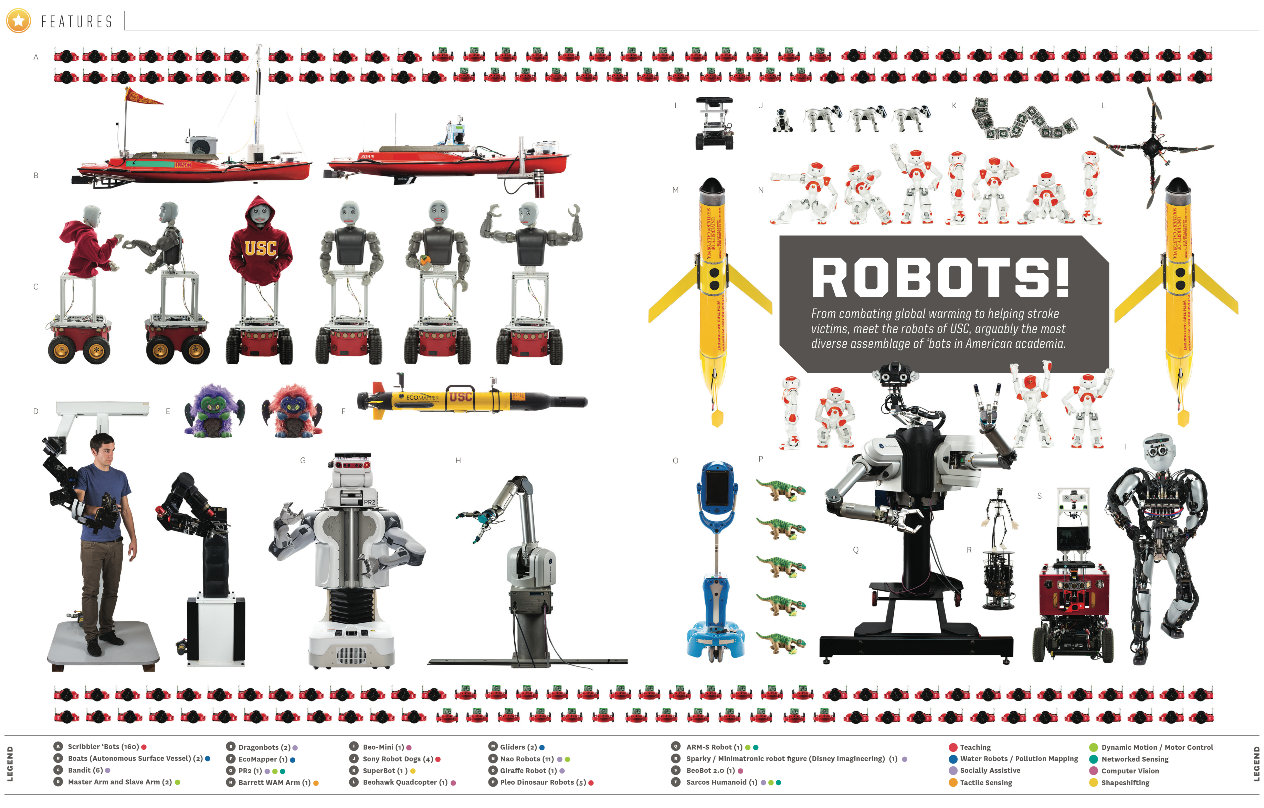
Introduction to Computer Science

CSCI 109



Andrew Goodney

Fall 2019

Robotics *Nov 25, 2019*

Schedule

Date	Topic		Assigned	Due	Quizzes/Midterm/Final	Slide Deck
26-Aug	Introduction	What is computing, how did computers come to be?				1
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25-Nov	Robotics	Robotics: background and modern systems (e.g., self-driving cars)			**Quiz 7** on material taught in class 11/18	12
2-Dec	Summary, recap, review	Summary, recap, review for final		HW4	**Quiz 8** on material taught in class 11/25	13
13-Dec	Final exam 11 am - 1 pm in SGM 123				**Final** on all material covered in the semester	

