Bounded Intention Planning Revisited

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Introduction

- Recent large interest in pruning methods for optimal planning
- Two existing methods:
  - Bounded Intention Planning (BIP) (Wolfe and Russell 2011)
  - Stubborn Sets (e. g. Valmari 1989, Wehrle and Helmert 2014)
- Our contribution: Relate BIP to strong stubborn sets

Stubborn Sets – High Level Idea

- At state s, restrict branching to $T_s \subseteq \mathcal{O}$
- Applicable operators not in T_s remain applicable
- Avoid looking at all permutations of an operator sequence leading to the same state

Stubborn Sets – More Details

- Operator set $T_s \subseteq \mathcal{O}$ is a generalized strong stubborn set (GSSS) in solvable state s iff:
  1. T_s contains all operators interfering with applicable operators from T_s
  2. T_s contains a necessary enabling set for all inapplicable operators in T_s
  3. T_s contains at least one operator starting a strongly optimal s-plan

Bounded Intention Planning – High Level Idea

- Method for domains with unary operators and acyclic CGs
- Repeatedly choose a subgoal
- Only plan for subgoal, avoiding unnecessary interleavings
- To do so, use augmented representation to explicitly set intention variables (representing subgoals)

Bounded Intention Planning – Operator Partitioning

- When expanding states:
  - Partition operators with identical preconditions and prevail conditions
  - Choose arbitrary partition: branch only inside partitions

BIP Theorem 2 (Wolfe and Russell 2011)

For every state s and applicable operator partition p there exists an optimal s-plan that begins with an operator in p.

Contribution – Relation of BIP to SSS

- Let s be a solvable state, let P_s be the set of applicable operator partitions in s

Theorem

For every $X \in P_s$, $T_s := X \cup \{o \mid o \text{ interferes with } o' \in X\}$ satisfies conditions (1) and (2) of the GSSS definition.

- Operators o interfering with X are not applicable in s
- X constitutes a necessary enabling set for all such o

Theorem

For at least one $X \in P_s$, $T_s := X \cup \{o \mid o \text{ interferes with } o' \in X\}$ satisfies condition (3) of the GSSS definition for and hence is a GSSS with the same applicable operators as X.

- From s solvable, there exists an operator o starting a strongly optimal s-plan
- P_s contains exactly the applicable operators, hence o is in some $X \in P_s$

Theorems – Remarks

- Preferably select partitions that correspond to a GSSS
- Problem: computationally hard to find those

Conclusion

- BIP's operator partitioning is a variant of a stubborn method:
  - All partitions induce sets that satisfy conditions (1) and (2) of the GSSS definition (semistubborn sets)
  - At least one partition induces a GSSS

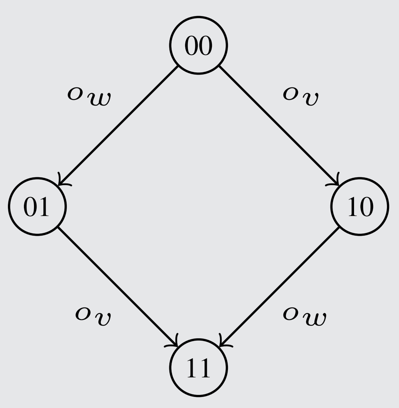
Future work

- What is the pruning power of BIP?
- Can BIP be generalized to arbitrary operators?

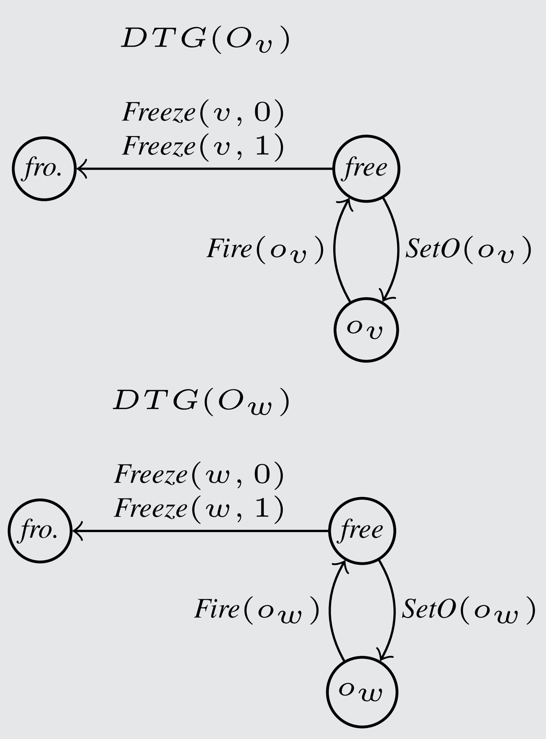
  $\Rightarrow$ Starting point: GSSS defined for arbitrary operators

Bounded Intention Planning – Example

- Example planning task:
  - $\mathcal{V}$: v, w, $\mathcal{D}(v) = \mathcal{D}(w) = \{0, 1\}$
  - $\mathcal{O}$: $o_v = (v = 0; v = 1; \emptyset)$, $o_w = (w = 0; w = 1; \emptyset)$
  - s_0: $v = 0$, $w = 0$
  - $s_\star$: $v = 1$, $w = 1$



- Augmented planning task: (simplified – without extra goal variable)
  - $\bar{\mathcal{V}}$: v, w, O_v, O_w, C_v, C_w
  - $\bar{\mathcal{O}}$:
    - $SetO(o_v) = (O_v = free; O_v = o_v; v = 0)$
    - $SetO(o_w) = (O_w = free; O_w = o_w; w = 0)$
    - $Freeze(v, 0) = (O_v = free; O_v = frozen; v = 0)$
    - $Freeze(v, 1) = (O_v = free; O_v = frozen; v = 1)$
    - $Freeze(w, 0) = (O_w = free; O_w = frozen; w = 0)$
    - $Freeze(w, 1) = (O_w = free; O_w = frozen; w = 1)$
    - $Fire(o_v) = (v = 0, O_v = o_v; v = 1, O_v = free; \emptyset)$
    - $Fire(o_w) = (w = 0, O_w = o_w; w = 1, O_w = free; \emptyset)$
  - $\bar{s}_0$: $v = 0$, $w = 0$, $O_v = free$, $O_w = free$, $C_v = free$, $C_w = free$
  - $\bar{s}_\star = s_\star$



- $\bar{s}_0$: applicable partitions
  - $SetO_{v=0} = \{SetO(o_v), Freeze(v, 0)\}$
  - $SetO_{w=0} = \{SetO(o_w), Freeze(w, 0)\}$
- $\bar{s}_0$: inapplicable partitions
  - $SetO_{v=1} = \{Freeze(v, 1)\}$
  - $SetO_{w=1} = \{Freeze(w, 1)\}$
  - $Fire_{o_v} = \{Fire(o_v)\}$
  - $Fire_{o_w} = \{Fire(o_w)\}$

Augmented search space: