An Analysis of Merge Strategies for Merge-and-Shrink Heuristics

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Setting

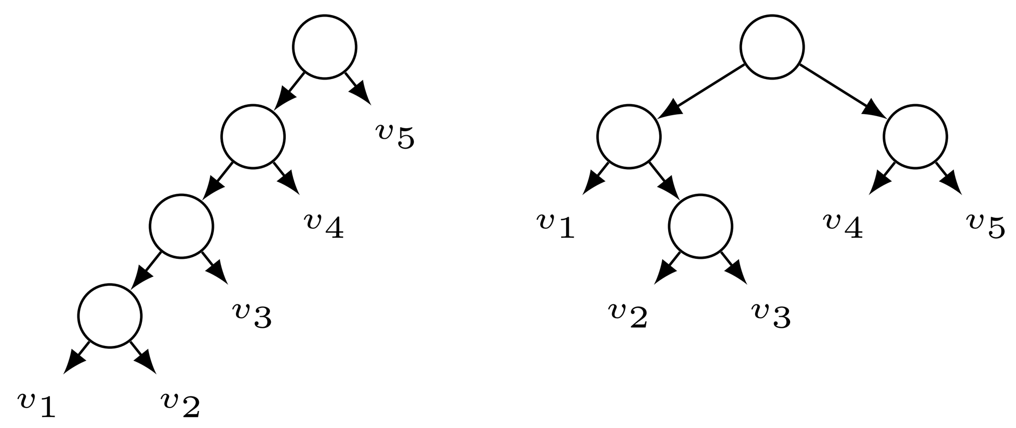
- Classical planning as heuristic search
- Merge-and-shrink: abstraction heuristic

Merge-and-Shrink in a Nutshell

$X \leftarrow$ {atomic transition systems}
while $|X| > 1$ **do**
  Choose $\Theta_1, \Theta_2 \in X$ according to merge strategy
  Shrink Θ_1, Θ_2 according to shrink strategy
  Merge by computing the synchronized product: $\Theta_1 \otimes \Theta_2$
  Replace Θ_1 and Θ_2 by $\Theta_1 \otimes \Theta_2$ in X
end while

Merge Strategy

- Binary tree over state variables



- Called linear if degenerated to a list, non-linear otherwise

Motivation

- Recent development allows (efficient) non-linear merge strategies
- Presumably large potential for better merge strategies
- Only little research on merge strategies

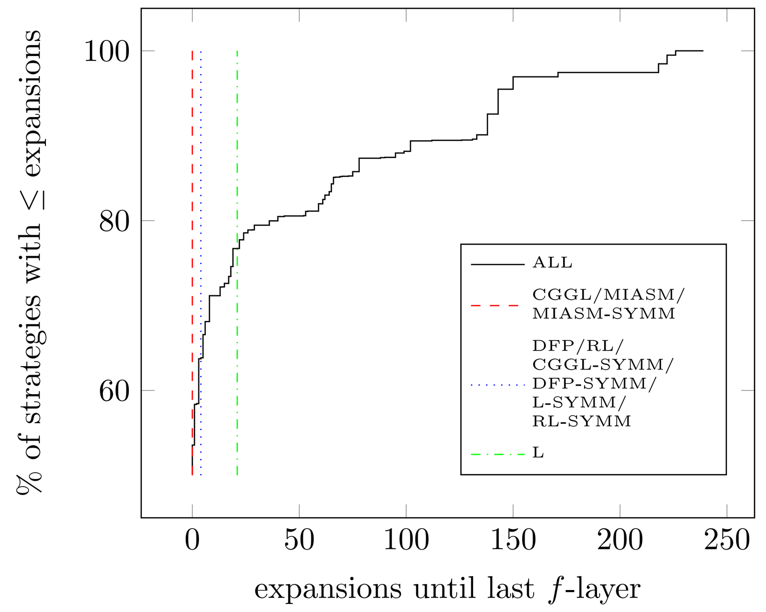
Table Legend

Constr (sec): Average construction time in seconds
Linear (%): Percentage of tasks for which the heuristic could be constructed and the strategy was linear
Exp (50th/75th): 50th/75th percentile for expansions (last f-layer)

Evaluation: Baseline Coverage Results

					symmetries enhanced				
CGGL	DFP	L	MIASM	RL	CGGL	DFP	L	MIASM	RL
710	745	704	757	725	747	752	742	749	749

