

# Introduction to Motion Planning

Algorithms and Data Structures 2 – Motion Planning and its applications

University of Applied Sciences Stuttgart

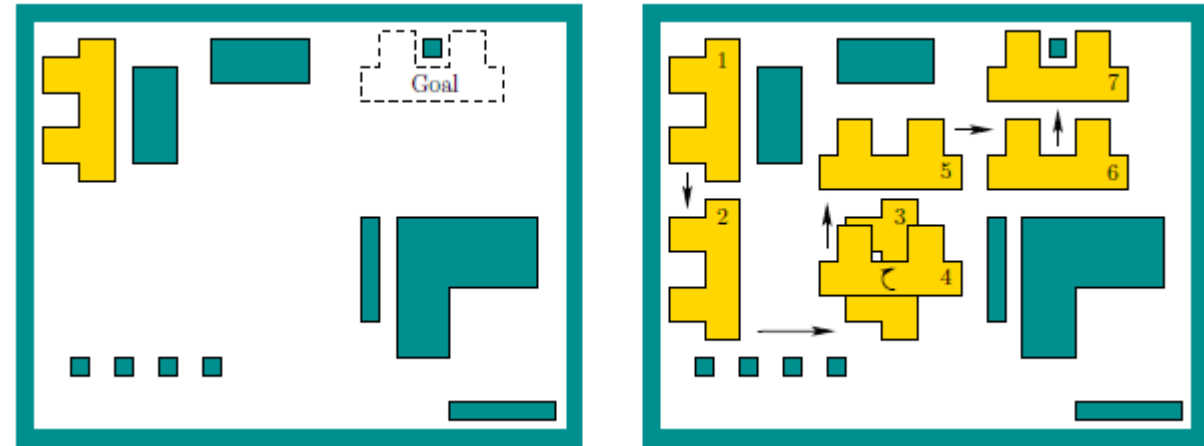
Dr. Daniel Schneider

# What is motion planning?

## Description:

Motion Planning describes the task to move a moveable objects (called robot) from one (or more) starting point to one (or more) goal point. During the movement the robot shall take its environment (called workspace) into account and avoid collisions with its environment (called obstacles).

Simple 2D example:



## Sources:

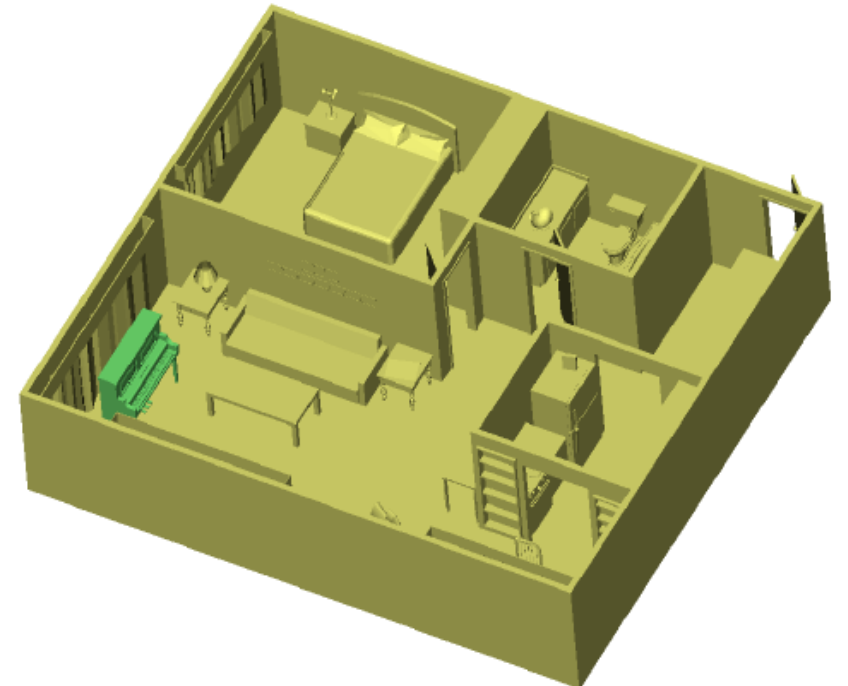
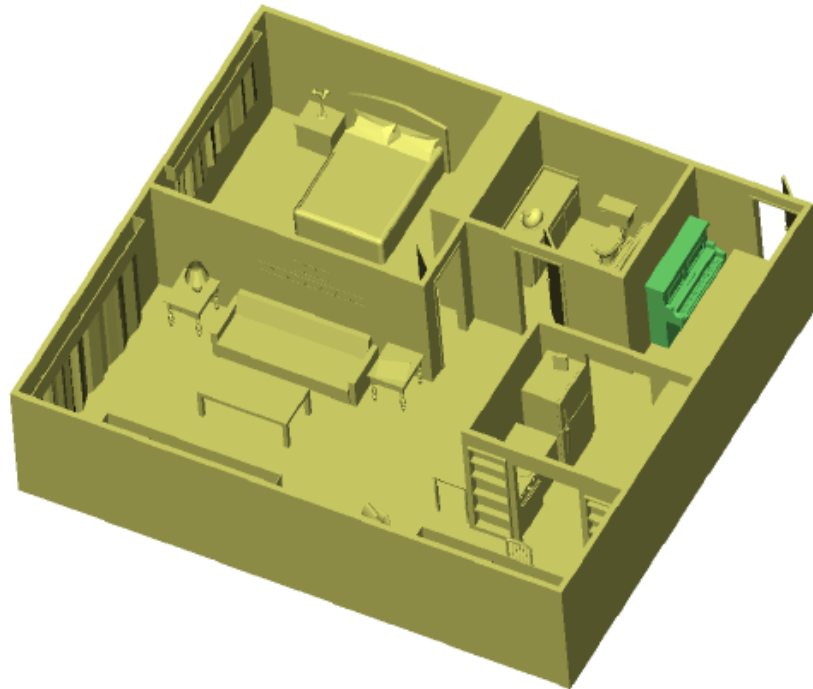
Motion Planning: The Essentials – LaValle - <http://msl.cs.illinois.edu/~lavalley/papers/Lav11b.pdf>

