Factored Symmetries for Merge-and-Shrink Abstractions
Silvan Sievers1, Martin Wehrle1, Malte Helmert1, Alexander Shleymah2 and Michael Katz3
1University of Basel, Switzerland 2Technion, Haifa, Israel 3IBM Haifa Research Lab, Israel

Introduction
Two existing successful techniques:
- Merge-and-shrink heuristic: state-of-the-art abstraction heuristic for classical planning
- Symmetry elimination: prominent example of a state space pruning technique

Contribution: use symmetries to construct better merge-and-shrink heuristics

Classical Planning
Planning task:
- State variables
- Initial state
- Goal description
- Operators

Merge-and-Shrink

1 Two existing successful techniques:
2 Merge-and-shrink heuristic: state-of-the-art abstraction heuristic for classical planning
3 Symmetry elimination: prominent example of a state space pruning technique

Interaction of Symmetries with Merge-and-Shrink
Interaction of symmetries with shrinking:
- Can break existing symmetries (e.g., combining $a_1$ and $a_2$ in example below)
- Can create new symmetries by removing obstacles to symmetries between states

Interaction of symmetries with merging:
- Can break existing symmetries (e.g., merging the two left-most transition systems in example below breaks symmetry between $a_1 b_1 c_1$ and $a_2 b_2 c_2$)
- Can create new symmetries (e.g., recover the same symmetry by merging the product with the third transition system)

Factored Symmetries and Merge-and-Shrink: Shrinking
Can we use factored symmetries for shrinking?

Proposition
Shrinking based on local symmetries is not information-preserving.

Proposition
Shrinking based on atomic symmetries is captured by shrinking based on bisimulation in combination with full (exact) label reduction.

Corollary
Shrinking based on atomic symmetries is information-preserving.

Factored Symmetries and Merge-and-Shrink: Merging
Can we use factored symmetries for merging?

Proposition
Merging all transition systems affected by a local non-atomic symmetry gives rise to an atomic symmetry.

Symmetry-Enhanced Merge-and-Shrink
Our integration of symmetries into merge-and-shrink:
- Atomic symmetries implicitly captured by bisimulation
- Compute non-atomic symmetries and merge affected transition systems

Algorithm:
1 $T' = \{\text{atomic transition systems}\}$
2 $N = \emptyset$
3 While $|T'| > 1$:
4 If $|N| \leq 1$
5 Compute a set $\Sigma$ of non-atomic symmetries of $T'$
6 If $\Sigma = \emptyset$
7 Let $N = \{ (-a \in T) \in N \}$
8 If $|N| \geq 2$
9 Choose $\theta_1, \theta_2 \in N$
10 else
11 Choose $\theta_1, \theta_2$ according to basic merging strategy $M$
12 Apply shrinking w.r.t. basic shrinking strategy $S$ on $\theta_1, \theta_2$
13 Replace $\theta_1, \theta_2$ by $\theta_1 \otimes \theta_2$ in $T'$ and in $N$ (if applicable)

Contributions
- Introduced notion of factored symmetries
- Merging and shrinking can lead to the loss and the discovery of symmetries
- Symmetry-enhanced merging strategies increase performance of merge-and-shrink heuristics