Evaluation: All Merge Strategies

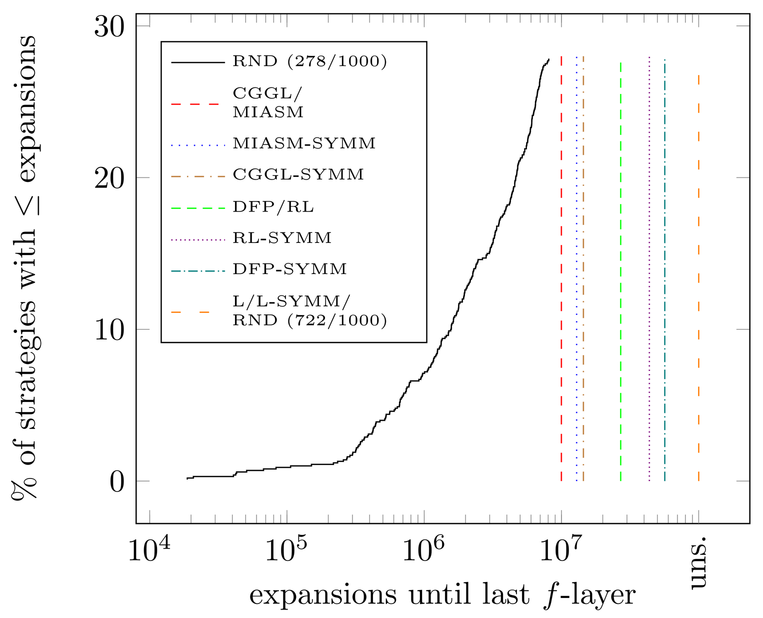


- Enumeration of all 1587600 merge strategies for Zenotravel #5 (8 variables)

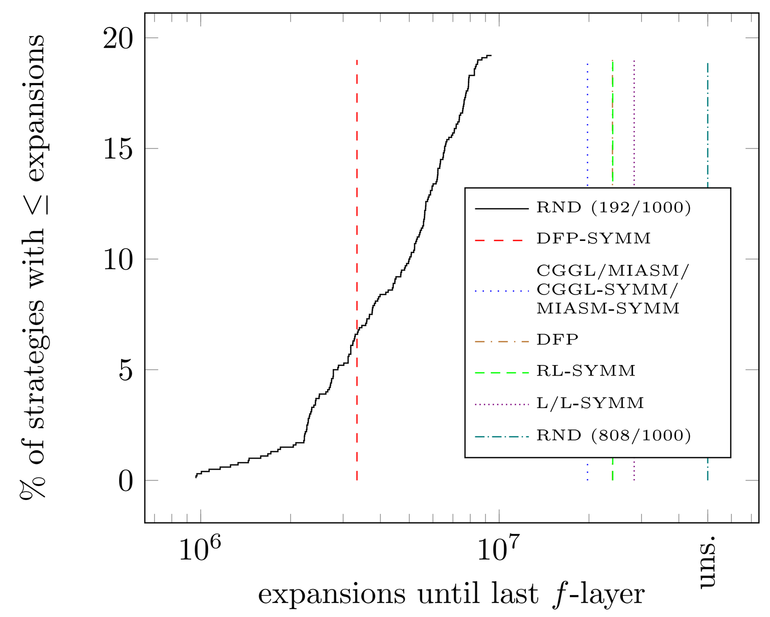
Evaluation: Random Merge Strategies

- Sample of 1000 random merge strategies on each planning task:
  - Expected coverage: 680.17
  - 72 tasks in 19 domains solved by some baseline, but no random strategy
  - 21 tasks in 9 domains solved by some random, but no baseline strategy

NoMystery-2011 #9



Elevators-2008 #7



(Higher memory/time limits for baseline strategies)

Evaluation: DFP

- Score-based merge strategy: prefer transition systems with common labels synchronizing close to abstract goal states
- Problem: many merge candidates with equal scores
- Use tie-breaking: prefer atomic or composite transition systems
- Further tie-breaking based on variable order (R, L, or RND)

	Prefer atomic			Prefer composite			Ran-
	RL	L	RND	RL	L	RND	dom
Coverage	**726**	**760**	**723**	**745**	**729**	**697**	***706***
Constr (sec)	60.1	61.4	65.0	60.4	*89.1*	74.9	60.2
Linear (%)	10.8	10.9	10.6	81.7	*86.5*	84.3	13.2
Exp (50th):	6776	2862	7340	3324	4008	13760	*15873*
Exp (75th):	596k	274k	536k	390k	488k	1332k	*1370k*

