Diverse and Additive
Cartesian Abstraction Heuristics

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Setting:

- Cost-optimal classical planning
- Admissible heuristic for A^*

Overview

- Single Cartesian abstraction
- Additive abstractions
- Diversification strategies

CEGAR
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Additive abstractions
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Diversification strategies
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Experiments
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Conclusion
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CEGAR

Counter-example guided abstraction refinement (CEGAR)

CEGAR algorithm

Start with coarsest abstraction

Until concrete solution is found or time runs out:

- Find abstract solution
- Check if and why it fails in the real world
- Refine abstraction

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Drawbacks:

- Diminishing returns
- Goal facts are considered one after another

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$\rightarrow$ Multiple abstractions

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# Additive abstractions

Multiple abstractions
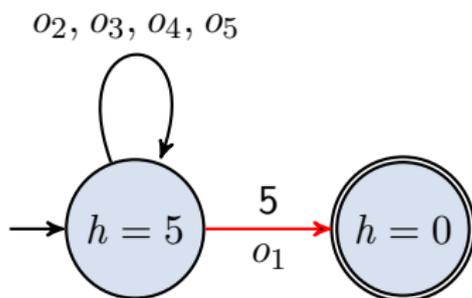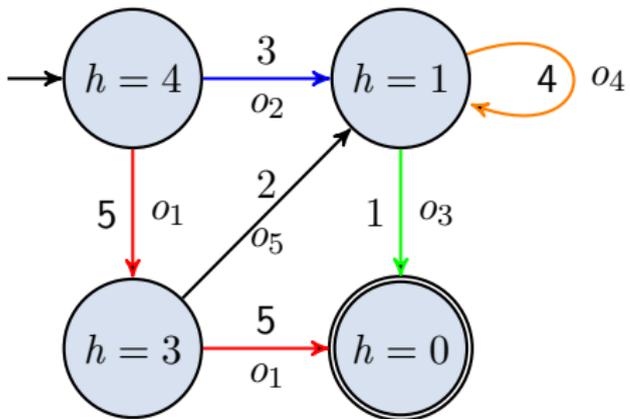
Multiple abstractions
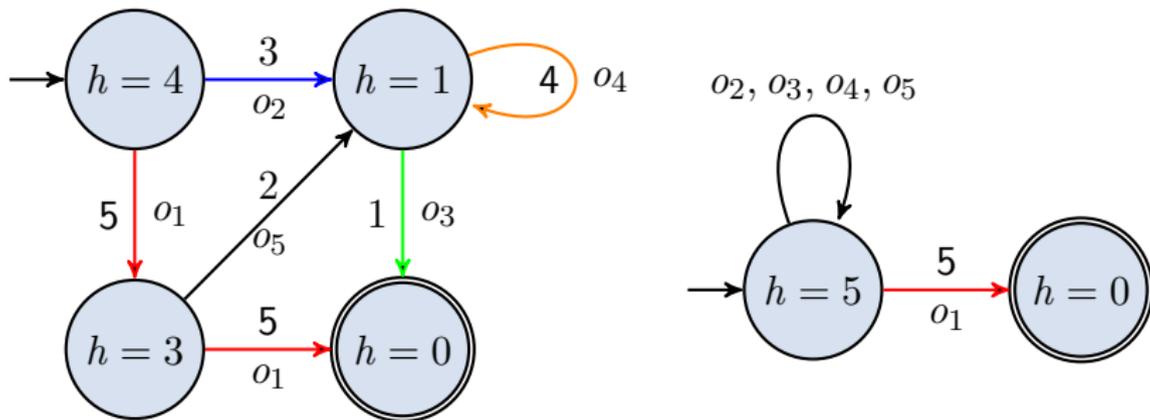
How to combine heuristic estimates?

