ICAPS - PlanRob 2013

Delegating Motion Planning to the Task PLanner

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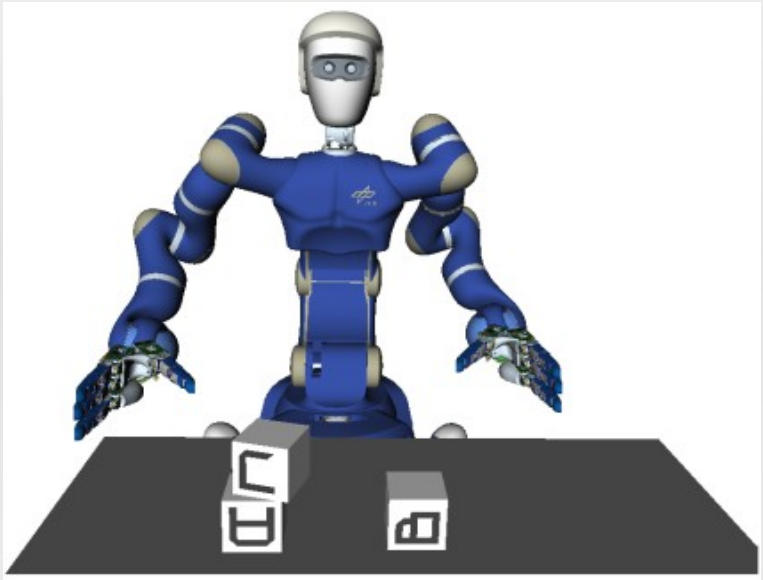
Örebro University - Sweden

Outline



1. Designing the domain
   - symbolic-- geometric++
   - symbolic++ geometric--
2. Choosing a plan
   - using simple metrics
   - using a simplified geometric reasoner
3. Experimental results

Designing the domain

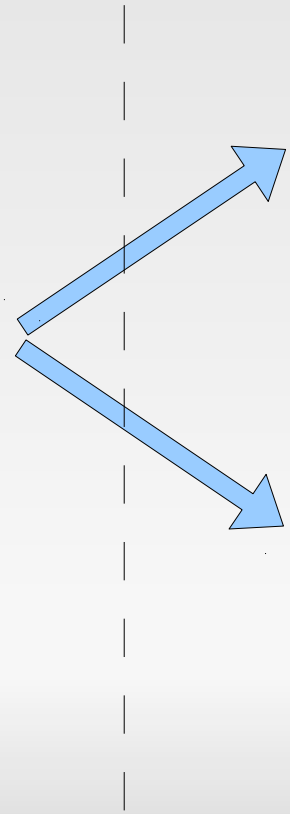
- Emphasis on geometric reasoning
- Delegating geometric reasoning to the task planner

Designing the domain

- Emphasis on geometric reasoning
- Delegating geometric reasoning to the task planner

A simple planning domain

```
Pick block_B
Place block_B block_A
Pick block_C
...
```



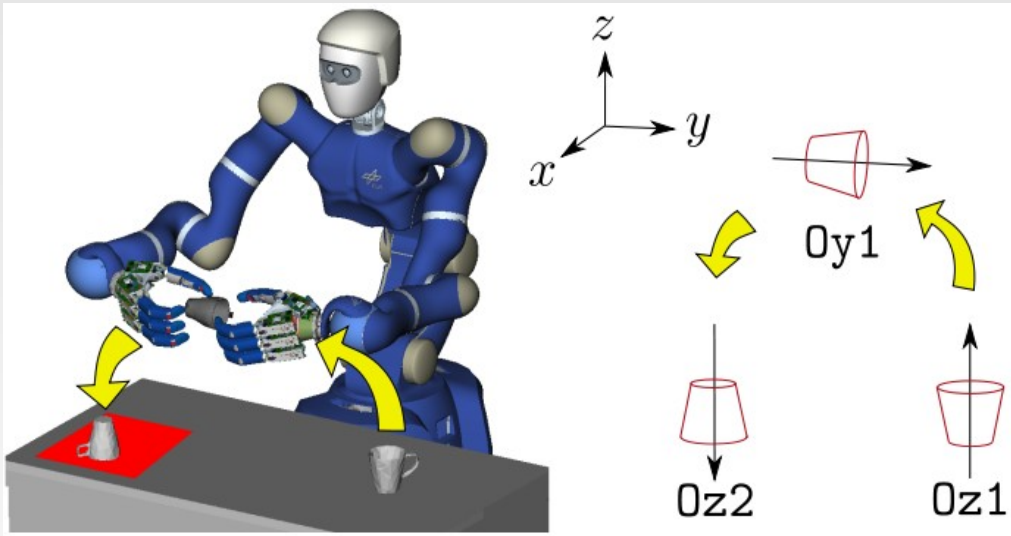
Dual-arm
motion planner

Re-grasp planner

Designing the domain

- Emphasis on geometric reasoning
- Delegating geometric reasoning to the task planner

A complex planning domain




```
pick left top Oz1 cup1
place_regrasp left top Oy1 cup1
pick_regrasp right bottom Oy1 cup1
place right bottom tray Oz2 cup1
...
```

side grasp-type coarse orientation

Predicates for coarse geometric reasoning:

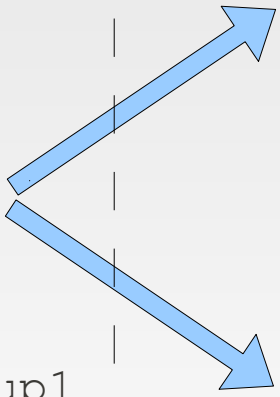
```
(is oriented ?obj ?axis)
(graspable ?obj ?grasp)
(allow regrasp ?axis ?grasp ?side)
```

Designing the domain

- Emphasis on geometric reasoning
- Delegating geometric reasoning to the task planner

A complex planning domain

```
pick left top Oz1 cup1
place_regrasp left top Oy1 cup1
pick_regrasp right bottom Oy1 cup1
place right bottom tray Oz2 cup1
...
```



Single-arm motion planner

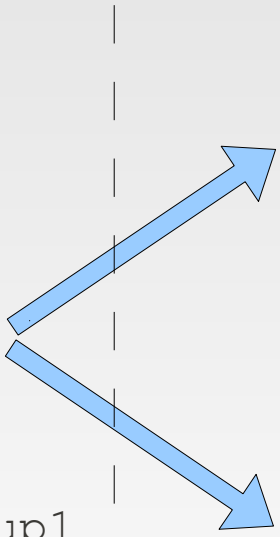
No re-grasp planner

Designing the domain

- Emphasis on geometric reasoning
- Delegating geometric reasoning to the task planner

A complex planning domain

```
pick left top Oz1 cup1
place_regrasp left top Oy1 cup1
pick_regrasp right bottom Oy1 cup1
place right bottom tray Oz2 cup1
...
```

