When Perfect is not Good Enough: On the Search Behaviour of Symbolic Heuristic Search

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Motivation

- Symbolic search and heuristic search are two successful approaches to optimal planning.

Symbolic Planner

- Symbolic state representation
- Blind search

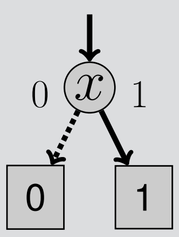
Heuristic Planner

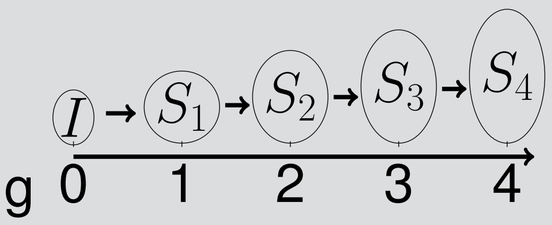
- Explicit state representation
- Informed search
  - Symbolic heuristics

Symbolic Heuristic Planner?

Symbolic Search for Optimal Planning

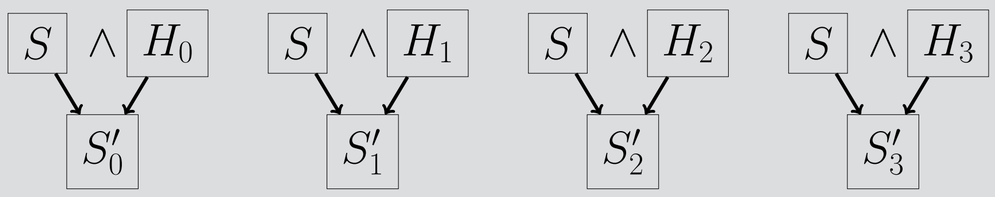
- Operations on sets of states
- $S \subseteq \mathcal{S}$ represented by characteristic function χ_S
- Manipulating $S \mathrel{\widehat{=}}$ Transforming χ_S
  - E.g. $S \cap S' \mathrel{\widehat{=}} \chi_S \wedge \chi_{S'}$
- Binary Decision Diagrams (BDDs)
- Search performance depends on the size of BDDs



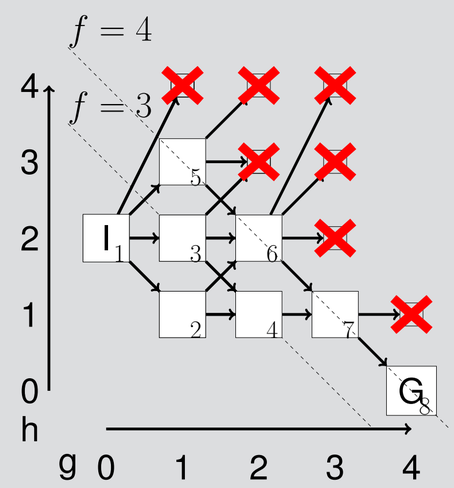


Symbolic Heuristic Search – BDDA*

- Given a set of states S, split it according to their h-value $S'_i = S \wedge H_i$.



- Consistent heuristics reduce the number of necessary state expansions
- Heuristic computation and state evaluation are expensive.



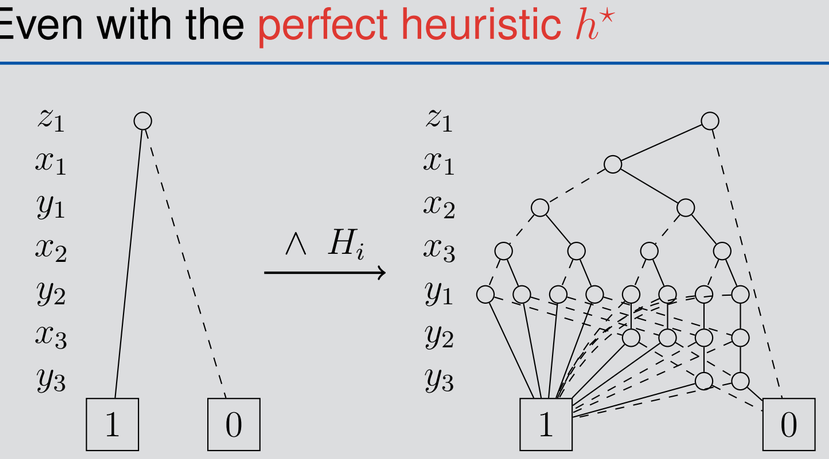
Symbolic Heuristic Search – Performance

- **Oberservation:** A BDD $B_{S'}$ can be larger than BDD B_S although the set of states S' is a strict subset of S, i.e. $S' \subsetneq S$.
- $\rightsquigarrow$ In symbolic search, the search performance is not directly related to the number of explicit states that have to be expanded.

Theoretical Results

Splitting BDDs according to heuristic values can increase or decrease the sizes of the resulting BDDs.

- In the worst case exponentially
- Even with the perfect heuristic $h^\star$ □



$\rightsquigarrow$ **Exponential increase or decrease in search performance!** □

Empirical Results

- BDDA* with fraction perfect heuristics $\rightsquigarrow c \cdot h^\star$
- BDD sizes can increase or decrease
- Successor computation can take longer
  - Although fewer states are expanded
  - $\rightsquigarrow$ Larger BDDs
- Similar results for uni- and bidirectional search

Conclusion

- Heuristic computation and state evaluation are expensive.
- Overall target: small BDDs
- Fewer States $\not\Rightarrow$ smaller BDDs

BDDs can become exp. larger by using heuristics.