On Weak Stubborn Sets in Classical Planning

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Setting

- optimal classical planning
- A^* search with safe pruning:
  - consider subset of applicable operators at expansion
  - guarantee optimality

Stubborn Sets

- origin in model checking (Valmari, APN 1989)
- established safe pruning technique in planning
- several flavors: weak and strong stubborn sets (Valmari, APN 1989), generalized strong stubborn sets (Wehrle & Helmert, ICAPS 2014)

Contributions

- recently introduced weak stubborn sets in planning are not stubborn sets in the original sense
- define (generalized) weak stubborn sets according to original definition
- analyze pruning power of the different types

SAS$^+$ Planning Tasks

- finite-domain state variables
- partial state: set of atoms
- operators o to modify states s:
  - o applicable in s if precondition of o satisfied
  - successor state $o(s)$ incorporates effect of o

Interference

o_1 weakly interferes with o_2 in state s if both operators are applicable in s and

- o_1 disables o_2 in s: o_2 not applicable in $o_1(s)$, or
- o_1 and o_2 conflict in s: $o_2(o_1(s)) \neq o_1(o_2(s))$

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Generalized Strong Stubborn Sets (GSSS)

Operator subset T GSSS in state s if:

C1 T contains at least one operator from at least one strongly optimal plan

C2 for all $o \in T$ not applicable in s, T contains necessary enabling set for o

C3 for all $o \in T$ applicable in s, T contains all o' which interfere with o in any state

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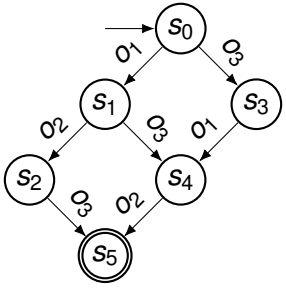
  approximation: syntax-based interference

GSSS: Example



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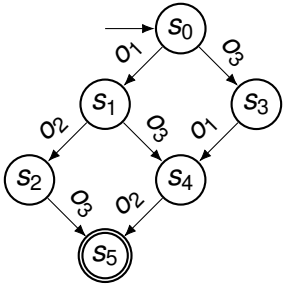

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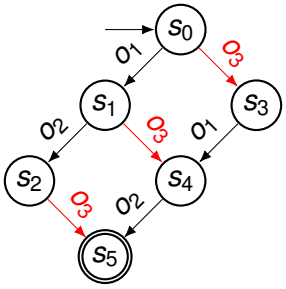

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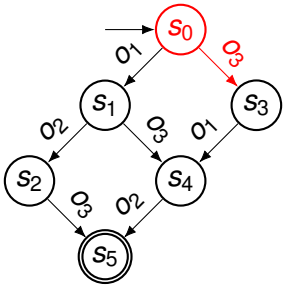

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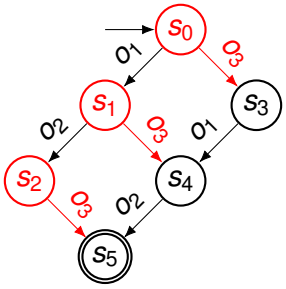

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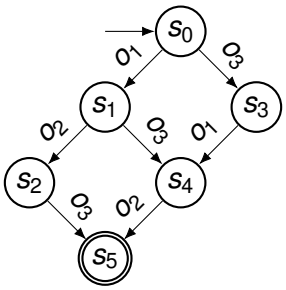

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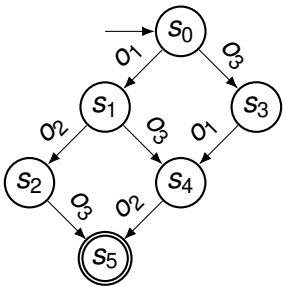

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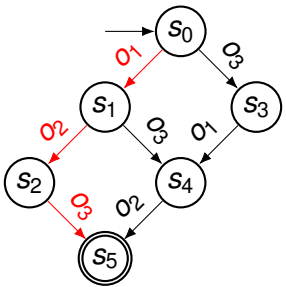

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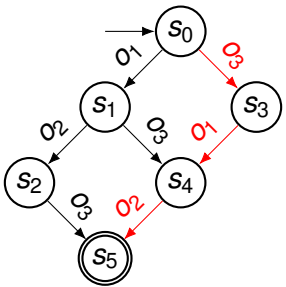

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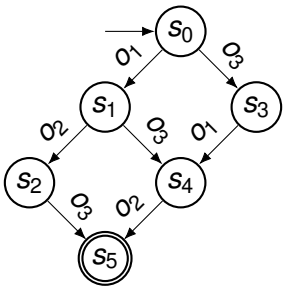

$T = \{o_3\}$ satisfies the operator shifting property in s_0:

- o_3 can be shifted to the front in all plans for s_0
- o_3 is applicable in the intermediate state o_1

