Robotics algorithms
CSE 410/510

Rob Platt
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Times: T/TH, 12:30-1:45
Location: ?
Course web page:
http://www.cse.buffalo.edu/~robplatt/cse510_2013.html
Office Hours: T/TH 1:45-2:45, 330 Davis Hall
TA: Suchismit Mahapatra

What is robotics?

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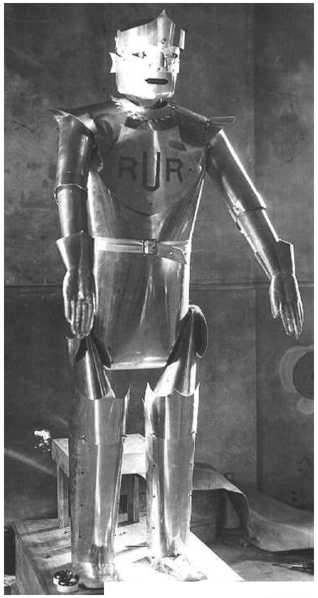
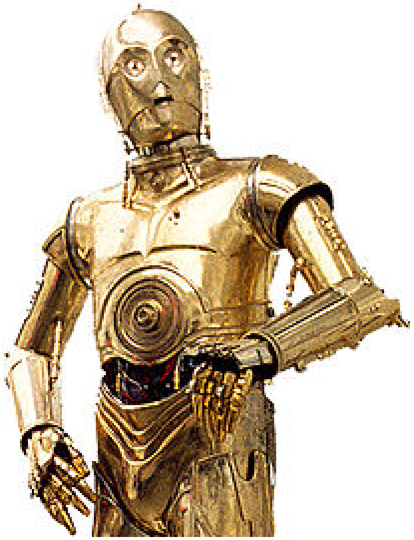
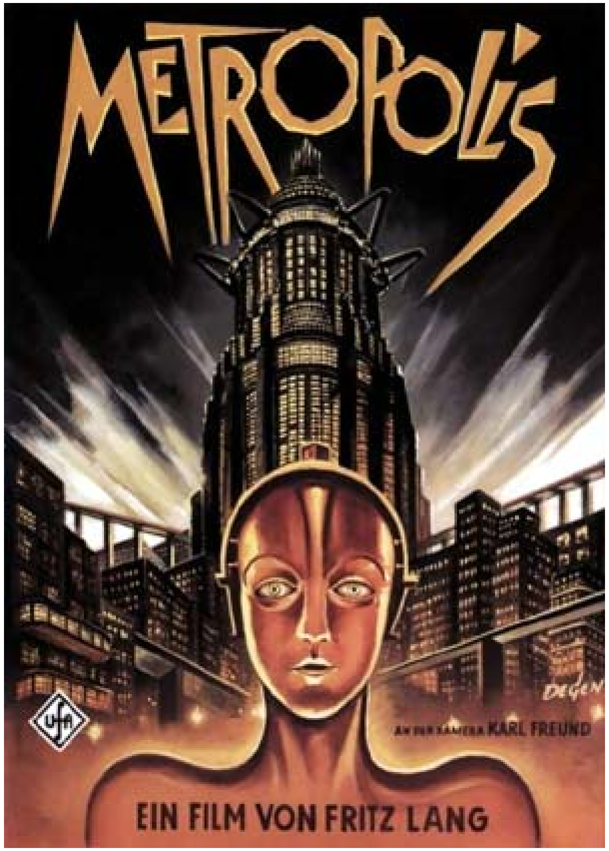
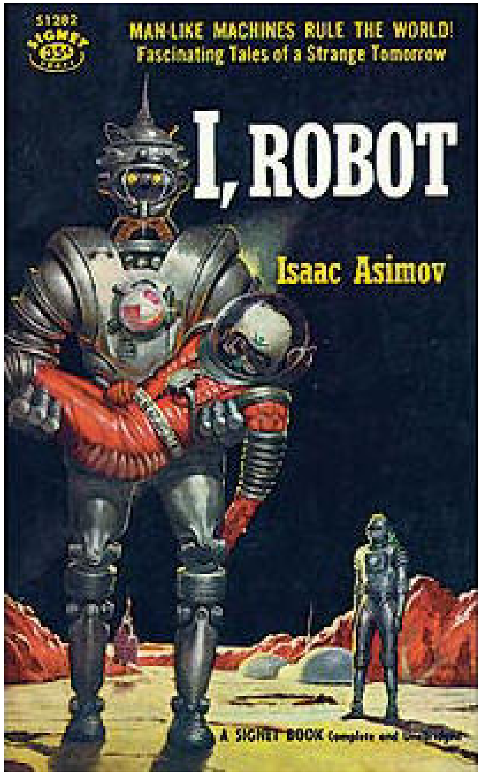
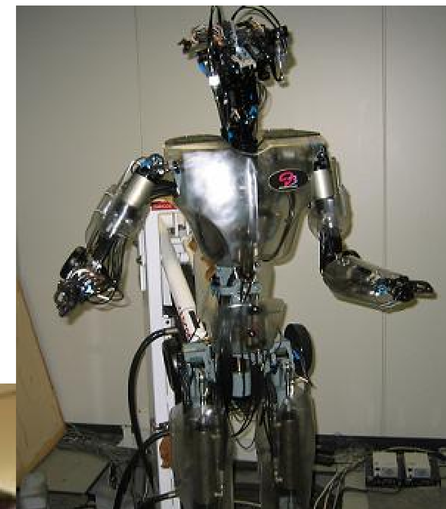








What is robotics?



