Concepts and Topic Overview

Intro to Robotics

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Some slides based in part on www.jhu.edu/virtlab/course-info/ei/ppt/robotics-part1.ppt and -part2.ppt

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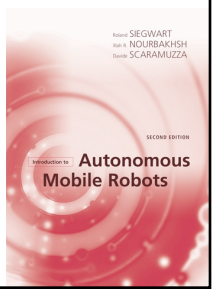
Bookkeeping

- You've read:
  - Syllabus: policies, general info
  - Schedule: readings, slides (notes), homework
  - Academic integrity
- Piazza: announcements, Q&A, resources, …
- Text: 2nd edition
  - How many people have it?
- Survey??



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Today's Class

- Why study robotics?
  - What precisely is robotics?
  - Where does it come from?
- Basic terminology and concepts
  - Mobility
  - Manipulation
  - HRI
  - Autonomy

Starring!
Kinematics
Environment modeling
Localization and map-building
Planning and control

- Each of these topics will be treated more in-depth throughout the course

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Robotics: Origin and Meaning

- Robota: Czech for useful (and forced) labor
  - Karel Capek, 1921 play "Rossum's Universal Robots"
  - Represents today's understanding of an android
- By this definition, the field is ancient
  - Clepsydra: water clocks of ancient greece
  - Windmills, steam engines

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"Modern" Robotics is Born

- Milestones in stationary robotics (industry)
  - Pick and place Unimates, 1956
  - Stanford arm, 6 dof, 1969
  - ABB and KUKA industrial arms, 1973
- Milestones in mobile robotics
  - Shakey the robot, 1966
  - NASA Viking program, 1976

c wikipedia.org

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Tasks for Robots

- **We don't want to do**
  - Dangerous
    - space exploration
    - chemical spill cleanup
    - disarming bombs
    - disaster cleanup
  - Boring and/or repetitive
    - welding car frames
    - part pick and place
    - manufacturing parts.
- **Robots can do better**
  - High precision or high speed
    - electronics testing
    - surgery
    - precision machining
- **Both**

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For example…

- Industry and Agriculture
  - Assembly, welding, painting, harvesting, mining, pick-and-place, packaging, inspection, …
- Transportation
  - Autonomous helicopters, pilot assistance, materials movement
- Cars
  - Antilock brakes, lane following, collision detection, GPS
- Exploration and hazardous environments
  - Mars rovers, search and rescue, underwater and mine exploration, mine detection
- Military
  - Reconnaissance, sentry, S&R, combat, EOD
- Household
  - Cleaning, mopping, ironing, tending bar, entertainment, telepresence/, surveillance

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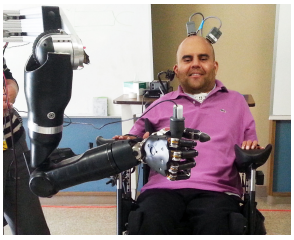
And more…

- Medical robotics
  - Autonomous surgery
  - Eldercare
- Biological Robots
  - Biomimetic robots
  - Neurorobotics
- Navigation
  - Collision avoidance
  - SLAM/Exploration
  - Mapping and localization



news.usc.edu/81927/neural-prosthetic-device-yields-fluid-motions-by-robotic-arm

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General Topics

- Hardware Design
- Sensing
  - Environment Models
- Actuation
  - Mobility
    - Mapping
    - Localization
  - Manipulation
- Motors
- Control
  - (Inverse) Kinematics
  - Dynamics
  - Motion planning
- Cognition
  - Machine learning
  - Classic AI
  - Others
- Human-robot interaction

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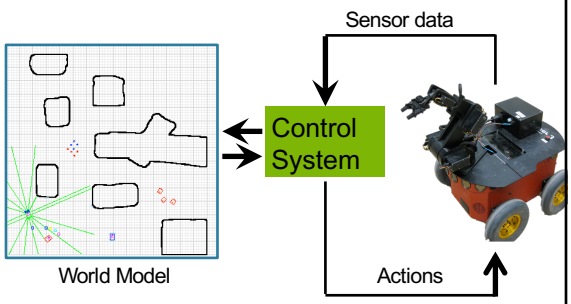
High(est) Level View



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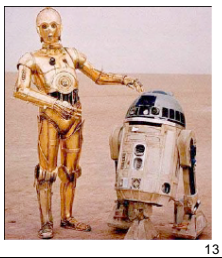
Control: The Brain

- Open loop (i.e., no feedback)
  - Instructions & rules
  - Repetitive/unchanging tasks
  - "Sensing" part of the loop is missing
- Closed loop (has feedback)
  - Adapts to changes in environment
  - Can *potentially* learn



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Sensors

- Perceive the world
- **Passive** sensors capture signals generated by environment.
  - Often background, lower power.
  - Example: cameras.
- **Active** sensors probe the environment.
  - Explicitly triggered, more info, higher power consumption.
  - Example: sonar

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Sensors II

- What are they sensing?
  - The environment: range finders, obstacle detection
  - The robot's location: GPS, wireless stations
  - Robot's internals: joint encoders
- There are **hundreds** of kinds of sensors
- We'll go into detail on some
  - Optical (including vision)
  - Depth
  - Joint encoding

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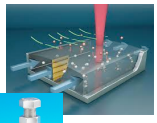
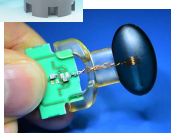
Some Typical Sensors

- Optical
  - 3D
  - Color spectrum
- Range sensing
  - Laser / radar / sonar
- Pressure, temperature, chemical
- Motion & Acceleration
- Acoustic
  - Sonar, ultrasonic
- Electric field Sensing





phys.org/news/2016-12-high-precision-magnetic-field.html

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Actuation: Movement

- Manipulators
  - Anchored somewhere: assembly lines, ISS, hospitals.
  - Common industrial robots

- Mobile Robots
  - Move around environment
  - UGVs, UAVs, AUVs, UUVs
  - Mars rovers, delivery bots, ocean explorers
- Mobile Manipulators
  - Both move and manipulate
  - Packbot, humanoid robots

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Actuators

- Take some kind of action in the world
  - Involve movement of robot or subcomponent of robot
- Robot actions can include
  - Pick and place: Move items between points
  - Path control: Move along a programmable path
  - Sensory: Deploy sensors for feedback (e-field sensing)
  - Manipulation: interact with objects in the world

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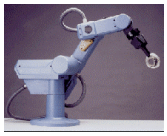
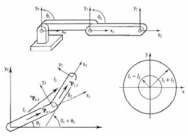
Some Typical Actuators

- Pneumatic
- Hydraulic
- Electric solenoid



- Motors
  - Analog (continuous)
  - Stepping (discrete increments)
  - Gears, belts, screws, levers



- What's missing?

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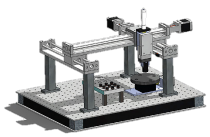
Manipulation

Overview, Concepts, Types



Many slides adapted from:
S. N. Kale, Assistant Professor, PVPIT, Budhgaon
www.amci.com/tutorials/tutorials-stepper-vs-servo.asp
www.modmypi.com/blog/whats-the-difference-between-dc-servo-stepper-motors
en.wikipedia.org

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What is Manipulation?

- How a robot:
  - Makes physical changes to the world around it
  - Physically interacts with the world and other agents (including itself)
- Moving, joining, reshaping, painting, etc. objects
- Grasping, pushing, carrying, dropping, throwing
- Using a manipulator with some sort of end-effector
  - End-effector: the bit on the end that does things
  - Example: gripper

slide adapted from www.cs.columbia.edu/~allen/F15/NOTES/graspingClass2_2.ppt 21

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Manipulation

- Manipulates something in the world
  - Physically alter the world through contact
  - As a primary goal
  - But **not its own position**
- When is this desirable?
  - Dangerous workspaces
    - Space; foundries; underwater; factories
  - Human-intractable workspaces
    - Too small; too big; too much precision needed
  - Boring, repetitive, unpleasant work