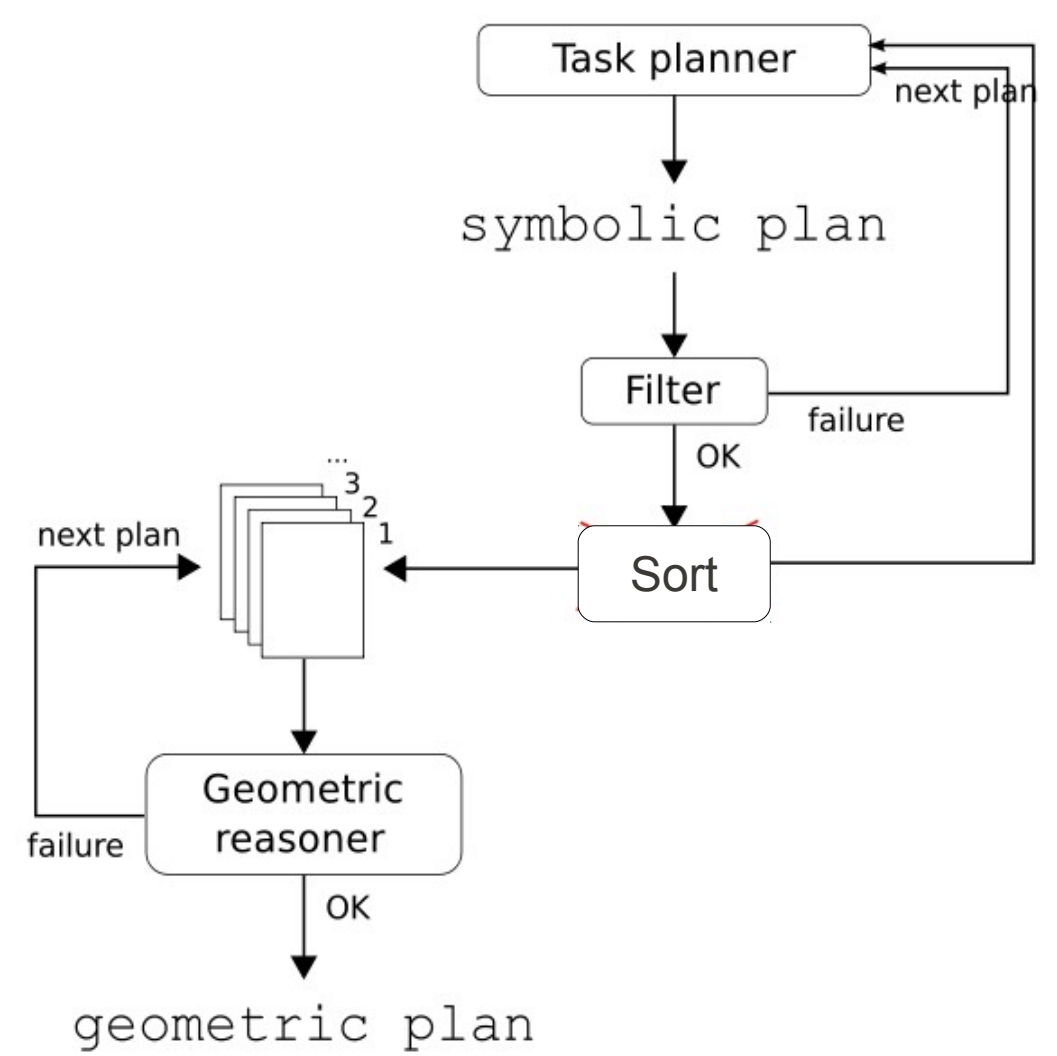


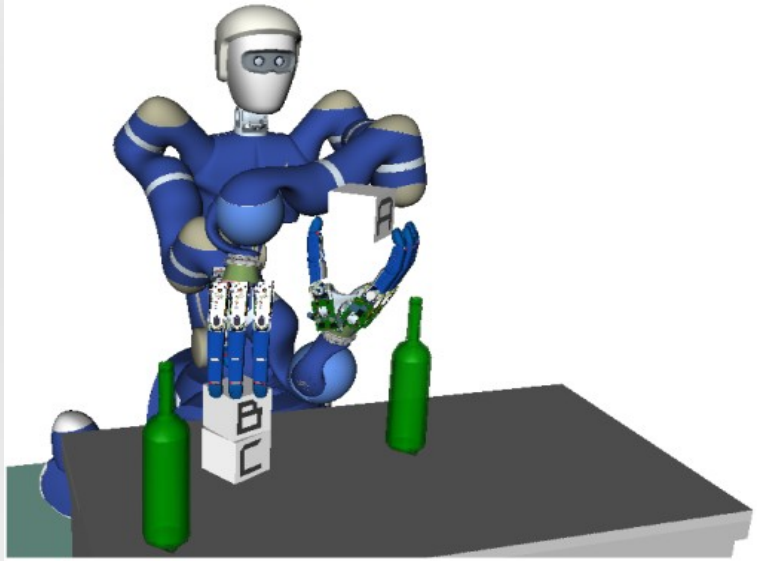
Single-arm motion planner

No re-grasp planner

→ Many plans achieve the goal, which one do we choose?

Choosing a plan

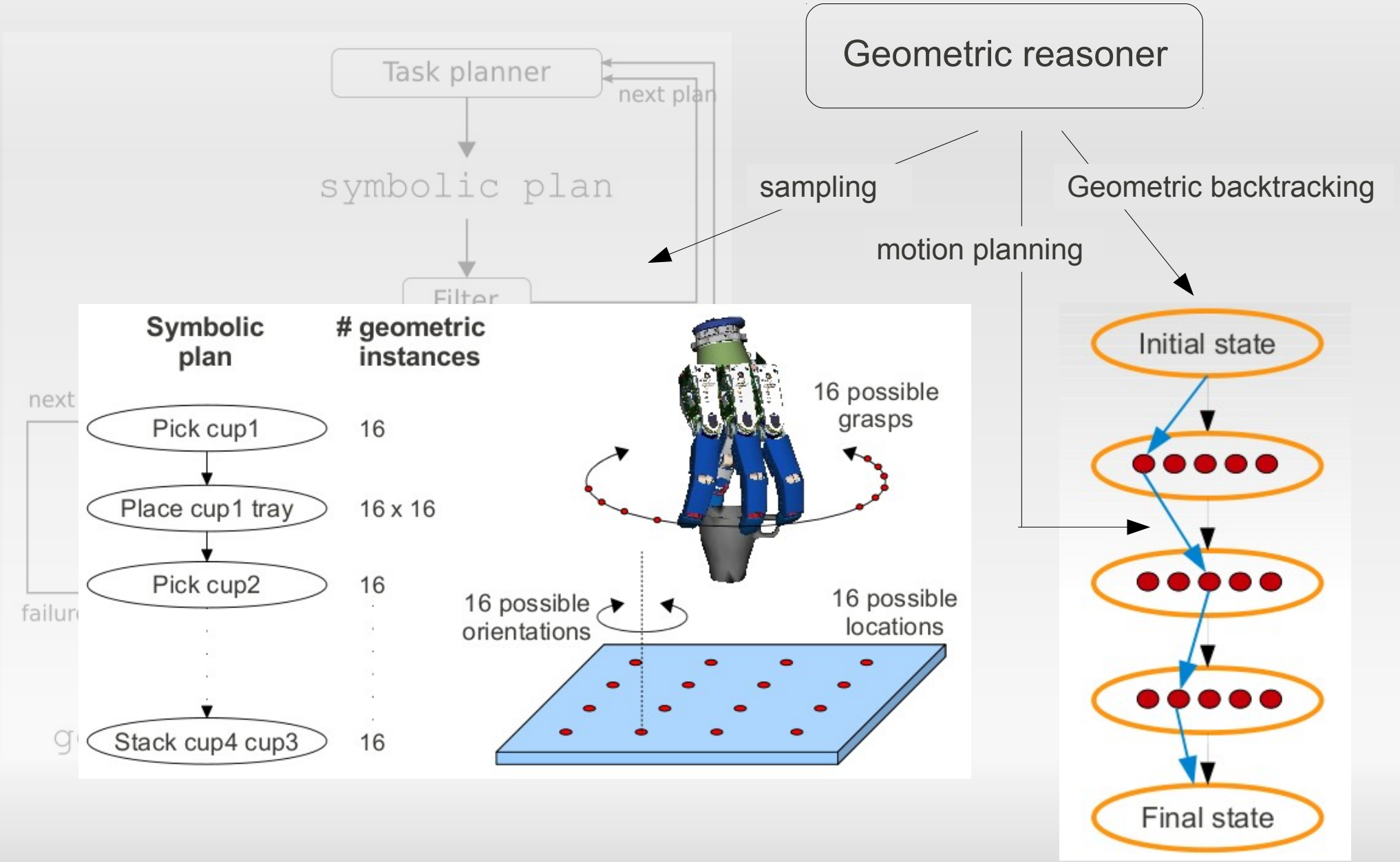




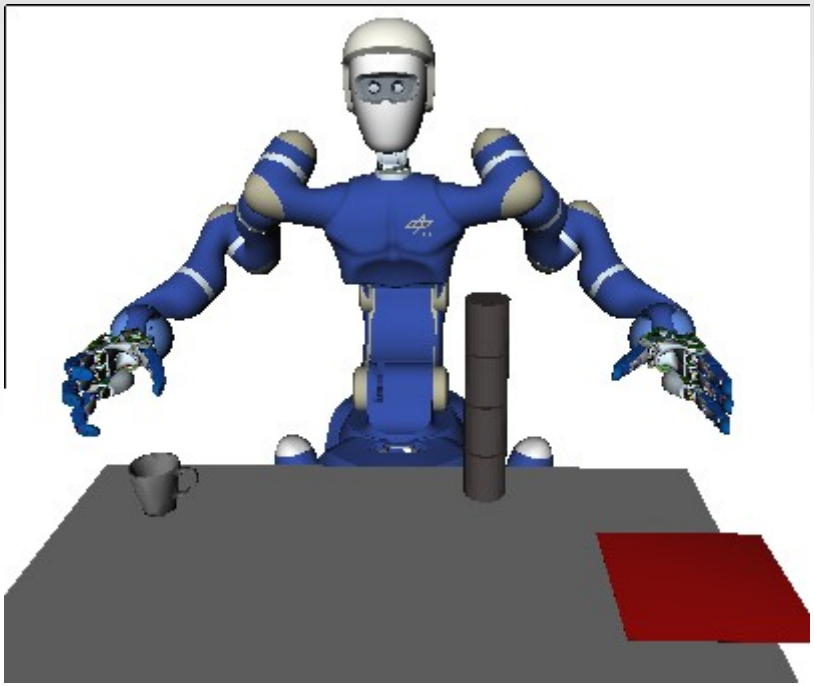
An example of geometrically difficult plan.

```
Oz1: up to 1min
Oy1: 5s
```

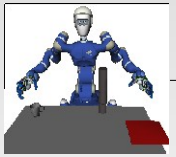
Choosing a plan



Geometric Backtracking



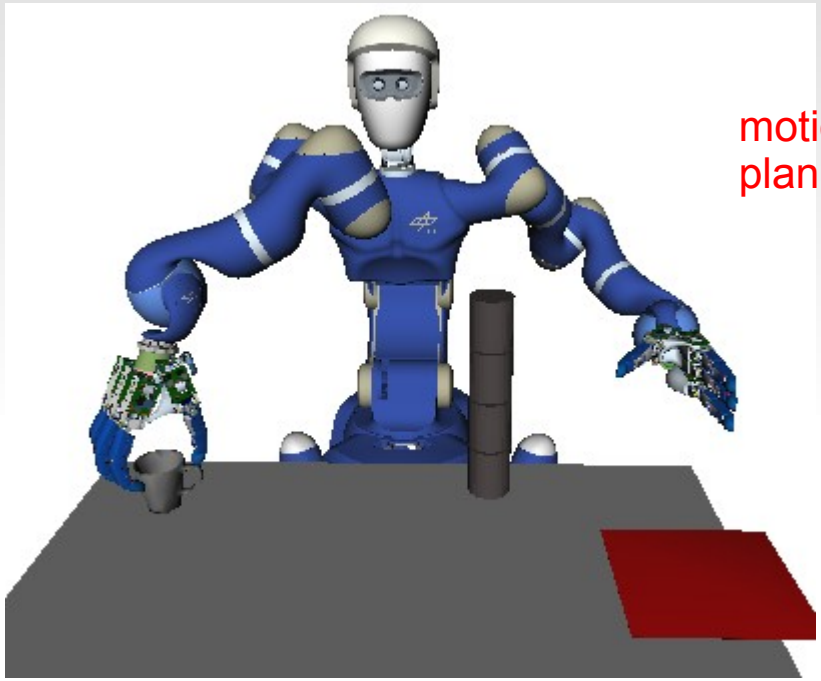
Geometric world model



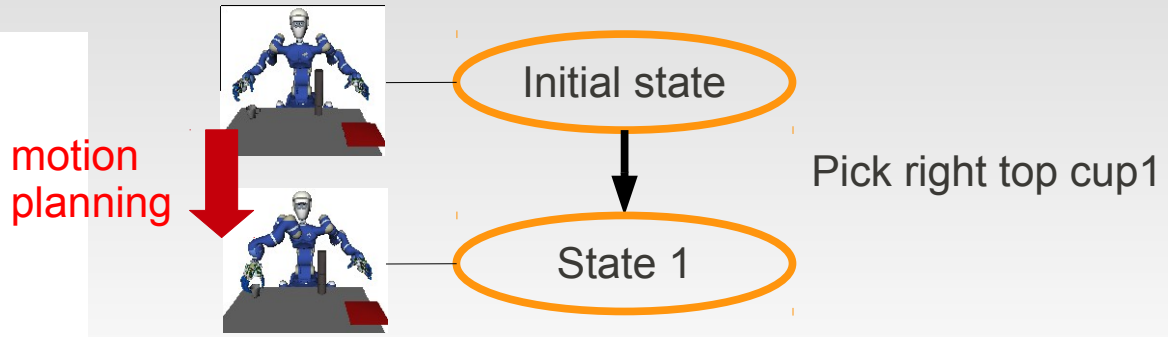
Initial state

On cup1 table
Empty left_hand
Empty right_hand
Graspable cup1
Is_location red_tray
...