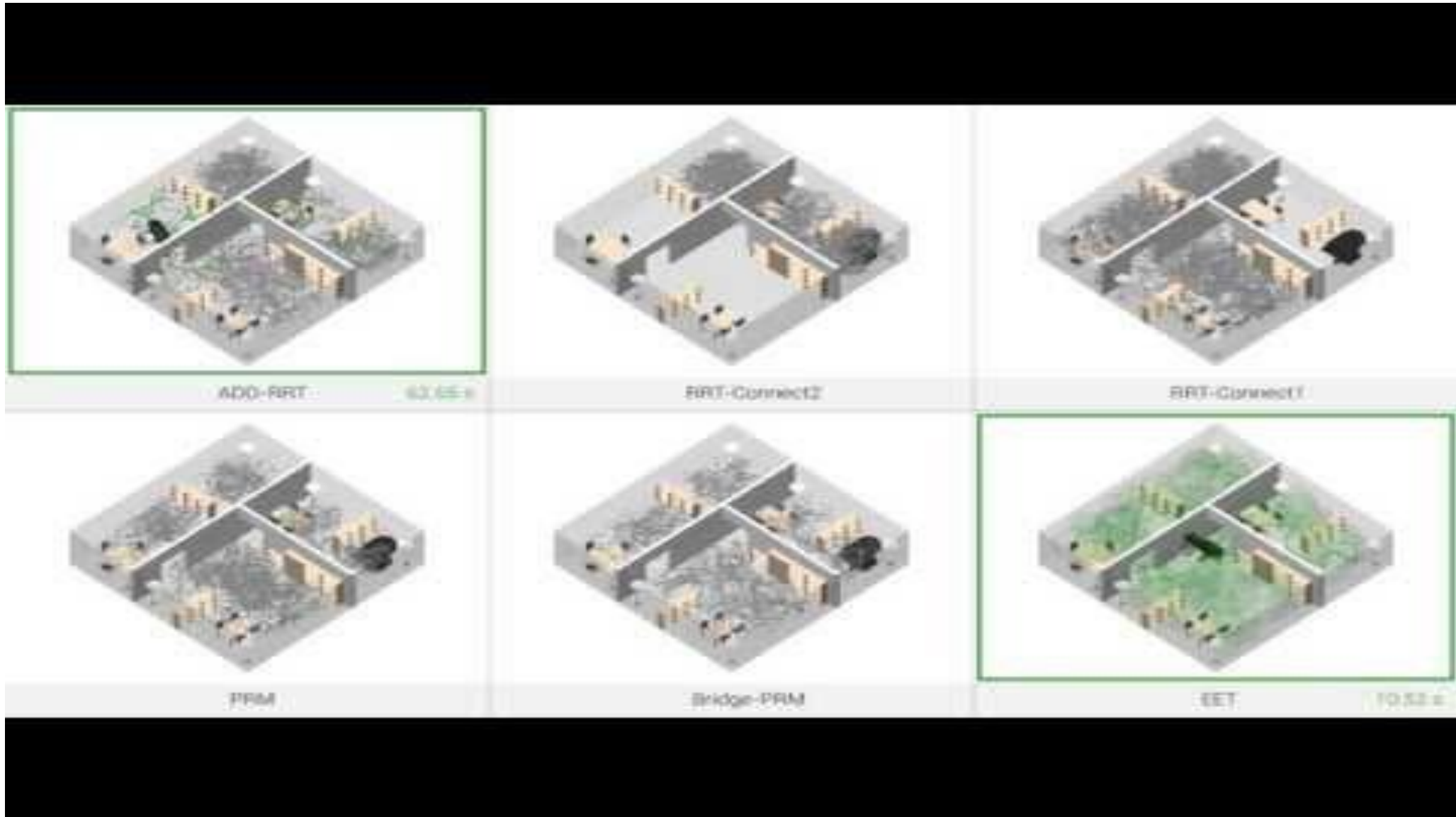
# Examples for motion planning Tasks

## The piano movers problem:

- The “original” Motion Planning problem.
- How to get the piano from the entrance to the edge of the living room?