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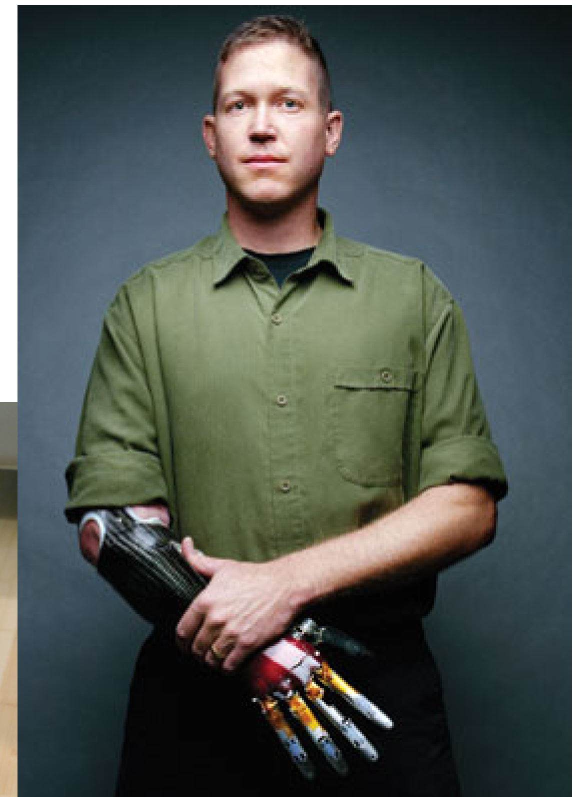
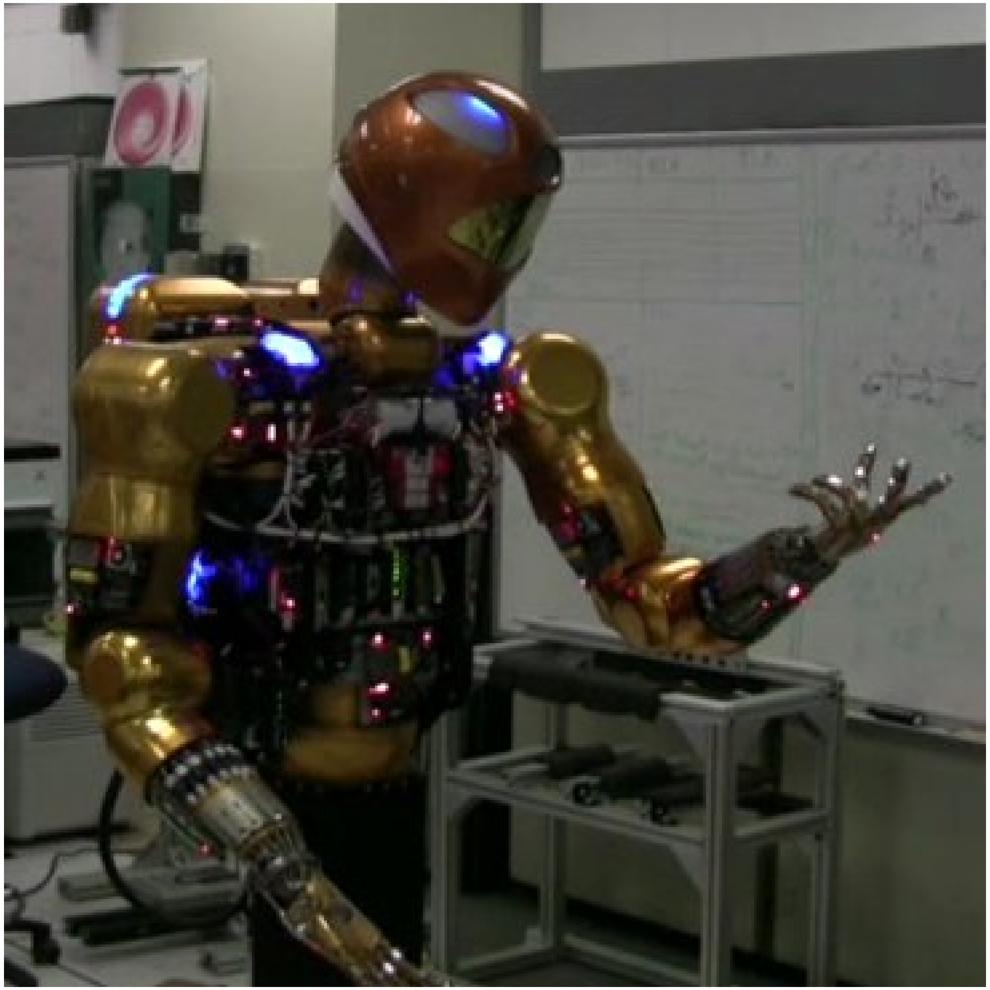
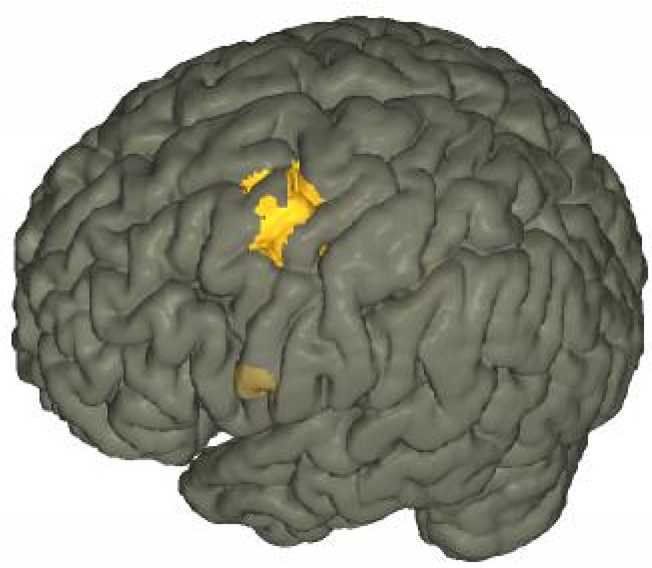


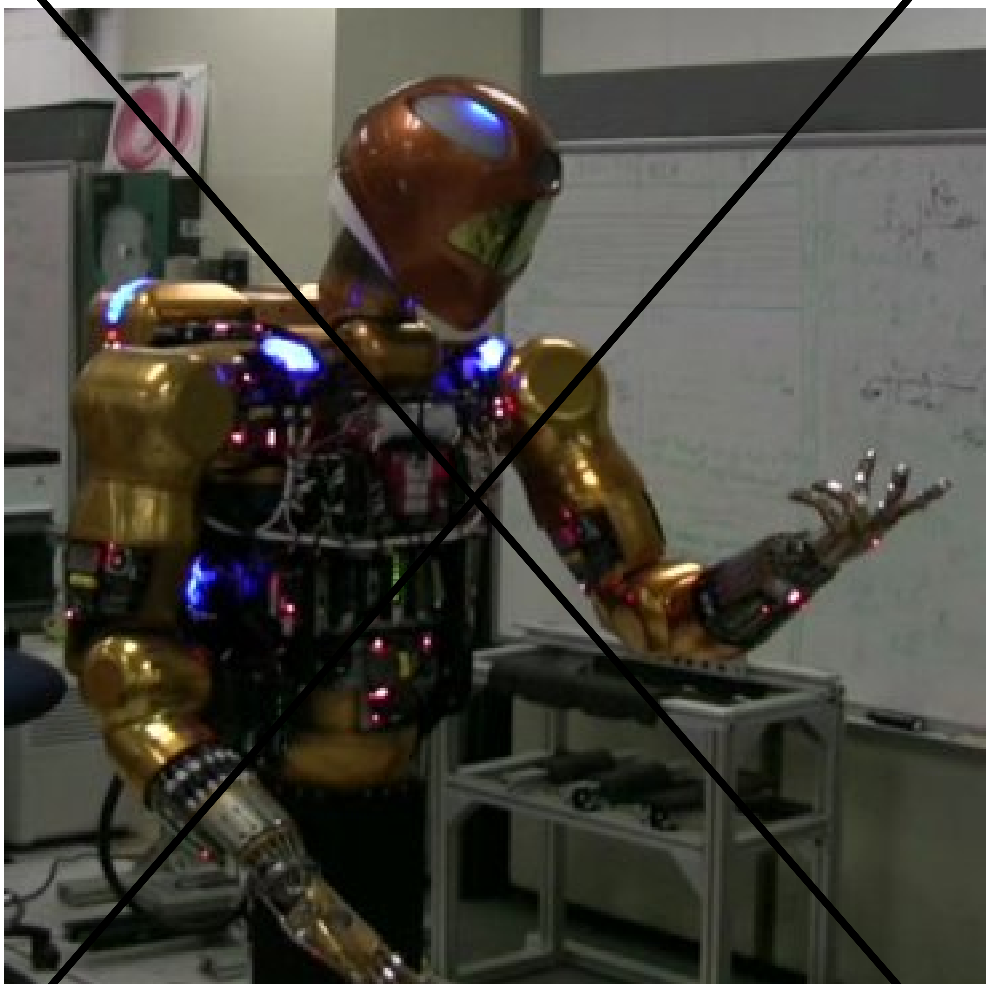
The hard part?

