“Advanced” path planning

ROS RoboCup Rescue Summer School 2012

Simon Lacroix LAAS-CNRS Toulouse, France

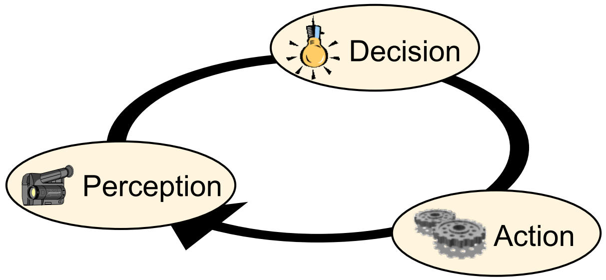
Basics on path planning

SSRR Rescue Robotics Camp 2013

Simon Lacroix LAAS-CNRS Toulouse, France

Where do I come from?

Robotics at LAAS/CNRS, Toulouse, France



- Research topics
  - Perception, planning and decision-making, control
  - Plus: control architecture, interactions, ambient intelligence systems, learning

A keyword: **autonomy**

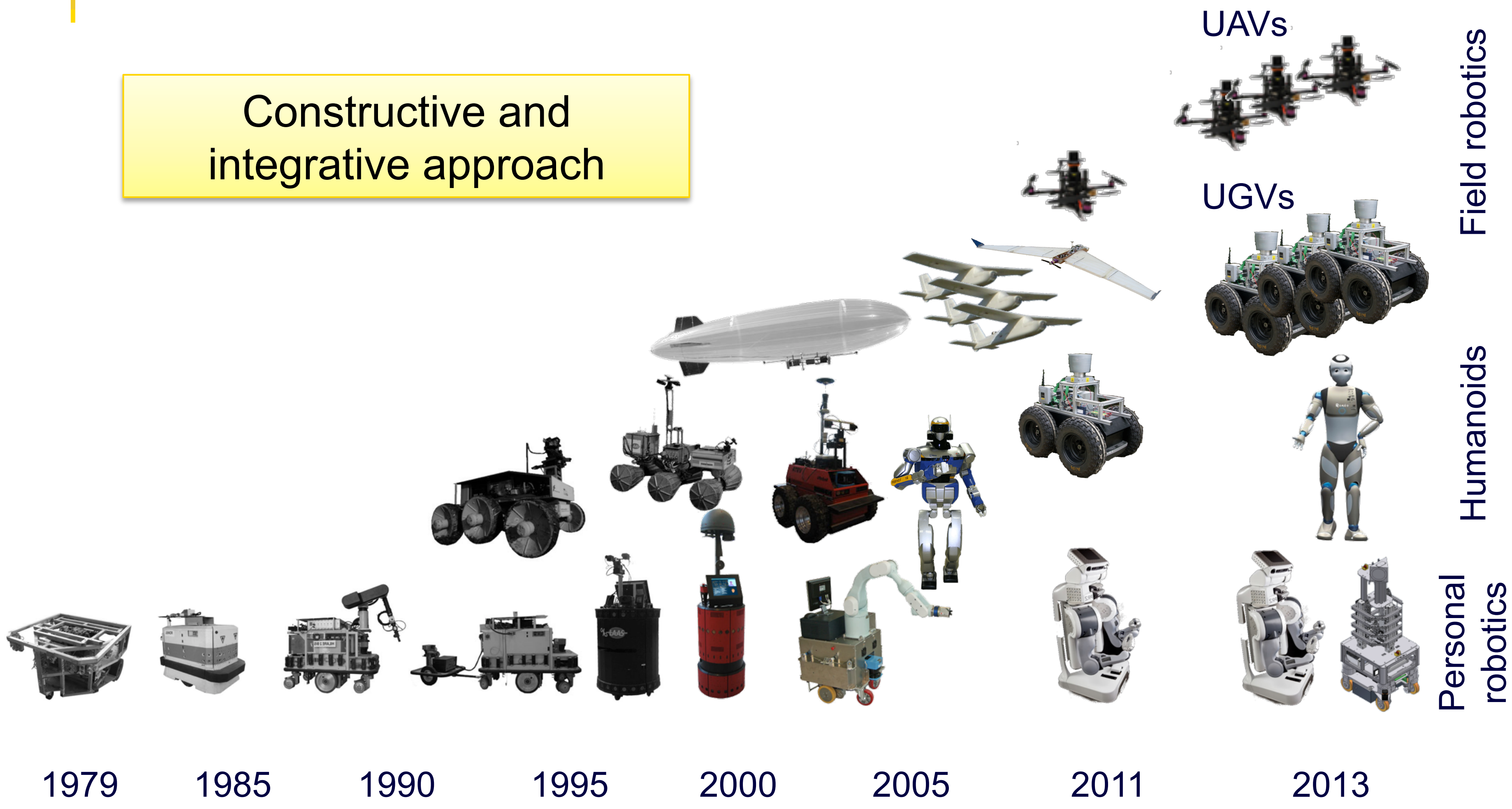
- Research domains
  - Cognitive and interactive Robotics
  - Aerial and Terrestrial Field Robotics
  - Human and anthropomorphic motion
  - Bio-informatics, Molecular motion

3 research groups :
12 full time researchers
10 university researchers
4 visitors
50 PhD students
10 post-docs

- Considered applications: Planetary exploration, Service and personal robotics, virtual worlds and animation, biochemistry, embedded systems, transport, driver assistance, defense, civil safety