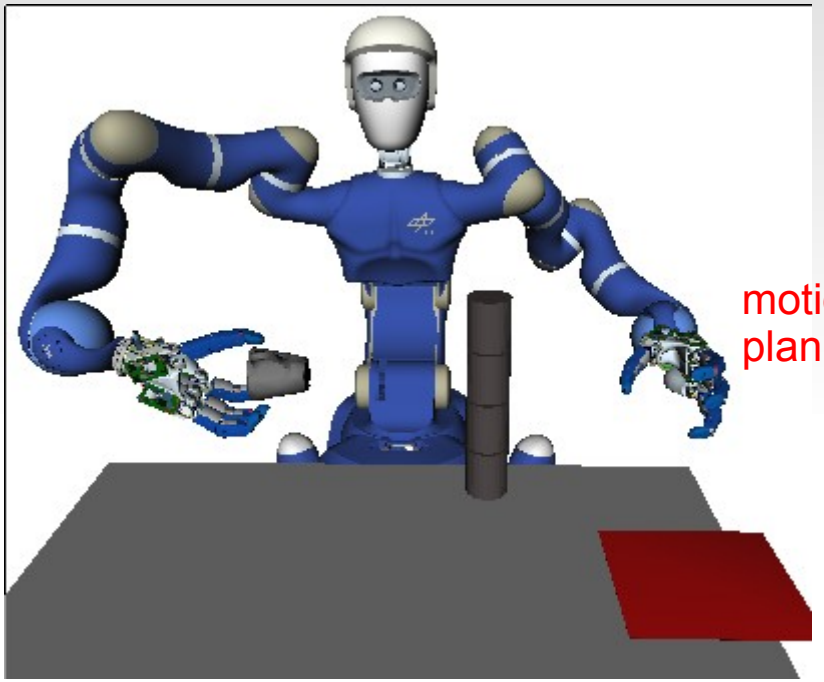
Geometric Backtracking



Geometric world model



Geometric Backtracking



Geometric world model

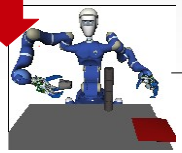
motion planning

Initial state

Pick right top cup1

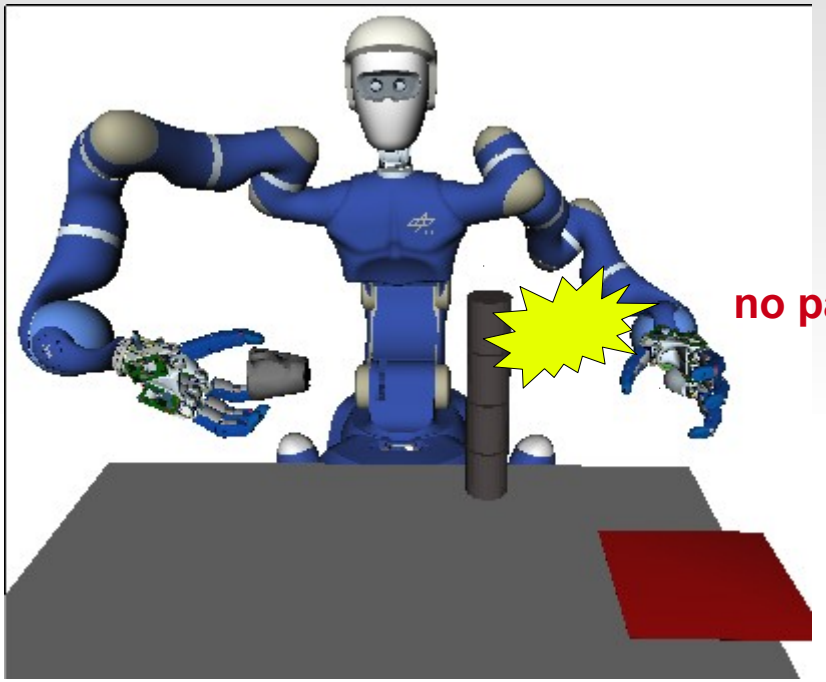
State 1

Place right re-grasp

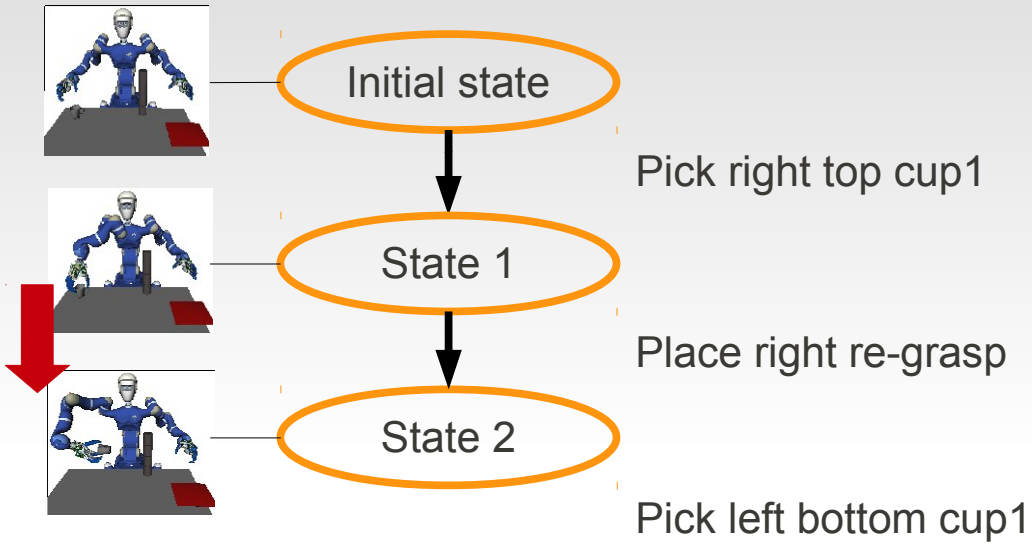


State 2

Geometric Backtracking

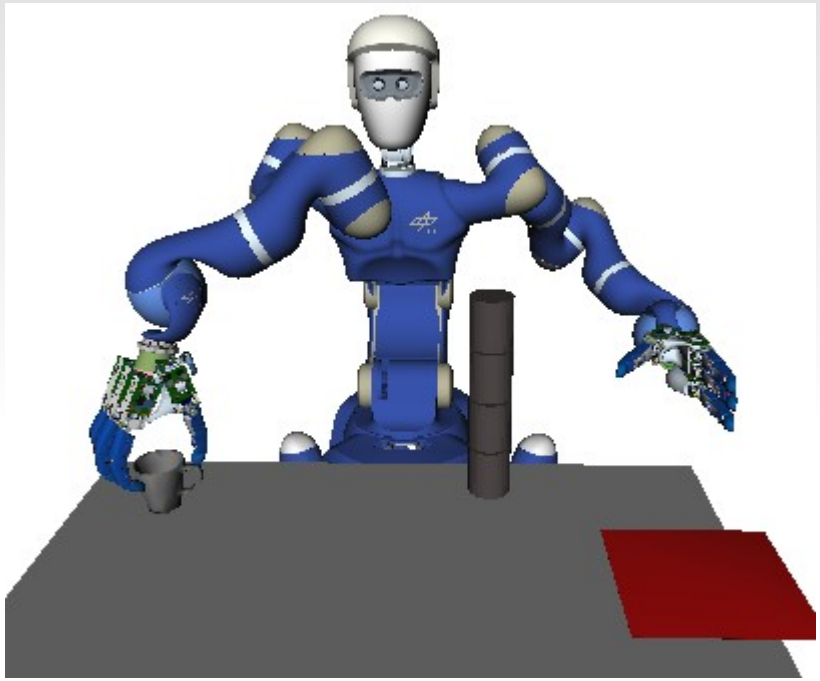


Geometric world model

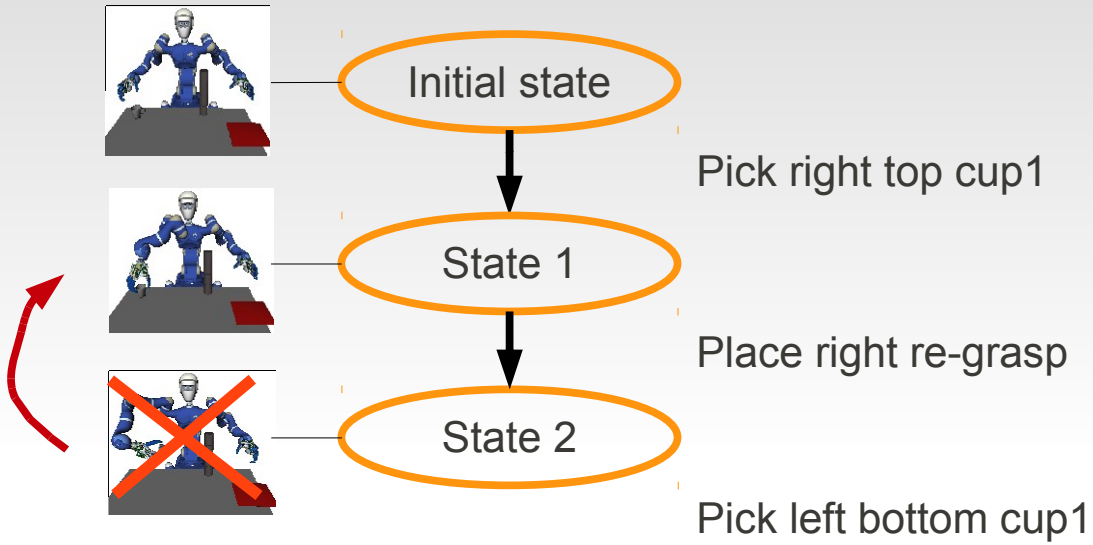


Aborting search at this level would lead to **incompleteness**!
We have to try alternative geometric instantiations of the symbolic actions.