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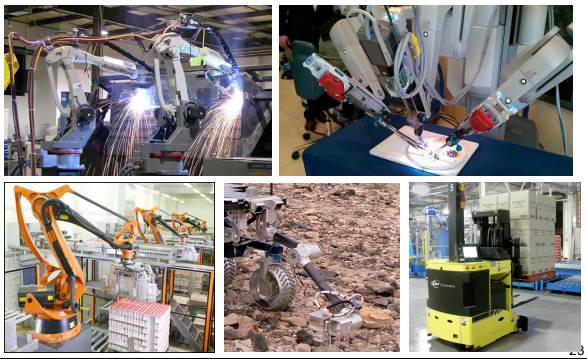
Manipulators



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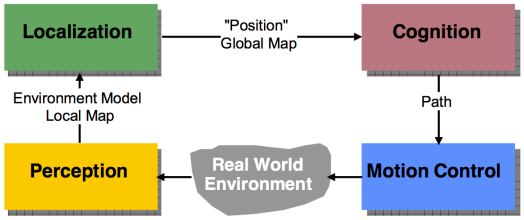
Mobility

Legs, Wheels, and Wings



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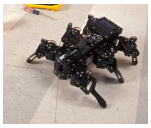
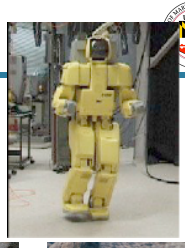
Mobility

- Legs
- Wheels
- Tracks
- Crawls
- Rolls
- Treads
- …

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Mobile Robots

- Space Rovers
  - Key issues: mobility in rough terrain, time delay, temperatures, maintenance, joint infiltration
- Autonomous Robotic Cars
  - Key issues: dynamic environments, safety
- Flying Robots
  - Key issues: limited computation power and payload
- Personal Robots
  - Key issues: safety, human-friendliness

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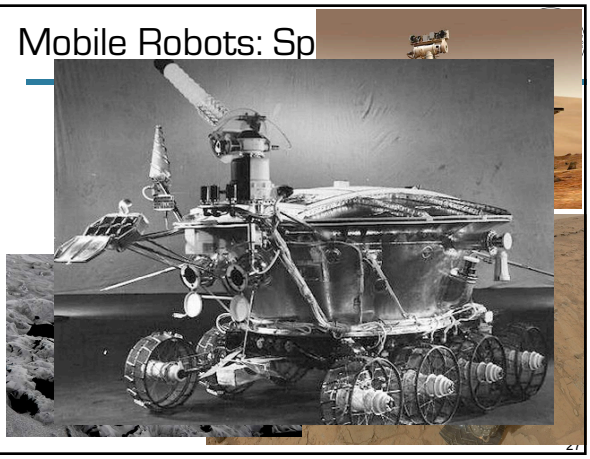
Mobile Robots: Sp



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Passive Dynamic Walking

- Gravity-powered walking with bipedal gait

https://www.youtube.com/watch?v=CK8lFEGmi28

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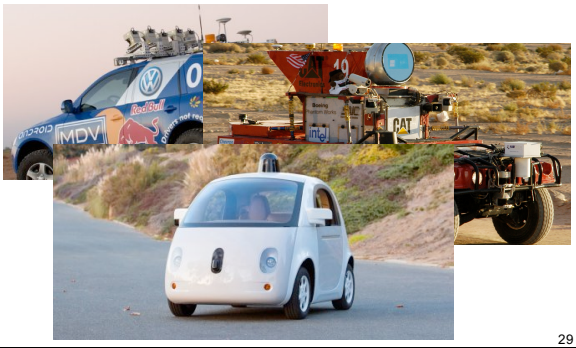
Mobile Robots: Cars



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Mobile Robots: Factories

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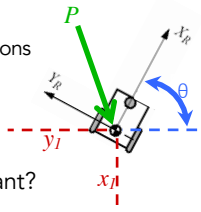
Kinematics: Study of Motion

- The study of the **motion of objects**
  1. The study of the geometrically possible motion of a body or system of bodies
  2. **Without** consideration of the causes and effects of the motions
- Movement determines the (eventual) position and orientation of the robot
- How do we get where we want?
- Where are we? How did we get there?



