Introduction

PAH (Planning and Games)

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Organization

- Lectures
  - Classical Planning (M.Pěchouček)
  - Planning for robotics, games, logistics (J.Vokřínek)
  - Planning with uncertainty (B.Bošanský)
- Tutorials
  - Classical Planing (M.Štolba)
  - The rest (M.Čáp)
- Assignments
  - 1: Design of a planning domain (PDDL)
  - 2: Implementation of a path planner

State Space

- State
    - Set
    - Propositional formula
    - State variable assignment
    - …
- Transitions
    - Operators (preconditions -> effects)
    - Function
    - …

State-space Search

- Search on large implicit graphs (systematic)
- Uninformed
    - Breadth-first Search (BFS)
    - Depth-first Search (DFS)
    - Iterative Deepening
- Informed (heuristic)
    - Greedy Best-first Search (BFS…)
    - A*
    - wA* and other variants

Heuristic State-space Search

- Optimal/perfect heuristic h^*
  - Maps each state to the length of a shortest path to any goal state.
- Properties of heuristics
  - admissible if $h(s) \leq h^*(s)$
  - safe if $h(s) = \infty$ for all dead ends
  - goal-aware if $h(s) = 0$ whenever s is goal
  - consistent (monotonic) if $h(s) \leq h(s') + c$, where s' is a successor of s via an operator of cost c

Heuristic State-space Search (contd.)

- Requirements on heuristics
  - informative – guides the search towards the goal
  - admissible – for optimal search
  - efficient – computed a LOT of times
  - domain-independent - automatically derived from the problem srtructure
- Commonly used methods
  - relaxation – solve *less constrained* version of the problem
  - abstraction – solve *smaller* version of the problem

Best-first Search

```
OPEN=[init], CLOSED=[]
while OPEN != [] do
    remove node $x$ with the best $f(x)$ value from OPEN
    if($x \in$ goal)
        return path from init to $x$
    else
        expand node $x$
        for each successor $x_i$ of $x$
            if($x_i \notin$ OPEN and $x_i \notin$ CLOSED) add $x$ to OPEN
            if($x_i \in$ OPEN with worse $f(x_i)$) update $f(x_i)$
            if($x_i \in$ CLOSED with worse $f(x_i)$) reopen $x_i$
    add $x$ to CLOSED
```

A*

- $f(x) = g(x) + h(x)$
- Optimal if *h* is admissible
  - Expands the least nodes among all optimal algorithms with the same heuristic
- If *h* is consistent, does not have to reconsider nodes (line-11.)
- Variants:
  - Weighted A* - $f(x) = g(x) + w*h(x)$ – solution at most *w*x longer than optimum
  - IDA* - Iterative Deepening A*
  - Many more...

Example

- State:
- <A|B><B|C><A|B|C|T|P>
- Init: ABA
- Goal: ??C
- Number of states: 20