Robots @ LAAS

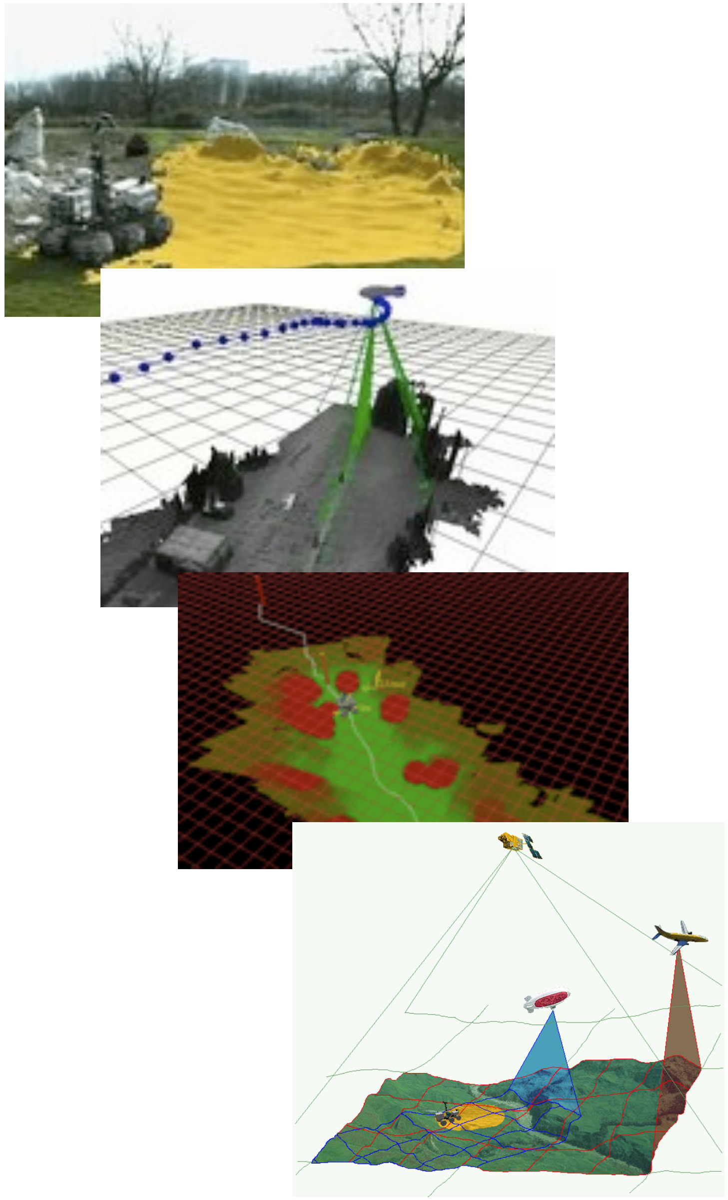
Constructive and integrative approach



Open source software tools: www.openrobots.org

What am I working on? Field robotics

- Environment perception and modeling
- Localization and SLAM
- Autonomous rover navigation
- Multi-Robot cooperation



“Advanced path planning”

- (my) definition of a robot: a machine that <u>moves</u> and whose motions a controlled by a computer

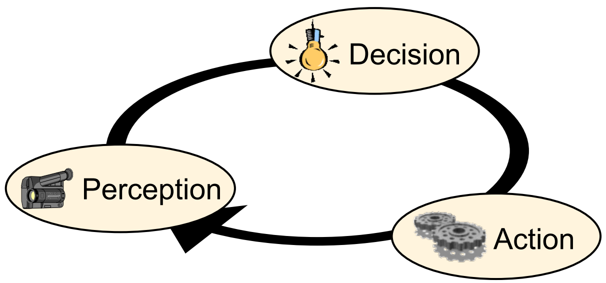
(plus: “intelligent” link between perception and action)

- Objectives of the lecture:
  - Discover a bit the motion planning scientific corpus
  - Have an overview of the various “levels” of motion planning
  - Understand some practical means to generate/compute/plan mobile robot motions

What is path planning about?

- Given
  - A current position
  - A goal position
  - Information on the environment
  - Constraints to satisfy / criteria to optimize
- Find
  - A trajectory that satisfies the constraints / optimizes the criteria

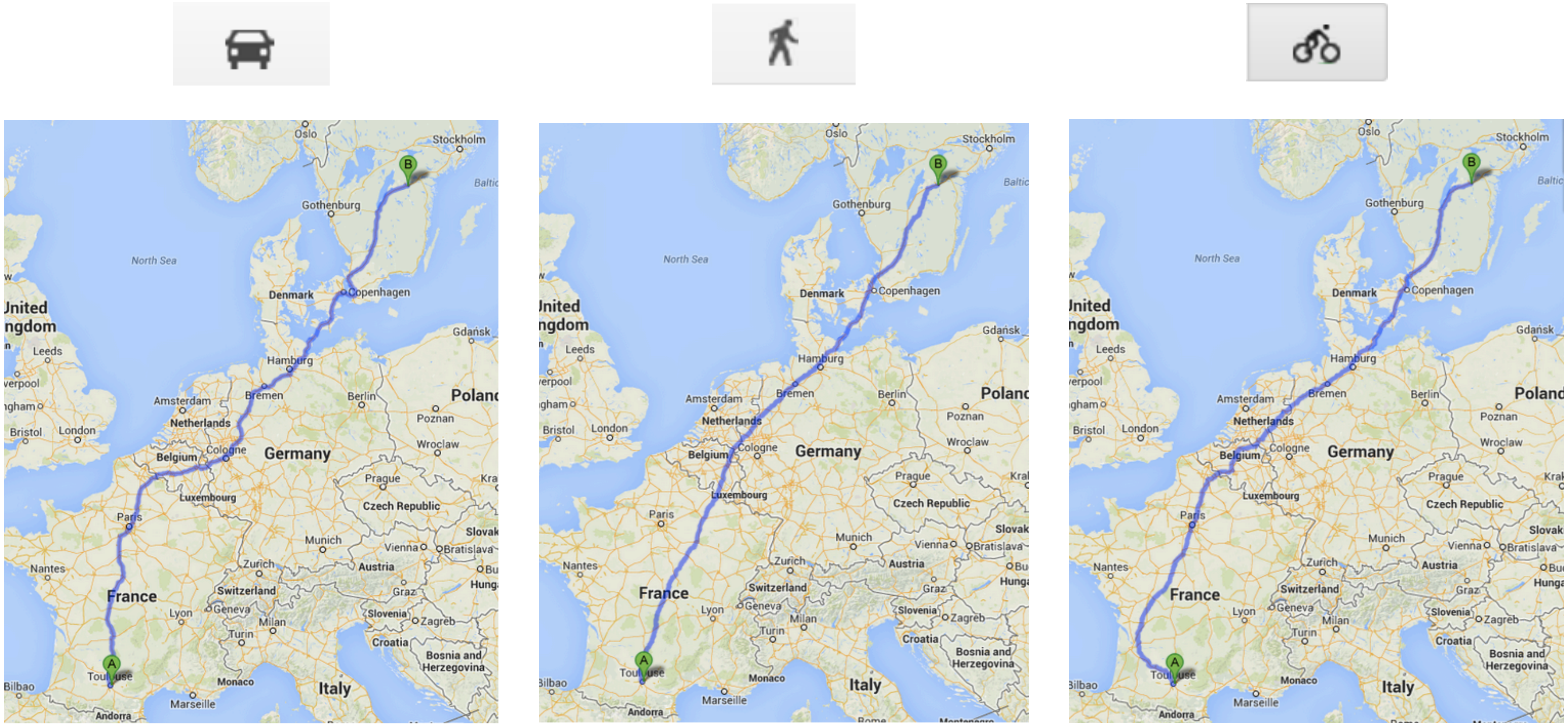
A trajectory = a continuous function from time to space