- Maximum: $h(s_0) = \max(4, 5) = 5$

Multiple abstractions
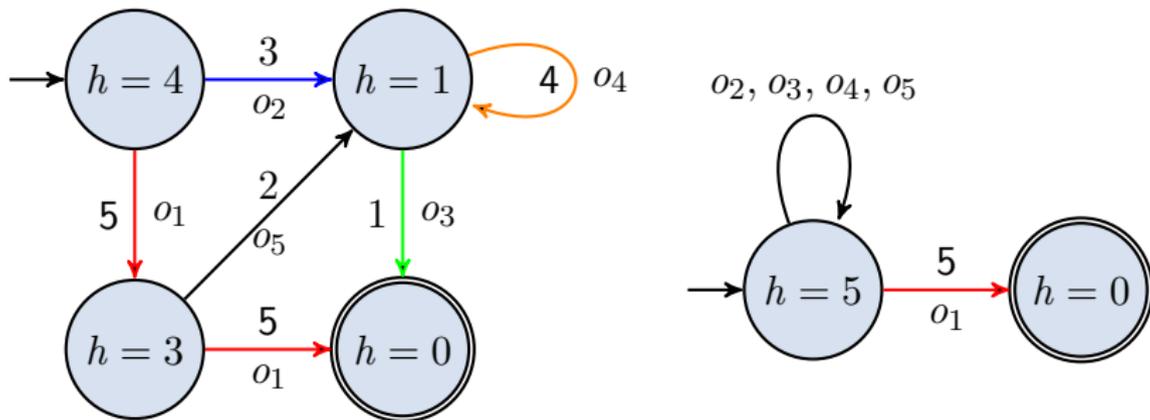
How to combine heuristic estimates?

- Maximum: $h(s_0) = \max(4, 5) = 5$
- Cost partitioning: $h(s_0) = 0 + 5 = 5$

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Additive abstractions
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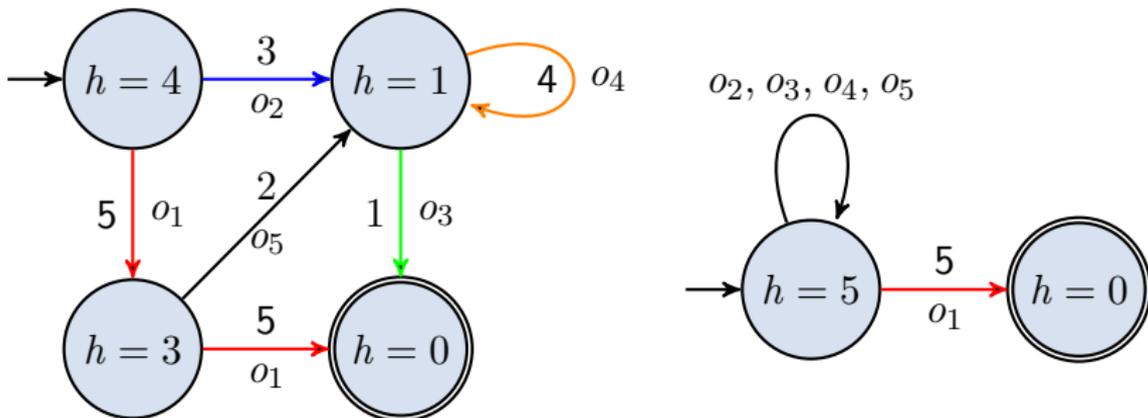
Saturated cost partitioning