Geometric Backtracking

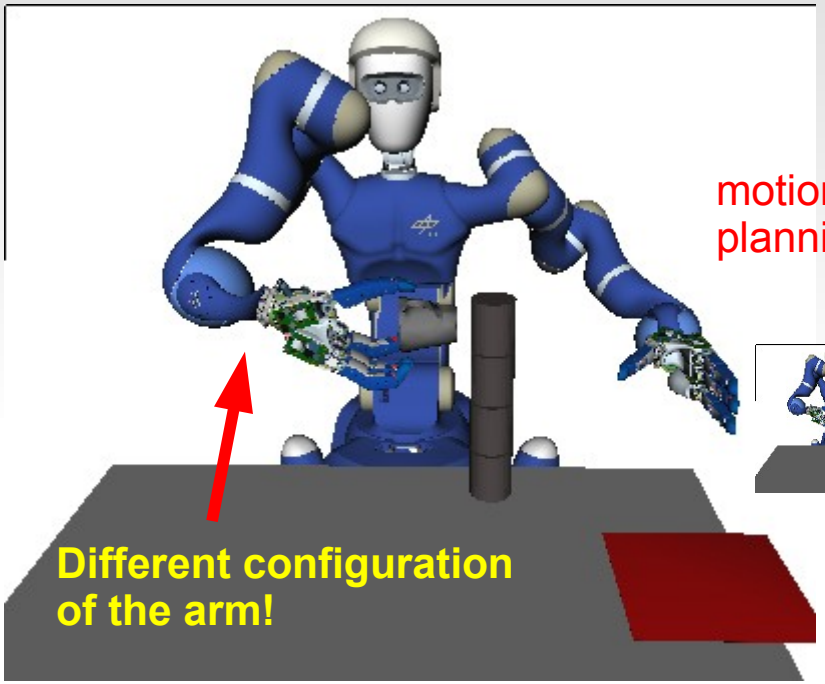


Geometric world model

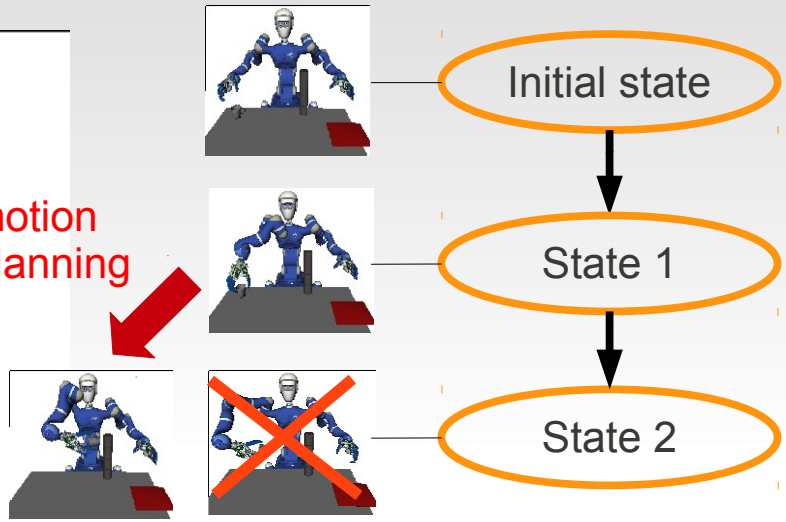


Geometric backtracking

Geometric Backtracking

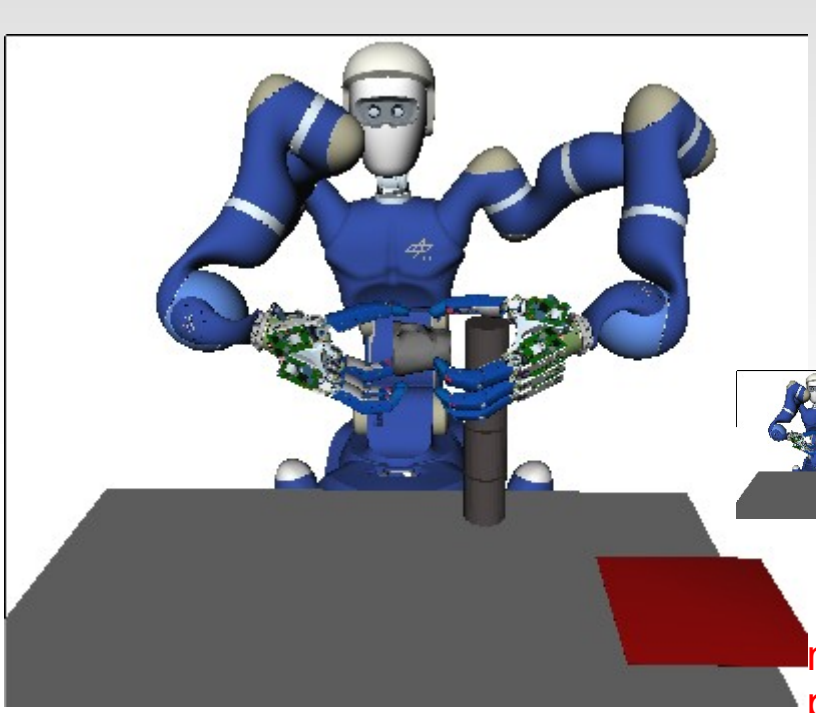


Geometric world model

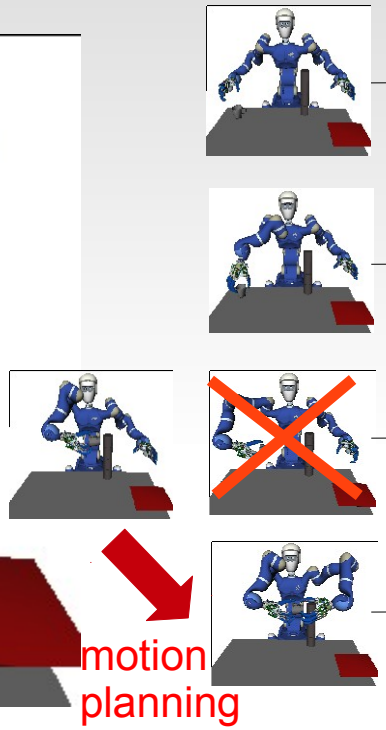


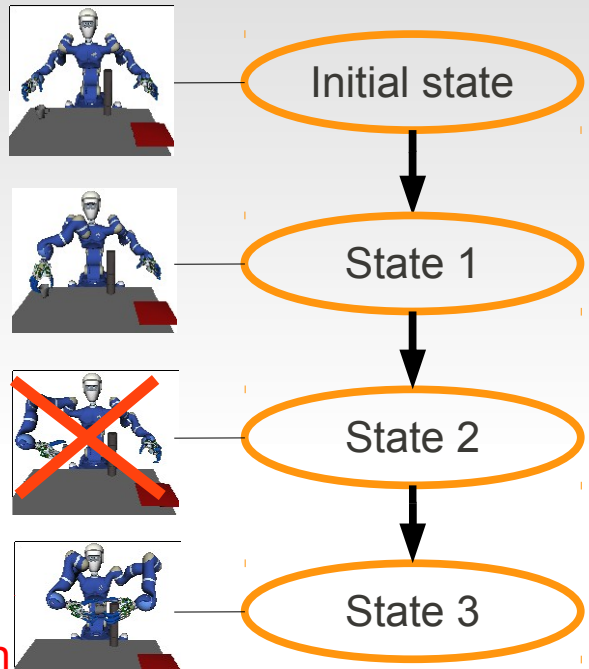
Geometric backtracking

Geometric Backtracking



Geometric world model





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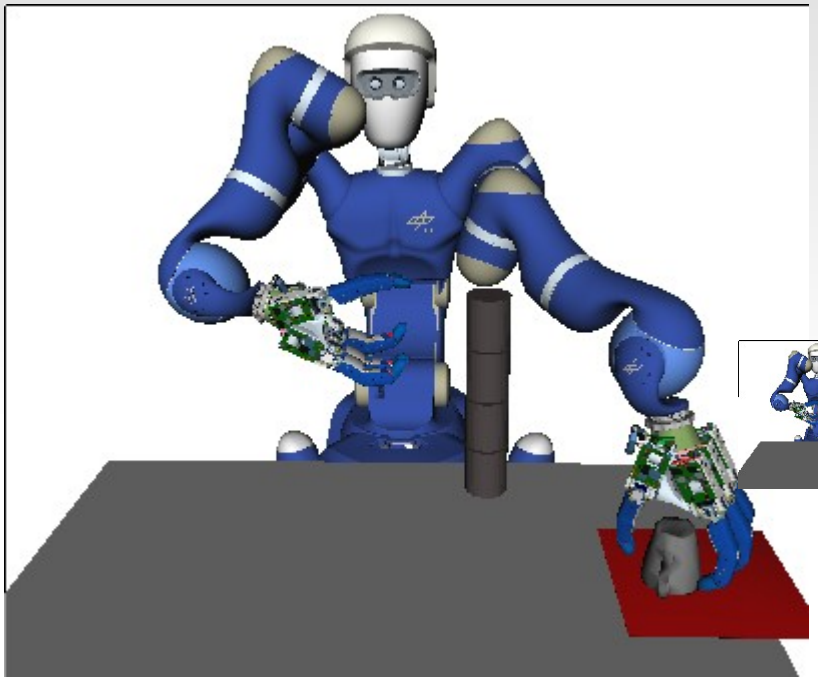