Decision in this talk = finding how to move

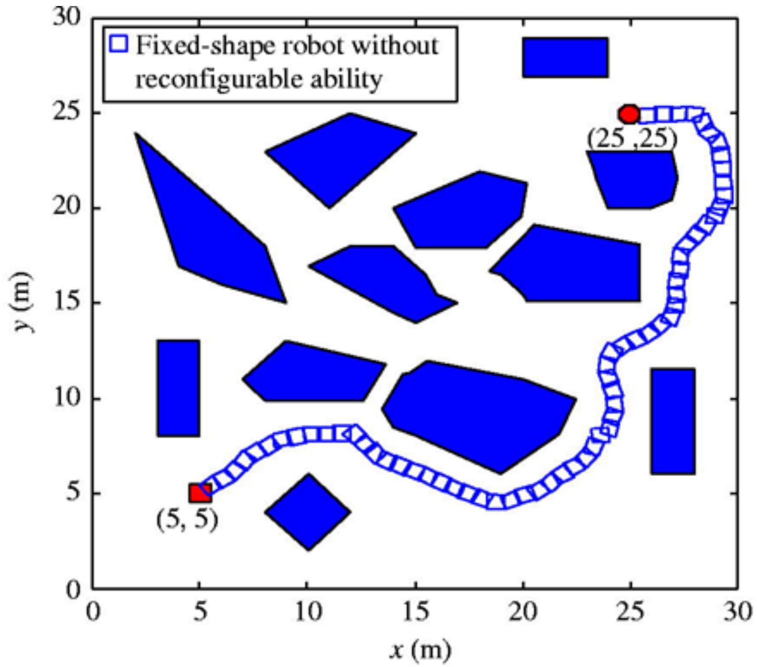
What is path planning about?

- With Google maps



What is path planning about?

- For a circular robot amidst obstacles



(a) Path planning of the fixed-shape robot

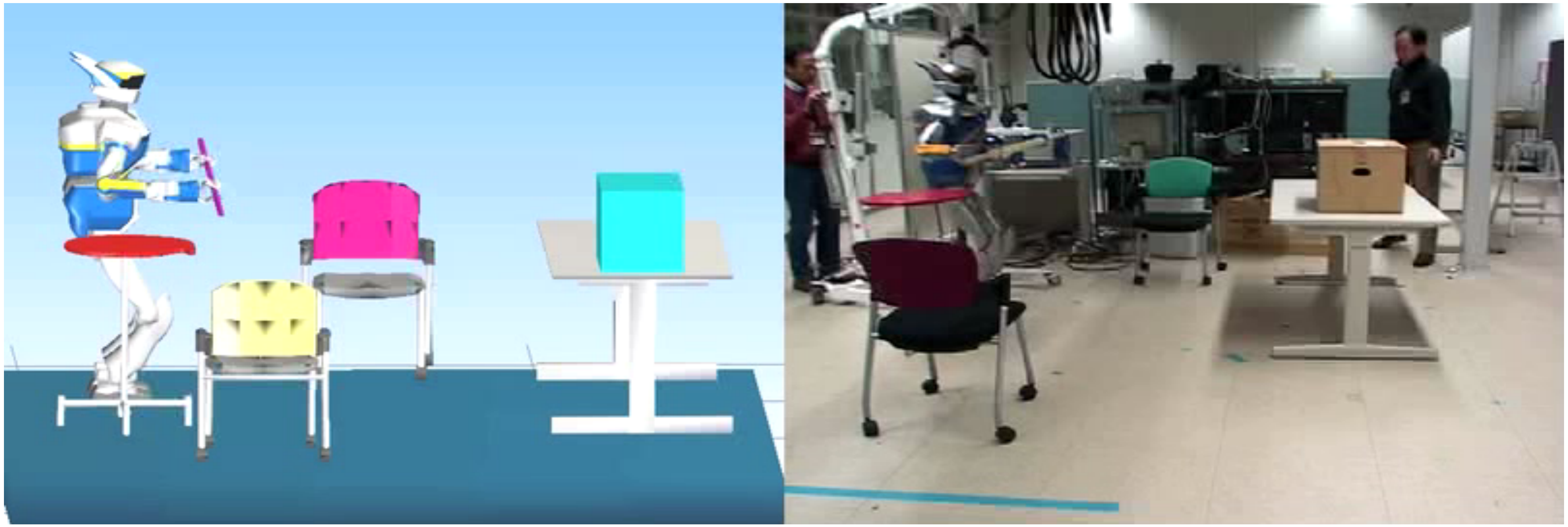
What is path planning about?

- For a wheeled robot with a trailer inside a cluttered building

[F. Lamiraux @ LAAS]

What is path planning about?

- For a humanoid robot



What is path planning about?

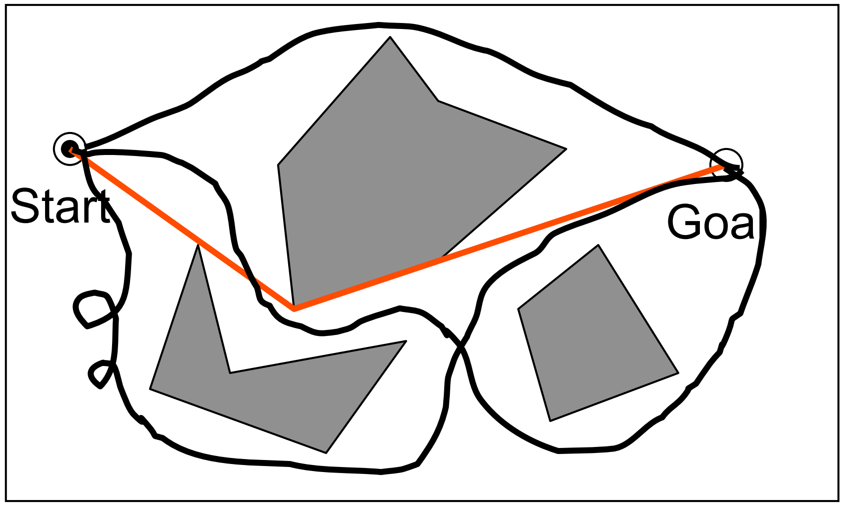
- In a intervention or rescue context

Outline

- Basic notions
  - Configuration space, kinematic constraints, search algorithms
- Practical field solutions
  - Potential field approaches
  - Short-term (“reactive”) planning
  - Long-term itineraries
- Other problems