- Saturated cost function

Saturated cost partitioning

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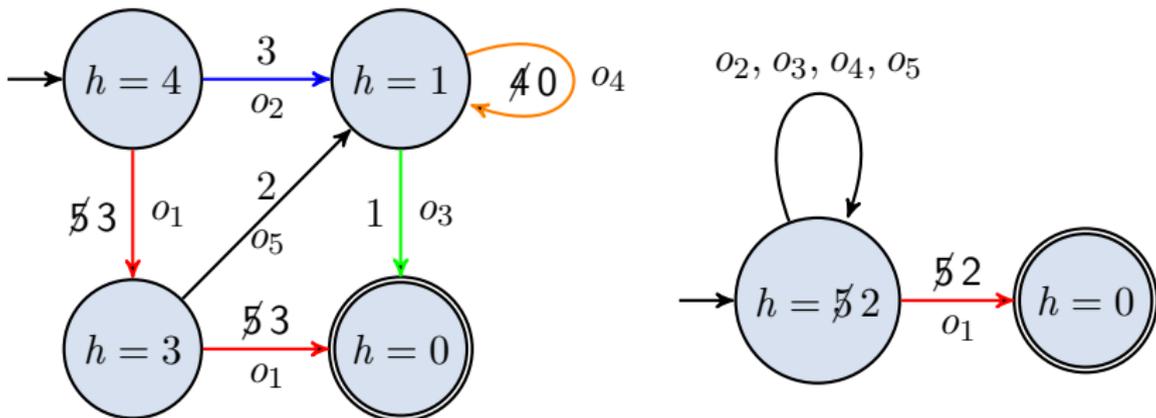
Saturated cost partitioning

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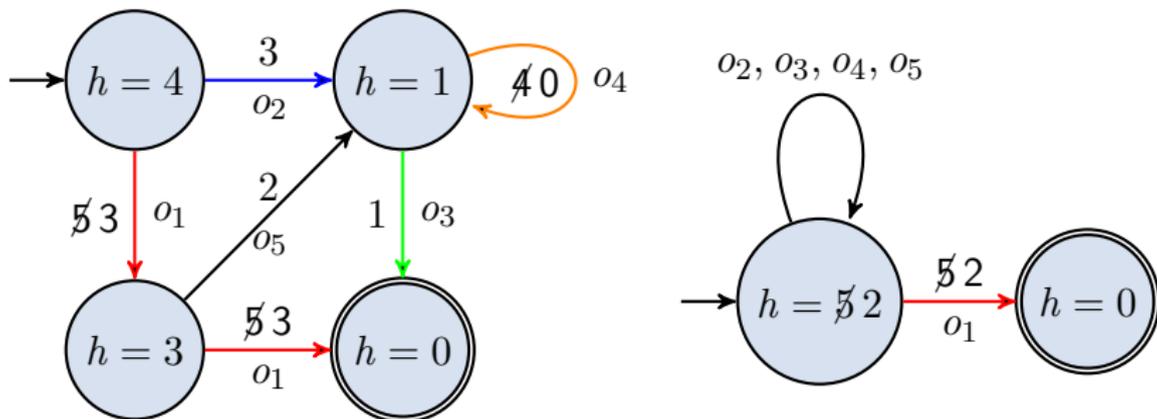
- $h(s_0) = 4 + 2 = 6$

Additive CEGAR abstractions

- Build n abstractions
- No changes to the CEGAR algorithm

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Experiment settings:

- 30 minutes, 2 GB
- 15 minutes refinement

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Results

	Abstractions					
Coverage	1	2	5	10	20	50
Sum (1396)	562	559	564	**566**	**566**	562

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Diversification strategies

Abstraction by goals

- Build an abstraction for each goal fact
- Focus on different subproblems
- Problem: tasks with single goal fact

Abstraction by landmarks

- Compute fact landmarks
- Build an abstraction for each fact landmark l
- Problem: landmarks as goals not admissible
- Solution: $h_l(s) = 0$ if l might have been achieved
- Path-dependent landmark heuristics $\rightarrow$ state-based criterion

Abstraction by landmarks

Modified task for landmark l:

- Compute *possibly-before* set $pb(l)$
- Facts: $pb(l) \cup \{l\}$
- Goal: l
- Operators:
  - discard operators with preconditions not in $pb(l)$
  - let operators achieving l achieve **only** l
- Initial state: unmodified

