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

Bookkeeping

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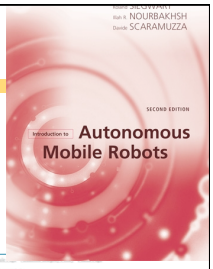
- Syllabus: policies, general info
- Schedule: readings, slides, homework
- Piazza (forum): announcements, Q&A, resources, …
- Text: 2nd edition
- Survey 1:
  - Please do if you haven't
- Academic integrity (or, where do I sign?)



Today's Class

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- Introduction to & motivation for studying robotics
  - What precisely is mobile robotics?
  - Where does it come from?
- Basic terminology and concepts behind robotics
  - Robot kinematics
  - Environment representation and modeling
  - Localization and map-building
  - Planning and control
- Each of these topics will be treated more in-depth throughout the course

Robotics: Origin and Meani

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

"Modern" Robotics is Born

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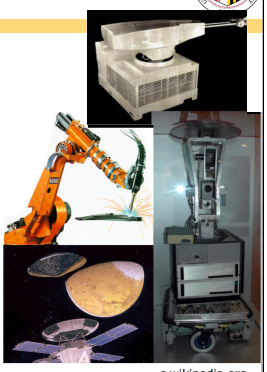
- Milestones in stationary robotics (industry)
  - Pick and place Unimates, 1956
  - Stanford arm, 6 dof, 1969
  - ABB and KUKA industrial arms, 1973
- Milestones in mobile robotics
  - Shakey the robot, 1966
  - NASA Viking program, 1976



c wikipedia.org

Tasks for Robots

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- 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

For example…

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- Industry and Agriculture
  - assembly, welding, painting, harvesting, mining, pick-and-place, packaging, inspection, ...
- Transportation
  - Autonomous helicopters, pilot assistance, materials movement
- Cars (DARPA Grand Challenge, Urban Challenge)
  - Antilock brakes, lane following, collision detection
- 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

Categories of Robots

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- Manipulators
  - Anchored somewhere
    - Factory assembly lines, International Space Station, 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

General Topics

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- 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

What Subsystems Are There?

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- Or: what does a robot need to know?
  - Where am I?
  - What's around me?
  - How am I posed?
    - How do I change it?
  - What do I want to do?
    - With respect to the environment?
    - Where do I go, and how?
    - What do I want to change?
  - How do I do that?
  - Who needs to be involved?
    - People? Other robots?

What Subsystems Are There?

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- Sensing
  - Perceiving the world
  - Creating a *world model*
- Actuation
  - Doing something in the (physical) world
  - Mobility, manipulation, …
- Control
  - Navigation, motion planning, kinematics, dynamics
- Cognition and Learning
- Interfaces

High Level View

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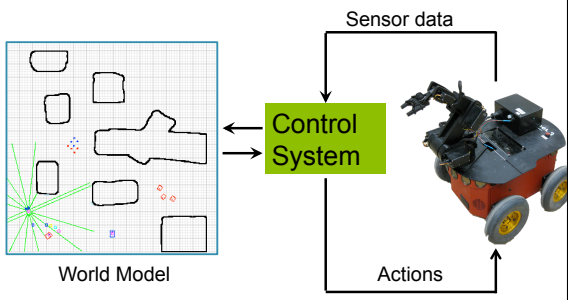

Control: The Brain

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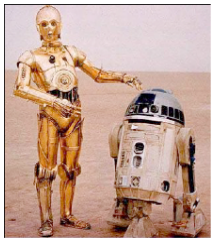
- Open loop, i.e., no feedback
  - Instructions & rules
  - Repetitive/unchanging tasks
  - "Sensing" part of the loop is missing
- Closed loop, i.e., feedback
  - Adapts to changes in environment
  - Can *potentially* learn



Sensors

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- Perceive the world
  - **Passive sensors** capture signals generated by environment.
    - Background, lower power. E.G.: cameras.
  - **Active sensors** probe the environment. Explicitly triggered,
    - More info, higher power consumption. Example: lidar
- What are they sensing?
  - The **environment**: e.g. range finders, obstacle detection
  - The robot's **location**: e.g., gps, wireless stations
  - Robot's **internals**: joint encoders
- Proprioception
  - Close your eyes - where's your hand?

Some Typical Sensors

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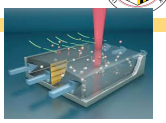

- Optical
  - Laser / radar
  - 3D
  - Color spectrum
- Pressure, temperature, chemical
- Motion & Accelerometer
- Acoustic
  - Sonar, ultrasonic
- E-field Sensing

Robot Systems

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- Manipulators
  - Anchored somewhere: assembly lines, ISS, hospitals.
  - Common industrial robots
- Mobile Robots
  - Move around environment
  - UGVs, UAVs, AUVs, UUVs
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Actuators

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- 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: Employ sensors for feedback (e-field sensing)
  - Manipulation: interact with objects in the world

Some Typical Actuators

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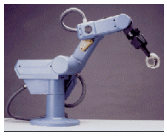
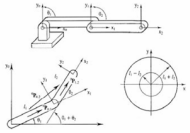
- Pneumatic
- Hydraulic
- Electric solenoid
- Motors
  - Analog (continuous)
  - Stepping (discrete increments)
  - Gears, belts, screws, levers
- What's missing?