Robotics

Acting on the physical world

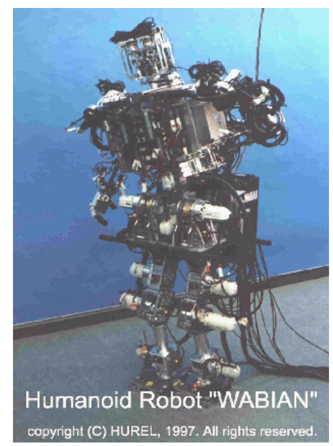
What is robotics?

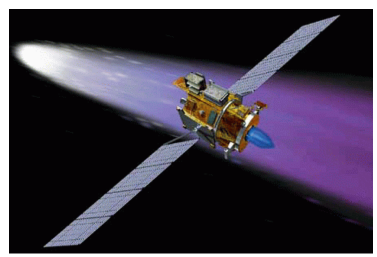
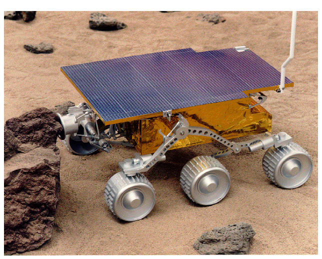
- The study of the ‘intelligent connection of perception to action’ [Brady]
- Operationally: “An intelligent robot is a machine able to extract information from its environment and use knowledge about its world to move safely and perform tasks in a meaningful and purposeful manner”

What makes a robot?

Sensors, effectors, locomotion/manipulation system, and an on-board computer system



What can be sensed?

- Depends on the sensors on the robot
- The robot exists in its *sensor space* (all possible values of sensory readings)
- Also called *perceptual space*
- Robot sensors are very different from biological ones
- A roboticist has to try to imagine the world in the robot's sensor space

State

- A sufficient description of the system
- Can be:
  - Observable: robot always knows its state (not for real robots)
  - Hidden/inaccessible/unobservable: robot never knows its state
  - Partially observable: the robot knows a part of its state
  - Discrete (e.g., up, down, blue, red)
  - Continuous (sampled) (e.g., 3.765 mph)

Types of state

- External state: state of the world
  - Sensed using the robot's sensors
  - E.g.: night, day, at-home, sleeping, sunny
- Internal state: state of the robot
  - Sensed using internal sensors
  - Stored/remembered
  - E.g.: velocity, mood
- The robot's state is a combination of its external and internal state

State and intelligence

- State space: all possible states the system can be in
- A challenge: sensors do not dictate state!
  - Examples ?
- How intelligent a robot appears is strongly dependent on how much it can sense about its environment and about itself

Internal models

- Internal state can be used to remember information about the world (e.g., remember paths to the goal, remember maps, remember friends vs. enemies, etc.)
- This is called a representation or an internal model
- Representations/models have a lot to do with how complicated the control program on the robot needs to be

Actuators

- A robot acts through its actuators (e.g. motors), which typically drive effectors (e.g., wheels)
- Robotic actuators are very different from biological ones, both are used for:
  - locomotion (moving around, going places)
  - manipulation (handling objects)
- This divides robotics into two areas
  - mobile robotics
  - manipulator robotics

Actions and behavior

- Behavior is what an external observer sees a robot doing.
- Robots are programmed to display desired behavior.
- Behavior is a result of a sequence of robot actions.
- Observing behavior may not tell us much about the internal control of a robot. Control can be a black box.