Configuration space

- Consider a punctual (0 width) robot



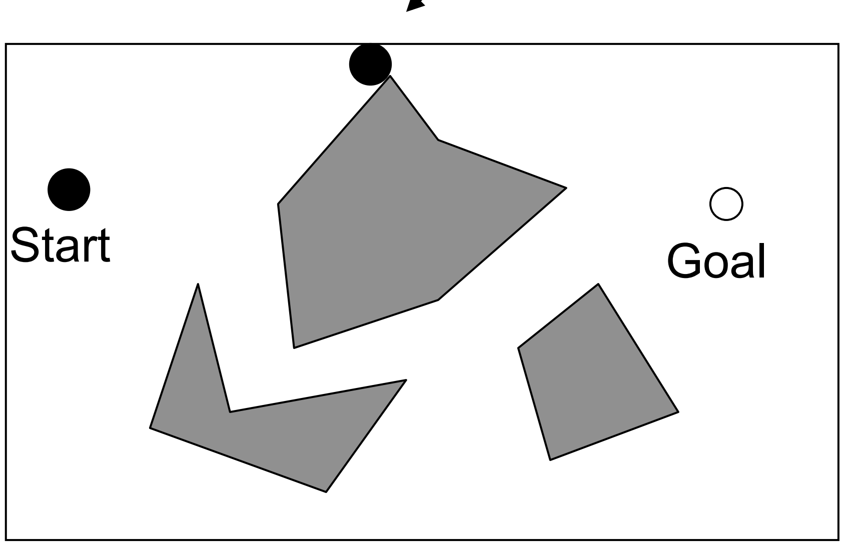
There are plenty of solution trajectories

And there is a shortest one

Configuration space

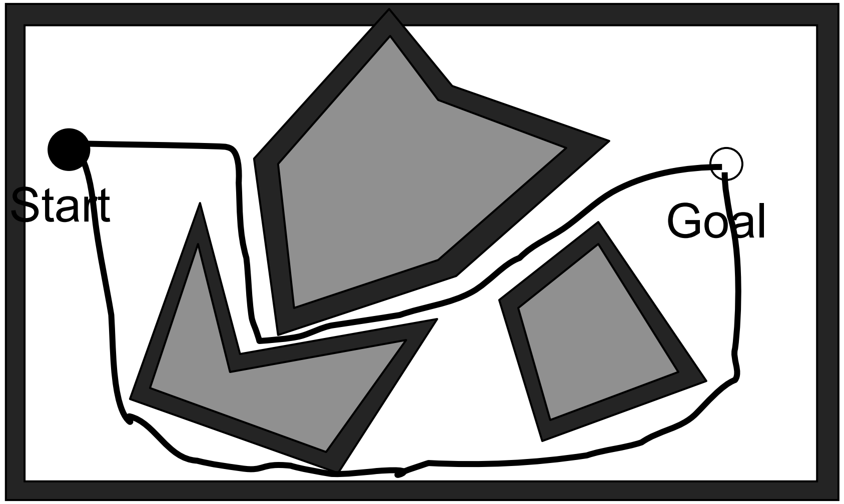
- Now consider a round shaped robot (radius r)

Cannot go this way !



Configuration space

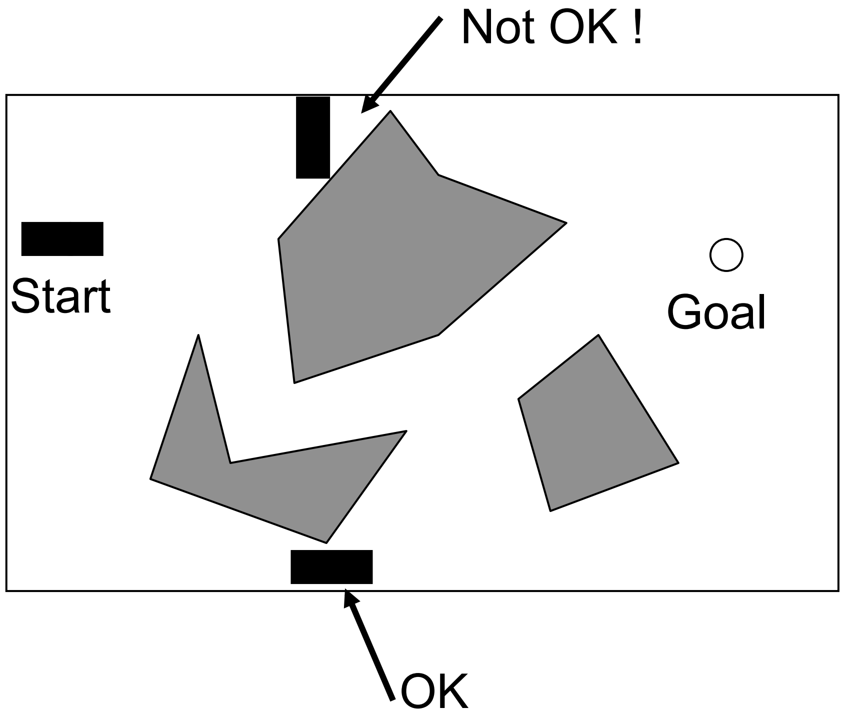
- Now consider a round shaped robot (radius r)