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- previously called “weak stubborn sets” in planning
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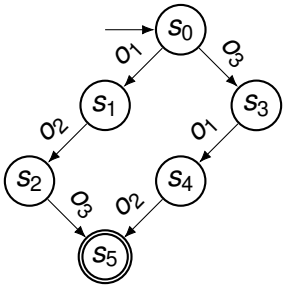
  C3 ~~for all $o \in T$ applicable in s, T contains all o' which interfere with o in any state~~

  C3’ for all $o \in T$ applicable in s, T contains all o' s.t. o syntactically weakly interferes with o’

Contribution: CSS do not Satisfy the Operator Shifting Property



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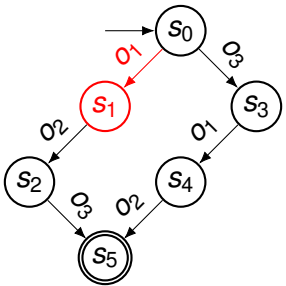

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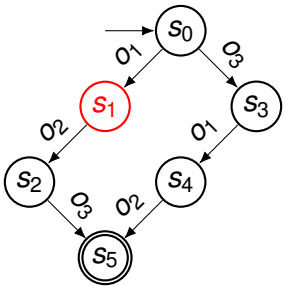

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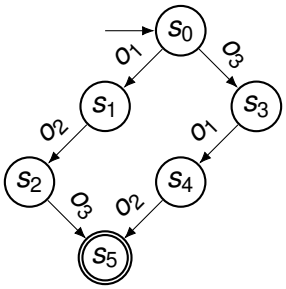

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- no longer satisfies operator shifting property: o_3 not applicable in s_1
- CSS in s_0 (o_3 does not syntactically weakly interfere with o_1)

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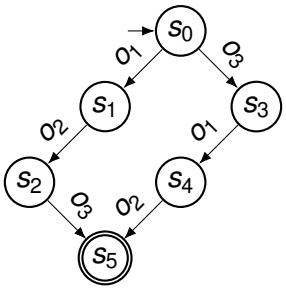
C3' for all $o \in T$ applicable in s, T contains all o' s.t. o weakly interferes with o' in any state, and additionally: T contains all disablers or enablers of o in any state

GWSS: Example



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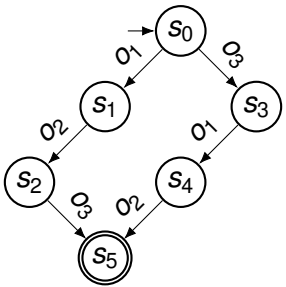

$T = \{o_3\}$ not GWSS in s_0: C3' requires including all disablers or all enablers of o_3:

- including disablers $\rightsquigarrow$ $T = \{o_1, o_3\}$ (= GSSS)
- including enablers $\rightsquigarrow$ $T = \{o_2, o_3\}$

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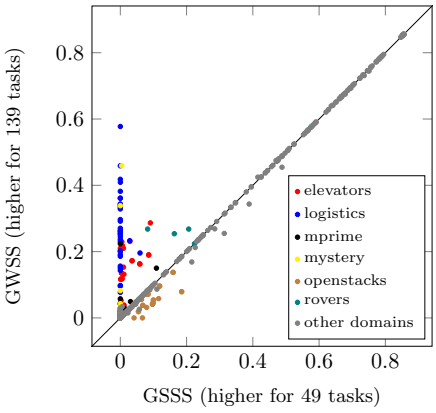
- comparison with CSS:
  - CSS stricter due to restriction to syntactic interference
  - CSS less restrictive due to not requiring operator shifting property
  - incomparable pruning power

Experimental Results: Strong vs. Weak



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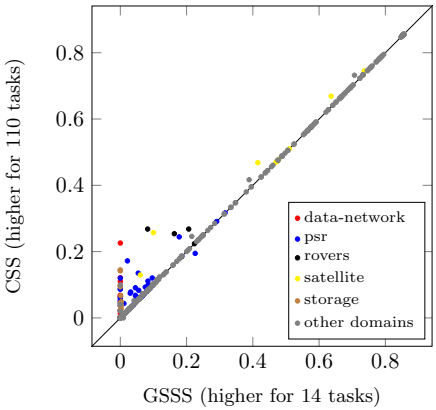
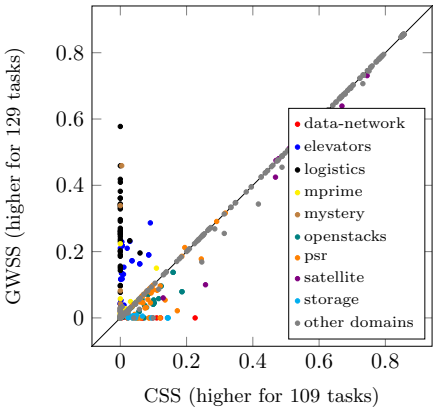


Experimental Results: Compliant vs. Weak



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future work:

- find strategies for deciding to include disablers or enablers for GWSS
- investigate if relaxing the operator shifting property beyond CSS is possible