New Refinement Strategies for Cartesian Abstractions

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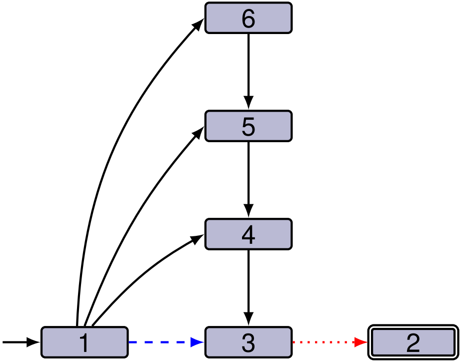
Motivation



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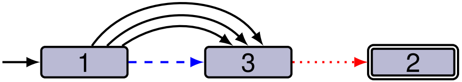

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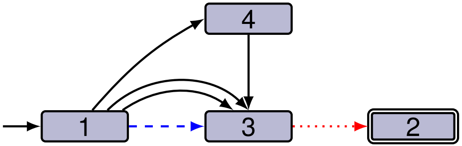

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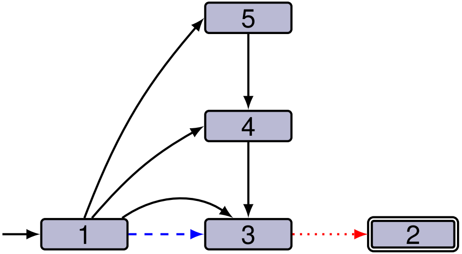

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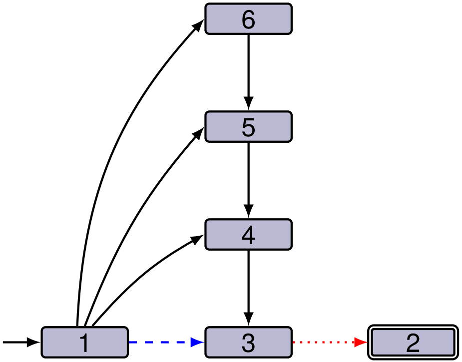

New refinement strategies

Counterexample-Guided Cartesian Abstraction Refinement (CEGAR)

- Repeatedly find counterexamples
  - I.e., abstract plans that fail for the concrete task
  - Repair the flaw by splitting a state

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Contribution

- Consider all optimal abstract plans
- New refinement strategies = flaw + split selection strategies

How can we find all flaws?

Flaw Search

- Consider all optimal abstract plans
- Depth-first search in the concrete transition system
- Consider only f-optimal transitions of the abstraction
- Collect all encountered flaws
- Goal state expanded $\rightsquigarrow$ optimal concrete plan
- Open list empty $\rightsquigarrow$ all flaws found

Flaw selection strategy

FIRST strategy [SH18]

- Considers an arbitrary optimal abstract plan π
- Selects the first flaw found for π
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Flaw selection strategy – Batch refinement

- Searching for all flaws in every step can be expensive

⇝ Repair several flaws at once

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Batch strategy

- Search for all flaws
- Return a concrete plan if the flaw search found one
- Iteratively repairs the flaw with the lowest h-value
- Attention: repairing a flaw can change the abstraction!
- Check if h-values of flaws have changed
- Repair all flaws that maintain the h-value

Flaw selection strategy – Theoretical results

FIRST/MAXH can lead to arbitrarily larger abstractions until a concrete solution is found, compared to MINH/BATCH.