Mobility

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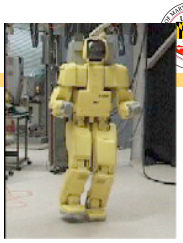
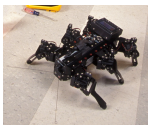
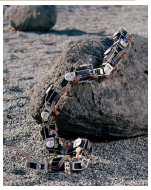
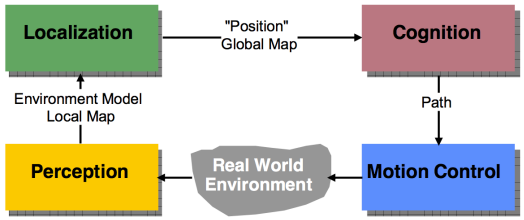
- Legs
- Wheels
- Tracks
- Crawls
- Rolls
- Treads
- …







Mobility
Legs, Wheels, and Wings



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Mobile Robots

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- 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

Mobile Robots: S

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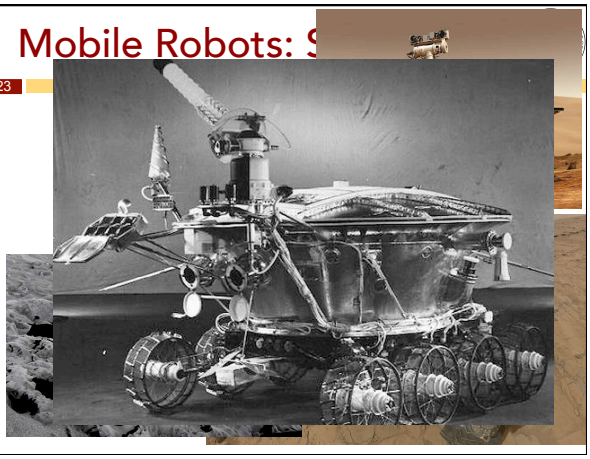

Passive Dynamic Walking

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- Gravity-powered walking with bipedal gait

https://www.youtube.com/watch?v=CK8IFEGmiKY

Mobile Robots: Cars

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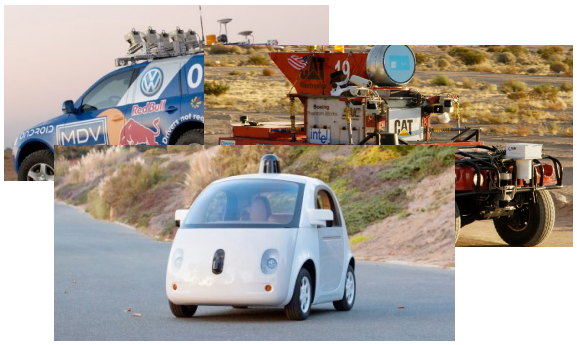

Mobile Robots: Factories

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Kinematics: Study of Motion

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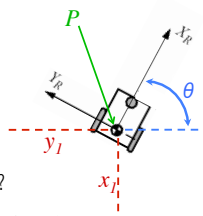
- The study of the **motion of objects**
  1. The study of the geometrically possible motion of a body or system of bodies
  2. without consideration of the
  3. causes and effects of the motions
- Movement determines the (eventual) position and orientation of the robot
- How do we get where we want?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



Position and Orientation

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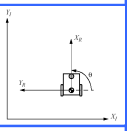
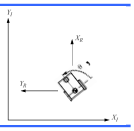
	Where is it?	What's its orientation?
Mobile	On an {x,y} plane 	Heading θ 
Manipulator	In some {x,y,z} space 	{r/p/y} of end effector 

Mobile Position & Orientation

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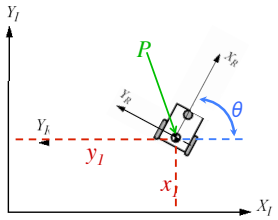
Frames of reference:
$\{X_I, Y_I\}$: Global
$\{X_R, Y_R\}$: Robot

Robot: point P

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

Heading:
$\{\theta\}$: I ∠ R



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

Mobile Position Change

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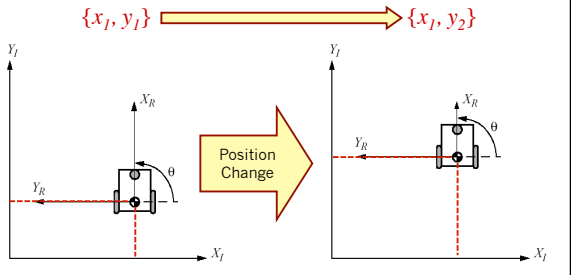

Human-Robot Interaction

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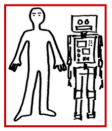
- Technical systems can be characterized by the increasing physical and psychological ***closeness and interaction*** between man and machine



Industrial Robots — *Service and Personal Robots* — *Cyborgs*

Self-X Robots

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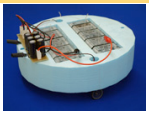
- Self-feeding
  - Literally
  - Electrically
- Self-replicating
- Self-repairing
- Self-assembly
- Self-organization
- Self-reconfiguration




Autonomy and Thought

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- Machine learning
- 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?

Project Possibilities

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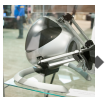
- Sensor based


- Actuator based
  - Manipulate objects
  - Move through an area
- Design & building
  - New end effector



- Cognition
  - Machine learning
  - Decision making

- HRI
  - Studies
  - Interface designs
- Algorithmic