$h_l(s) = 0$ if $s \nsubseteq pb(l) \cup \{l\}$

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Abstraction by landmarks: improved
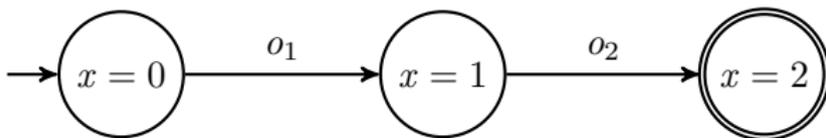
Abstraction by landmarks: improved
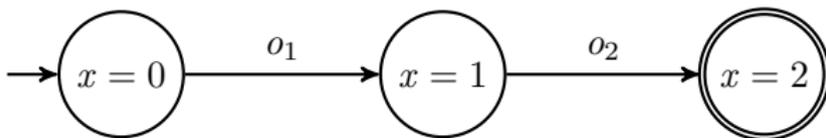
Solution:

- Compute landmark orderings
- Combine facts that have probably already been achieved

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Abstraction by landmarks: improved
Example

- $x = 1$: $\{y = 0, y = 1\}$
- $x = 2$: $\{y = 0, y = 1, y = 2\}, \{x = 0, x = 1\}$

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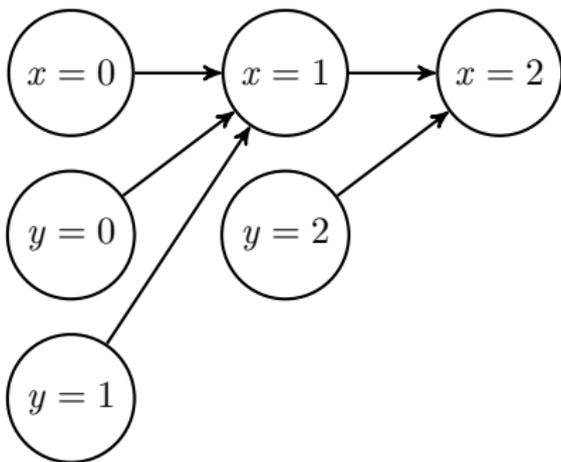
Experiments
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Experiments