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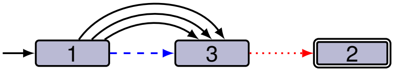

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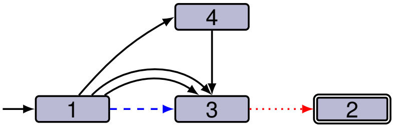

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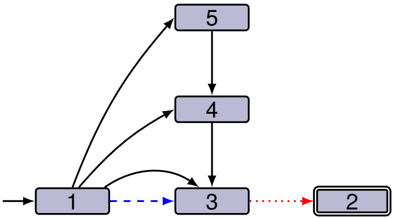

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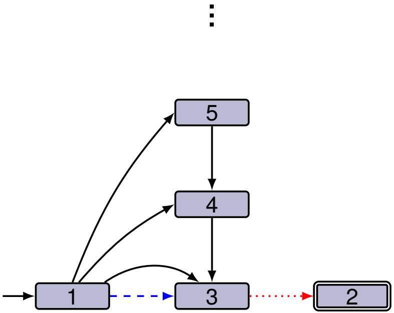

Split selection strategy

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Cover strategy

- Consider multiple flaws at once
- Chooses split that addresses the most flaws at once

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Experiments

- Implemented refinement strategies in Scorpion [Sei18]
- Planning tasks from optimal track of IPCs
- 15 min and 3.5GB for CEGAR
- 30 min and 4GB memory for $A^* + h^{\text{CEGAR}}$

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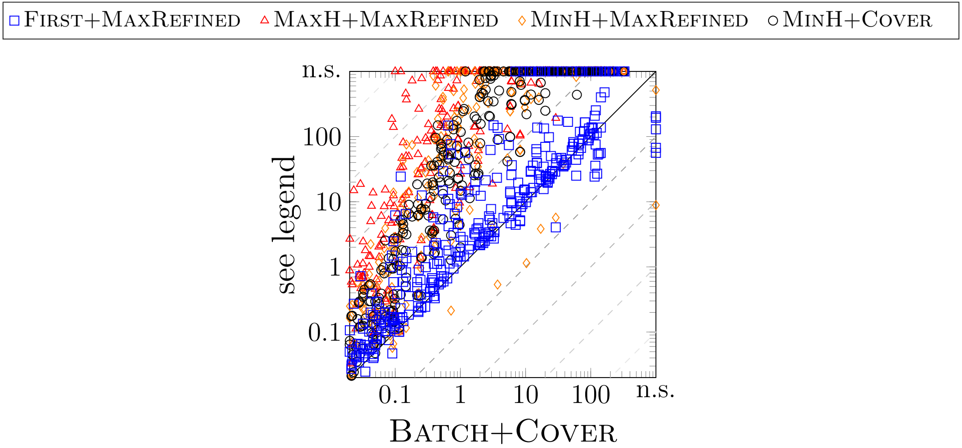
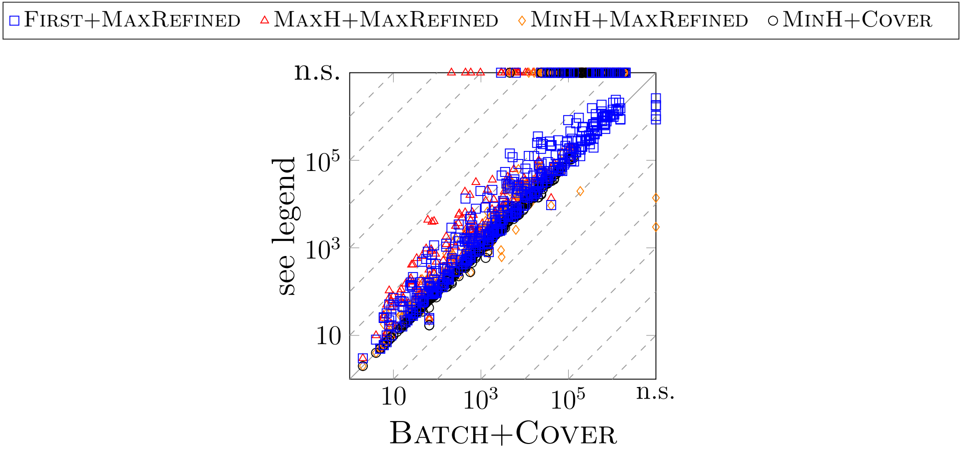
Experiments – Coverage

	MaxRefined			Cover	
Strategy	First	MaxH	MinH	MinH	Batch
CEGAR	499	345	382	393	**534**