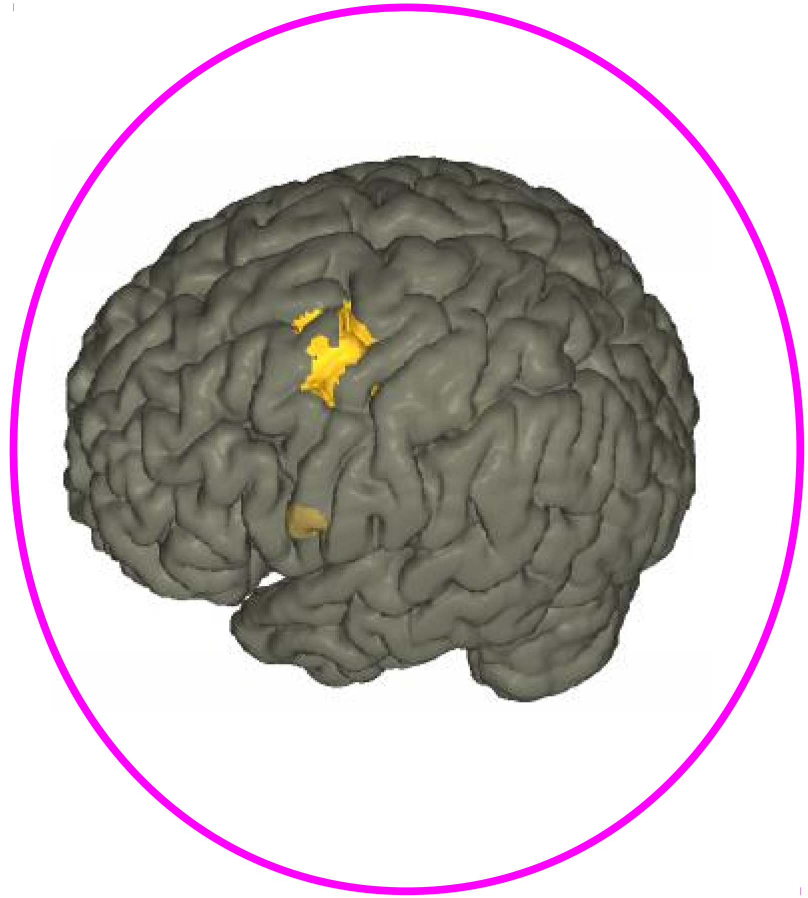




Hardware? or Smarts?

The hard part?





Hardware? or Smarts!

This course: objectives

1. Understand “the” basic problems in robotics
2. Understand a few key algorithms in detail
3. Learn mathematical/algorithmic tools that you can use elsewhere

Course Prerequisites

1. Ability to program in Matlab (or the ability to learn to do this)

2. Comfortable with linear algebra and math in general.

Reading material, notes

There is no single assigned text. I will assign papers and chapters as we go. This will be posted to the course website.

Course Requirements

1. Five or six homework/lab assignments

2. Final exam

   - you can be tested on things that I say in class as well as what's in the notes and reading.

3. NO CHEATING!!!

Topics

1. Control
2. Planning
3. Localization and mapping
4. Optimization

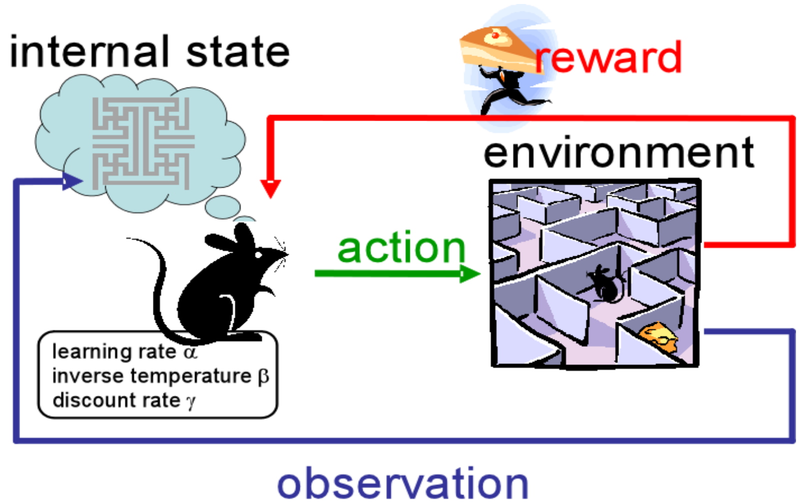
Reinforcement learning

Given: the ability to take actions

Given: the ability to perceive state exactly

Given: “rewards”

Objective: gradually calculate a policy for acting optimally with respect to the reward function.

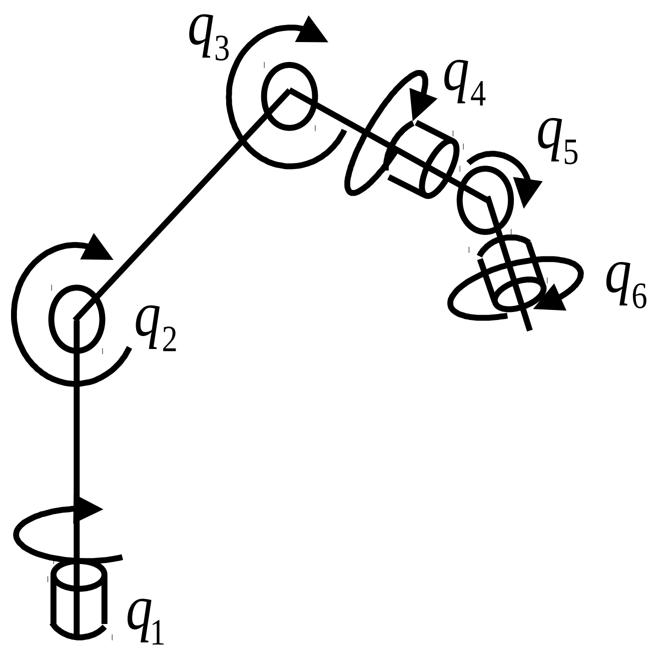


(image from healthandphysicaleducationteacher.com as of 1/2013)

Cartesian Control

Given: a model of a robot arm

Objective: calculate how to move the joints in order to cause the end-effector (i.e. the hand) to reach a particular point.



Motion Planning

Problem statement:

<u>Given:</u> model of state space

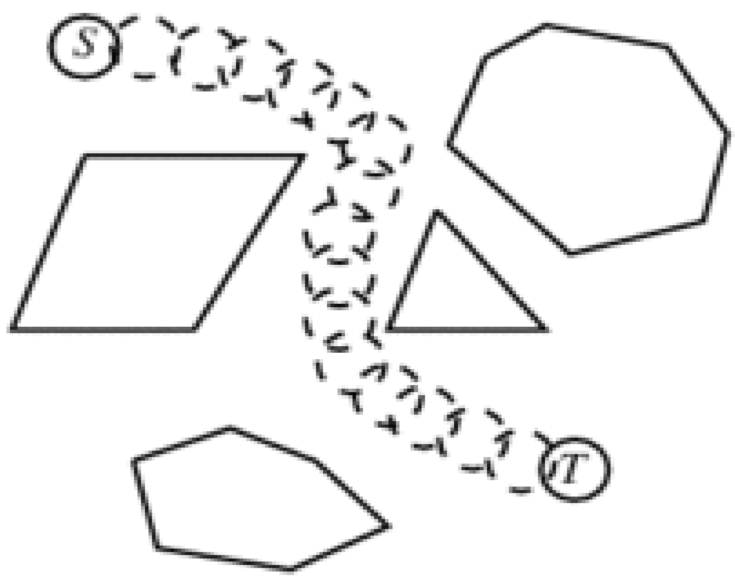
<u>Given:</u> a model obstacles in state space

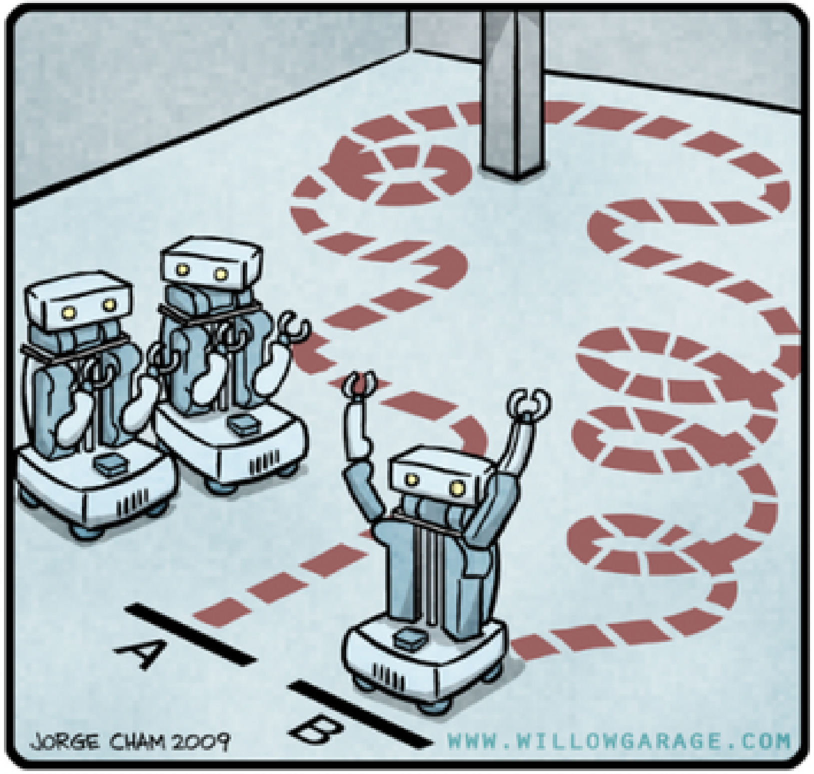
<u>Problem:</u> find a path from start to goal

Motion Planning

Applications:

1. mobile robot path planning



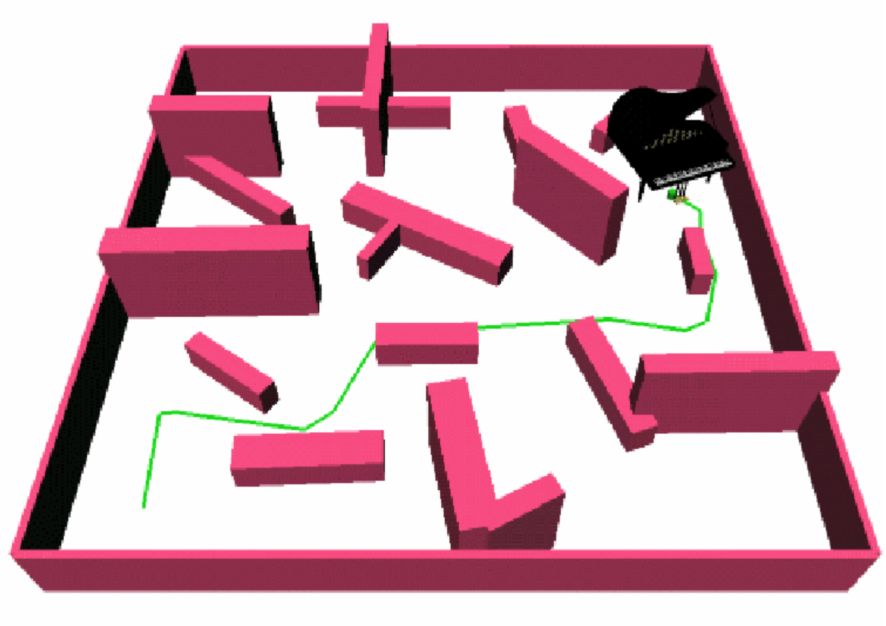


"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."

Motion Planning

Applications:

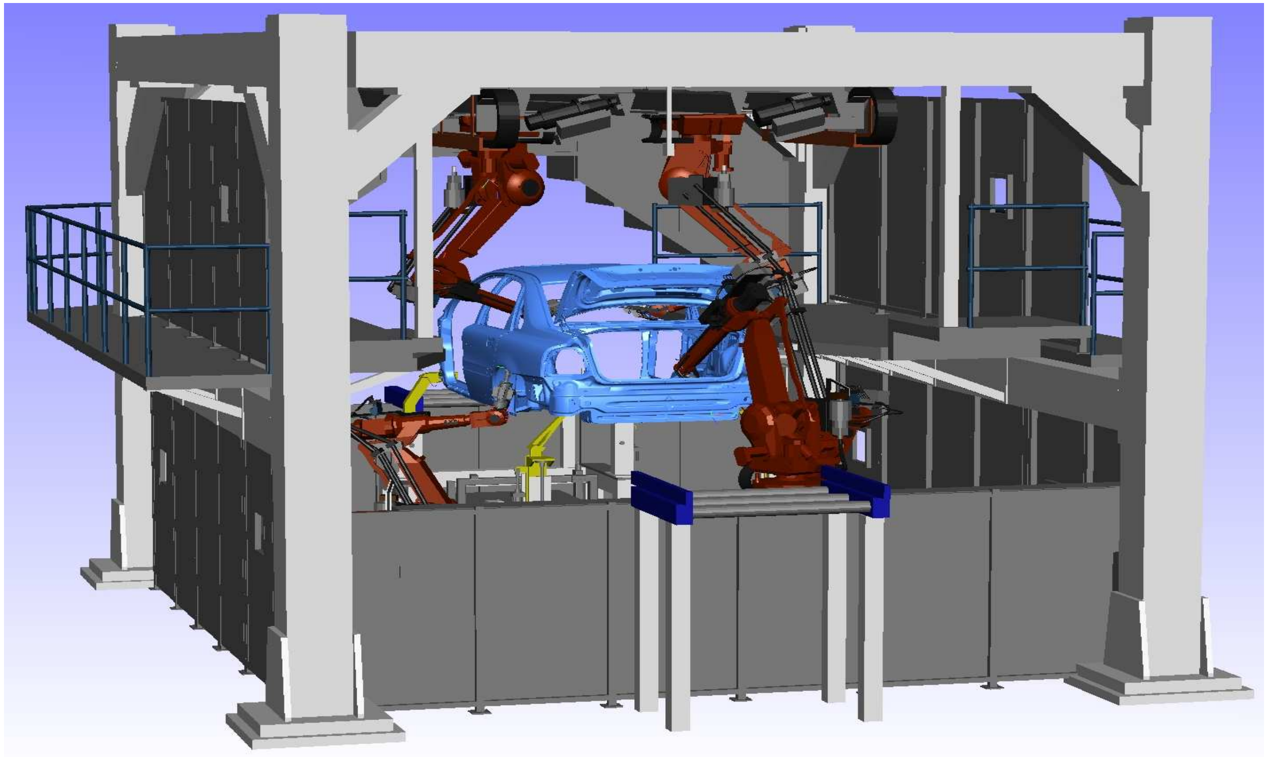
2. “Piano movers problem”



Motion Planning

Applications:

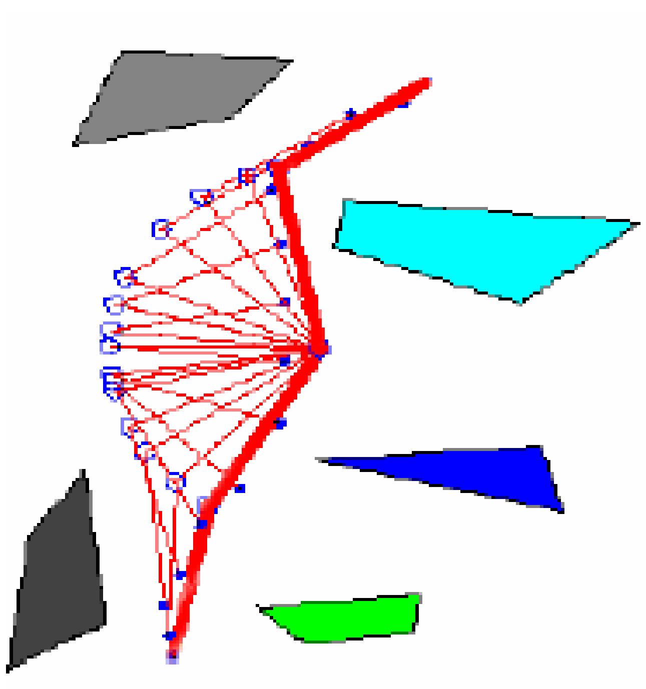
3. articulated arm motion planning

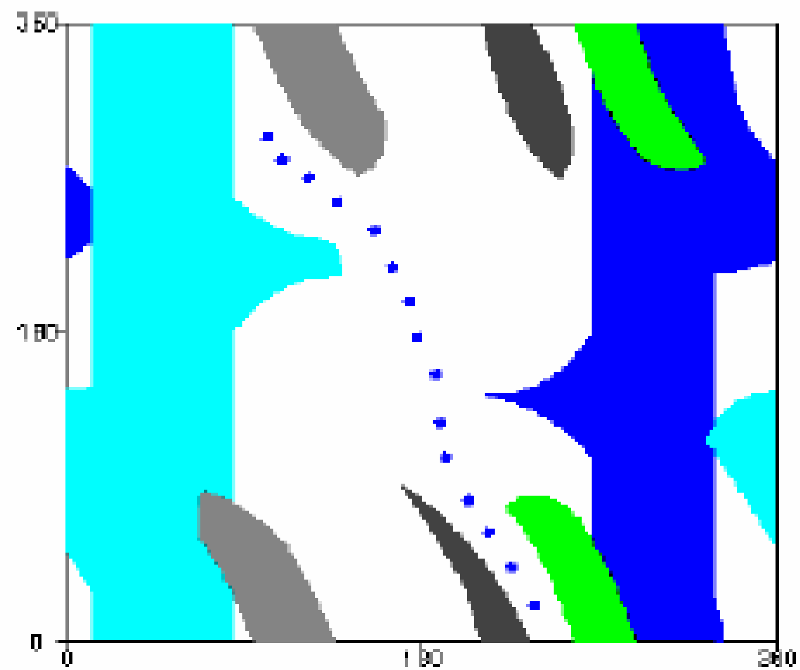


Motion Planning

Applications:

3. articulated arm motion planning



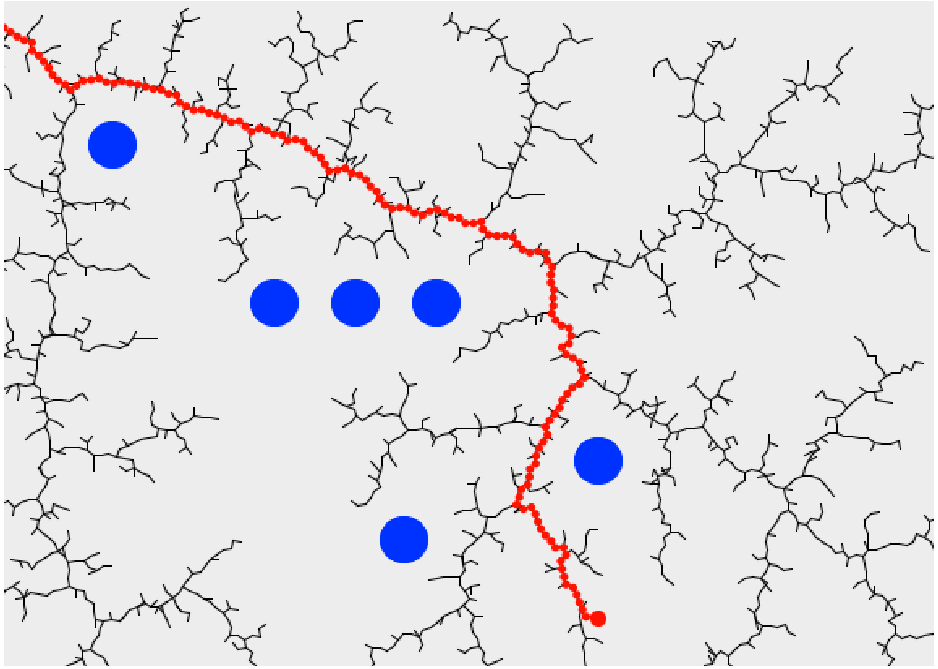


Motion Planning

Two main algorithms:

1. Probabilistic Road Maps (PRM)

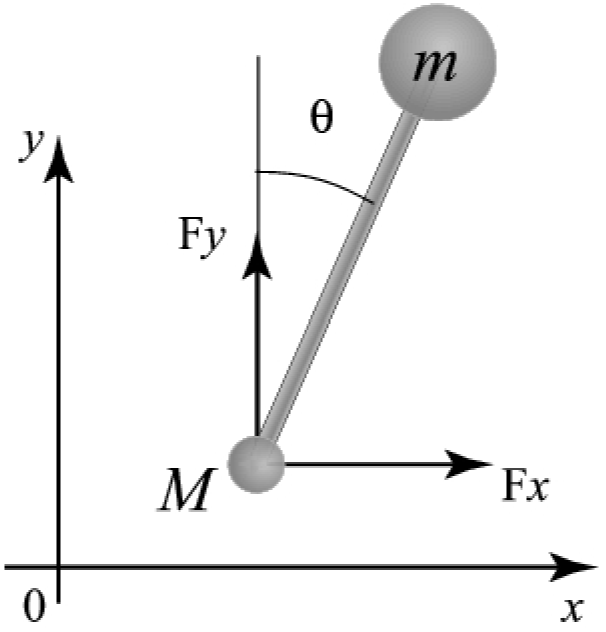
2. Rapidly Exploring Random Tree (RRT)