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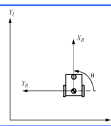
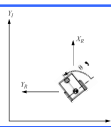
Position and Orientation

	Where is it?	What's its orientation?
Mobile	On an $\{x,y\}$ plane 	Heading θ 
Manipulator	In some $\{x,y,z\}$ space 	$\{r/p/y\}$ of end effector 

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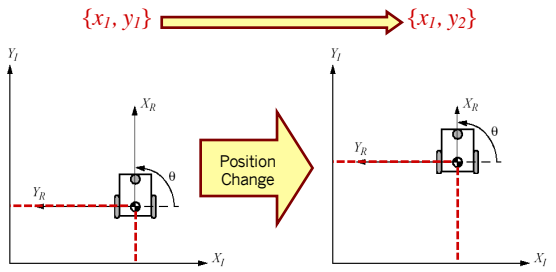
Mobile Position Change



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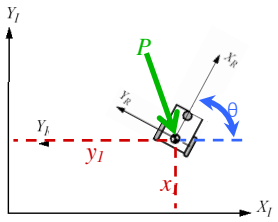
Mobile Position & Orientation

Frames of reference:
$\{X_I, Y_I\}$: Global
$\{X_R, Y_R\}$: Robot

Robot: point P

Position (of P):
$\{x_{I,1}, y_{I,1}\}$

Heading:
$\{\theta\}$: I ∠ R



$$\xi_I = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix}$$

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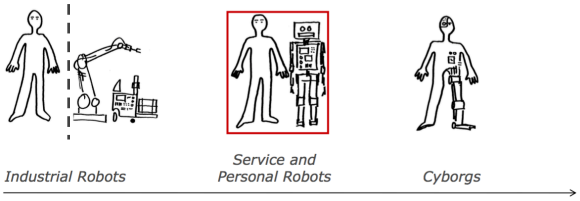
Human-Robot Interaction

- Technical systems can be characterized by the increasing physical and psychological ***closeness and interaction*** between man and machine



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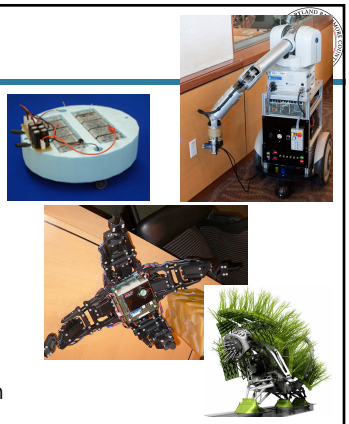
Self-X Robots

- Self-feeding
  - Literally
  - Electrically
- Self-replicating
- Self-repairing
- Self-assembly
- Self-organization
- Self-reconfiguration



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Autonomy and Thought

- Learning and machine learning
  - Not all learning is ML, or "deep"
- Autonomous decision making
  - What kind of learning agent are we thinking of?
- Independent action
- Philosophically…
  - Can they think?
  - Can they reason?
  - Are they "truly" intelligent?

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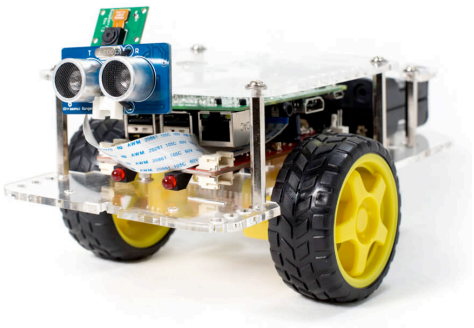
Project sneak peek



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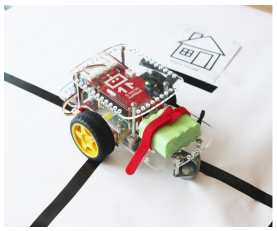
Project sneak peek

- Build!
  - No soldering, plenty of instructions
- Get working under ROS
- Perform a task
  - Line-following
  - More complex
- Tournament/demos
- Unbuild ☹



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A Sample of Questions

- Mechanisms
  - Morphology: What should robots look like?
  - What novel actuators/sensors can we build?
- Estimation and Learning
  - Deep Learning
  - Graphical Models
  - Learning by Demonstration
- Manipulation
  - What does the far side of an object look like? How heavy is it? How hard should it be gripped? How can it rotate? Regrasping?

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