Geometric world model

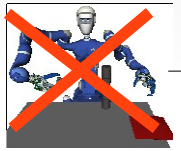
motion planning

Initial state

Pick right top cup1

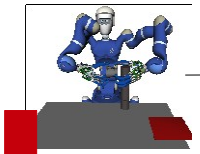
State 1

Place right re-grasp



State 2

Pick left bottom cup1

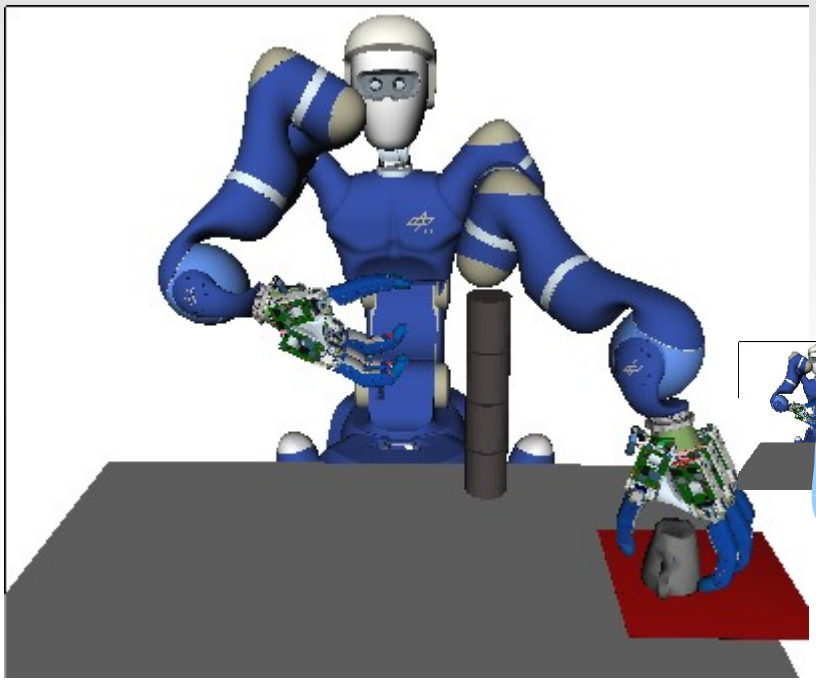


State 3

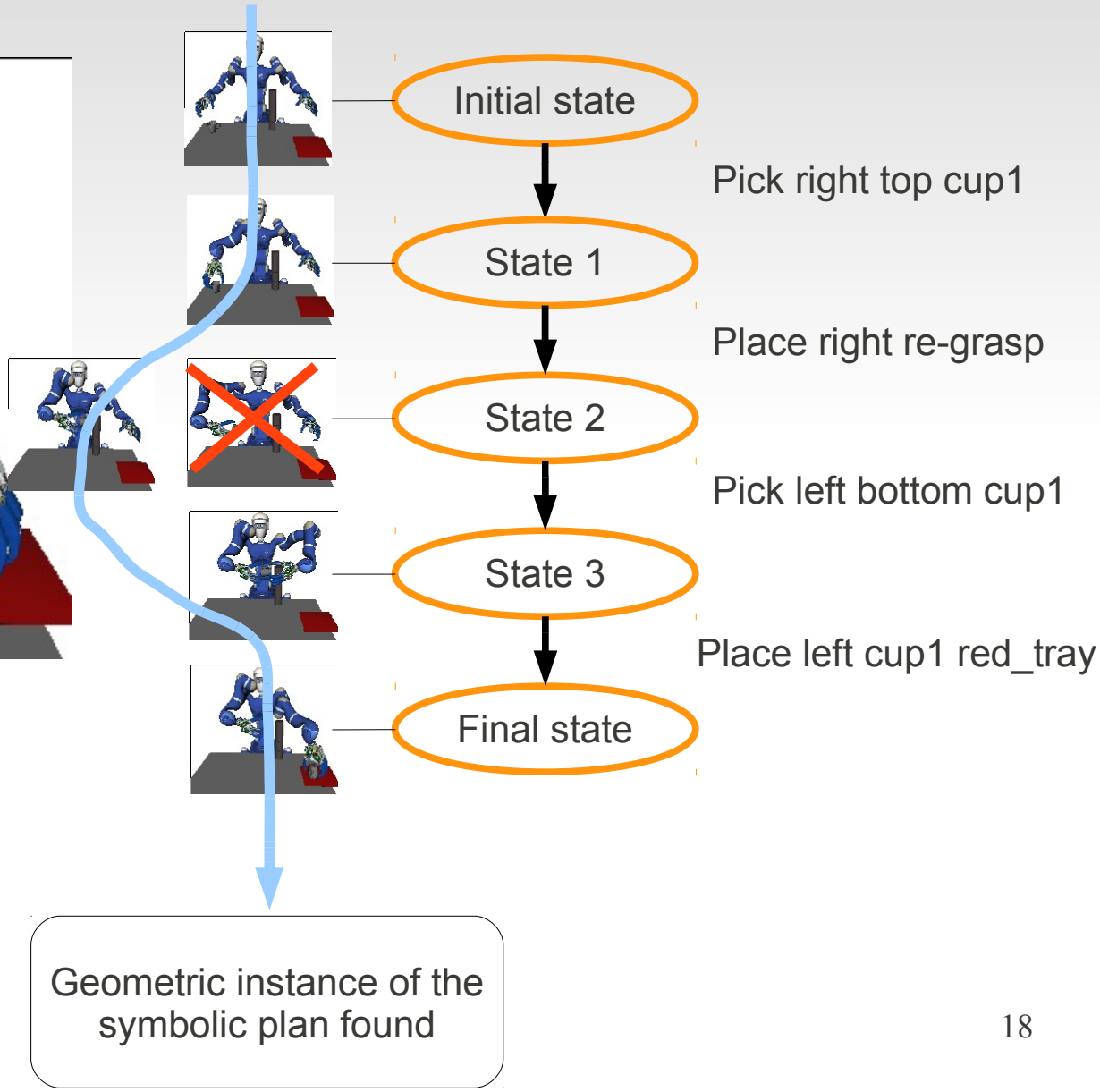
Place left cup1 red_tray

Final state

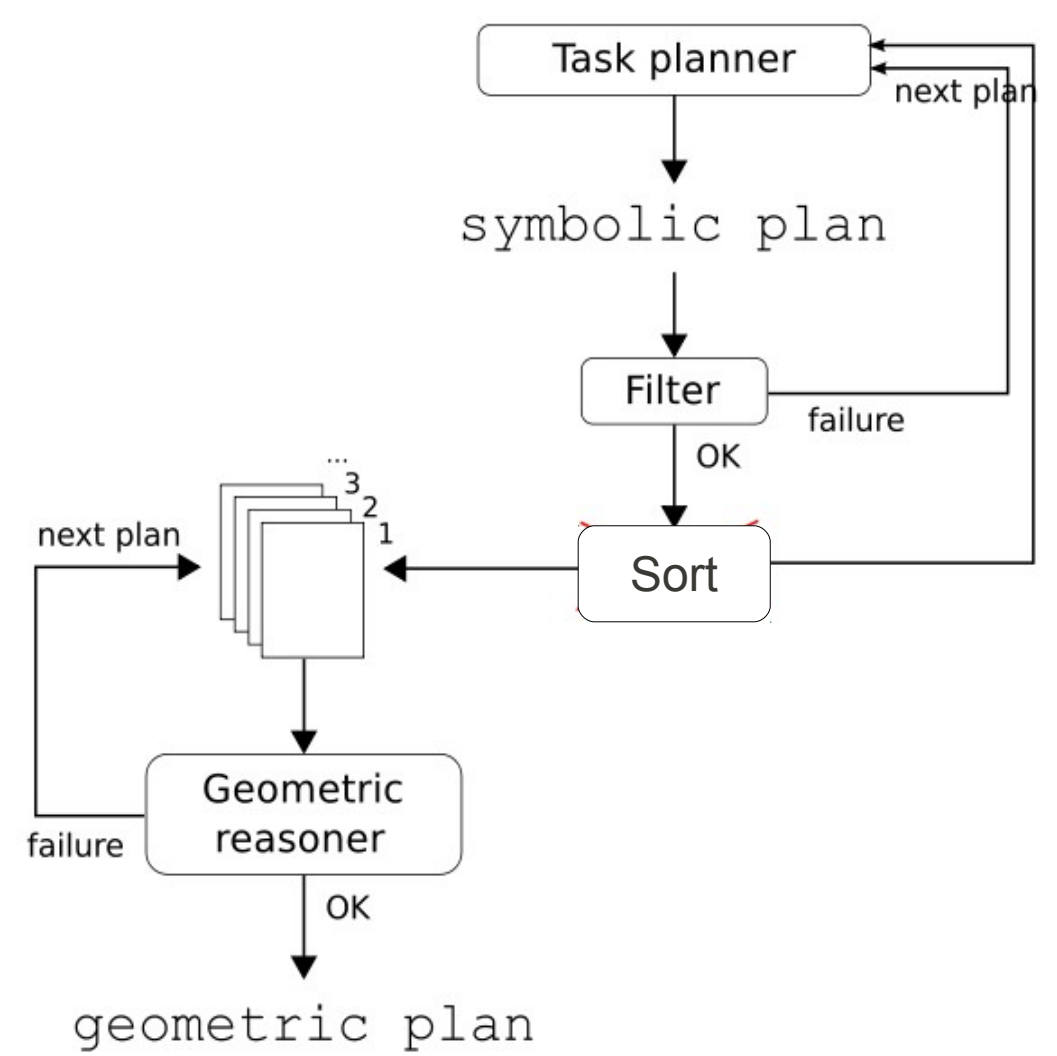
Geometric Backtracking

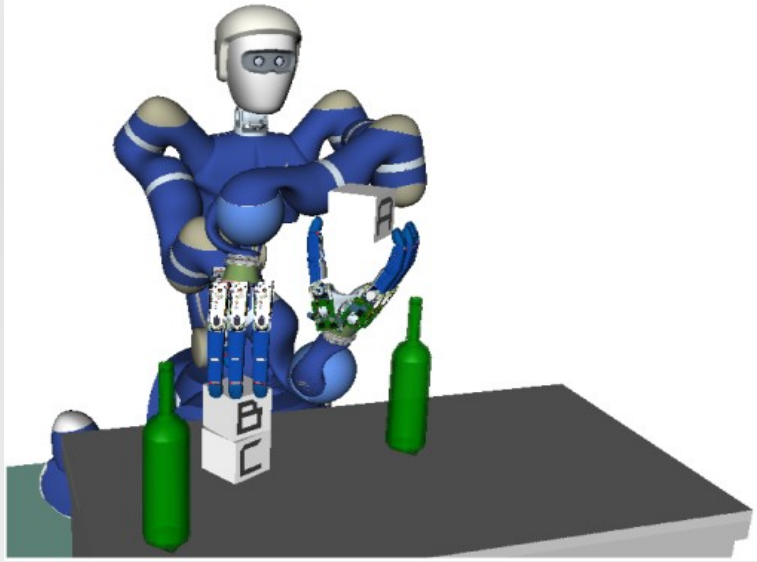


Geometric world model



