledge engineering

- Knowledge representation is crucial for efficient reasoning
- Ontologies are a widely used way for representing knowledge
- Upper ontology to describe main concepts and object classes of the world
- Individual ontologies for specific domains needed
- Different ways of reasoning
  - Navigation in semantic networks
  - Formal reasoning using logical representations
- Problem: Handling of default values
Reasoning under uncertainty

- Probability is a rigorous formalism for uncertain knowledge
- Joint probability distribution specifies probability of every atomic event
- Queries can be answered by summing over atomic events
- For nontrivial domains, we must find a way to reduce the joint size
- Independence and conditional independence provide the tools
Bayesian networks

- Bayes nets provide a natural representation for (causally induced) conditional independence
- Topology + CPTs = compact representation of joint distribution
- Generally easy for (non)experts to construct
- Canonical distributions (e.g., noisy-OR) = compact representation of CPTs
Approximate inference

- In general, inference in Bayesian networks is NP-hard.
- For polytrees, exact inference has linear time and space complexity.
- For all other network topologies, approximate algorithms are needed.

- One promising approach: Sampling (stochastic simulation)
  - Direct sampling
  - Rejection sampling
  - Likelihood weighting
Learning – decision trees

- Learning needed for unknown environments, lazy designers

- Learning agent = performance element + learning element

- Learning method depends on type of performance element, available feedback, type of component to be improved, and its representation

- For supervised learning, the aim is to find a simple hypothesis that is approximately consistent with training examples

- Decision tree learning using an information theoretic approach: entropy and information gain

- Learning performance = prediction accuracy measured on test set