A Beginner's Introduction to Heuristic Search Planning

7. Going Further

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What else happens. . .
. . . in heuristic planning?

Heuristics

Other current topics on heuristics for classical planning:

- making delete relaxations less relaxed
  - semi-relaxed planning (Keyder et al., ICAPS 2012)
  - red-black planning (e.g., Katz et al., AAAI 2013)
- heuristics based on linear programming (e.g., Pommerening et al., ICAPS 2014; AAAI 2015)
- heuristics vs. search vs. inference (e.g., Lipovetzky & Geffner, ECAI 2012)

Search Algorithms

Search algorithms mostly interesting for satisficing planning:

- escaping local minima and heuristic plateaus:
  - using multiple heuristics (e.g. Röger & Helmert, ICAPS 2010)
  - combining local and systematic search (e.g. Hoffmann & Nebel, JAIR 2001; Xie et al., AAAI 2014)
  - randomized systematic search (e.g. Valenzano et al., AAAI 2014)
  - random-walk algorithms (e.g. Nakhost & Müller, IJCAI 2013)
- search algorithms tailored to specific objectives:
  - anytime strategies for satisficing planning (Richter & Westphal, JAIR 2010)
  - many papers from Wheeler Ruml's research group (e.g., Thayer et al., ICAPS 2012)

Search Space Pruning

Search space pruning (mainly for optimal search):

- with symmetries (e.g., Pochter et al., IJCAI 2011)
- with redundant paths ("partial-order reduction"):
  (e.g. Wehrle et al., ICAPS 2013)

Invariant Synthesis

- invariant: property of all reachable states
  (e.g., Rintanen, ECAI 2008)
- example: mutually exclusive atoms
  - set of atoms of which at most one is true in each state
  - basis of translation from PDDL to SAS^{+}(Helmert, AIJ 2009)
  - useful for strengthening heuristics, e.g., constrained PDBs (Haslum et al., AAAI 2005))

Preferred Operators

- heuristics often can identify promising actions
- for example helpful action: first action in a relaxed plan
  (Hoffmann & Nebel, JAIR 2001)
- try these actions first during search
- often highly positive impact on overall performance
  (Richter & Helmert, ICAPS 2009)

Portfolios

- Idea: solve tasks by running multiple (more or less) independent planning systems
- different strategies:
  - fixed schedule
  - select planners after task analysis

⇝ results of IPC 2014 "classic tracks"
`http://helios.hud.ac.uk/scommv/IPC-14/`

⇝ results of IPC 2014 "learning track"
`http://www.cs.colostate.edu/~ipc2014/`

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Symbolic Planning

Symbolic search algorithms:

- search processes sets of states at a time
- operators, state sets, heuristics etc. represented by binary decision diagrams (BDDs) (or related structures)
- planning systems:
  - Gamer (Edelkamp & Kissmann, IPC 2008)
  - SymBA* (Torralba et al., IPC 2014)
  - ...
- comprehensive treatment: Álvaro Torralba's PhD thesis (Torralba, 2015)

SAT Planning

SAT planning:

- create propositional formula that is satisfiable iff there is a plan with at most k steps
- use off-the-shelf or specially tailored SAT solver to find plans
- e.g., Madagascar planner (Rintanen, IPC 2011 & 2014)
- many papers by Jussi Rintanen (e.g., Rintanen; AIJ 2012)
- related: property-directed reachability (Suda, JAIR 2014)

Other Approaches

Many other approaches:

- partial-order causal link planning (POCL)
- compilation to (mixed) integer programming (IP/MIP)
- compilation to answer-set programming (ASP)
- compilation to quantified boolean formulae (QBF)
- . . .

. . . but heuristic search, symbolic search and SAT
are currently working best

What else happens . . .
. . . in planning?

More general planning topics

More general kinds of planning include:

- ~~offline~~: online planning; planning and execution
- ~~discrete~~: continuous planning (e.g., real-time/hybrid systems)
- ~~deterministic~~: FOND planning; probabilistic planning
- ~~single-agent~~: multi-agent planning; general game playing; game-theoretic planning
- ~~fully observable~~: POND planning; conformant planning
- ~~sequential~~: e.g., temporal planning

Domain-dependent planning problems in AI include:

- pathfinding, including grid-based and multi-agent (MAPF)
- continuous motion planning

Resources

Resources

- ICAPS conferences (International Conference for Automated Planning and Scheduling):
  `http://www.icaps-conference.org/`
  `http://icaps15.icaps-conference.org/`
- Planing Domain Definition Language (PDDL):
  `http://ipc.informatik.uni-freiburg.de/PddlResources`
- International Planning Competitions (IPC):
  `http://ipc.icaps-conference.org/`
- Fast Downward planning system:
  `http://www.fast-downward.org/`
- VAL plan validator:
  `https://github.com/KCL-Planning/VAL`

The End

Thank you for your attention!