After growing the obstacles, we are back to the point problem

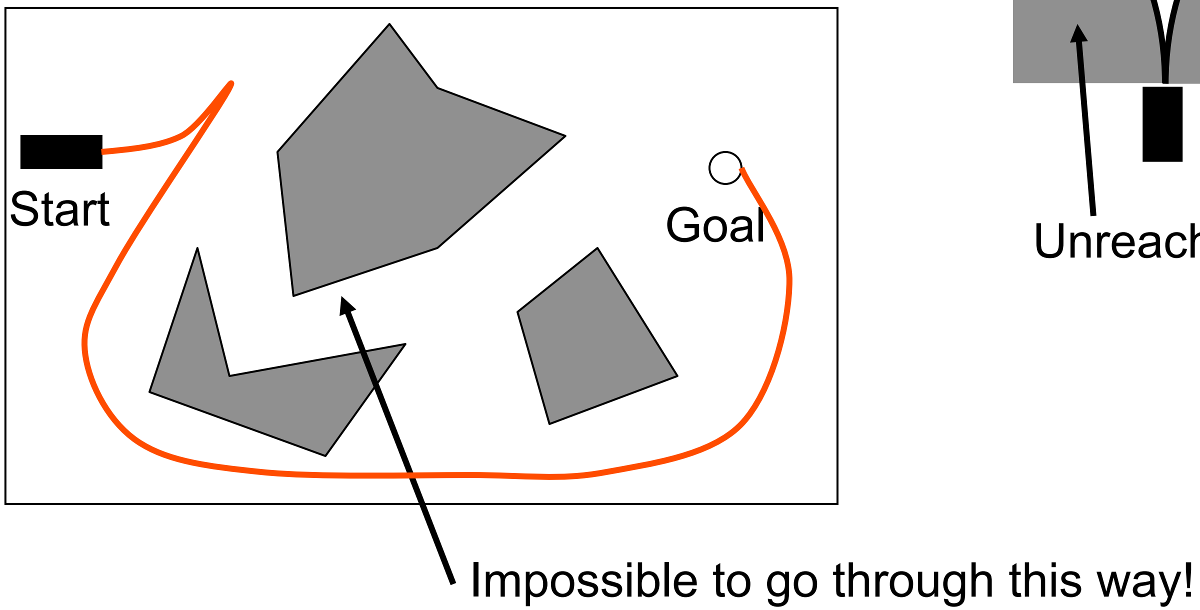
Configuration space

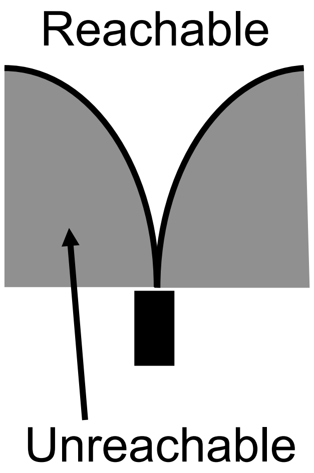
- Now consider a rectangular robot



Configuration space

- Now consider a rectangular robot with *kinematic constraints* (e.g. a car)

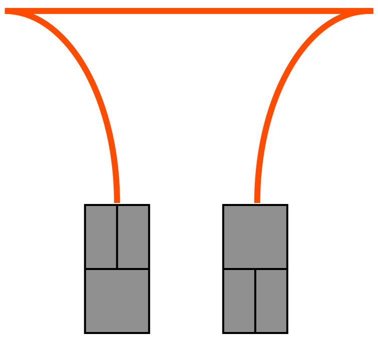




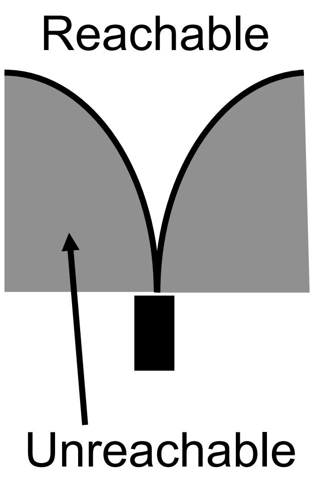
The feasable paths are much more difficult to find...

Configuration space

- Now consider a rectangular robot with *kinematic constraints* (e.g. a car)



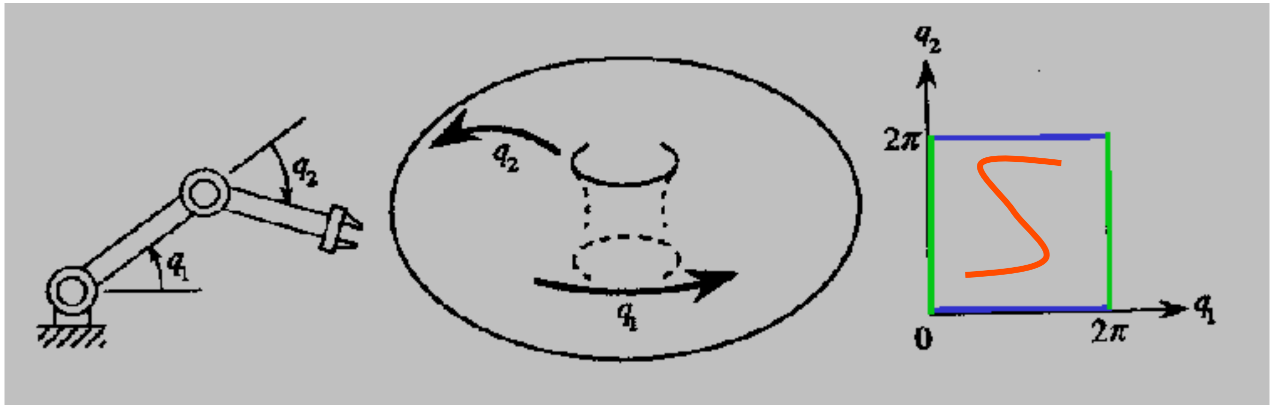
Shortest path



… and finding the shortest path is not so easy, even when there is no obstacle

Configuration space

- Configuration of a robot: set of independent parameters that specify the position and orientation of every component of the robot



