Delegating Motion Planning to the Task PLanner

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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
...```

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 0y1 cup1
pick_regrasp right bottom 0y1 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

- Task planner
- symbolic plan
- Geometric reasoner
  - sampling
  - Geometric backtracking
  - motion planning

## Symbolic plan

<table>
<thead>
<tr>
<th>Plan</th>
<th># geometric instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick cup1</td>
<td>16</td>
</tr>
<tr>
<td>Place cup1 tray</td>
<td>16 x 16</td>
</tr>
<tr>
<td>Pick cup2</td>
<td>16</td>
</tr>
<tr>
<td>Stack cup4 cup3</td>
<td>16</td>
</tr>
</tbody>
</table>

Initial state

Final state

16 possible grasps

16 possible orientations

16 possible locations
Geometric Backtracking

Initial state

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

Geometric world model
Geometric Backtracking

Geometric world model

Initial state

Pick right top cup1

State 1

motion planning
Geometric Backtracking

Initial state

Pick right top cup1

State 1

Place right re-grasp

State 2

motion planning

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

Initial state

Pick right top cup1

State 1

Place right re-grasp

State 2

Pick left bottom cup1

Geometric backtracking

Geometric world model
Geometric Backtracking

Different configuration of the arm!

Geometric world model

Initial state

State 1

State 2

Pick right top cup1

Place right re-grasp

Pick left bottom cup1

Geometric backtracking
Geometric Backtracking

Geometric world model

Initial state

State 1
Pick right top cup1

State 2
Place right re-grasp

State 3
Pick left bottom cup1

OK
Geometric Backtracking

Initial state
- Pick right top cup1
- Place right re-grasp

State 1
- Pick left bottom cup1

State 2
- Place left cup1 red_tray

State 3
- Final state

Geometric world model

motion planning
Geometric Backtracking

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 instance of the symbolic plan found

Geometric world model
Choosing a plan

An example of geometrically difficult plan.

Oz1: up to 1 min
Oy1: 5s
Choosing a plan

- 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.

Heuristics for sorting the plans:
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

Task planner

symbolic plan

Filter

OK

failure

next plan

next plan

1 2 3

Sort

failure

Geometric reasoner

OK

geometric plan
Choosing a plan

Task planner

symbolic plan

Filter

OK

Sort

next plan

failure

next plan

failure

geometric plan

Simplified geometric reasoner

Geometric reasoner

1

2

3

OK
Experimental results

Simplified geometric reasoner results:

Task planner
\[\text{symbolic plan}\]
Filter
\[\text{OK failure}\]
Sort
\[\text{next plan}\]

Geometric reasoner
\[\text{failure OK geometric plan}\]
Simplified geometric reasoner

results:
Thank you for your attention.