Evaluation: MIASM

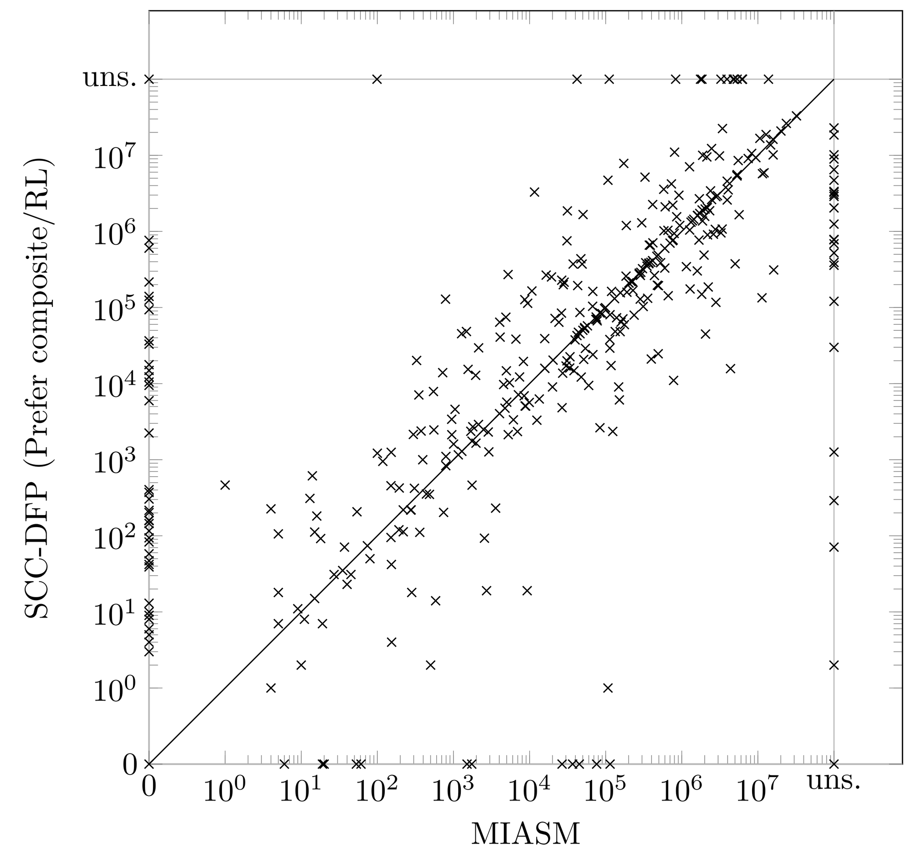
- Precomputed merge strategy: partition state variables based on searching for variable subsets that "maximize pruning"
- Simple score-based variant of MIASM: compute all merges, choose the one with highest amount of pruning

	Prefer atomic			Prefer composite			Ran-
	RL	L	RND	RL	L	RND	dom
Coverage	**743**	**746**	**745**	**747**	**724**	**730**	***726***
Constr (sec)	137.5	143.0	141.9	194.1	*236.9*	234.0	169.0
Linear (%)	10.4	10.5	11.9	45.2	*53.2*	51.2	11.8
Exp (50th):	383	412	641	67	370	397	*1282*
Exp (75th):	231k	231k	231k	185k	231k	279k	*359k*

Evaluation: New Strategy (SCC-DFP)

- Based on the causal graph (CG)
- Compute clusters of variables corresponding to SCCs of the CG
- Use DFP for merging within and between SCCs
- "Plan ahead": mixture of precomputed and score-based strategies

	Prefer atomic			Prefer composite			Ran-
	RL	L	RND	RL	L	RND	dom
Coverage	**751**	**760**	***732***	**776**	**751**	**741**	**736**
Constr (sec)	61.7	61.7	66.5	59.8	*86.0*	73.8	60.7
Linear (%)	8.2	8.4	8.2	58.2	58.7	*61.6*	11.5
Exp (50th):	2252	1796	*2649*	350	1410	2288	2352
Exp (75th):	349k	258k	370k	221k	362k	409k	*410k*



- Comparison of the previous state of the art MIASM to new SCC-DFP (best configuration)

Conclusions

- Random strategies show potential for devising better strategies
- DFP strongly susceptible to tie-breaking
- Simple MIASM variant performs close to original MIASM
- New state-of-the-art non-linear merge-strategy based on CG-SCCs