Robot configurations

Associated (q_1,q_2) configuration space

There is a mapping between the CS and the world space

A path is a continuous set of configurations

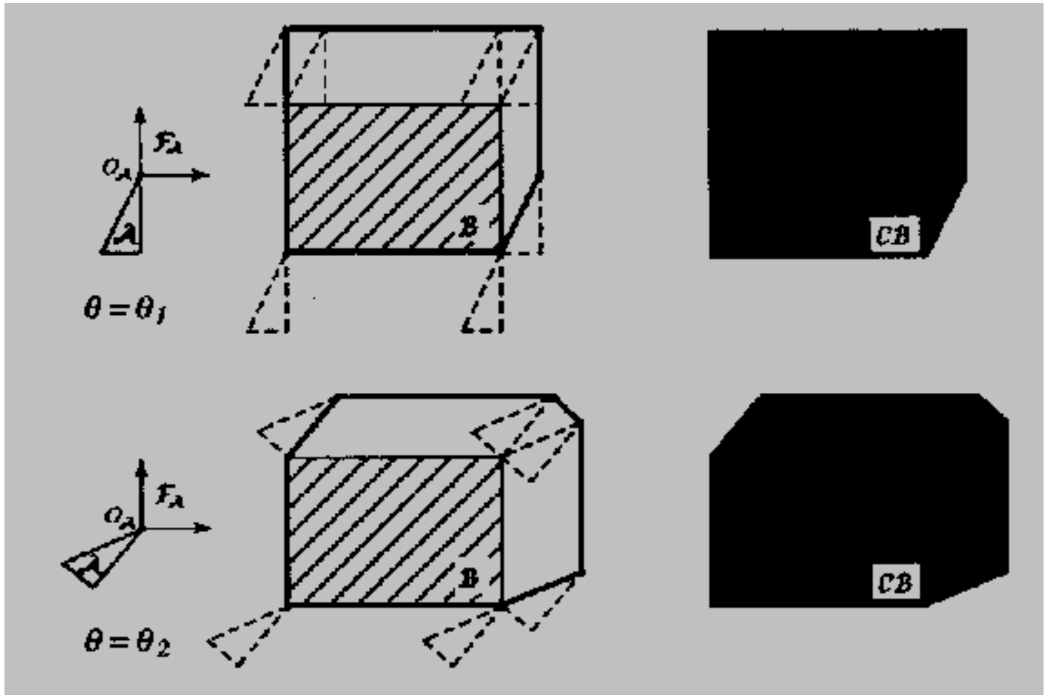
Configuration space

- Case of a robot in the plane:
  - 2D environment
  - 3 configuration parameters: 3D configuration space

- Case of a humanoid robot
  - 3D environment
  - 6 position parameters + numerous internal degrees of freedom: very high dimension configuration space

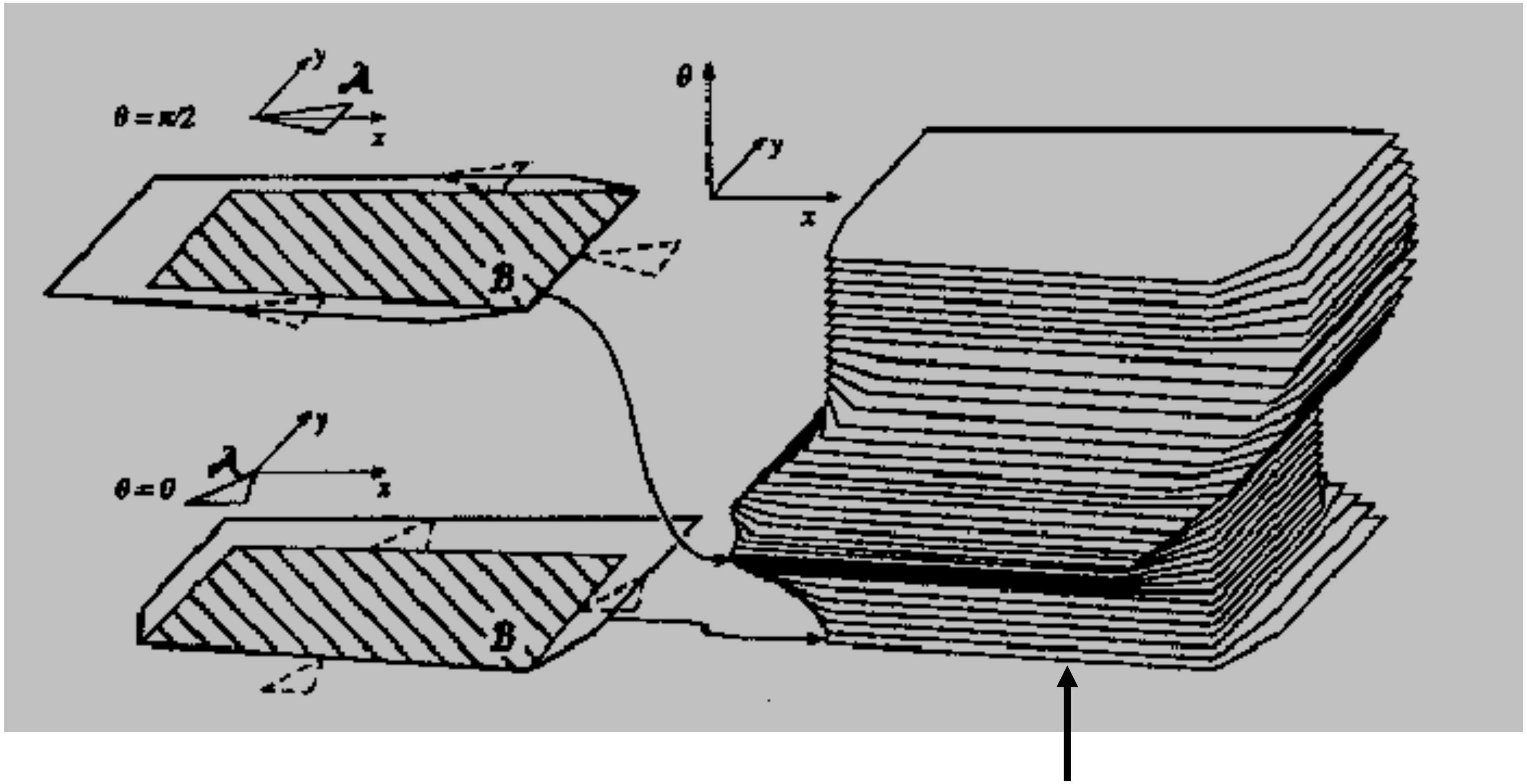
Obstacles in the configuration space

- Case of a triangular robot on the plane:



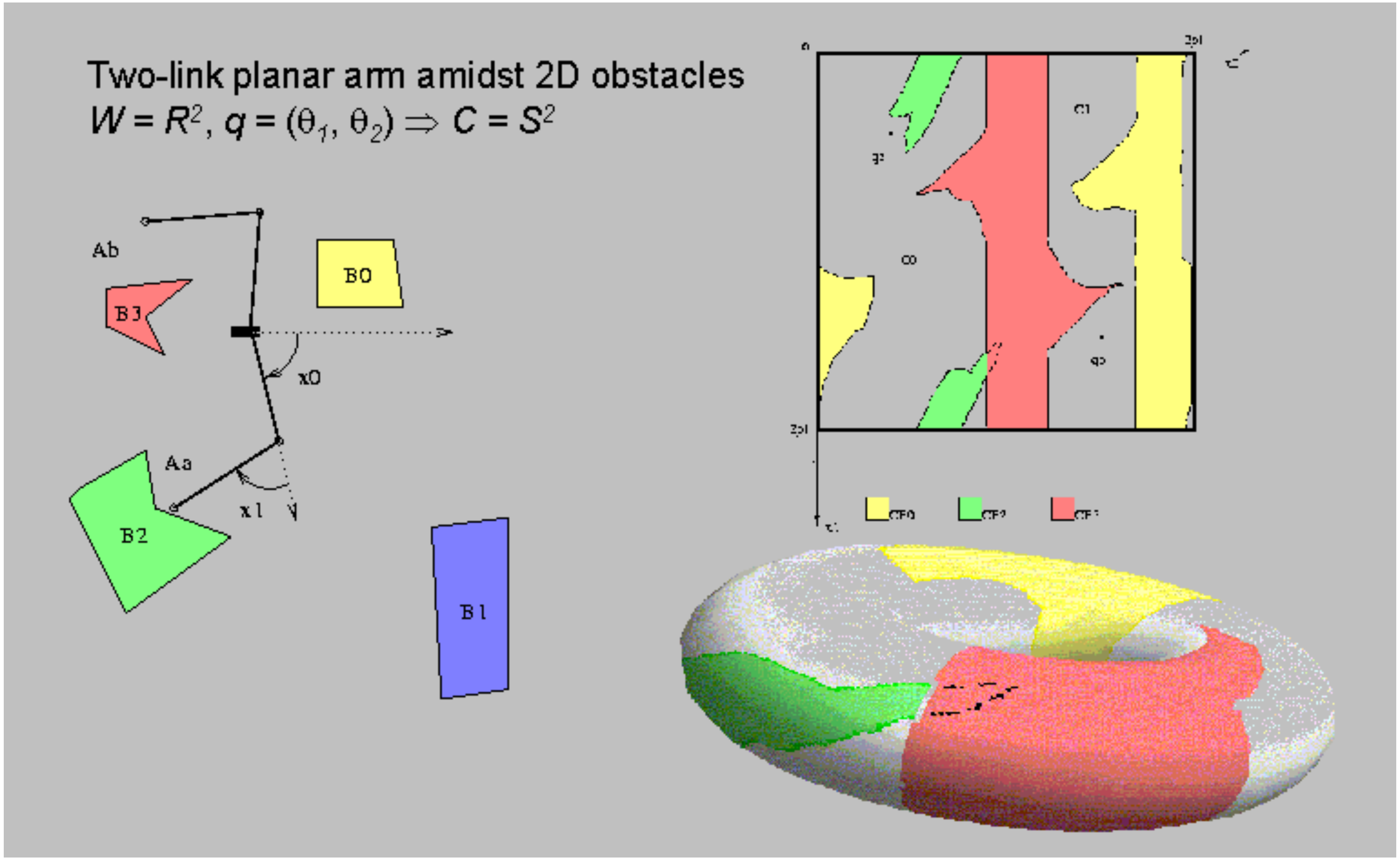
Obstacles in the configuration space

- Case of a triangular robot on the plane:

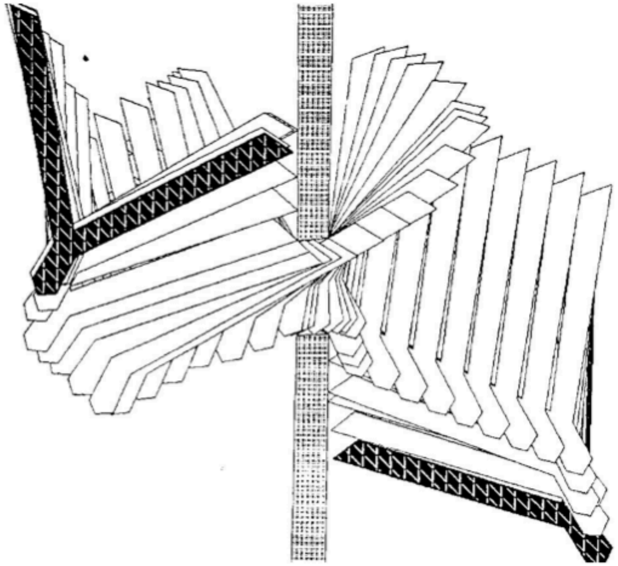


A rectangular obstacle in the configuration space

Obstacles in the configuration space



Obstacles in the configuration space



Searching for paths

- A complete algorithm: finds a solution if one exists, reports if not
- General complete algorithms have been proposed, but are not tractable in practice
  - Complexity: grows exponentially with *n*, the CS dimension
  - Difficult geometric computations (requires infinite precision)

- Weaker notions of completeness:
  - Resolution completeness: based on a systematic discretisation of the CS
  - Probabilistic completeness: the probability of finding a solution converges to 1 with infinite time