[Video](#)



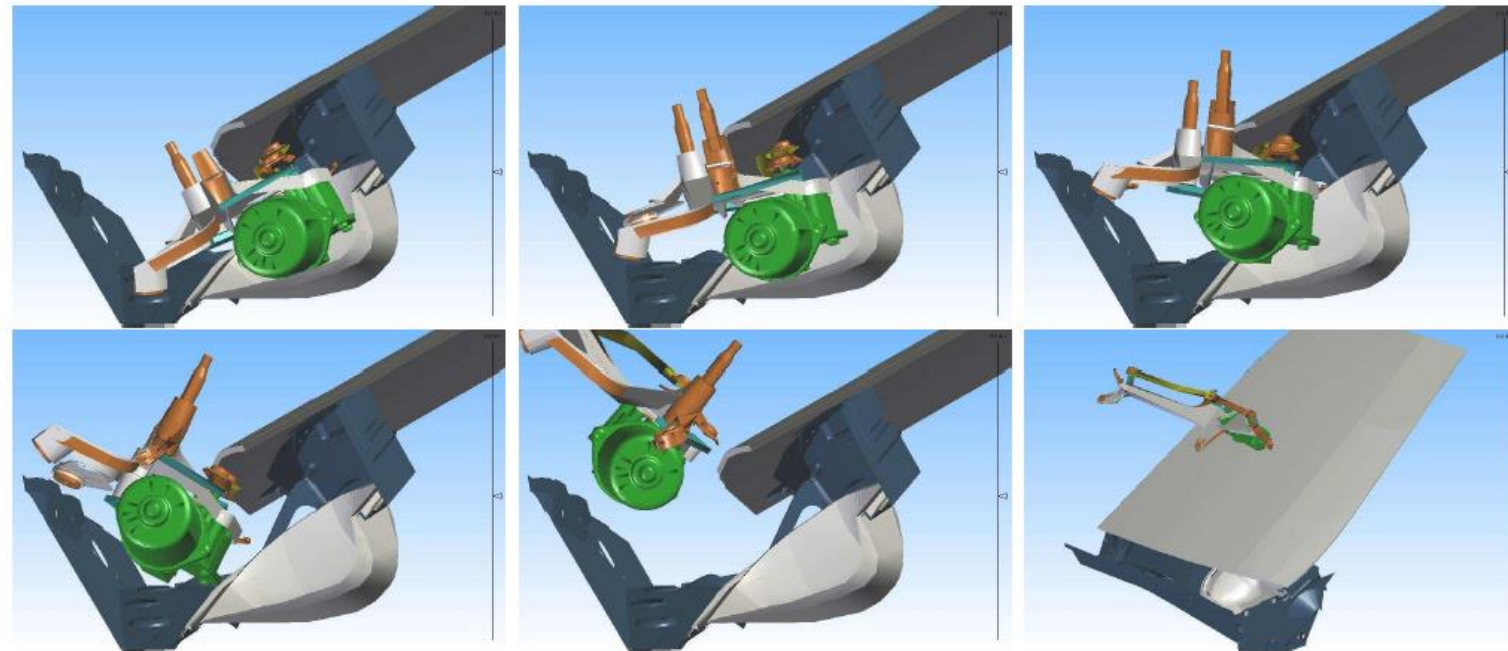


# Examples for motion planning Tasks

## The disassembly problem:

- A major problem in CAD
- How to disassemble a given part of a car from its environment.
  - Without collision
  - With safety distance
  - “Little” effort
  - With robots movement taken into account.