Choosing a plan

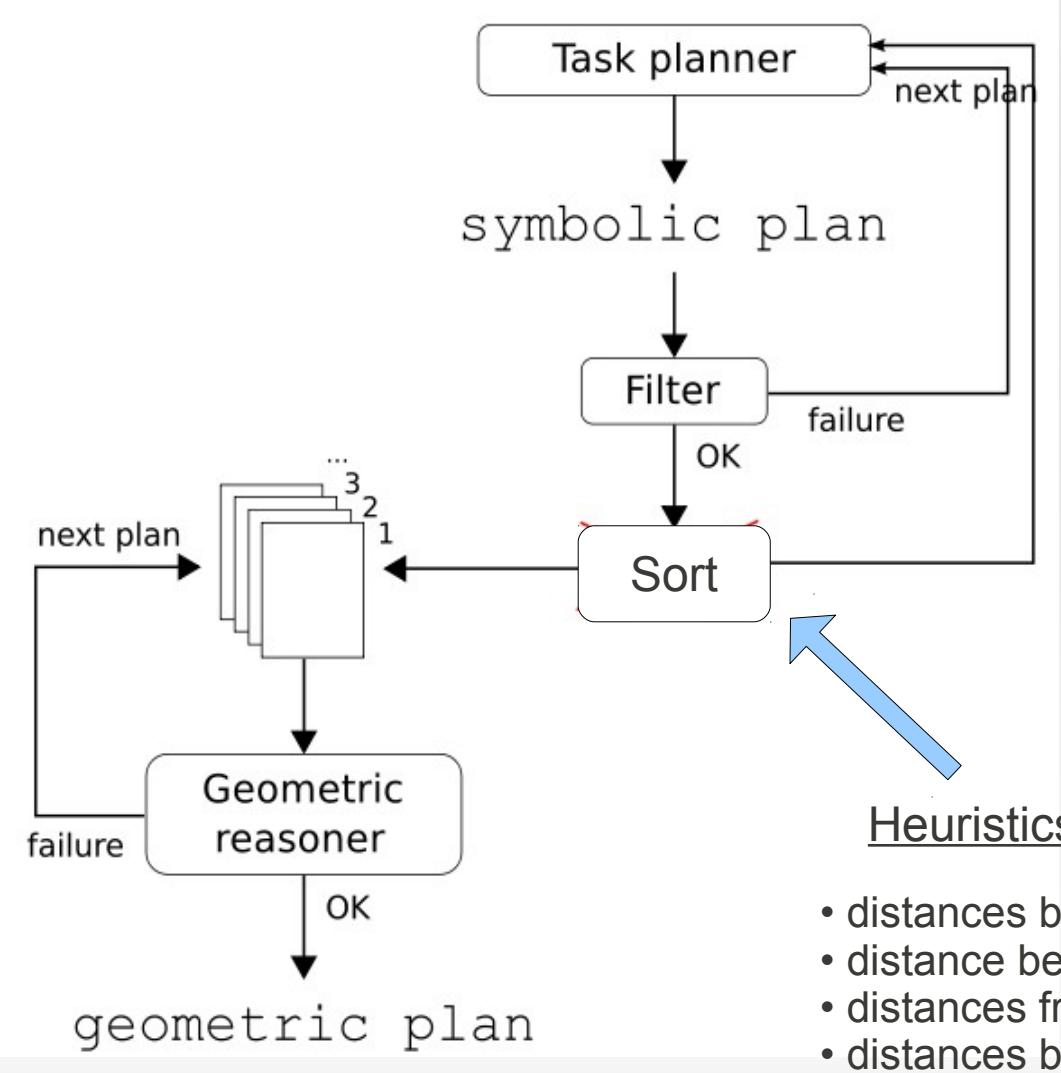


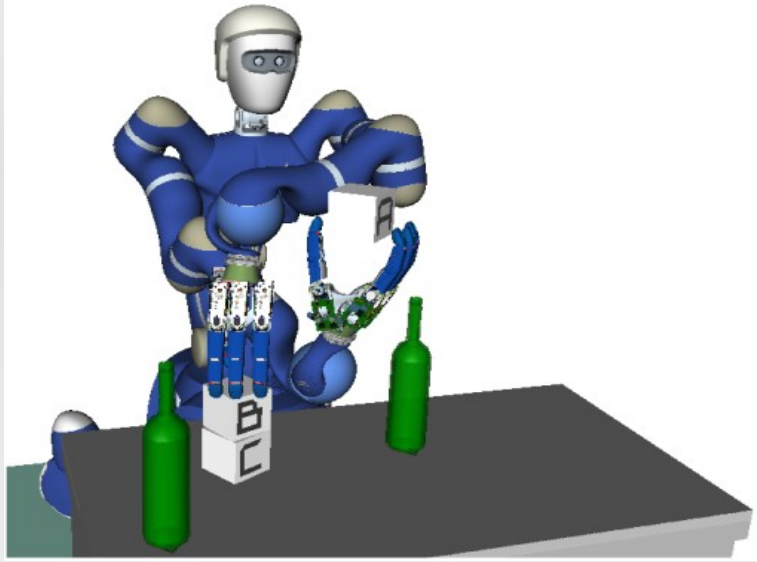


An example of geometrically difficult plan.

```
Oz1: up to 1 min
Oy1: 5s
```

Choosing a plan

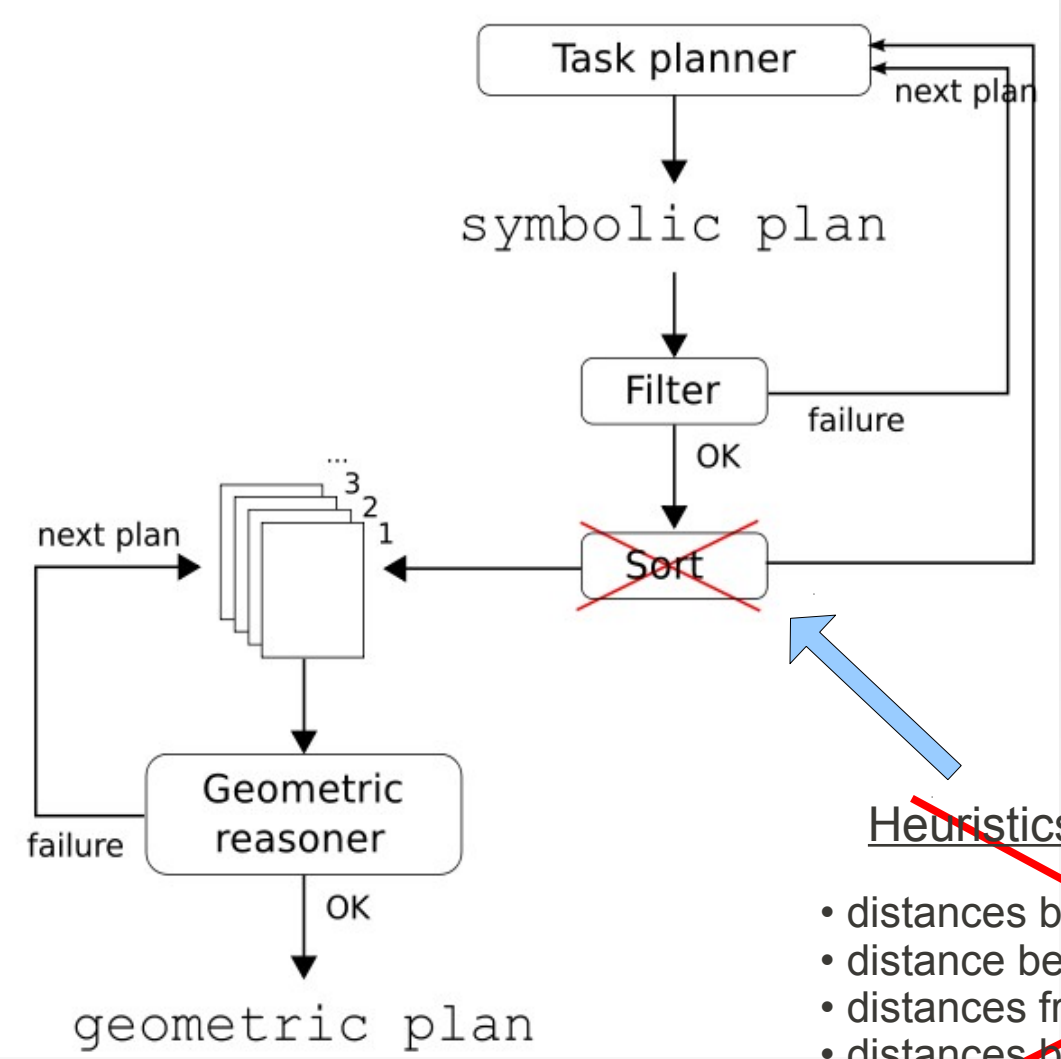


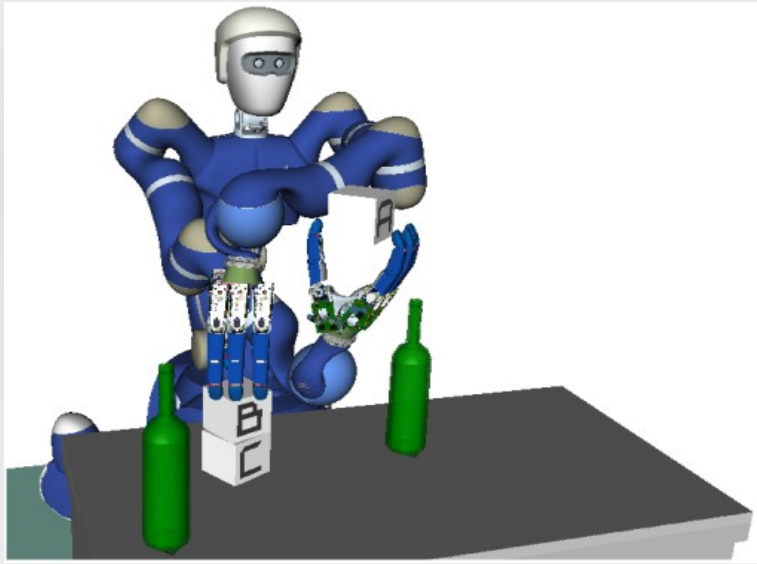


Heuristics for sorting the plans:

- distances between the links of left and right arm;
- distance between left and right TCP;
- distances from the joint limits;
- distances between all objects and TCPs;