Autonomy

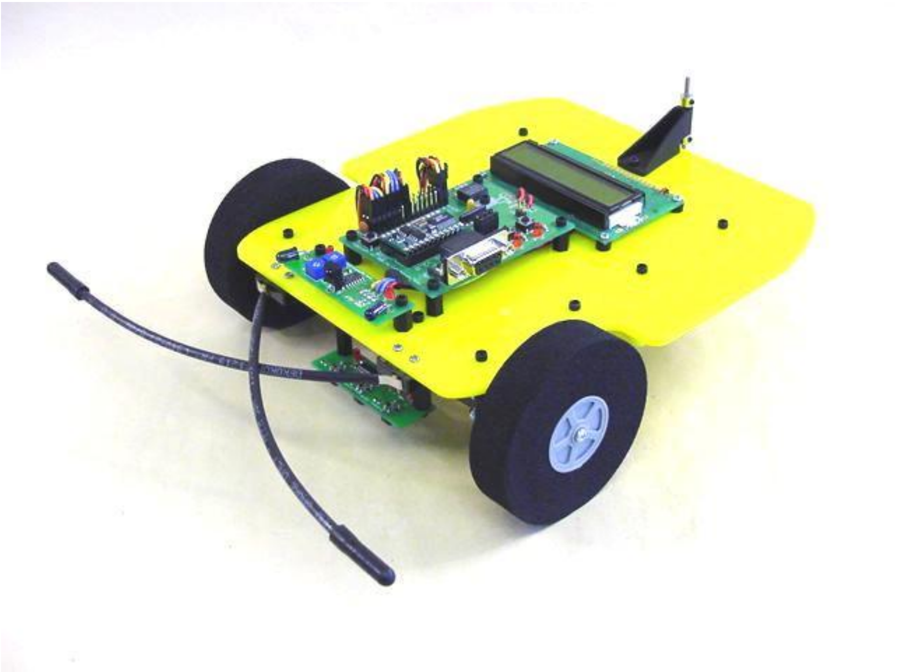
- Autonomy is the ability to make one's own decisions and act on them.
- For robots, autonomy means the ability to sense and act on a given situation appropriately.
- Autonomy can be:
  - complete (e.g., autonomous drones)
  - partial (e.g., tele-operated robots)

Control

- Robot control refers to the way in which the sensing and action of a robot are coordinated.
- The many different ways in which robots can be controlled all fall along a well-defined spectrum of control.
  - Reactive Control: Don’t think, (re)act.
  - Behavior-Based Control: Think the way you act.
  - Deliberative Control: Think hard, act later.
  - Hybrid Control: Think & act independently, in parallel.

Reactive Control

- Very little programming or internal state
- Robot reacts to inputs
- Bump sensor triggers -> back up

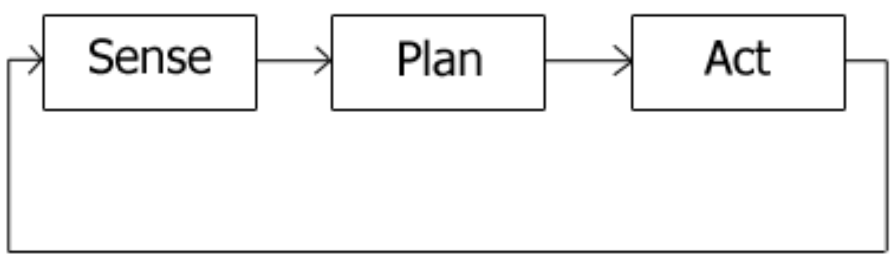


Behavior Based Control

- Programed with library of behaviors
  - Basic set to start off
  - “[behavior based] robots are programmed with many independent behaviors that are coupled together to produce coordinated action.”
- Don’t build world models
- Learn and refine how to apply given behaviors to achieve goal
  - Some can modify/learn new behaviors to add to library

Deliberative Control

- Control System is heavy (lots of programming/algorithms)
- Builds detailed world models
  - Where am I? What am I supposed to do? What is in the way?
- The robot operates in a top-down fashion, heavy on planning.
- The robot senses the world, plans the next action, acts; at each step the robot explicitly plans the next move.



