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

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# Classical Planning (FDR)



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

drive(x, y):

refuel:

- $pre = \{at = x, fuel = 1\}$   $pre = \emptyset$
- $eff = \{at = y, fuel = 0\}$   $eff = \{fuel = 1\}$
- Initial State:  $\{at = A, fuel = 1\}$
- Goal:  $\{at = C\}$

Variables accumulate values instead of switching between them



Relaxed plan: drive(A, B), drive(B, C)

The  $h^{\rm FF}$  heuristic yields the length of a (non-optimal) relaxed plan

# A B C Relaxed plan: drive(A, B), drive(B, C)

The relaxed plan provides more information than just a heuristic value:

- Preferred operators (Hoffmann 2001, Helmert 2006)
- Generate lookahead state using executable prefix (YAHSP; Vidal 2004, 2011)
- Relaxed subgoal counting (BFWS; Lipovetzky and Geffner, 2017)

At each expansion of a state s:

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

#### VisitAll (30×30)



# Expansion 1 Relaxed Plan



# Expansion 1 Lookahead Search Tree



# Expansion 1 Lookahead Path





# Expansion 2 Lookahead Path





# Expansion 3 Lookahead Path





# Expansion 4 Lookahead Path





# Expansion 5 Lookahead Path





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

49 IPC domains, 30min timeout, 4GB memory Lazy GBFS with dual-queue for preferred operators

-	RSL	YAHSP	
1494	1518	1529	
1508	1513	1541	
1498	1577	1603	
_	1665	1573	
	- 1494 1508 1498 -	<ul> <li>- RSL</li> <li>1494</li> <li>1518</li> <li>1508</li> <li>1513</li> <li>1498</li> <li>1577</li> <li>- 1665</li> </ul>	

	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

- New lookahead strategy for GBFS using relaxed subgoals
- Beats state-of-the-art planners with  $h^{C\rm FF}$  and online refinement
- Lookahead strategy is fairly general, and could be used with other methods that provide subgoals or abstract plans