Welcome to

CSE 571
Probabilistic Robotics

Instructor: Dieter Fox

Teaching Assistant:
Arun Byravan

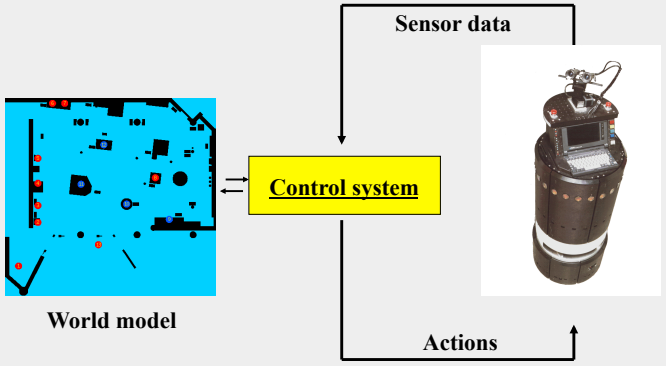
Organization

- M/W 1:30 – 2:20
  - Lectures, discussions (EEB 045)
  - Homework, project
- Readings:
  - Papers
  - Chapters from *Probabilistic Robotics*
- Web page:
  - http://www.cs.washington.edu/571

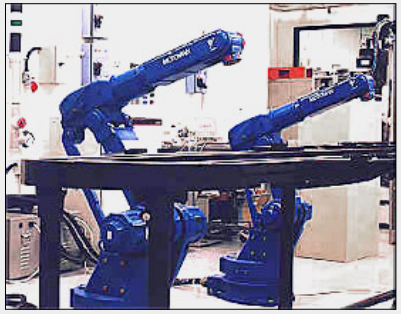
Goal of this course

- Provide an overview of problems / techniques in robotics
- Deep understanding of estimation in dynamic systems
  - Probabilistic models
  - Inference, learning
- Hands-on experience

High-level View on Robot Systems



Robotics Yesterday



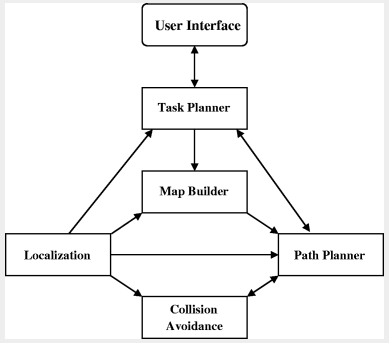
Current Trends in Robotics

Robots are moving away from factory floors to

- Entertainment, toys
- Homes, hotels (personal robotics)
- Medical, surgery
- Industrial automation
  (mining, harvesting, warehouses, …)
- Hazardous environments
  (space, underwater, battlefields, …)
- Roads

Minerva (CMU + Univ. Bonn, 1998)

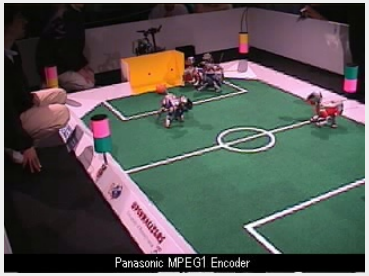
Architecture of the Control System



RoboCup: Integrated System Research

- Focus on addressing all problems at once
  - Hardware development
  - Perception
  - Low level control
  - High level planning and decision making
  - Multi robot systems

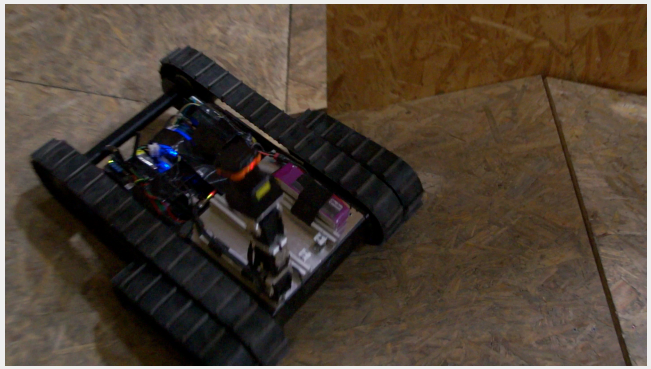
RoboCup-99, Stockholm, Sweden



RoboCup Small Humanoid League

RoboCup: Midsize League

RoboCup Rescue

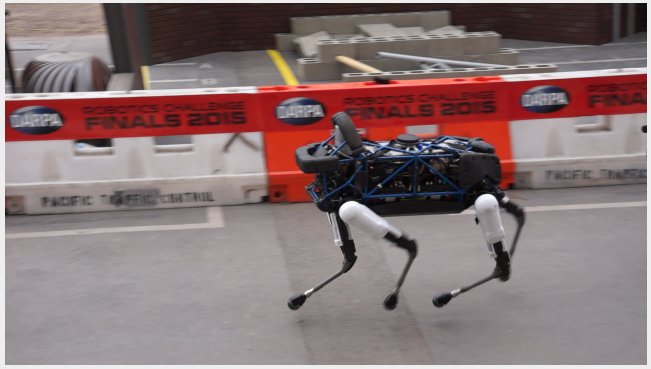


DARPA Urban Challenge 2007

Google Self-Driving Car

Control: BigDog

Cheetah



Massachusetts Institute of Technology

Autonomous Running Jumps Over Obstacles in the MIT Cheetah 2

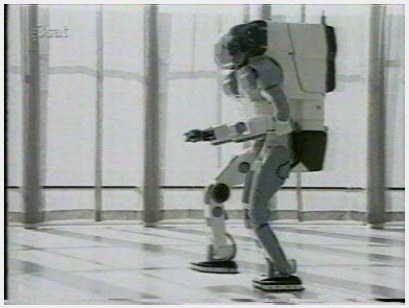
Hae-Won Park, Patrick Wensing, and Sangbae Kim

MITMECHE BIOMIMETIC ROBOTICS LAB

Boston Dynamics Cheetah

DARPA Robotics Challenge 2015

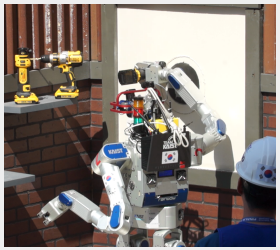
Humanoids: Honda P2

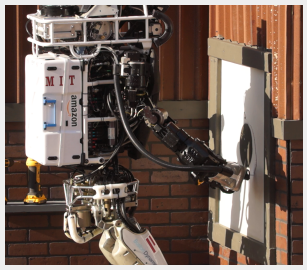


Honda P2 '97

Getting out of Car

Drilling Hole





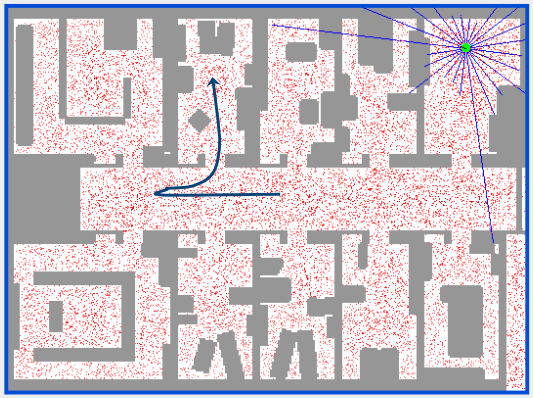
Current Research Trends / Topics

- Manipulation of everyday objects
- Complex household tasks (cooking, cleaning, …)
- Kinect for object detection, 3D mapping, tracking, interaction
- Human robot interaction
- Machine learning for control, imitation learning, recognition
- Deep learning