- “crossing” of the arms.

Choosing a plan



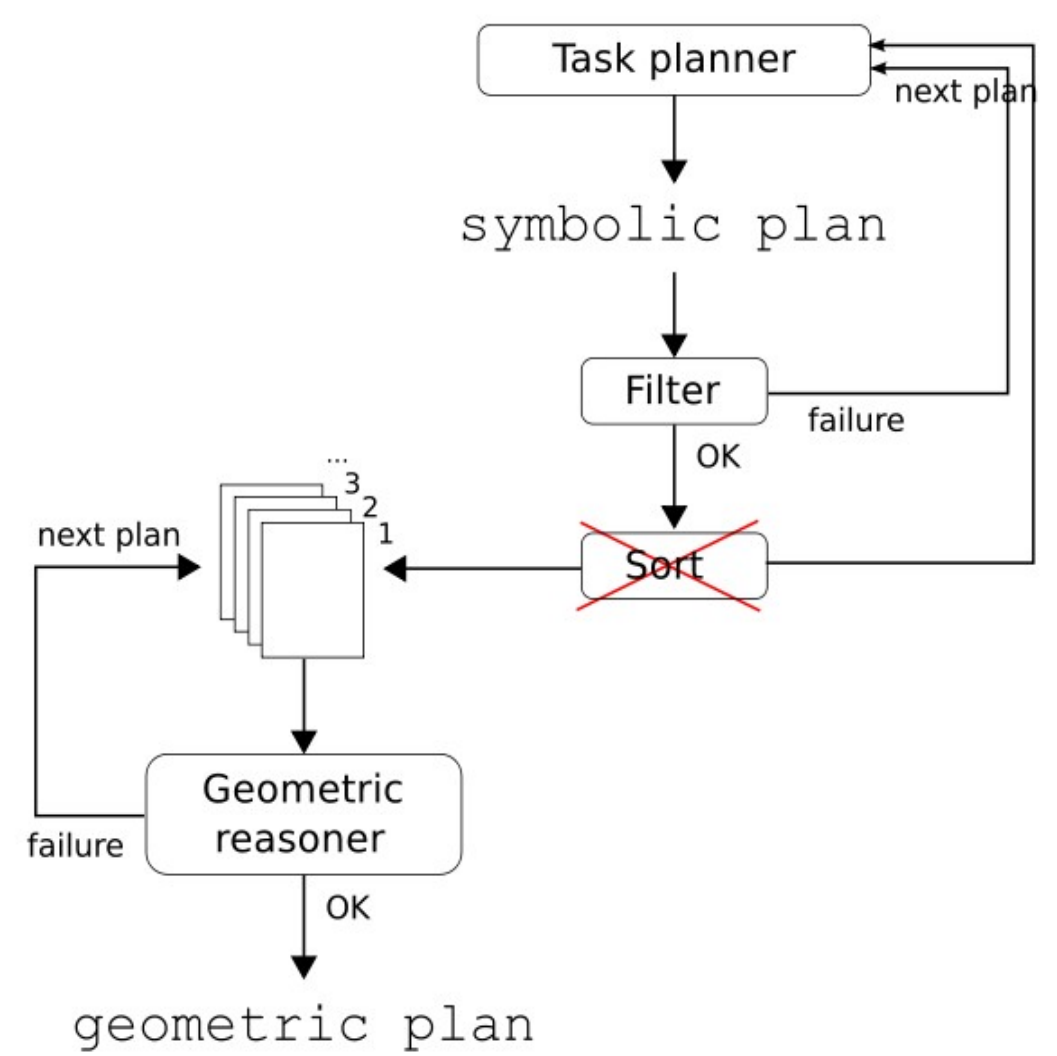


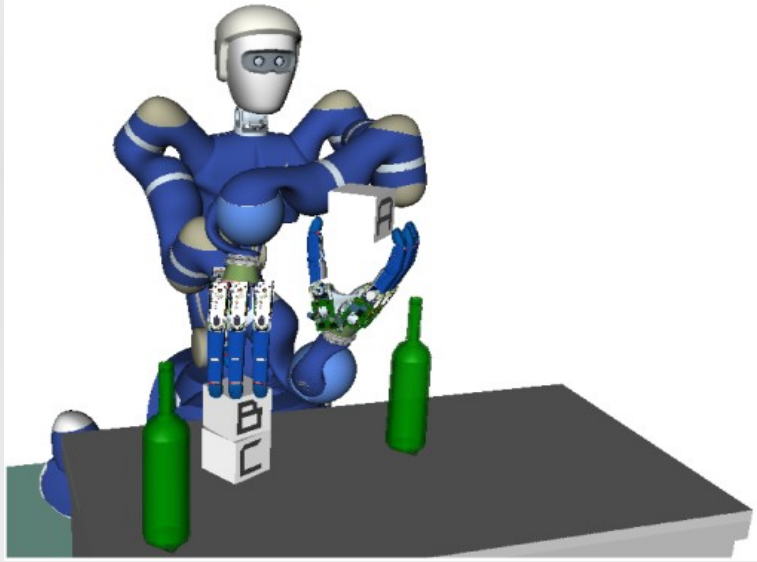
Heuristics for sorting the plans:

- distances between the links of left and right arm;
- distance between left and right TCP;
- distances from the joint limits;
- distances between all objects and TCPs;
- "crossing" of the arms.

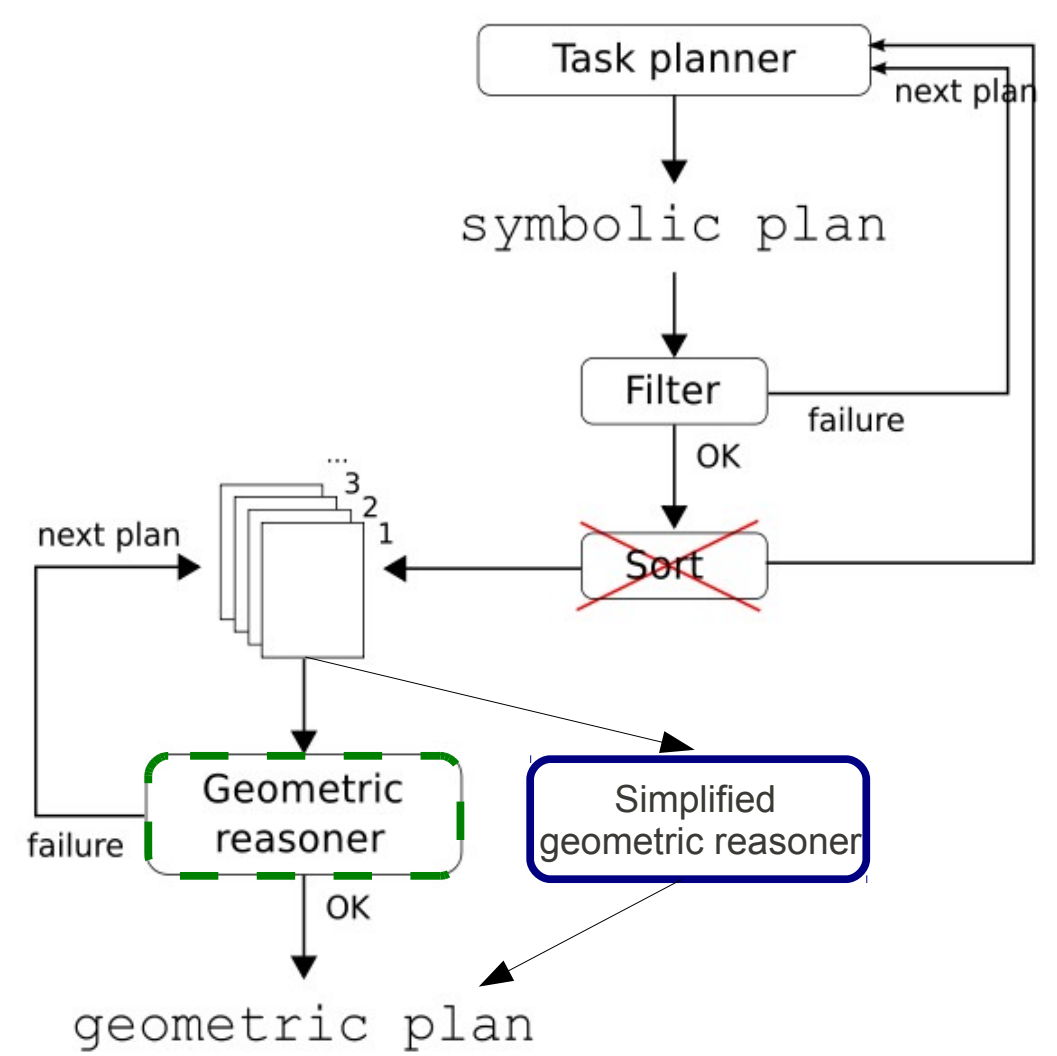
no significant correlation with the actual geometric reasoning effort.