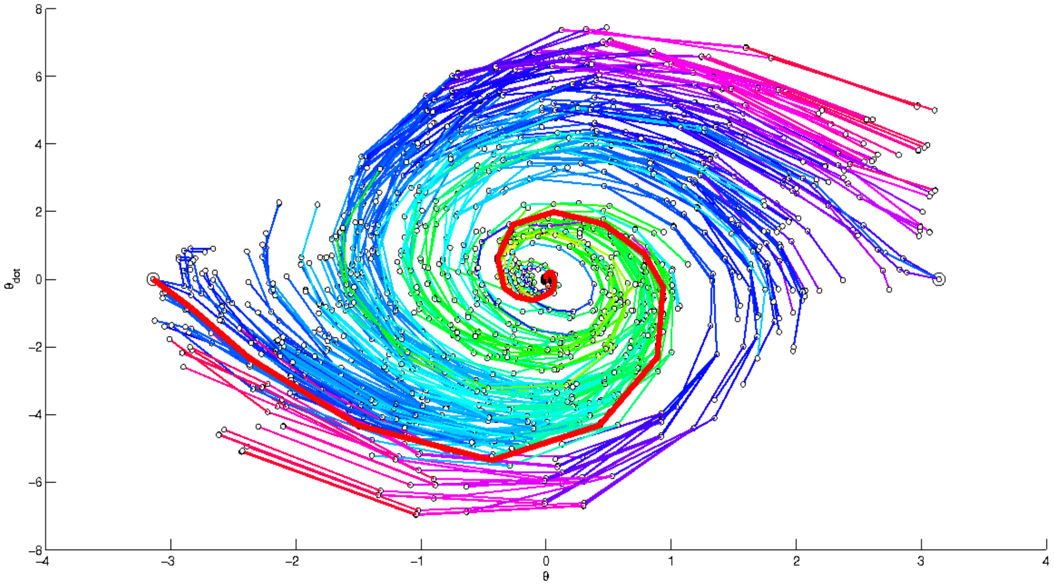


Motion Planning

Also kinodynamic applications:

- inverted pendulum

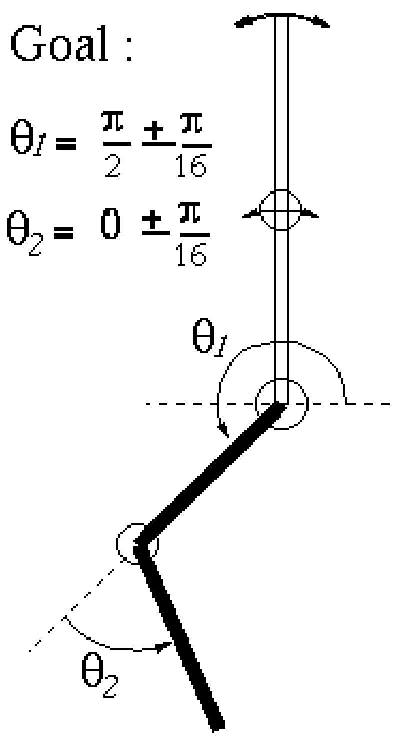




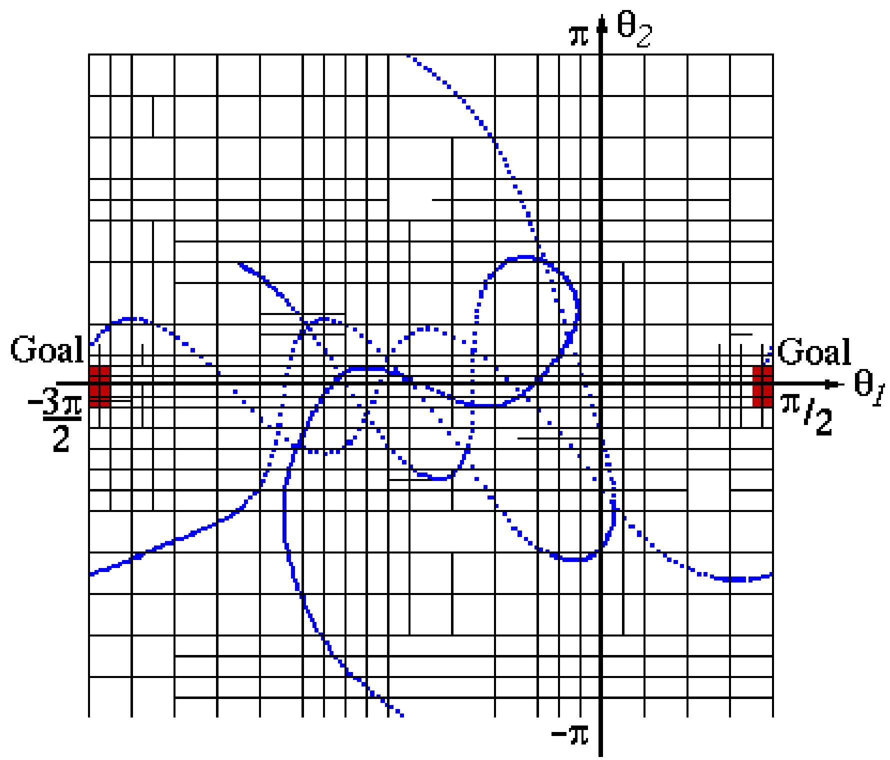
Motion Planning

Also kinodynamic applications:

- "Acrobot"



(a) The Acrobot



(b) Projection of the state space

Estimation: localization

Problem statement:

Given: noisy sensors that measure partial information

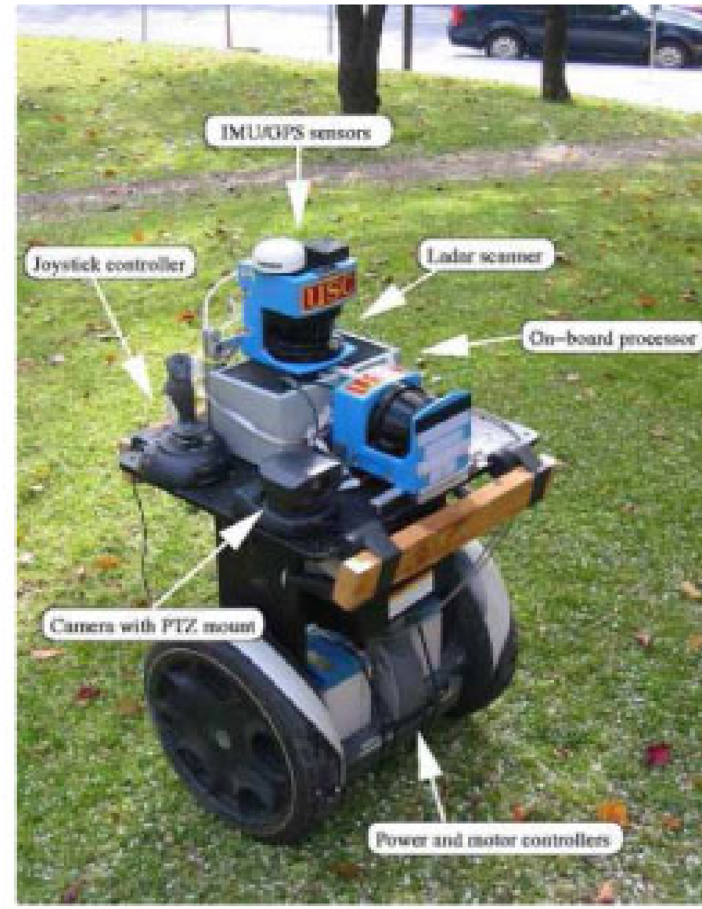
Given: a model of the system

Problem: estimate state

Estimation: localization

For example:

<u>Given:</u> mobile robot with laser scanners moving in an office building



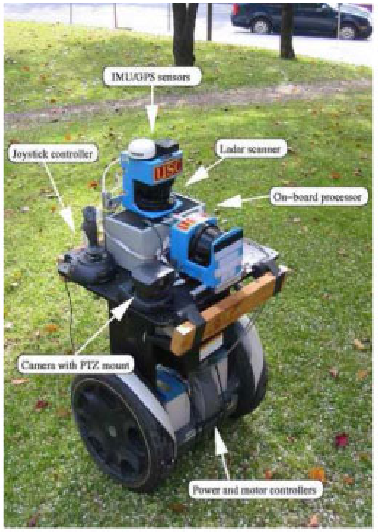
A Segway RMP equipped with laser range finders
IMU.