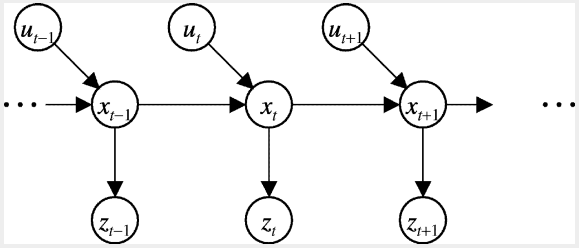
Course Outline

Week	Content	HW / Project
#1	Introduction	
	Probabilistic Models / State Estimation	
#2	Bayesian state estimation / filtering	
#2	Motion and sensor models, Gaussian processes	HW 1: GP modeling
	Filtering (localization, mapping)	
#3 / 4	Robot localization: grid, particle filters, EKF, UKF	HW2: Filtering
#5 / 6	Map building: EKF-SLAM, Fast-SLAM, RGBD	
	Planning / Control	
#6 / 7 / 8	Path planning, exploration, MDPs, POMDPs	Project
#9	Reinforcement learning, inverse RL	
	Other Topics	
#10	Object detection and tracking	

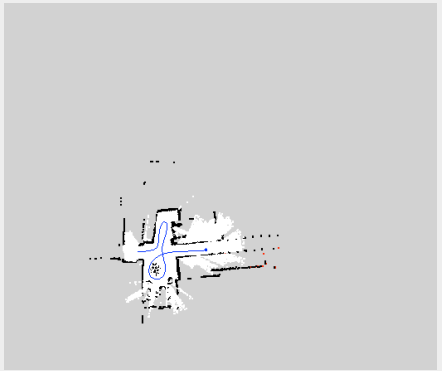
Sample-based Localization (sonar)



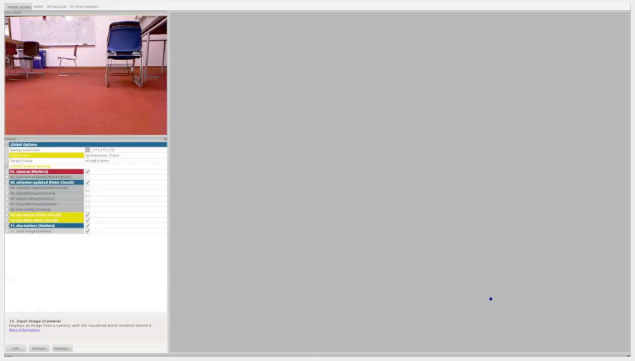
Graphical Model Representation of Localization Problem



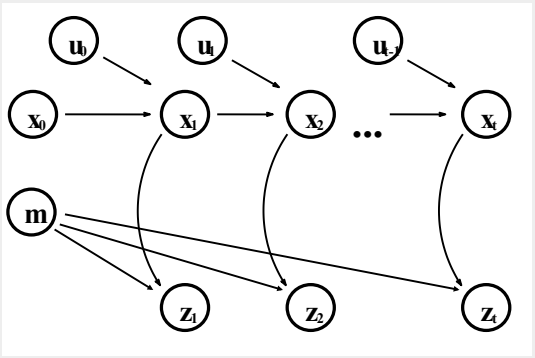
Mapping with Laser Scanners



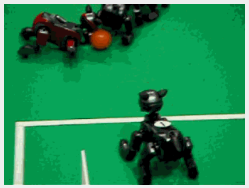
Mapping with Kinect

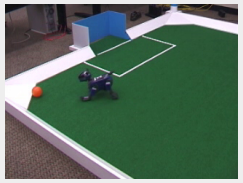


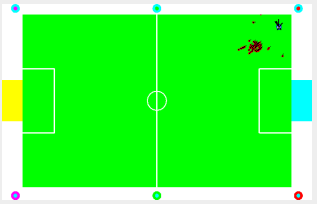
SLAM: Simultaneous Localization and Mapping