[Video](#)



### Sources:

Planning Algorithms– LaValle - <http://planning.cs.uiuc.edu/>

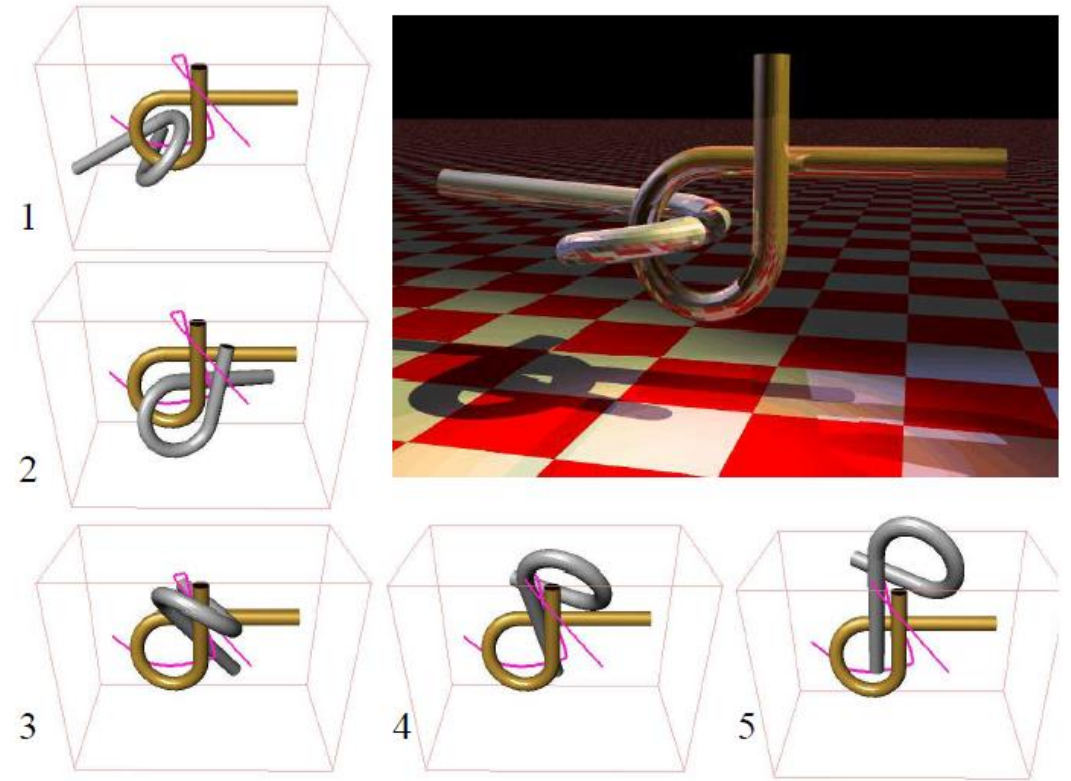


# Examples for motion planning Tasks

## The Alpha puzzle:

- A benchmark that was unsolved for a long time.
- Simple algorithms can not solve this problem.
- A challenging example even for humans

[Video](#)



## Sources:

Planning Algorithms– LaValle - <http://planning.cs.uiuc.edu/>

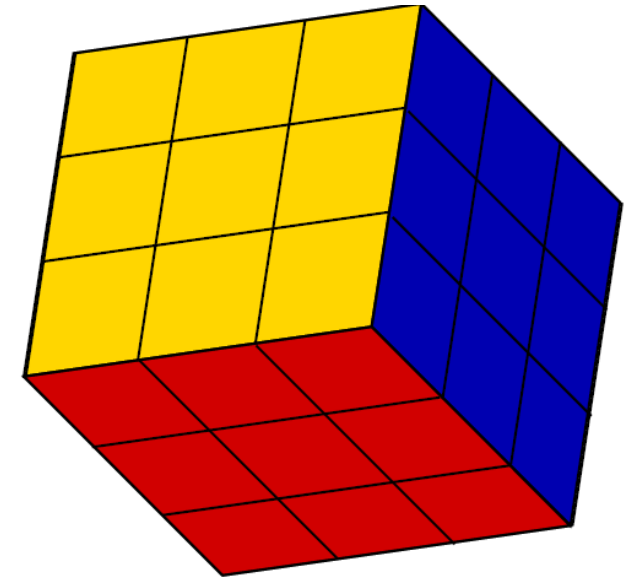




# Examples for motion planning Tasks

## The Rubik`s cube:

- This is also a motion planning problem  
(Although there exists a deterministic method to solve it).
- There are multiple start states.
- There is one goal state.