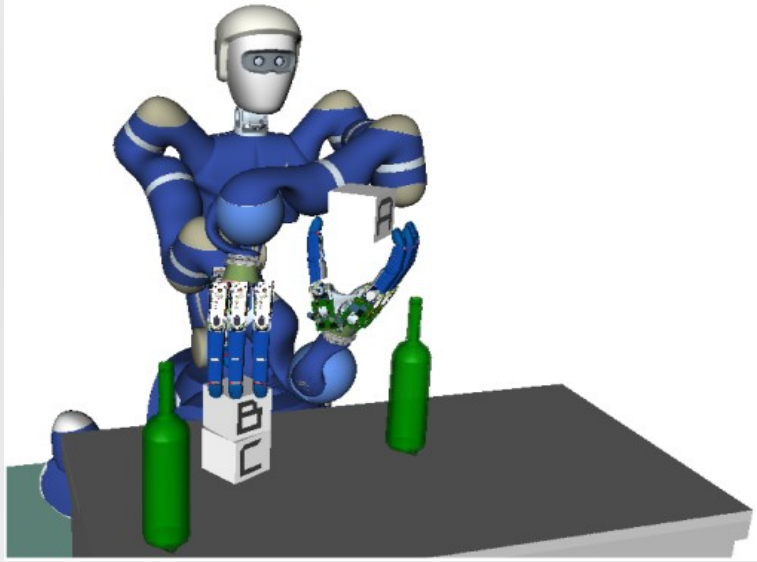
Choosing a plan



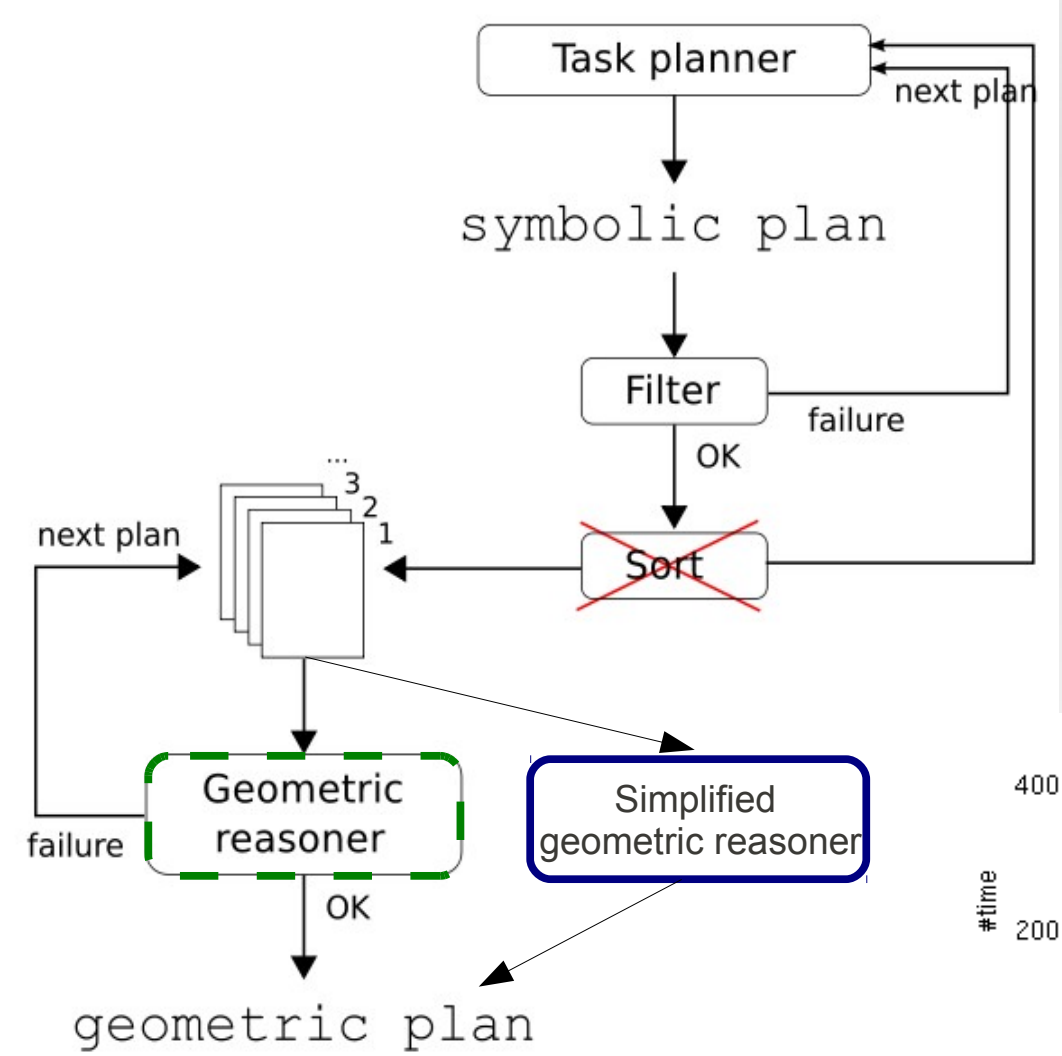


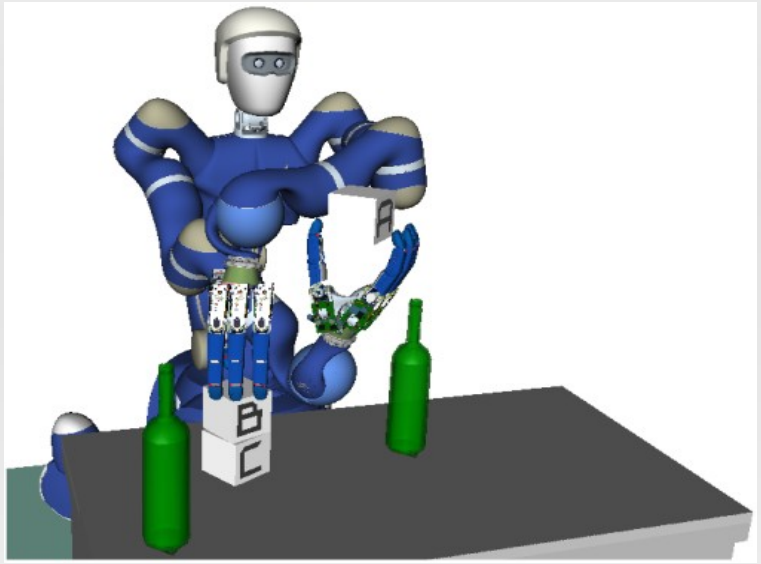
Choosing a plan



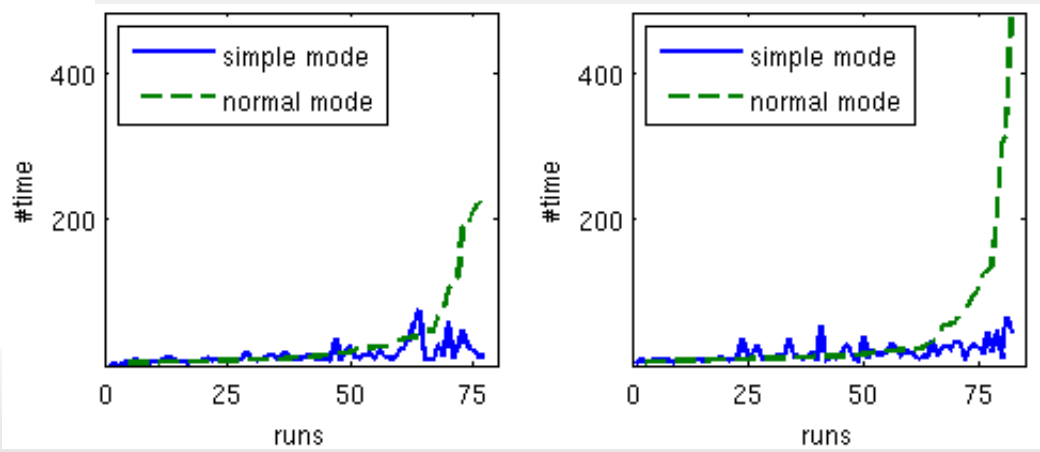


Experimental results





results:



Thank you for your attention.