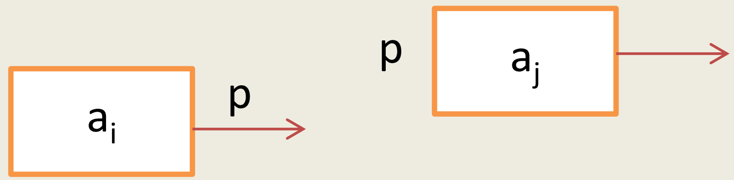

Optimizing Plans through Analysis of Action Dependencies and Independencies *[aka.. post plan analysis to shorten plans..]*

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Context - Chrpa's research

Useful Tools that can augment Existing Planning Engines

Post planning analysis
⇒Plan optimality
ICAPS 2012 short paper [this talk!]

Planning Problem Reformulation
⇒Plan Generation Speed-up
ECAI 2012 long paper

Techniques to some degree are domain independent, can be "slotted in" with planning engines to improve optimality and speed.

Basic Idea

- Modern Planning Engines are often “satisficing” – they are good at producing correct plans but the plans are often not optimal: “fast planning” systems do not guarantee optimal solutions.
- Some “speed up” techniques like using macro operators make matters worse – they are prone to introducing redundant actions into solutions.
- *We try to use post-planning analysis to reduce plan length regardless of planner used …. without compromising plan generation times. So a method with low polynomial time with respect to length of plan.*

Assumptions

- *This work assumes*
  - *we're working in simple STRIPS formalisms*
  - *solutions to planning problem (actions, initial state I, goal conditions G) are sequences of ground actions with preconditions, add and delete lists*
  - *looking to create domain independent methods - action inverses and replacability are computed for each domain in the runtime of the method*

Examples of potential optimization

- Some situations where an action and its inverse may be removed ..

[…,stack (a,b), …, unstack(a,b)]

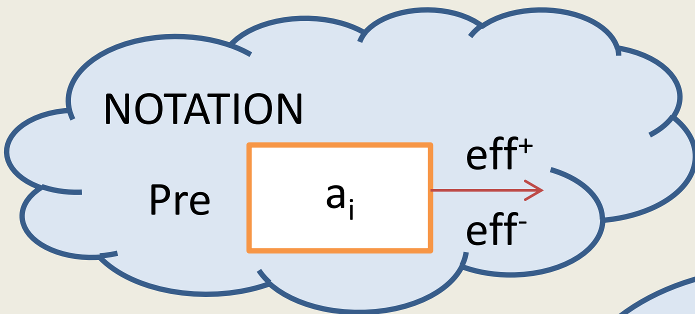
- Some situations where a two actions may be replaced by one action

[…,drive (x,y), …, drive(y,z),..]

- Some complex situations

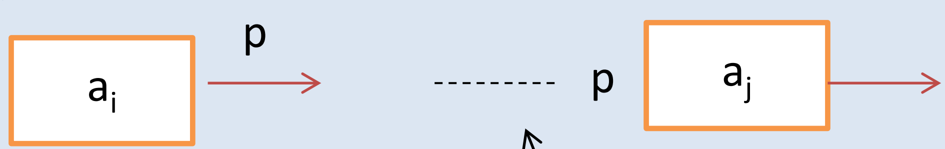
[…,pickup(a), .., stack(a,b), .., pickup(c), .., stack(c,d), …, unstack(a,b), … , putdown(a)]

Definition 1



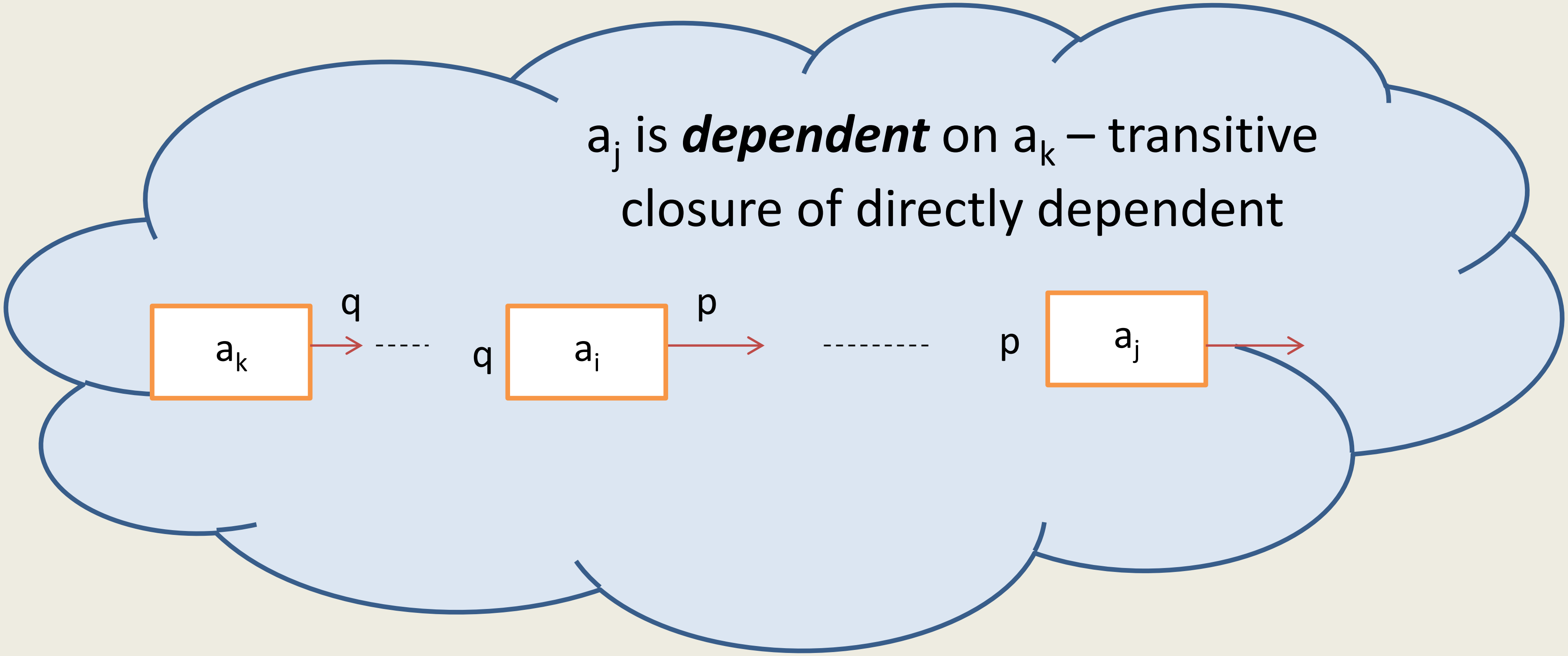
a_j is ***directly dependent*** on a_i

(like "causal link")



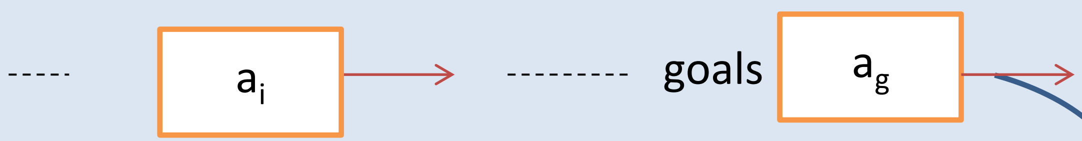
\+ NO other action between a_i and a_j has p in its add list

Definition 1 +

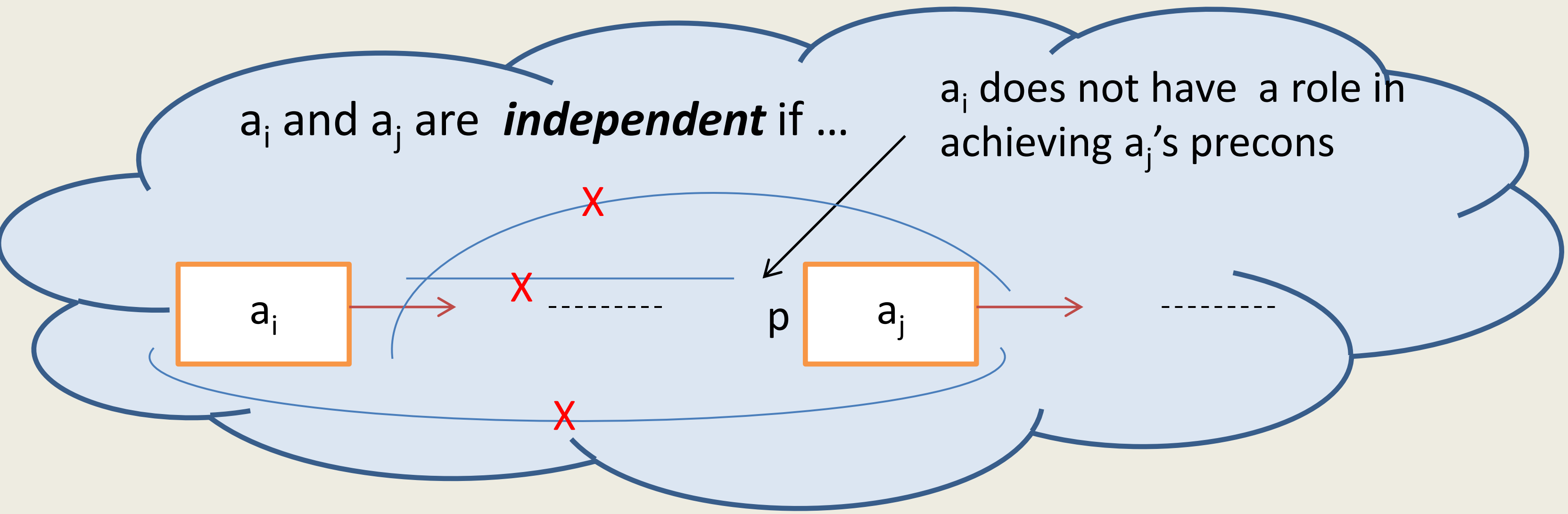


Observation

Necessary condition for optimal plan – a_g *dependent on every action*

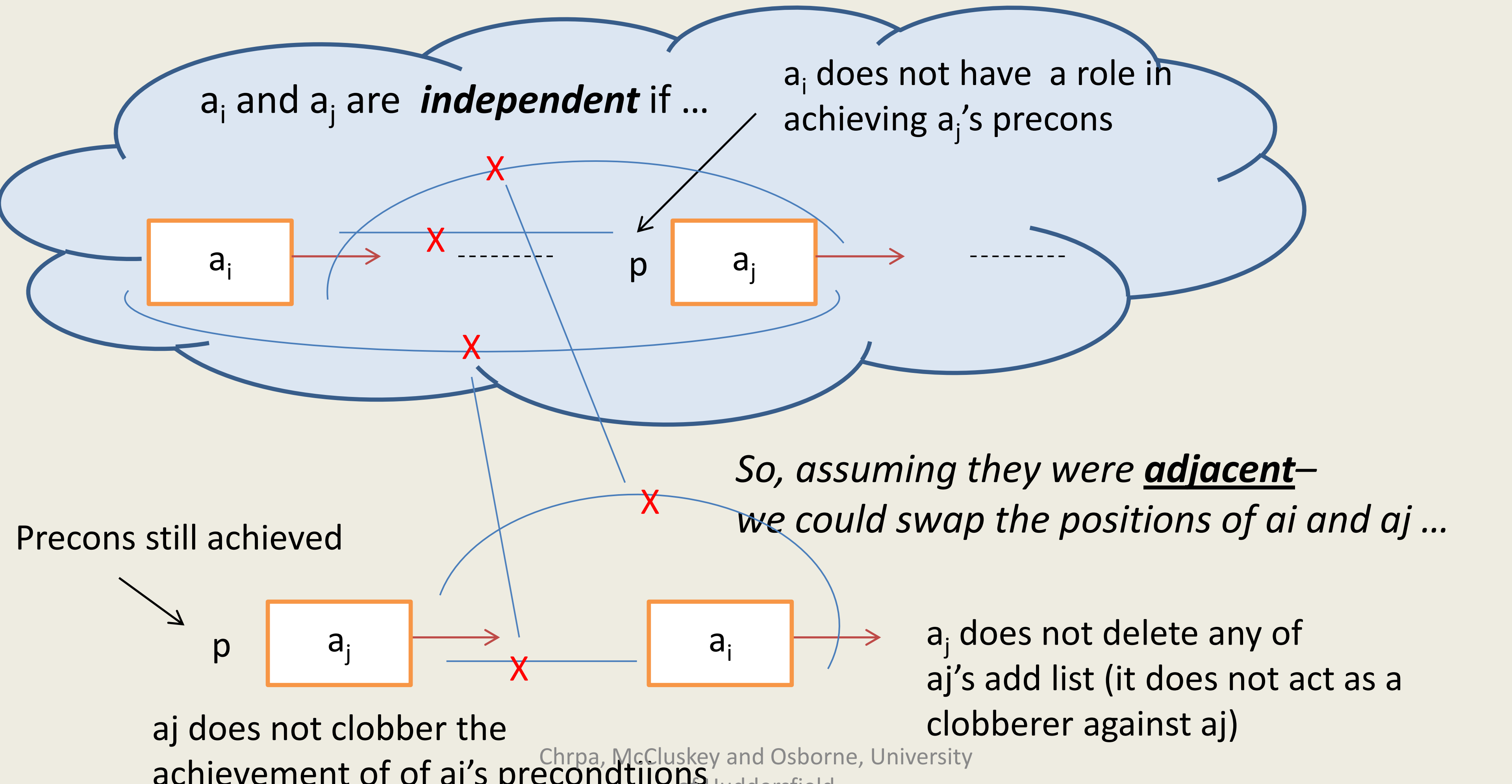


Definition 2

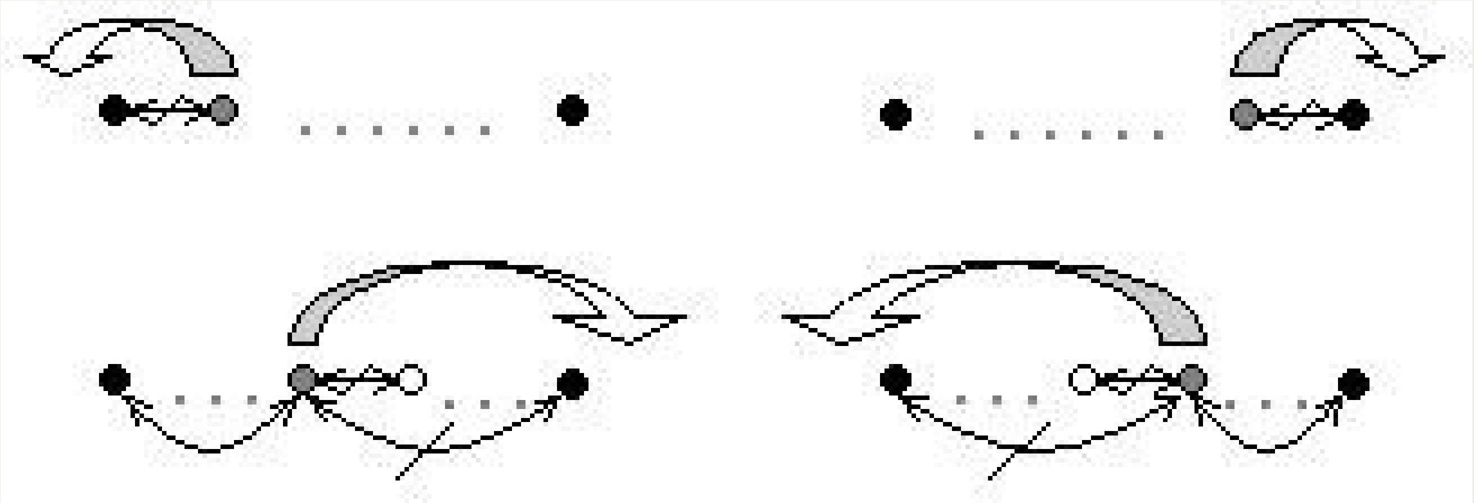


In words, a_j is not dependent on a_i, the later action does not `clobber` atoms needed by the earlier one, the earlier action does not `clobber` positive effects of the later one

Definition 2



Moving actions to each other – looking for **weak adjacency**



Four different situations for moving the intermediate actions (grey-filled) before or after one of the boundary actions (black-filled).

Replacing (weakly) adjacent actions with one action - **replacability**..

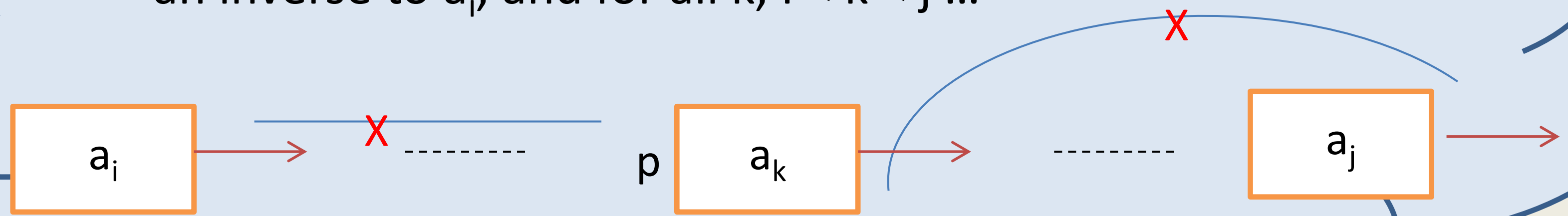
Action (or action sequence) a is ***replaceable*** by a' if

- $pre(a') \subseteq pre(a)$
- $eff^-(a') \subseteq eff^-(a)$
- $eff^+(a') \supseteq eff^+(a)$

[where a is a sequence, pre(a) etc are computed as if a is macro]

Efficiently removing inverses - Proposition 2

a_i and a_j can be safely removed from a plan if a_j is an inverse to a_i, and for all k, I < k < j …



This special case of the independence relation is for when a_j is inverse to a_i so that these inverse pairs can be removed efficiently

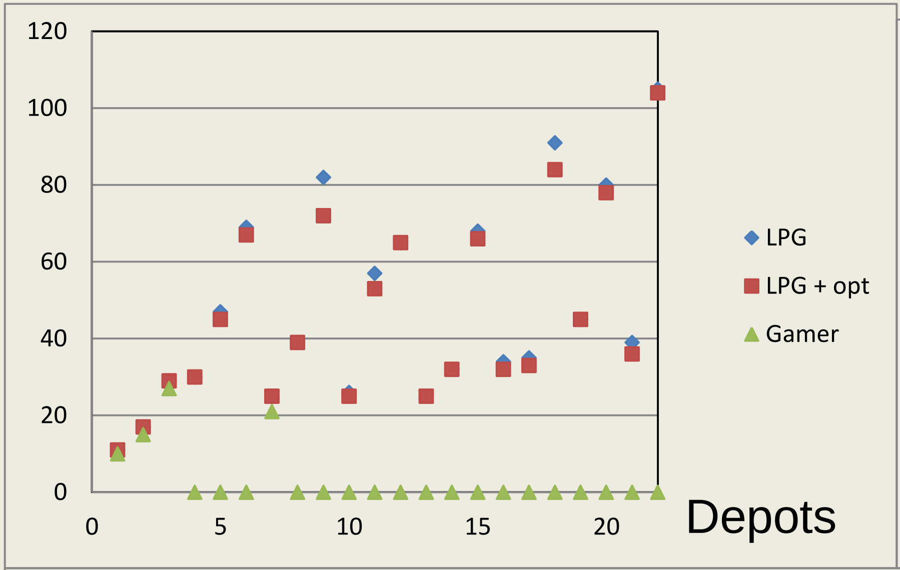
Implemented **algorithm** which inputs plan and shortens it:

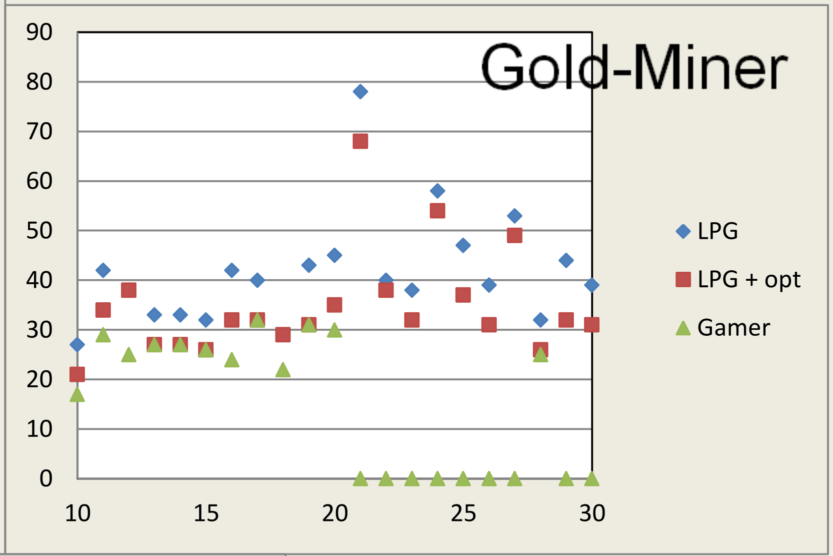
1. Compute action dependencies, and **remove all actions** on which the goal is not dependent .
2. *Repeat*

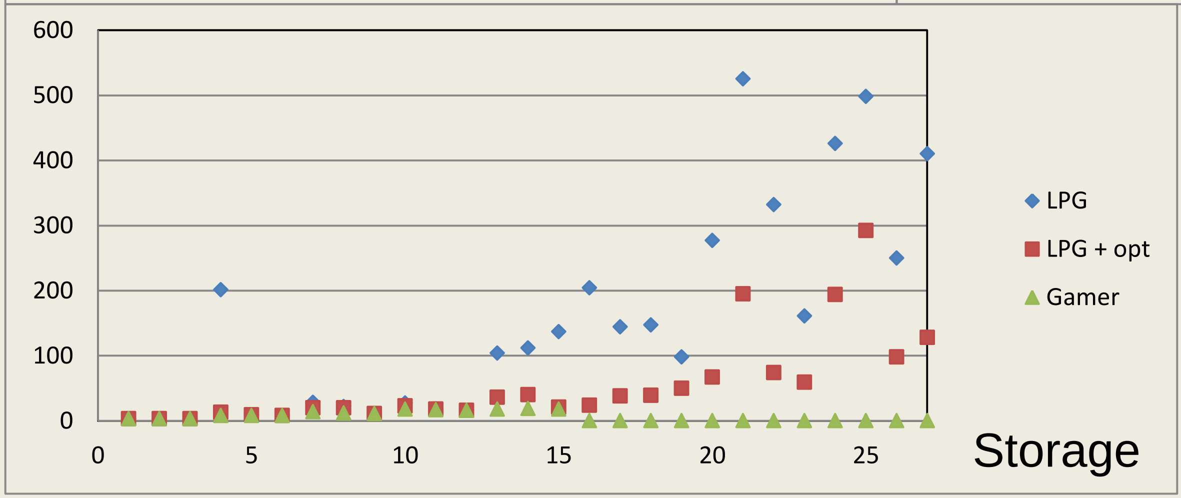
   Identify and **remove all pairs** of inverse actions using Proposition 2

   Until no actions are removed.
3. Compute independencies. Identify pairs of weakly adjacent actions which are replaceable by a single action (and **replace** if applicable).
4. if any pair in 3. is replaced, goto step 2 else end.

Experiments with 5 Domains





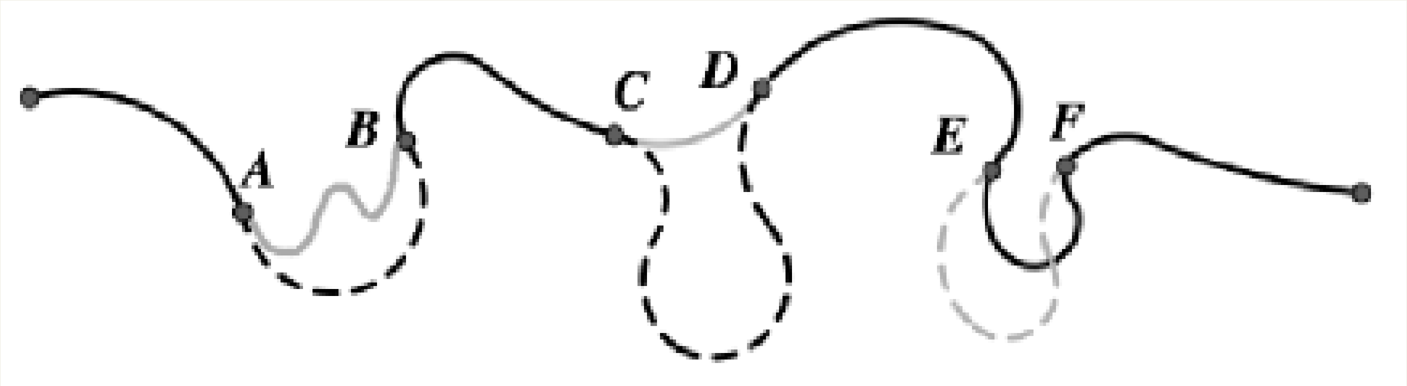


Depots (small)
Gold-Miner (16%)
Storage (63%)
(Zeno and Sattelite c.5%, not shown)

Example Related Work 1: AIRS

- Estrem & Krebsbach – FLAIRS 2012
- Identify (by heuristic) which states (visited during the execution of the plan) might be closer to each other
- Use an optimal or nearly-optimal planner to re-plan between these states

-- comment – for local reduction, includes re-planning, specifically aimed at anytime planning



Example Related Work 2: Neighborhood Graph

- Nakhost & Muller – ICAPS 2010
- Expand each state visited during plan execution to a pre-defined depth
- Then by applying Dijkstra's algorithm find a (better) solution

- comment: as AIRS, aimed at local improvement in parts of the plan

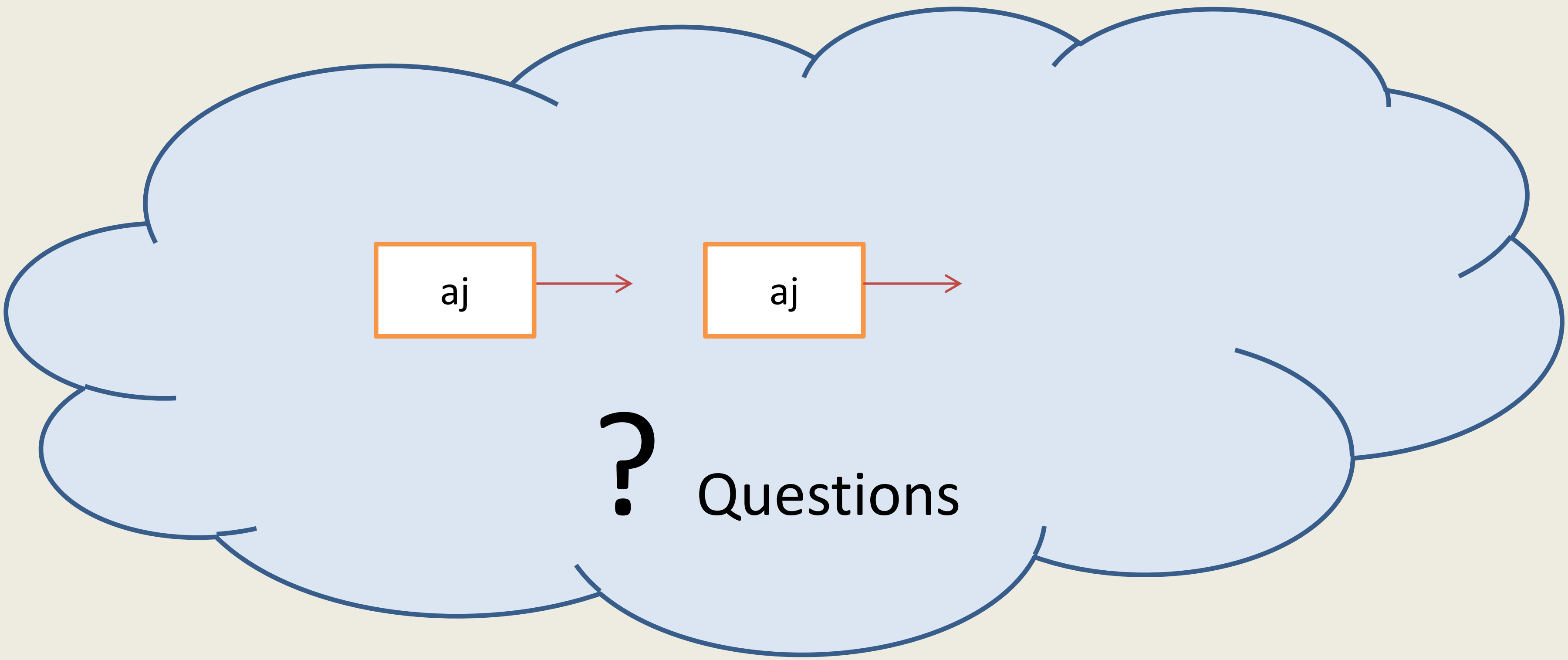
Results and Conclusions 1

- Initial experimental results are promising
- Method is low order polynomial in length of plan (see paper for details)
- particular features – analytical method possible to remove/replace pairs of actions near or far away from each other in the input plan

Results and Conclusions 2

- Method in the paper cannot deal with some nesting scenarios e.g. cannot remove these pairs of inverse actions sucessively (pair by pair) but all together:

[…,pickup(a), .., stack(a,b), .., pickup(c), .., stack(c,d), …, unstack(a,b), … , putdown(a)]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? Questions