### Sources:

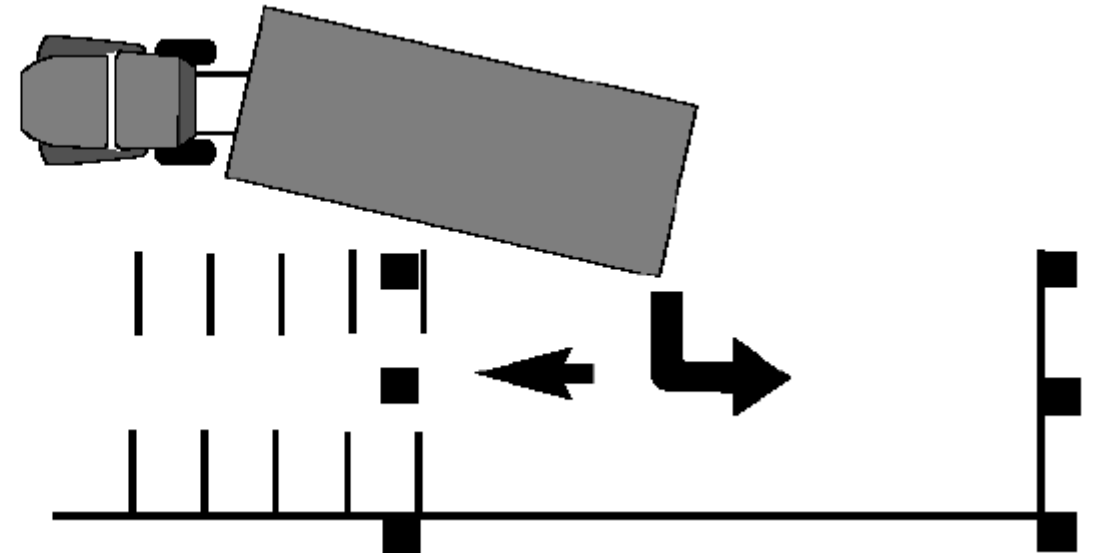
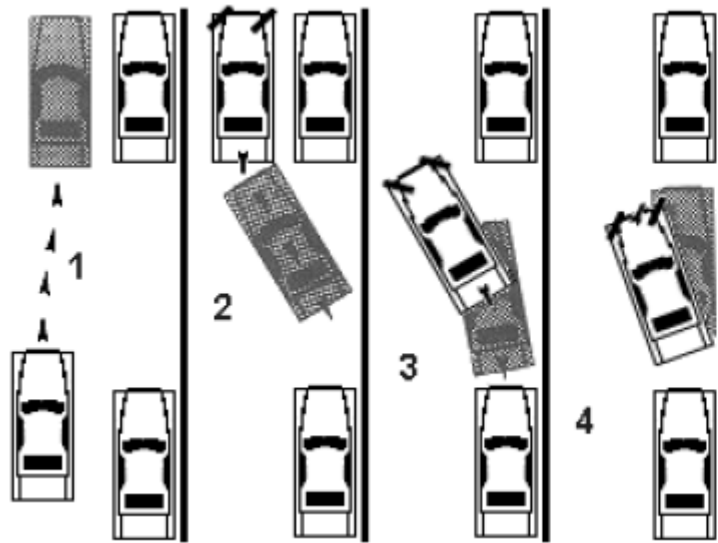
Planning Algorithms– LaValle - <http://planning.cs.uiuc.edu/>

Any motion planning problem that you know?

# Examples for motion planning Tasks

## The **parking** problem:

- Well known problem in autonomous driving.
- Solved today, but:
- There are still challenging examples like with parking a vehicle and its trailer.

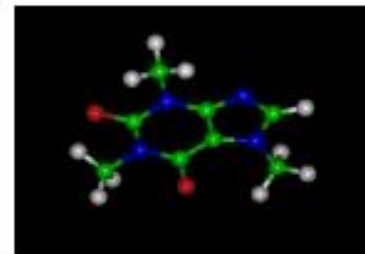


Sources:  
Planning Algorithms– LaValle - <http://planning.cs.uiuc.edu/>

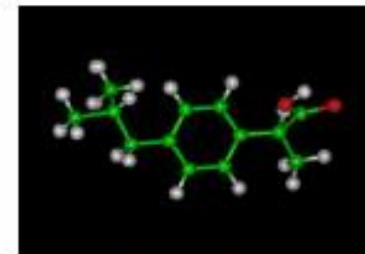
# Examples for motion planning Tasks

## The **protein folding and docking** problem:

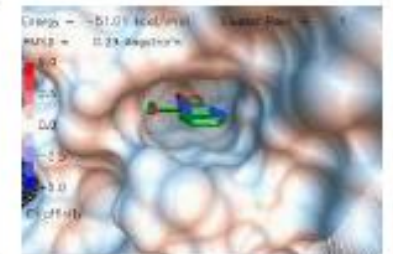
- Designing of medicine by folding the protein by taking the energy function (and repulsion between each other) into account.
- Planning the docking process for the medicine.



