A Novel Lookahead Strategy for Delete Relaxation Heuristics in Greedy Best-First Search

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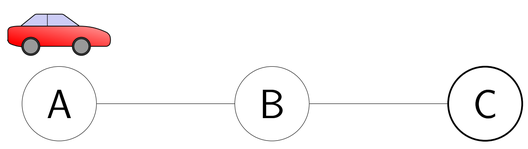
Setting

Satisficing AI Planning (FDR without action costs)

Running Example:



- Variables: *at*, *fuel*
- Actions:

  drive(x, y):
  - $pre = \{at = x, fuel = 1\}$
  - $eff = \{at = y, fuel = 0\}$

  refuel:
  - $pre = \emptyset$
  - $eff = \{fuel = 1\}$
- Initial State: $\{at = A, fuel = 1\}$
- Goal: $\{at = C\}$

Example plan: *drive(A, B)*, *refuel*, *drive(B, C)*

Delete Relaxation

Variables accumulate their values instead of switching between them
Example relaxed plan: *drive(A, B)*, *drive(B, C)*

The h^{FF} heuristic yields the length of a (non-optimal) delete-relaxed plan [Hoffmann and Nebel 2001]

There are methods to extract more information from the relaxed plan:

- Helpful actions/preferred operators [Hoffmann 2001, Helmert 2006]
  → Applicable actions: *drive(A, B)*
- Generate lookahead state using executable prefix
  [YAHSP; Vidal 2004, 2011]
  → Executable prefix: *drive(A, B)*
- Relaxed subgoal counting [BFWS; Lipovetzky and Geffner 2017]
  → Subgoals: $at = B$, $at = C$

Partial Delete Relaxation

Take some delete information into account:

- Red-Black Planning (Katz and Hoffmann 2014, Domshlak et al. 2015)
  → un-relax *fuel* variable
- Explicit Conjunctions (Keyder et al. 2014, Fickert et al. 2016)
  → achieve $fuel = 1$ and $at = B$ at the same time
  Works best if the conjunctions are generated during search

GBFS-RSL

After each expansion of a state s:

1. Initialize relaxed subgoal counting heuristic h^{rsc} with the relaxed plan for s
2. Perform a bounded lookahead search with h^{rsc}
3. Return the best state s' according to h^{rsc}
4. Insert s' at the front of the open list if $h^{\mathsf{FF}}(s') < h^{\mathsf{FF}}(s)$, else discard it (with $h^{C\mathsf{FF}}$: ...and refine the set of conjunctions C)

Lookahead search is bounded by using novelty: expand a state only if it contains a fact that was not seen before in this lookahead
→ expand at most as many states as there are different facts.

Experiments

STRIPS domains from satisficing IPC tracks (1825 instances/49 domains), 30min timeout, 4GB memory limit

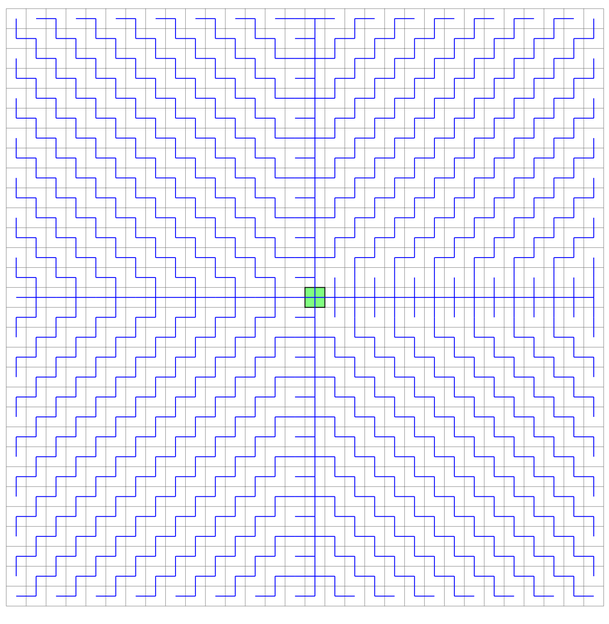
Comparison of GBFS without vs. RSL vs. YAHSP lookahead (all configurations with dual-queue for preferred operators):

Lookahead	none	RSL	YAHSP
h^{FF}	1494	1518	1529
h^{rb}	1508	1513	1541
h^{gray}	1555	1543	1579
$h^{C\mathsf{FF}}_{offline}$	1498	1577	1603
$h^{C\mathsf{FF}}_{online}$	–	**1665**	1573

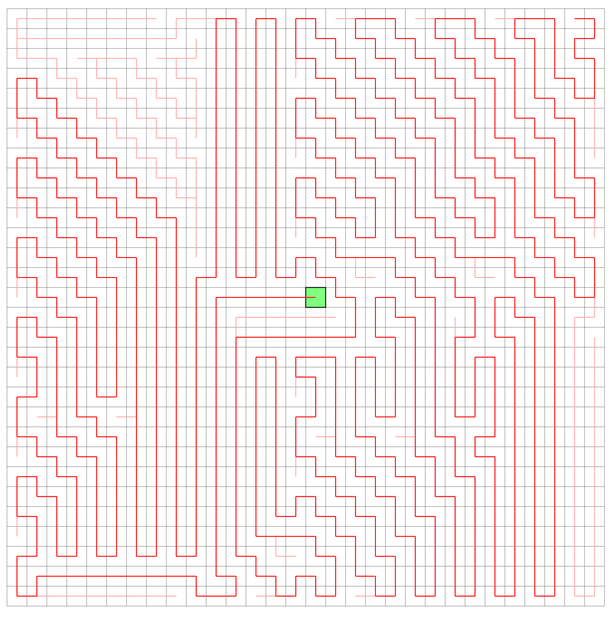
Comparison with other state-of-the-art planners:

	GBFS-RSL	LAMA	BFWS(f_5)	Dual-BFWS	Mercury	MERWIN	Coverage
GBFS-RSL	–	20	20	16	15	13	**1665**
LAMA	6	–	19	10	5	4	1574
BFWS(f_5)	8	15	–	5	11	9	1530
Dual-BFWS	9	18	22	–	12	10	1623
Mercury	9	14	19	13	–	2	1605
MERWIN	10	17	20	14	12	–	1634

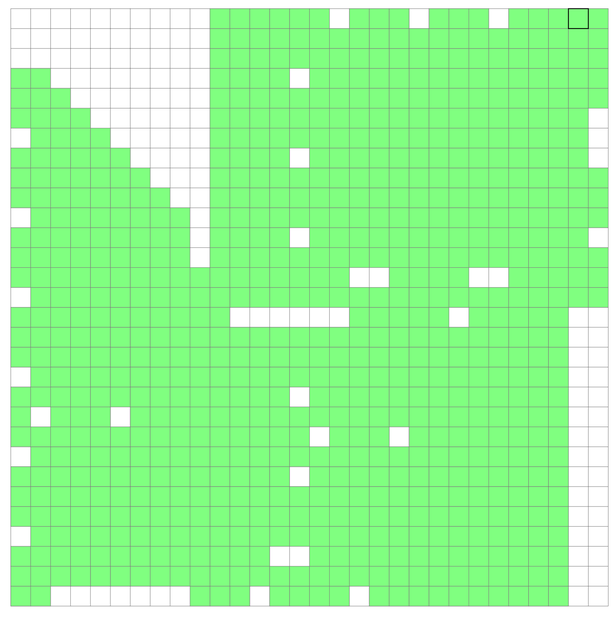
GBFS-RSL on VisitAll



Relaxed Plan



Lookahead Search Tree



Lookahead State