Planning Domain Repair as a Diagnosis Problem

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Issue with Model Based Approaches

Modelling is hard!

This is also true for planning:

```
(:action move
  :parameters (?from - location ?to - location)
  :precondition (and (at-location ?from) (road ?from ?to))
  :effect (and (at-location ?to) (not (at-location ?to)))
)
```

Our Goal

We have:

- a domain
- a (incorrect) model of the domain
- a plan that is valid for the domain, but invalid according to the model

We want to

- compute the "minimal" "repair" of the model so that the plan is valid for the repaired model

Content

Classical Planning (STRIPS)

Classical planning problem: $\mathcal{P} = \langle \mathcal{F}, A, \alpha, s_I, g \rangle$ where

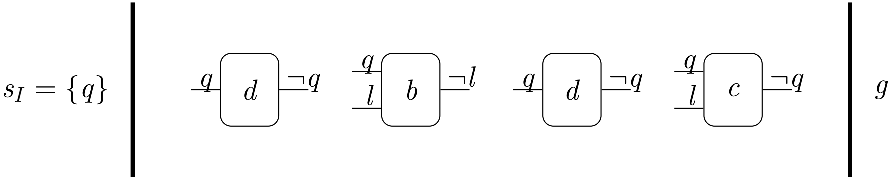
- $\mathcal{F}$ set of **facts** (Boolean state variables)
  - $s_I \subseteq \mathcal{F}$: **initial state**
  - $g \subseteq \mathcal{F}$: **goal facts**
- A: set of **action names** (or **actions**)
- $\alpha : A \to 2^F \times 2^F \times 2^F$: action description

An action is described by $\alpha(a) = \langle pre, \mathit{eff}^+, \mathit{eff}^- \rangle$:

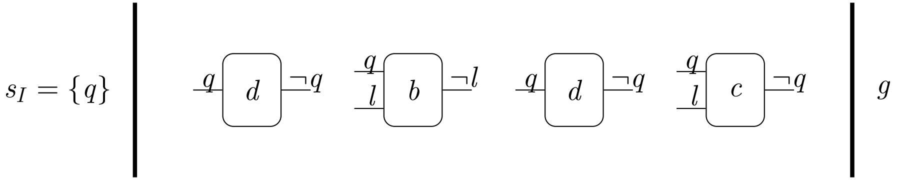
- **applicable** in state s iff $pre \subseteq s$
- leads to state $s[a] := s \setminus \mathit{eff}^- \cup \mathit{eff}^+$

A plan π is a sequence of actions. It is **valid** iff it is applicable in s_I and leads to a goal state ($g \subseteq s_I[\pi]$)

Example of Invalid Plan



Example of Invalid Plan



An **atomic repair** is one of three things:

- Remove a fact f from the preconditions of action a: $\langle F_a|_f^p \rangle$
- Remove a fact f from the negative effects of action a: $\langle F_a|_f^- \rangle$
- Add a fact f to the positive effects of action a: $\langle F_a|_f^+ \rangle$

Repair Problem

Applying a repair set R: $\mathcal{P} \Rightarrow_R \mathcal{P}'$

Repair Problem

Given a planning problem $\mathcal{P}$ and a plan π, find a **cardinality minimal** repair set R such that π is valid for problem $\mathcal{P}'$ where $\mathcal{P} \Rightarrow_R \mathcal{P}'$.

Model Based Diagnosis

A model based diagnosis problem is a tuple $\langle \mathit{Comps}, \mathit{SD}, Obs \rangle$ where

- *Comps* is a set of **components**
- *SD* is the **system description** (logical statement)
  - $\mathit{Ab}(c)$ = component c is *abnormal*
- Obs is an **observation** (logical statement)

A **diagnosis** δ is a set of components that satisfies:

$$\mathit{SD}, Obs, \{\mathit{Ab}(c) \mid c \in \delta\}, \{\neg \mathit{Ab}(c) \mid c \in \mathit{Comps} \setminus \delta\} \not\models \bot.$$

Repair as Diagnosis

- Each potential atomic repair is interpreted as a component
  - A component is faulty = the atomic repair should be performed
  - A diagnosis is a repair set
- The system description explains the value of each fact in each state during the execution the plan
- The observation is "the plan is valid"

System Description

1. If $f \notin \mathit{eff}^{+}(a_t)$ and $f \notin \mathit{eff}^{-}(a_t)$

$$\boxed{\neg \mathsf{Ab}(\langle F_{a_t}|_f^{+}\rangle) \rightarrow (\neg f@(t-1) \rightarrow \neg f@t)}$$

2. If $f \in \mathit{eff}^{-}(a_t)$ and $f \notin \mathit{eff}^{+}(a_t)$

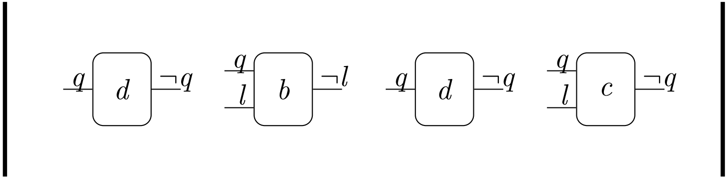
$$\boxed{\neg \mathsf{Ab}(\langle F_{a_t}|_f^{+}\rangle) \rightarrow \Big((\neg f@(t-1) \vee \neg \mathsf{Ab}(\langle F_{a_t}|_f^{-}\rangle)) \rightarrow \neg f@t\Big)}$$

3. If $f \in pre(a)$

$$\boxed{\neg \mathsf{Ab}(\langle F_{a_t}|_f^{p}\rangle) \rightarrow (\neg f@(t-1) \rightarrow \neg\, VALID)}$$

System Description (Example)

$s_I = \{q\}$



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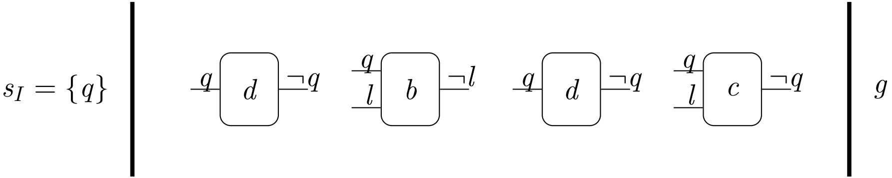
System Description (Example)



$$\boxed{\neg Ab(\langle F_d|_l^+\rangle) \rightarrow (\neg l@0 \rightarrow \neg l@1)}$$

$$\boxed{\neg Ab(\langle F_d|_q^+\rangle) \rightarrow \big((\neg q@0 \vee \neg Ab(\langle F_d|_q^-\rangle)) \rightarrow \neg q@1\big)}$$

$$\boxed{\neg Ab(\langle F_d|_q^p\rangle) \rightarrow (\neg q@0 \rightarrow \neg VALID)}$$

Solving MBD Problems

Input: A diagnosis problem $(\mathit{Comps}, \mathit{SD}, Obs)$
Output: A minimal cardinality diagnosis

$\triangleright$ Collection of known conflicts
$\mathcal{C} \leftarrow \emptyset$
loop
  $\delta \leftarrow$ a minimal cardinality hitting set of $\mathcal{C}$
  if $\boxed{\mathit{SD}, Obs, \varphi(\delta) \not\models \bot}$ **then**
    return δ
  $\boxed{C \leftarrow \text{a conflict } C \text{ with } C \subseteq \mathit{Comps} \setminus \delta}$
  $\mathcal{C} \leftarrow \mathcal{C} \cup \{C\}$

Slaney, John. "**Set-theoretic duality: A fundamental feature of combinatorial optimisation**." *ECAI 2014*. IOS Press, 2014. 843-848.

1. Verifying that a Repair Set is Correct

Simulate the execution of the plan

2. Computing a Conflict

1. Identify in $\mathcal{P}'$ a time step t when the precondition f is not satisfied
2. Determine the time step $t' < t$ when this fact was made false
3. A correct conflict is:

$$\{\langle F_{a_{t'}}|_f^- \rangle, \langle F_{a_t}|_f^p \rangle\} \cup \{\langle F_{a_i}|_f^+ \rangle \mid i \in \{t'+1, \ldots, t-1\}\}$$

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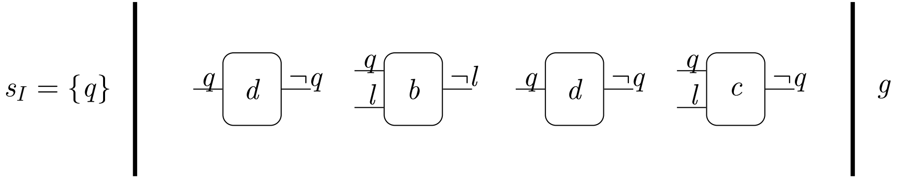
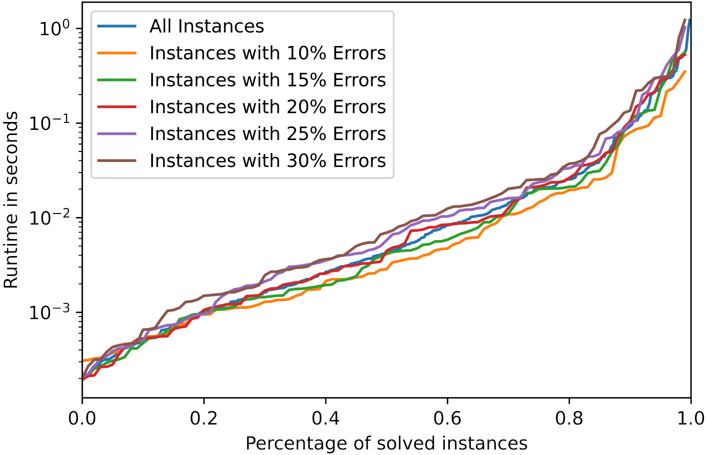


Here, l is required by c: $\{\langle F_b|_l^- \rangle, \langle F_c|_l^p \rangle, \langle F_d|_l^+ \rangle\}$

Experiments

Important implementation result: each fact $f \in \mathcal{F}$ can be diagnosed individually!



Extensions

- Negative preconditions (“strong-fault model”)
- Lifted representation
- Multiple problems and plans, same domain
- A priori probabilities
- More sophisticated repairs (swap a variable with another one)