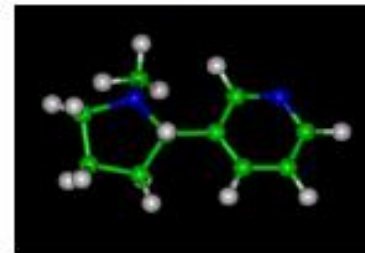
Caffeine



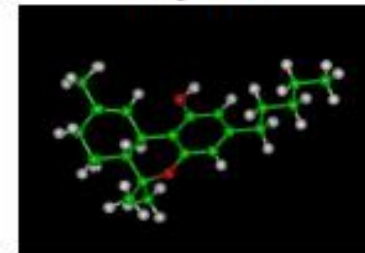
Ibuprofen



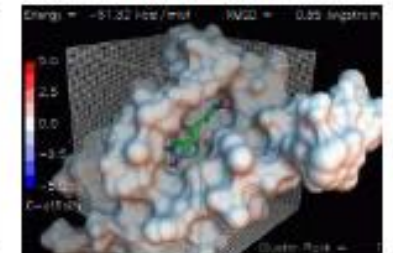
AutoDock



Nicotine



THC



AutoDock

### Sources:

Planning Algorithms– LaValle - <http://planning.cs.uiuc.edu/>

# Examples for motion planning Tasks

## The **vacuum cleaner robot** problem:

- Highly depended on how the environment is captured.
  - Scan data
  - Try and Error
  - 2d model
- Solved by current available vacuum cleaners.
  - You have one? How does it navigate?



### Sources:

Robot Motion Planning– Wolfram Burgard et al. \_

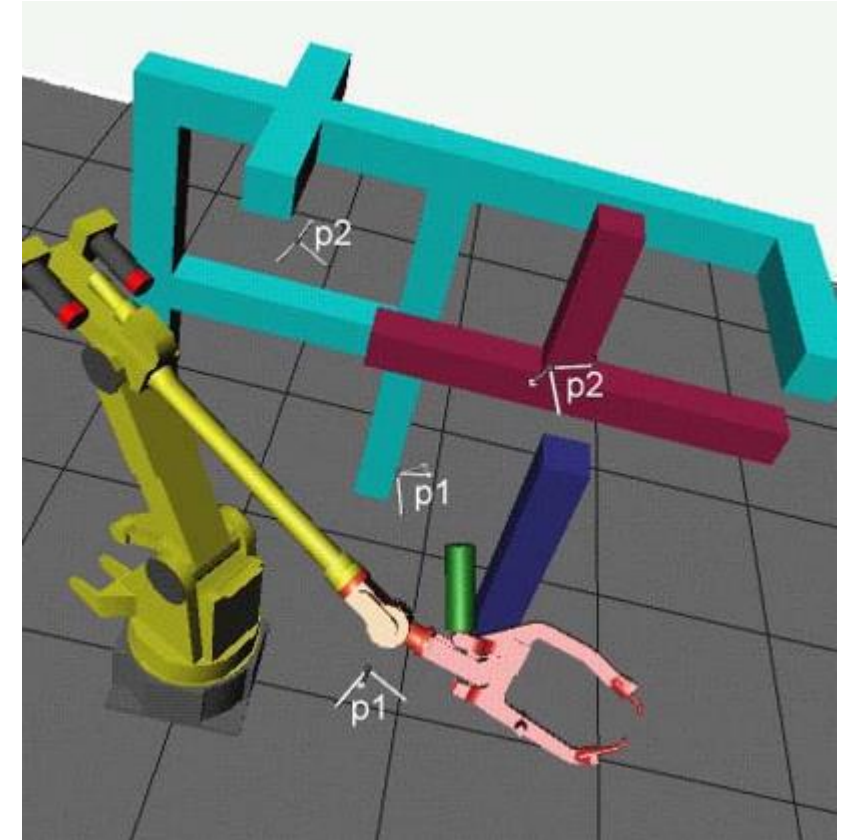
<http://ais.informatik.uni-freiburg.de/teaching/ss11/robotics/slides/18-robot-motion-planning.pdf>