Comparison to other abstraction heuristics

h^{CEGAR} vs. $h^{\text{CEGAR}}_{\text{LM}+s_\star}$

$h(s_0)$
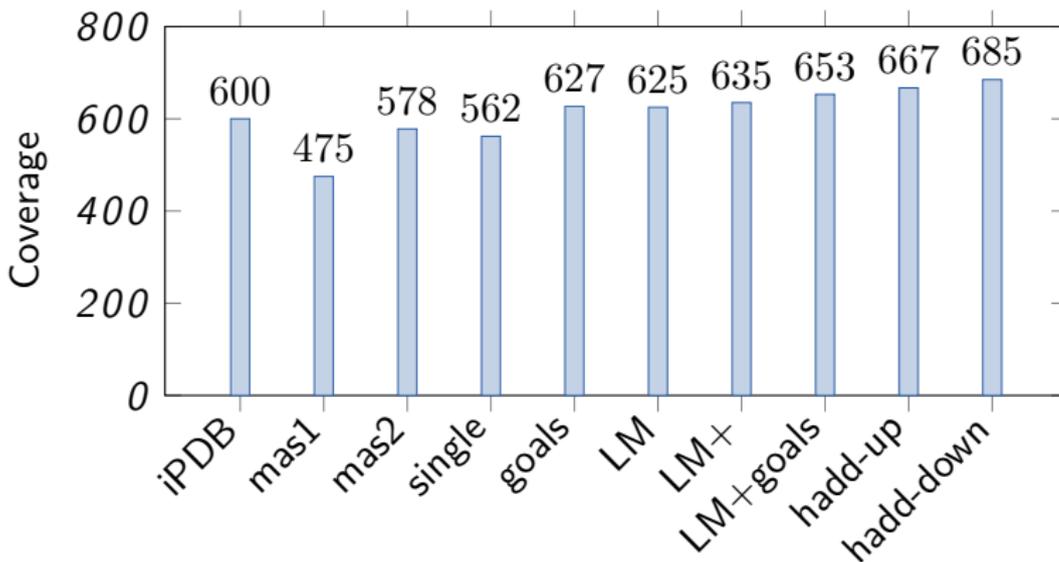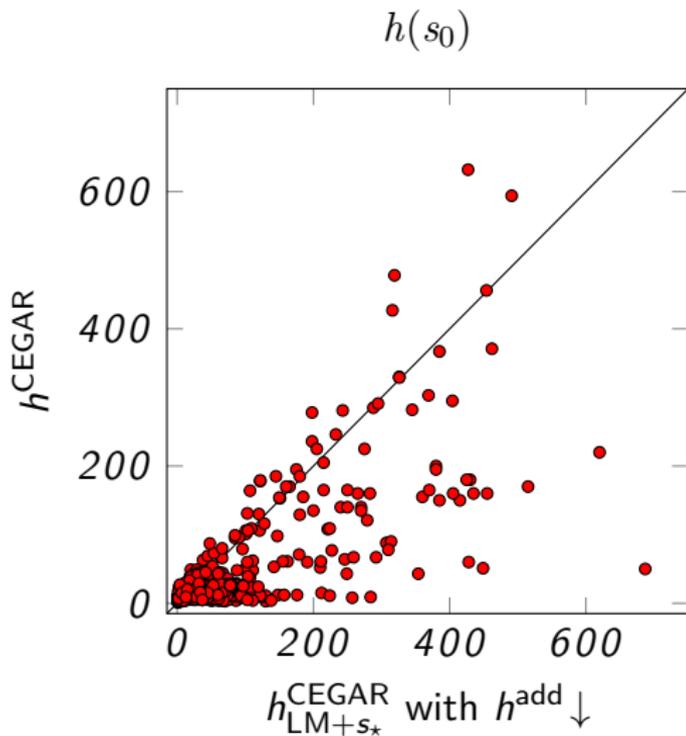
h^{CEGAR} vs. $h^{\text{CEGAR}}_{\text{LM}+s_\star}$

Time for Computing Abstractions (secs)

$h^{\text{CEGAR}}_{\text{LM}+s_\star}$ with $h^{\text{add}}\downarrow$

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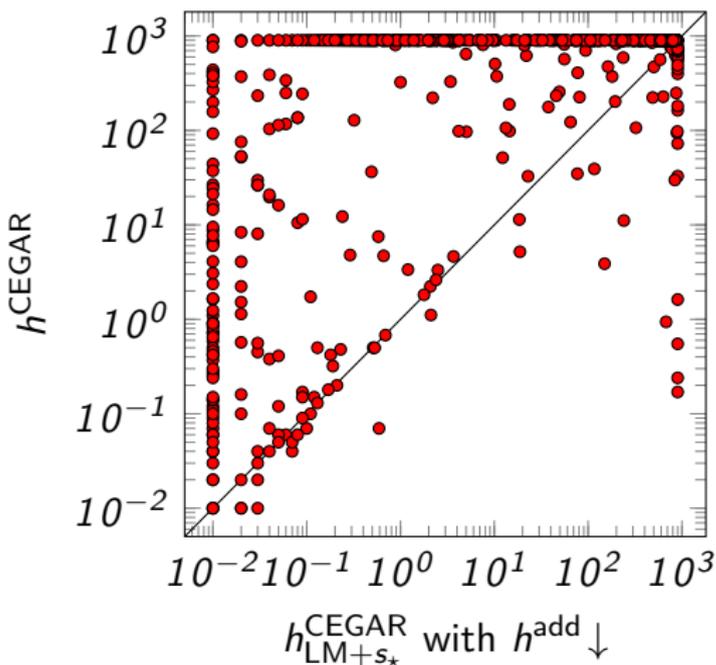
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Future work

- Investigate impact of fact ordering
- Use saturated cost partitioning for other abstraction heuristics

Summary

- New cost partitioning algorithm
- Several diversification strategies
- Competitive performance