Control tradeoffs

- Thinking is slow
- Reaction must be fast
- Thinking enables looking ahead (planning) to avoid bad solutions
- Thinking too long can be dangerous (e.g., falling off a cliff, being run over)
- To think, the robot needs (a lot of) accurate information => world models.

Hybrid Control

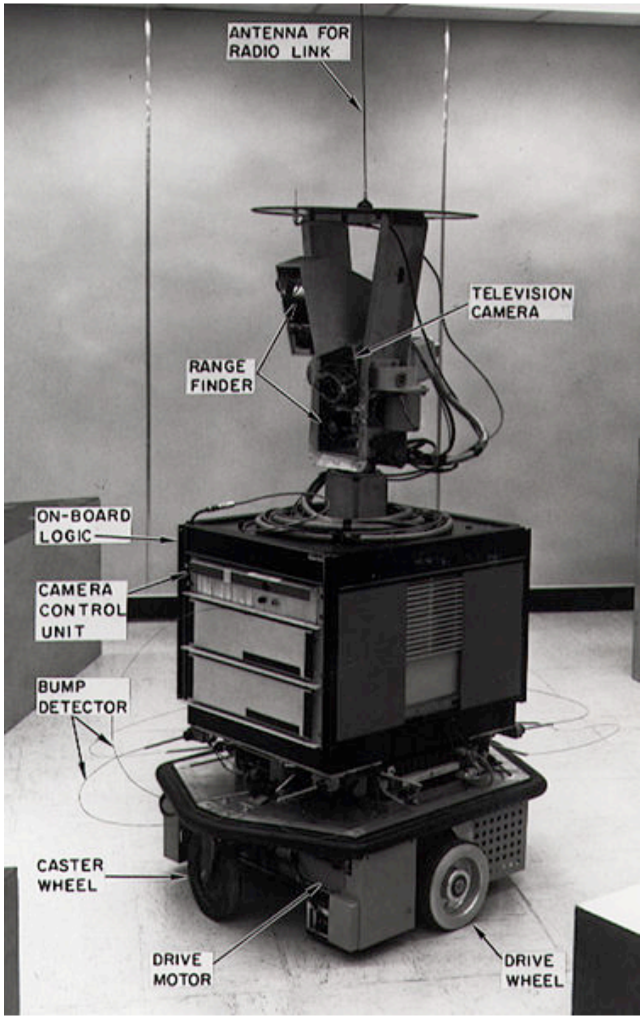
- Sophisticated robots are often a hybrid of control methods
- Deliberative
  - Self-driving car plans route
- Reactive
  - Self-driving car avoids unexpected pedestrian

A historical note: reactive beginnings

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

A historical note: Shakey and planning

- First general-purpose mobile robot to be able to reason about its own actions
- Could analyze each human command and break it down into basic chunks autonomously – a **planning** process
- https://www.youtube.com/watch?v=qXdn6ynwpiI



Where we are today

- Boston Dynamics – leading robot firm
  - Specializes in “humanoid” and similar

- https://www.youtube.com/watch?v=fRj34o4hN4I
- https://www.youtube.com/watch?v=fUyU3lKzoio
- https://www.youtube.com/watch?v=aFuA50H9uek
- https://www.youtube.com/watch?v=LikxFZZO2sk
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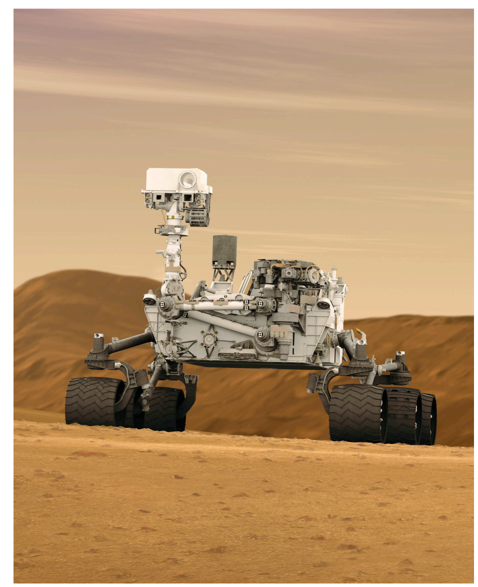
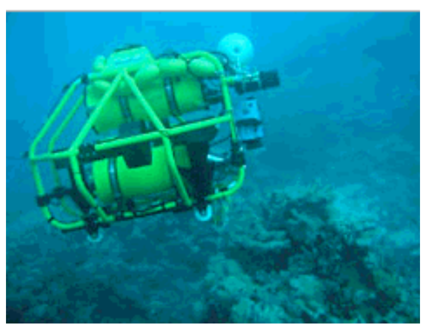
Robotics today

