Manipulation Planning

A Geometrical Formulation
Manipulation Planning

- Hanoï Tower Problem
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- Hanoï Tower Problem: a “pure” combinatorial problem

Finite state space
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- A disk manipulating another disk
Manipulation Planning

• A disk manipulating another disk

The state space is no more finite!
Manipulation Space

- Any solution appears a collision-free path in the composite space \((CS_{Robot} \; CS_{Object})_{Admissible}\)

- However: any path in \((CS_{Robot} \; CS_{Object})_{Admissible}\) is not necessarily a manipulation path
Manipulation Space

- Any solution appears a collision-free path in the composite space \((CS^{Robot} \quad CS^{Object})_{Admissible}\)

- What is the topological structure of the manipulation space?

- How to translate the continuous problem into a combinatorial one?
A work example
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A work example
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Allowed configurations

- Grasp
- Placement
- Not allowed
Allowed configurations

- Grasp Space $GS$
- Placement Space $PS$
- Manipulation Space $GS \cup PS$
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Allowed paths

- Transit paths
- Transfer paths
- Not allowed paths
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Allowed paths induce foliations in $GS \quad PS$

- Transit paths
- Transfer paths
- Not allowed paths
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- Manipulation space topology

\[ GS \cup PS \]
\[ GS \cap PS \]
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Manipulation space topology

$GS \cup PS$

$GS \cap PS$

Adjacency by transfer paths
Manipulation space topology

$GS \cup PS$

$GS \cap PS$

Adjacency by transit paths
Manipulation space graph
Theorem: When two foliations intersect, any path can be approximated by paths along both foliations.
Corollary: Paths in $GS \cap PS$ can be approximated by finite sequences of transit and transfer paths.
Corollary: A manipulation path exists iff both starting and goal configurations can be retracted on two connected nodes of the manipulation graph.
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Manipulation space graph

Proof
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Manipulation space

Transit Path

GS$\cap$PS Path

Transit Path

GS$\cap$PS Path

Transfer Path

Transit Path
Manipulation algorithms

- Capturing the topology of $GS \cap PS$
- Compute adjacency
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The case of finite grasps and placements

- Graph search
The case of one single object

- Capturing the topology of $GS \cap PS$: projection of the cell decomposition of the composite space

- Adjacency by retraction

B. Dacre Wright, J.P. Laumond, R. Alami

*Motion planning for a robot and a movable object amidst polygonal obstacles.*

J. Schwartz, M. Sharir

*On the Piano Mover III*

The case of one single object

A: Initial and goal configurations.  
B: Coordinated motions.  
C: The five stages manipulation path.
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The case of one single object
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The case of one single object
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The case of one single object
The general case

- Capturing the topology of $GS \cap PS$

- Compute adjacency
The general case

- Capturing the topology of $GS \cap PS$:
  \textit{Path planning for closed chain systems}

- Compute adjacency
  \textit{Inverse kinematics}
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The general case: probabilistic algorithms

T. Siméon, J.P. Laumond, J. Cortes, A. Sahbani
Manipulation planning with probabilistic roadmaps

J. Cortès, T. Siméon, J.P. Laumond
A random loop generator for planning motions of closed chains with PRM methods
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A random loop generator for planning motions of closed chains with PRM methods
J. Cortès, T. Siméon, J.P. Laumond

A random loop generator for planning motions of closed chains with PRM methods

C. Esteves, G. Arechavaleta, J. Pettré, J.P. Laumond

Animation planning for virtual mannequins cooperation

Manipulation Planning
E. Yoshida, M. Poirier, J.P. Laumond, O. Kanoun, F. Lamiraux, R. Alami, K. Yokoi

*Pivoting based manipulation by a humanoid robot*

E. Yoshida, M. Poirier, J.-P. Laumond, O. Kanoun, F. Lamiraux, R. Alami, K. Yokoi
Regrasp Planning for Pivoting Manipulation by a Humanoid Robot
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