Midterm review

Milos Hauskrecht
milos@cs.pitt.edu
5329 Sennott Square

Search

• **Basic definition of the search problem**
  – Search space, operators, initial state, goal condition

• **Formulation of a problem:**
  – We have some control over the complexity of the search space size

• **Two types:**
  – Path vs. configuration search
Search

- Methods for searching the search space:
- Search trace captured by the search tree

- Search methods properties:
  - Completeness, Optimality, Space and time complexity.
- Complexities
  - measured in terms of a branching factor \( b \), depth of the optimal solution \( d \), maximum depth of the state space \( m \)

---

Search

- Uninformed methods:
  - Breadth first search, Depth first search, Iterative deepening, Bi-directional search, Uniform cost search (for the weighted path search)
- Informed methods:
  - **Heuristic function** \( h \): potential of a state to reach the goal
  - **Evaluation function** \( f \) : desirability of a state to be expanded next
  - **Best first search**:
    - Greedy \( f(n) = h(n) \)
    - A*:
      \[
      f(n) = g(n) + h(n)
      \]
      the role of admissible heuristics, optimality
Search

- **Constraint satisfaction problem (CSP)**
  - Variables, constraints on values (reflect the goal)
  - Formulation of a CSP as search
  - Methods and heuristics for CSP search
    - Backtracking, constraint propagation, most constrained variable, least constrained value

- **Complex configuration searches. Use iterative algorithms:**
  - **Methods:** Hill climbing, Simulated annealing, Genetic algorithms
  - **Advantage:** memory !! Useful for very large optimization problems.

---

Search

- **Adversarial search (game playing)**
  - Specifics of a game search, game problem formulation
  - rational opponent

- **Algorithms:**
  - **Minimax algorithm**
    - Complexity bottleneck for large games
  - **Alpha-Beta pruning:** prunes branches not affecting the decision of players
  - **Cutoff** of the search tree and heuristics
KR and logic

• Knowledge representation:
  – Syntax (how sentences are build), Semantics (meaning of sentences), Computational aspect (how sentences are manipulated)

• Logic:
  – A formal language for expressing knowledge and ways of reasoning
  – Three components:
    • A set of sentences
    • A set of interpretations
    • The valuation (meaning) function

Propositional logic

• A language for symbolic reasoning

• Language:
  – Syntax, Semantics

• Satisfiability of a sentence: at least one interpretation under which the sentence can evaluate to True.

• Entailment:
  $KB \models \alpha$ is true in all worlds in which KB is true

• Inference procedure
  – Soundness  If $KB \not\models \alpha$ then $KB \models \alpha$
  – Completeness  If $KB = \models \alpha$ then $KB \models \alpha$
Propositional logic

- **Logical inference problem:** $KB \models \alpha$?
  - Does KB entail the sentence $\alpha$?
- Logical inference problem for the propositional logic is **decidable**.
  - A procedure (program) that stops in finite time exists
- **Approaches:**
  - Truth table approach
  - Inference rule approach
  - Resolution refutation

| $KB \models \alpha$ if and only if $(KB \land \neg \alpha)$ is unsatisfiable |

- **Normal forms:** DNF, CNF, Horn NF (conversions)

First order logic

- Deficiencies of propositional logic
- **First order logic (FOL):**
  - allows us to represent objects, their properties, relations and statements about them
    - Variables, predicates, functions, quantifiers
    - Syntax and semantics of the sentences in FOL
- Translation of English sentences to FOL
CSP

- Constraint propagation
- Congruency network from the homework

\[
x=2\quad y=0\quad z\quad w\quad u
\]

Initial assignments
\[ z \neq 0, 1, 3, 4, 6, 7, 9 \]

\[ z \neq 0, 1, 3, 4, 6, 7, 9, 2, 8 \]
z ≠ 0, 1, 3, 4, 6, 7, 8, 2, 9
z = 5 via exhaustions of alternatives

v ≠ 1, 2, 3, 4, 5, 6, 7, 8, 9
v = 0 via exhaustion of alternatives
CSP

$u \neq 1, 2, 4, 5, 7, 8 \quad \Rightarrow \quad u=\{0,3,6,9\}$

CSP

$u \neq 1, 2, 4, 5, 7, 8 \quad \Rightarrow \quad u=\{0,3,6,9\}$

$w \neq 0, 2, 3, 4, 6, 7, 8 \quad \Rightarrow \quad w=\{1,5\}$
CSP

\[ u \neq 1, 2, 4, 5, 7, 8 \implies u = \{0, 3, 6, 0\} \]
\[ w \neq 0, 2, 3, 4, 6, 7, 8 \implies w = \{1, 5, 9\} \]

Forward checking stops

---

Arc consistency

\[ w = \{1, 5, 9\} \text{ and } u = \{0, 3, 6, 0\} \]
Arc consistency

\[ w = \{1,5,9\} \quad \& \quad u = \{0,3,6,9\} \]

\[ w = 1 \rightarrow \text{no valid value for } u \text{ exists} \quad (u \text{ should be either } 1,4,7) \]

Hence \( w \neq 1 \rightarrow w = \{5,9\} \)

---

Arc consistency

\[ w = \{5,9\} \quad \& \quad u = \{0,3,6,9\} \]

\[ w = 5 \rightarrow \text{no valid value for } u \text{ exists} \quad (u \text{ should be either } 2,5,8) \]

Hence \( w \neq 5 \rightarrow w = \{9\} \)
CSP

Arc consistency

w = {9} \& u = \{0, 3, 6, 9\}

w = 9 \rightarrow \text{consistent with the remaining u values}

Hence w = \{9\}
CSP

Arc consistency

u={0,3,6,9} & w= {9}
All u consistent are consistent with w=9

Arc consistency stops