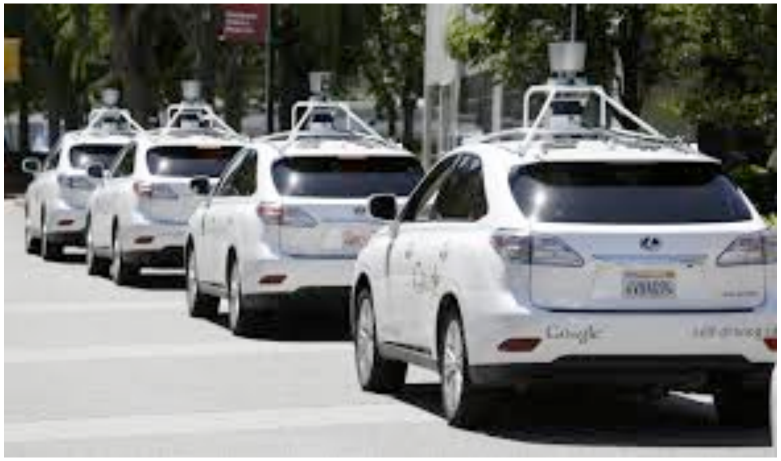




Robotics today

- How is the software/control on these organized?
  - **Self-driving car**
  - Industrial robots
  - Mars rovers
  - Underwater vehicle
- Humanoids near LA
  - DARPA robotics challenge
    - https://en.wikipedia.org/wiki/DARPA_Robotics_Challenge

Self driving cars



How many players?