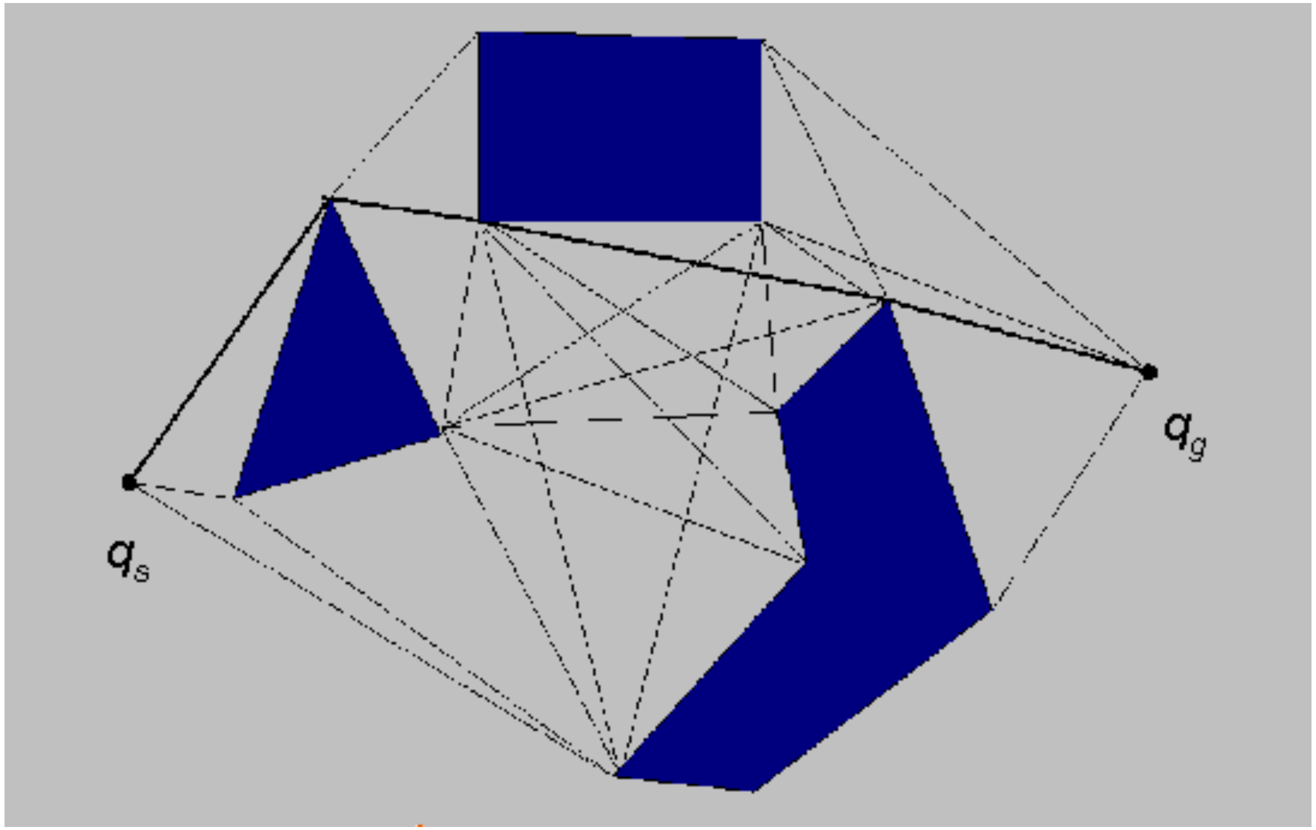
Searching for paths

- Two search families:
  - Graph search
    - Build a graph that captures the topology of the CS
    - Can handle multiple query
  - Building a search tree
    - No attempt to capture the topology of the CS
    - Goal dependant (single query)

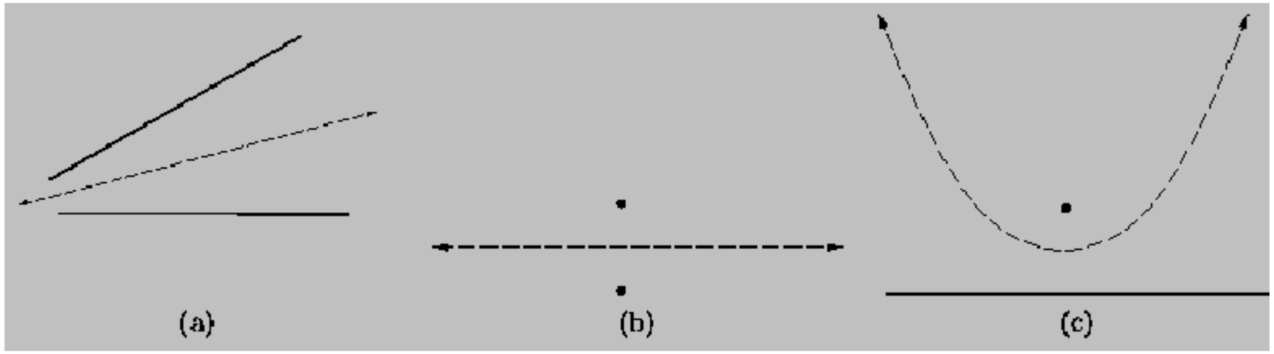
Approach 1: visibility graph

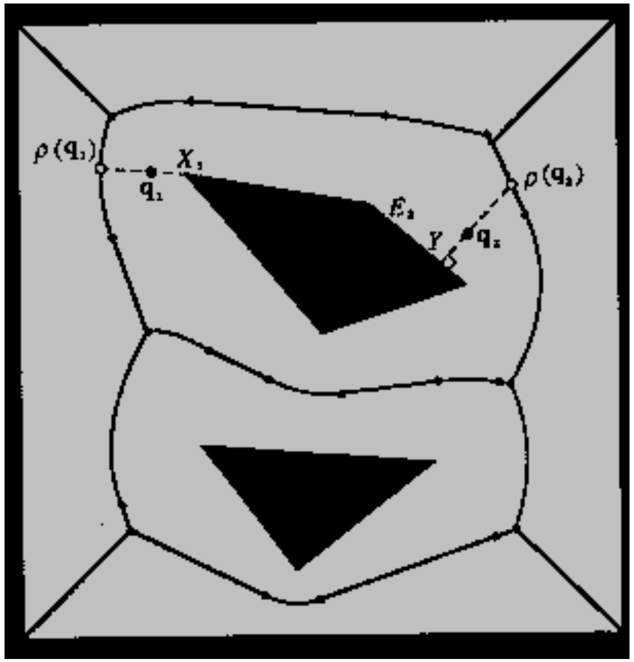
- Given a polygonal environment description

1. Build the graph (considering start and goal as nodes)
2. Shortest path search in the graph

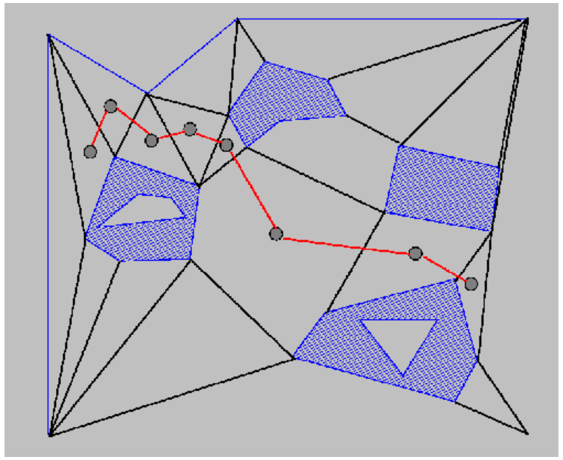


Approach 2: Voronoi diagram

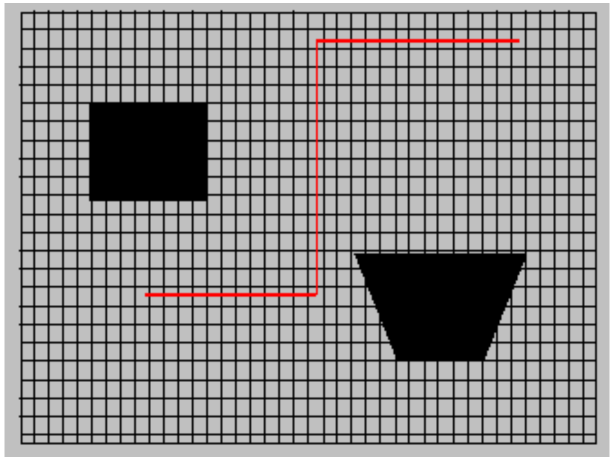




Approach 3: Cellular decomposition



Exact triangular decomposition



Approximate decomposition

Overall principle of the search