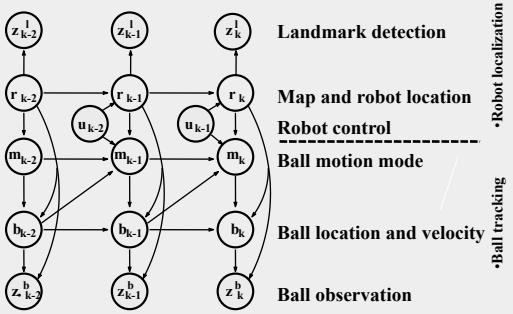
Structured Estimation





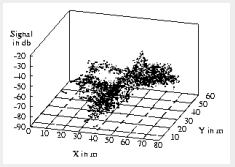


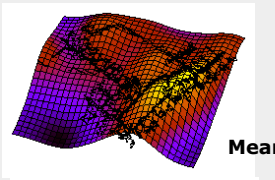
Localization and Ball Tracking



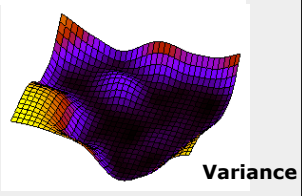
Articulated Tracking (42 DOF)

Gaussian Process Sensor Model for WiFi Signal Strength

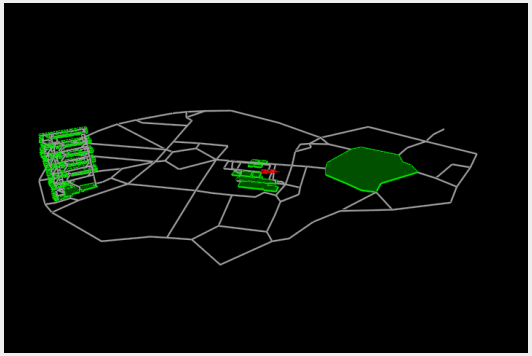




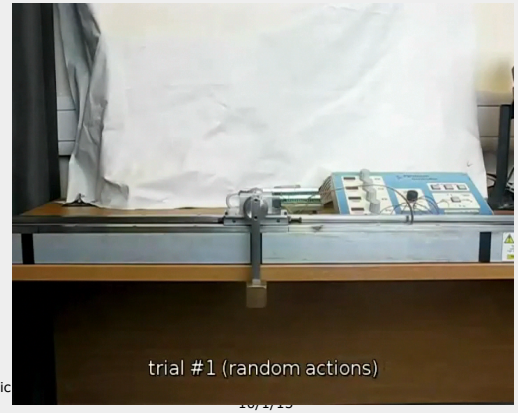
- Non-parametric regression
- GP regression
  - continuous locations
  - smooth interpolation
  - uncertainty estimates



Tracking Example

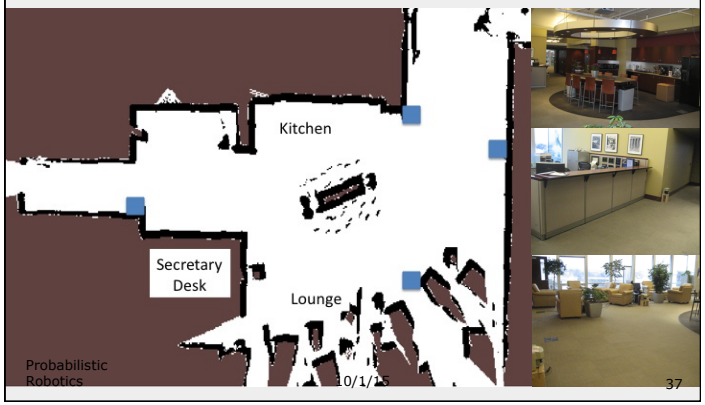


RL with GP Dynamics Models: PILCO (Probabilistic Inference for Learning Control)



[Ziebart-Bagnell-etal]

Pedestrian Trajectory Prediction



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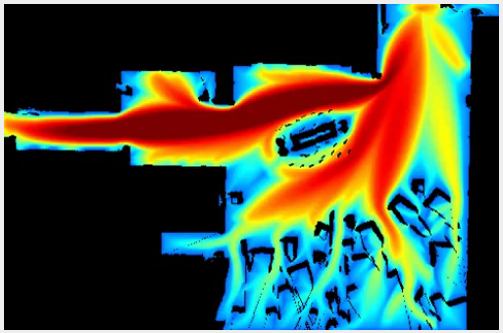

- Inverse optimal control: Learn cost function that explains human behavior; use that to estimate goal

Planning for Manipulation