# Examples for motion planning Tasks

## The robot motion planning problem:

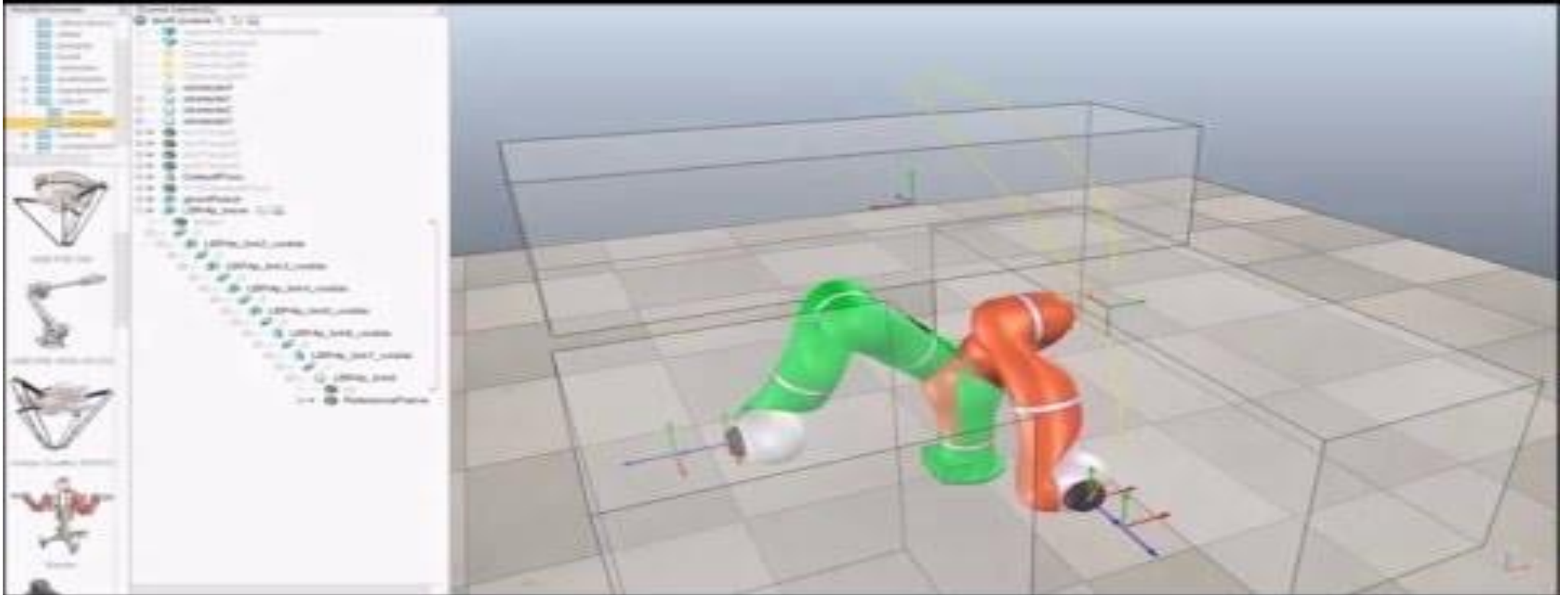
- Basic task in application focused motion planning.
- DOF are very variable
- DOF depends on the amount

[Video](#)



## Sources:

A Journey of Robots, Digital Actors, Molecules and Other Artifacts – Jean Claude Latombe – <https://robotics.stanford.edu/~latombe/projects/motion-planning.ppt>

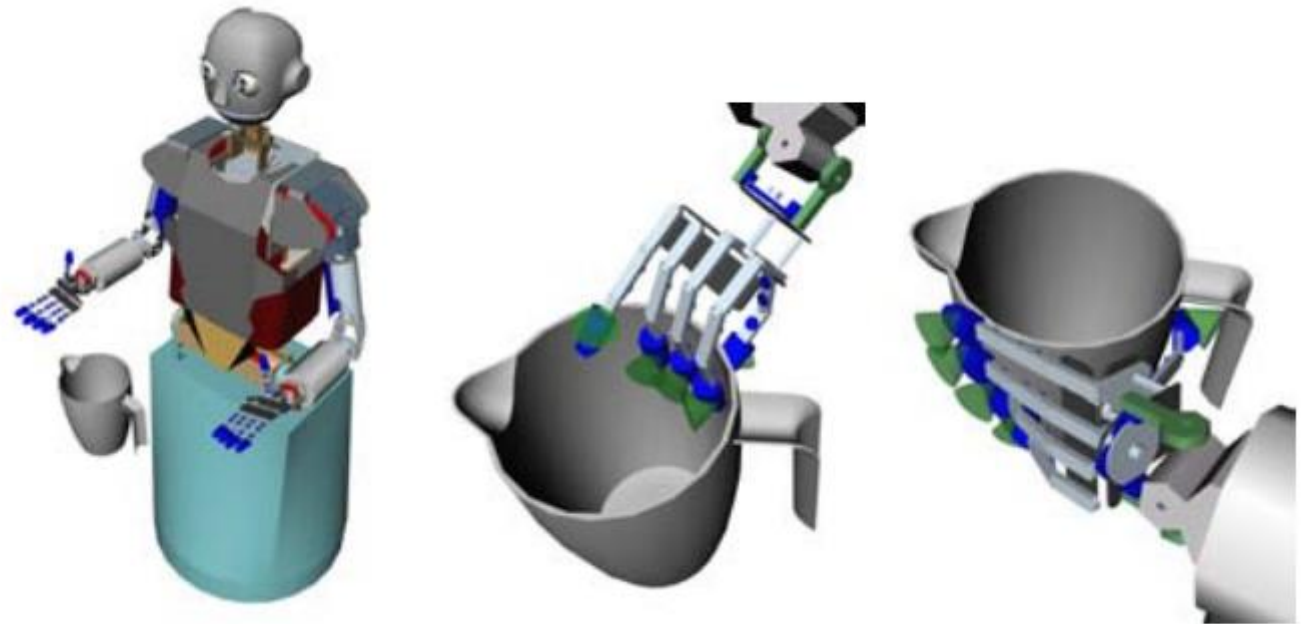


# Examples for motion planning Tasks

## The grasp motion problem:

- Additional challenge in robotics.
- Often physical simulation included.