Experiments – Runtime



Experiments – Abstraction Size



Experiments – Coverage

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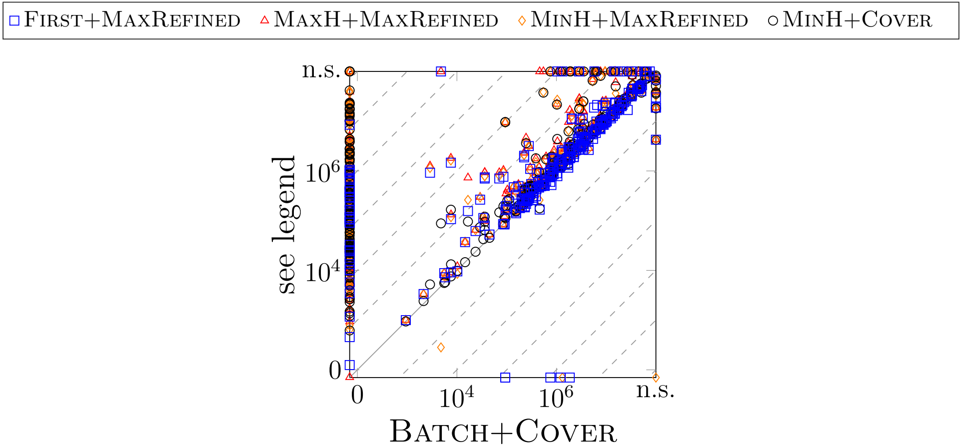
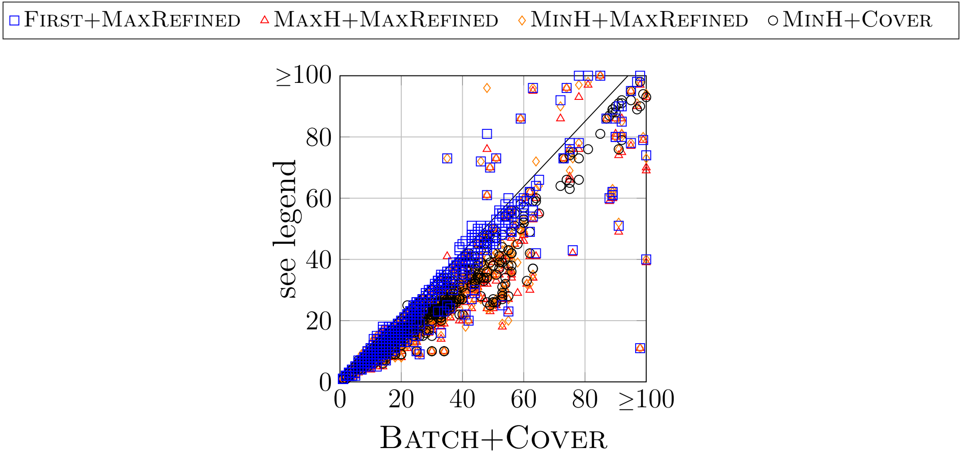
$A^* + h^{\text{CEGAR}}$	802	780	792	797	**812**

Experiments – Expansions



Experiments – Heuristic Accuracy



Conclusion

- New refinement strategies for CEGAR $\rightsquigarrow$ flaw + split selection strategies
- Flaw Search $\rightsquigarrow$ determine all flaws simultaneously

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Findings

- Refine states close to the goal
- Split states such that multiple flaws are repaired at once
- Repair as many flaws as possible in one step (batch)

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- Flaw Search $\rightsquigarrow$ determine all flaws simultaneously

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Future work

- Compare refinement strategies for multiple Cartesian abstractions

References I

[Sei18] Jendrik Seipp, *Fast Downward Scorpion*, IPC-9 Planner Abstracts, 2018, pp. 77–79.

[SH18] Jendrik Seipp and Malte Helmert, *Counterexample-guided Cartesian abstraction refinement for classical planning*, JAIR **62** (2018), 535–577.