Estimation: localization

For example:

<u>Given:</u> mobile robot with laser scanners moving in an office building

<u>Given:</u> a map of the building, model of how wheels move



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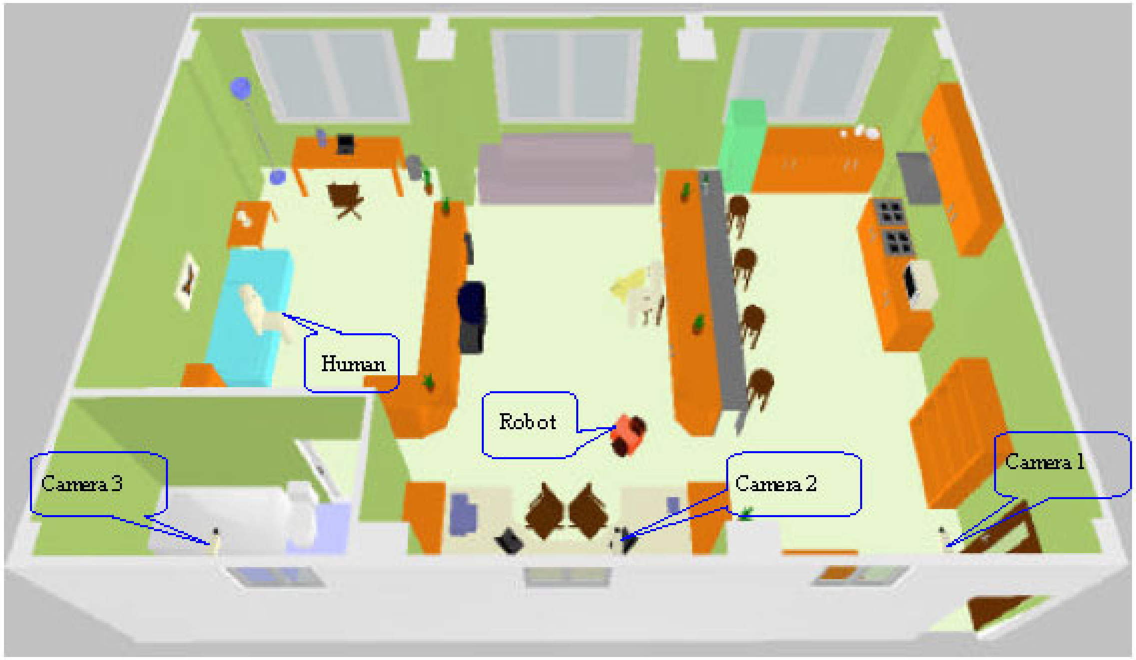


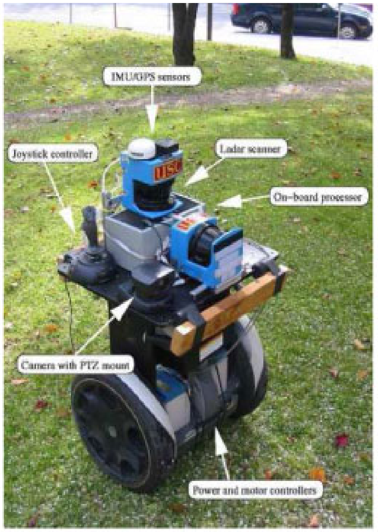
Estimation: localization

For example:

<u>Given:</u> mobile robot with laser scanners moving in an office building

<u>Given:</u> a map of the building, model of how wheels move

<u>Objective</u>: localize robot



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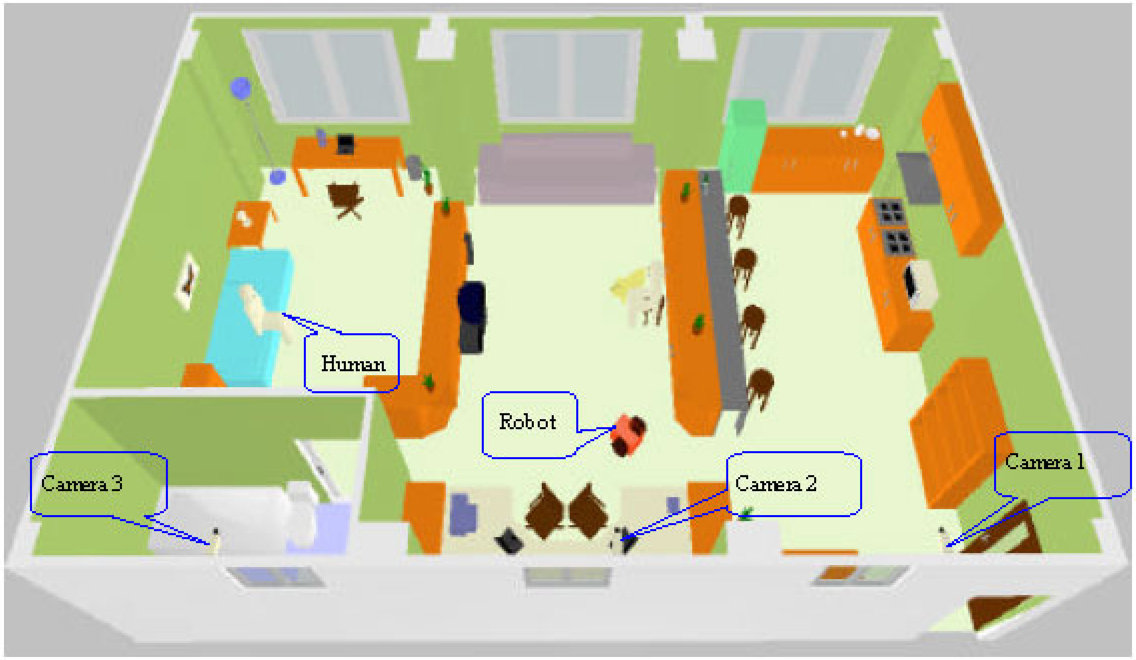
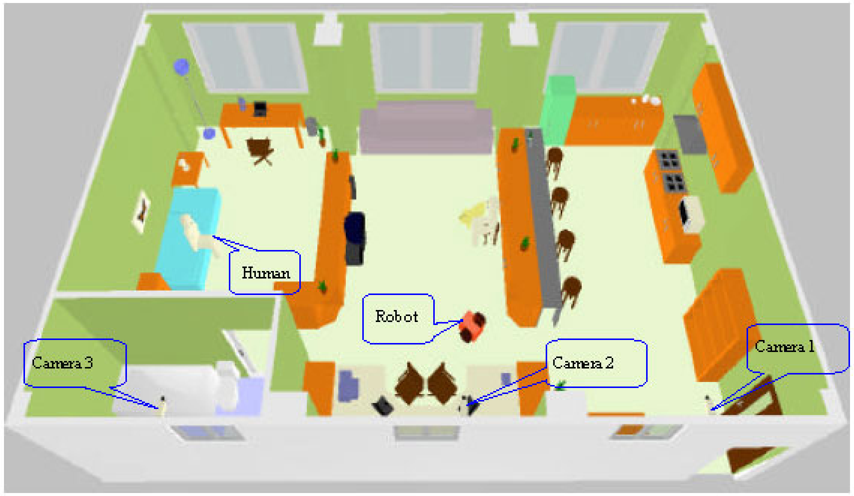
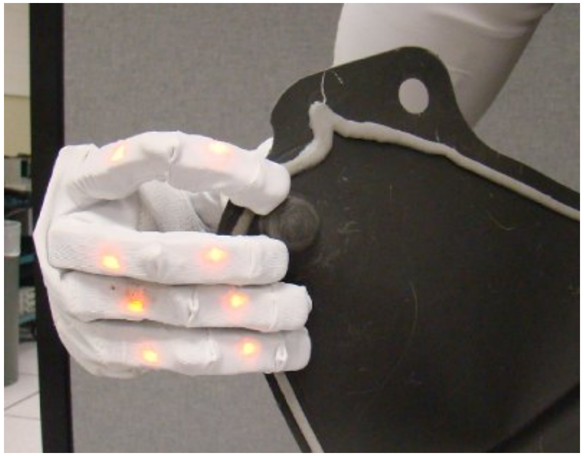


Estimation: localization

Potential algorithms: variants of Bayesian filtering:



1. Extended Kalman filter (EKF)
2. Unscented Kalman filter (UKF)
3. Ensemble Kalman filter
4. Histogram (Markov) filter
5. Particle filter
6. Others?