- **33** according to CB Insights, Aug 2016
- Could be as many as 100 worldwide

CBINSIGHTS www.cbinsights.com

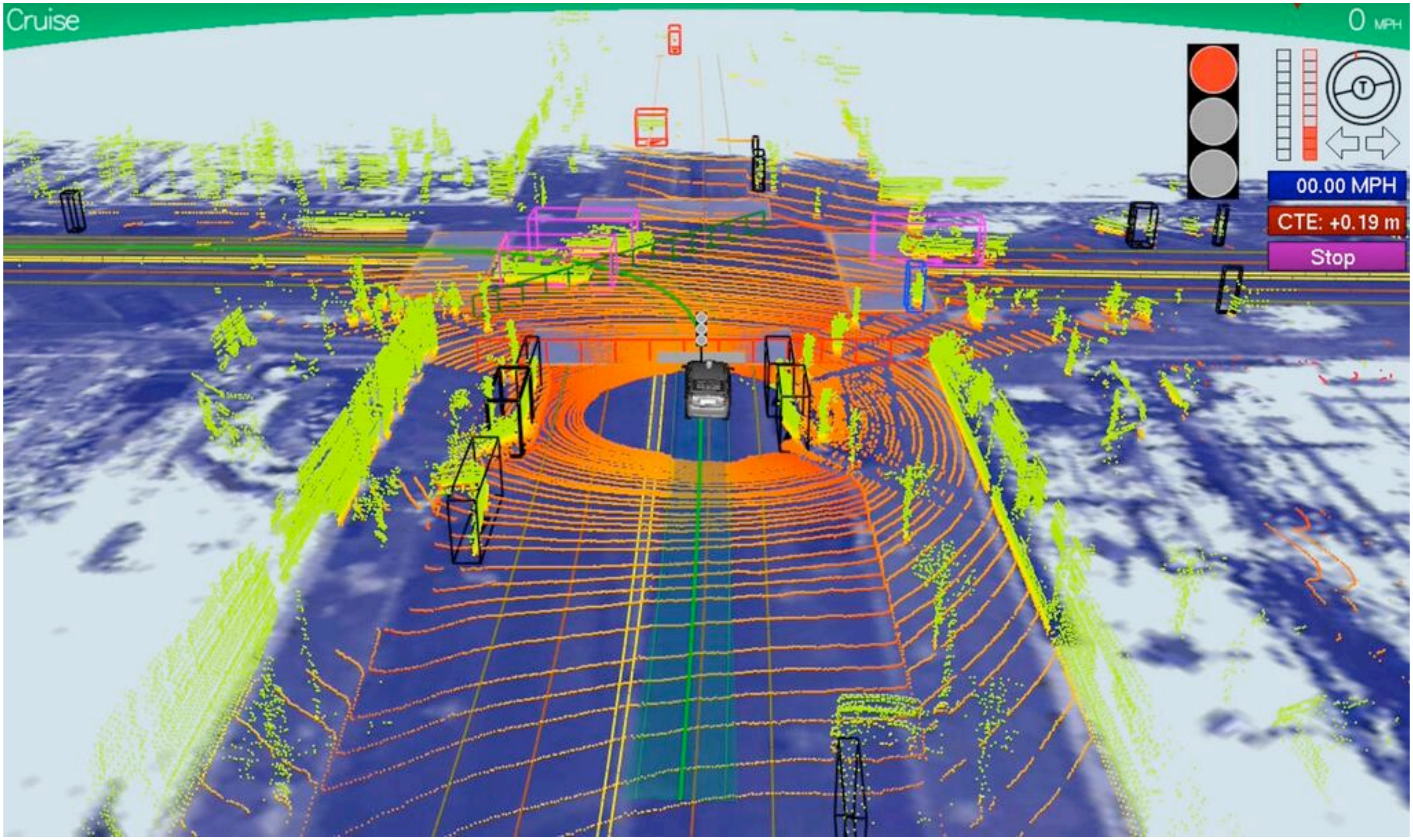
Sensing on a self-driving car

- GPS unit, Inertial navigation system, Laser rangefinders, Radar, Cameras
- Position and orientation from GPS + inertial navigation system (localization)
- Laser, radar and cameras used to build a three-dimensional image of environment (mapping)
- Interplay of **localization** and **mapping**

Control

- Control is hybrid (mix of deliberative and reactive)
- Car maintains an internal map of their world
- Uses the map to find an optimal path to destination that avoids obstacles (e.g., pedestrians and other vehicles) from a set of possible paths.
- Once the best path is determined, it is broken down into commands, which are fed to the car's actuators. These control the car's steering, braking and throttle

A typical piece of a map



Modern approaches tradeoff

- How much computation on the car vs. cloud
- How much to rely on what is being sensed vs. what is already in the map
- How often to update the map
- How much to rely on human driver
- How much to rely on sensors embedded in the road
- How to signal intentions to human drivers
- How much to automate the environment (e.g., traffic lights)

Issues with Self Driving Cars

- http://moralmachine.mit.edu/
  - Survey about ”lesser of two evils”
- Uber accident in AZ
  - NTSB report came out this week (Nov. 2019)
  - “Insufficient culture of safety…”
- Who is responsible?
  - Algorithm designer?
  - ML researcher?
  - Programmer?

~~Playing Around~~ Learning with Robots

- Lots of kits!
- Software
  - Simulate the robot
  - Construct a virtual world
  - Experiment with sensors and control systems
- CSCI 445L
  - Only pre-req is 103!

More Fun

- https://minghsiehece.usc.edu/race-on/
  - Racing self-driving model cars

Next week: final review + quiz

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