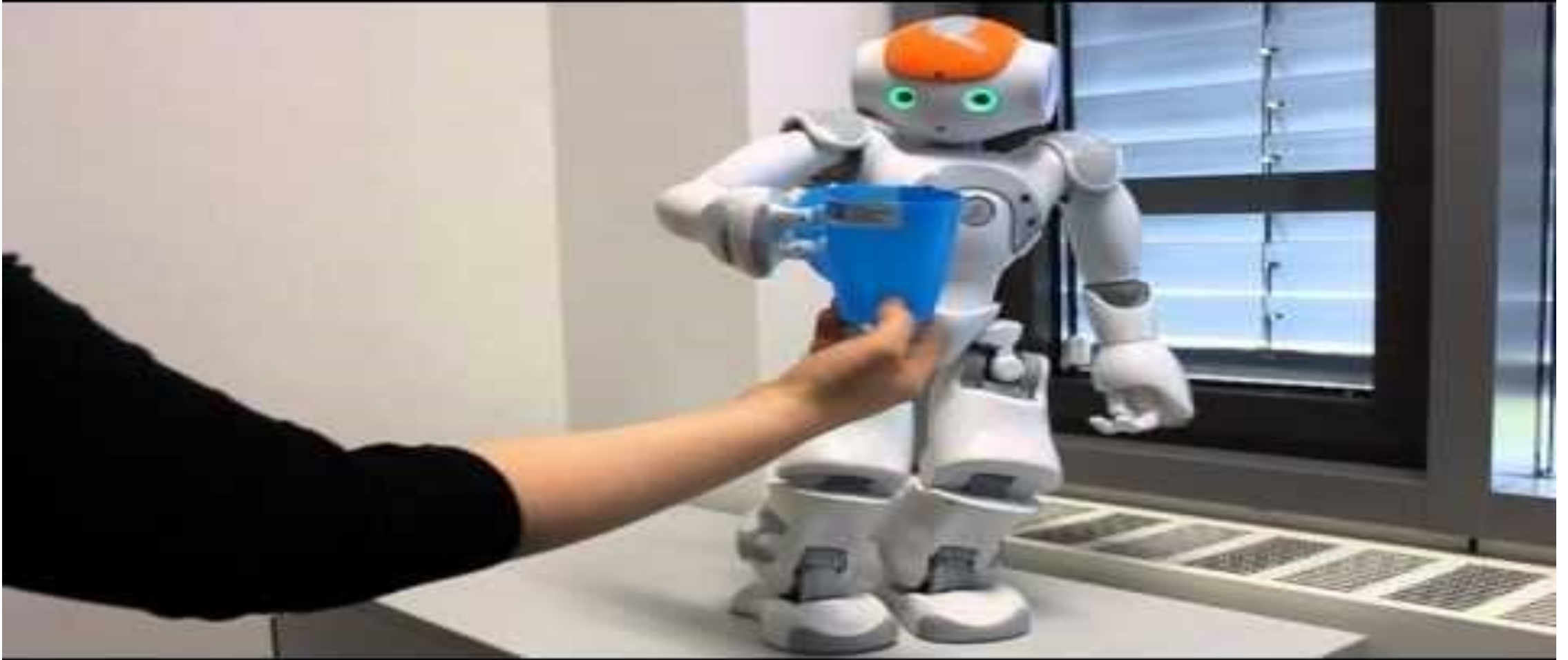
[Video](#)



### Sources:

Simultaneous Grasp and Motion Planning – Nikolaus Vahrenkamp et al.  
<https://h2t.anthropomatik.kit.edu/pdf/Vahrenkamp2012.pdf>





# Some history

- Started in the 1970s for the first algorithm in 2D.
- Solving higher dimensions started in the late 90s. Two major papers:
  - Kavraki, Lydia E., Petr Svestka, Jean-Claude Latombe, and Mark H. Overmars (1996) “Probabilistic roadmaps for path planning in high-dimensional configuration spaces”
  - Lavalley, Steven M. (1998). *Rapidly-Exploring Random Trees: A New Tool for Path*
- Both papers will be covered in this lecture.

# Some Future

- Most algorithms were tuned until 2010.

## **New topics:**

- Increasing mobile hardware → Real-time Motion planning

July 2019: Why is Motion Planning the Big Trend Now? <https://hackernoon.com/why-is-motion-planning-the-big-trend-now-kfo03zhz>

- Motion Planning is some kind of intelligence but is in general not consider as “artificial intelligence” as there is no learning involved in the algorithms yet. → Advances in **Artificial Intelligence** opens possibilities in Motion Planning.
- Motion Planning in deformable environment and/or deformable robots is still a challenge with no clear approach.