Potential applications:
1. mobile robot localization
2. localization of object held in hand
3. ?

Mapping

In principle, same as localization:

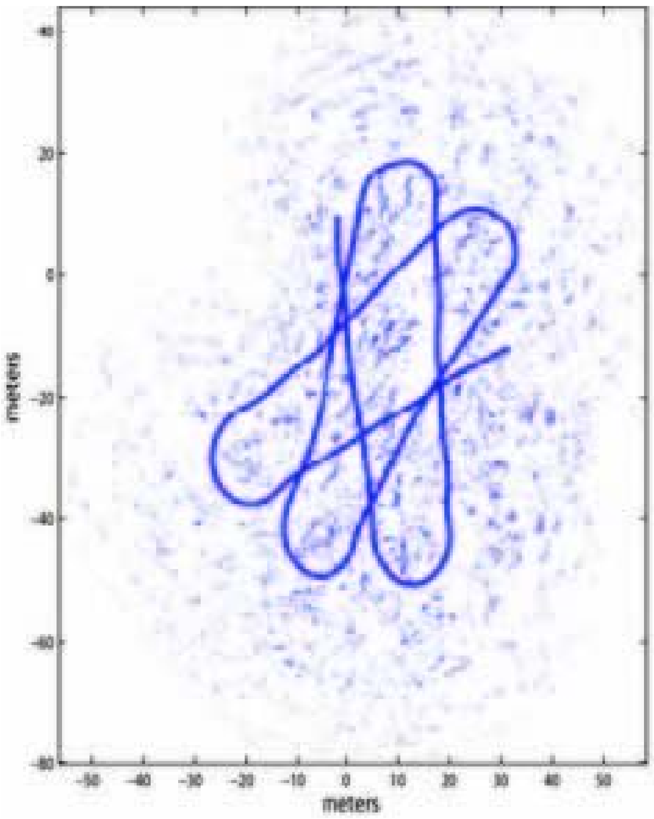
Given: mobile robot with laser scanners moving in an office building

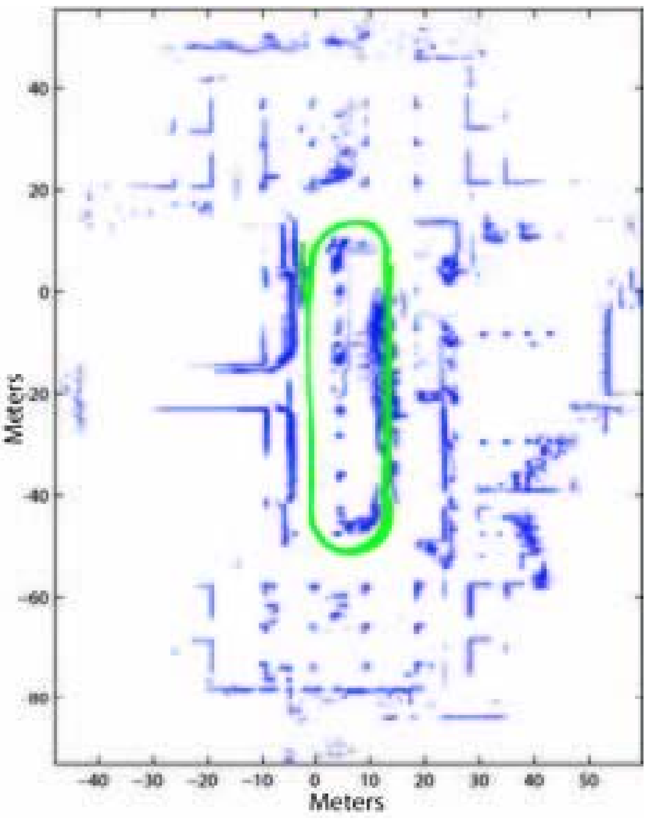
Given: no map!

Objective: localize robot, estimate map

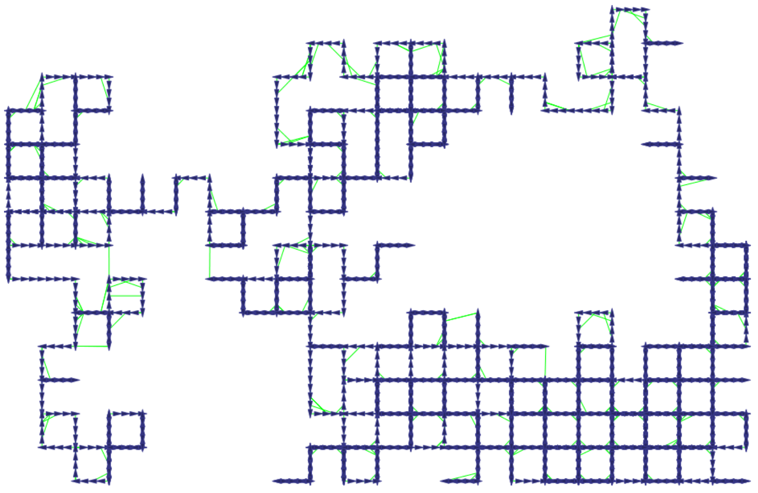
Algorithms:
- same as for localization
- new problem: high dimensionality of estimation problem
- other problems too...
- solutions: various tricks to deal w/ high dimensionality

Mapping

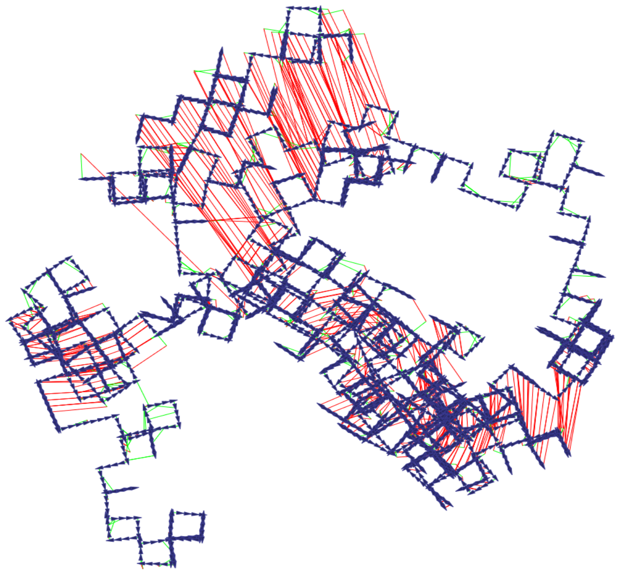




Mapping



Ground truth



Odometry

Reconstructed