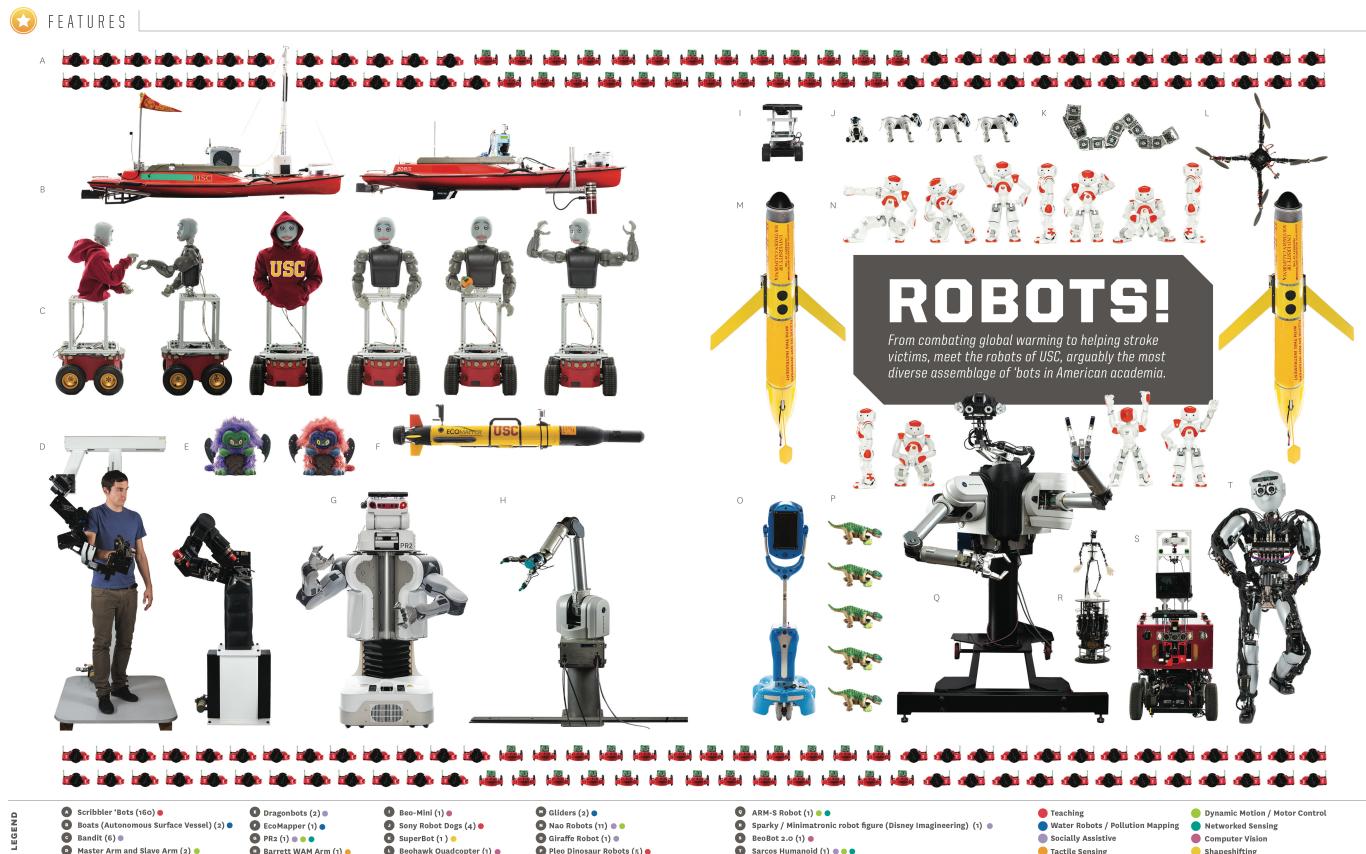


Introduction to Computer Science

CSCI 109



Andrew Goodney
Fall 2017

Robotics

Nov. 20, 2017

Schedule

Date	Topic		Assigned	Due	Quizzes/Midterm/Final
21-Aug	Introduction	What is computing, how did computers come to be?			
28-Aug	Computer architecture	How is a modern computer built? Basic architecture and assembly	HW1		
4-Sep	Labor day				
11-Sep	Data structures	Why organize data? Basic structures for organizing data		HW1	
12-Sep		Last day to drop a Monday-only class without a mark of "W" and receive a refund or change to Pass/No Pass or Audit for Session 001			
18-Sep	Data structures	Trees, Graphs and Traversals	HW2		Quiz 1 on material taught in class 8/21-8/28
25-Sep	More Algorithms/Data Structures	Recursion and run-time			
2-Oct	Complexity and combinatorics	How "long" does it take to run an algorithm.		HW2	Quiz 2 on material taught in class 9/11-9/25
6-Oct		Last day to drop a course without a mark of "W" on the transcript			
9-Oct	Algorithms and programming	(Somewhat) More complicated algorithms and simple programming constructs			Quiz 3 on material taught in class 10/2
16-Oct	Operating systems	What is an OS? Why do you need one?	HW3		Quiz 4 on material taught in class 10/9
23-Oct	Midterm	Midterm			Midterm on all material taught so far.
30-Oct	Computer networks	How are networks organized? How is the Internet organized?		HW3	
6-Nov	Artificial intelligence	What is AI? Search, planning and a quick introduction to machine learning			Quiz 5 on material taught in class 10/30
10-Nov		Last day to drop a class with a mark of "W" for Session 001			
13-Nov	The limits of computation	What can (and can't) be computed?	HW4		Quiz 6 on material taught in class 11/6
20-Nov	Robotics	Robotics: background and modern systems (e.g., self-driving cars)			Quiz 7 on material taught in class 11/13
27-Nov	Summary, recap, review	Summary, recap, review for final		HW4	Quiz 8 on material taught in class 11/20
8-Dec		Final exam 11 am - 1 pm in SAL 101			Final on all material covered in the semester



Robotics

Acting on the physical world

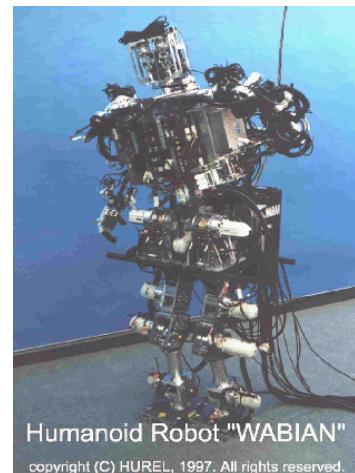


What is robotics?

- ◆ 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



Humanoid Robot "WABIAN"
copyright (C) HUREL, 1997. All rights reserved.



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

- ◆ A sufficient description of the system
- ◆ Can be:
 - ❖ Observable: robot always knows its state
 - ❖ 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 (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 provide 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., R2D2)
 - ❖ partial (e.g., tele-operated robots)

- ◆ 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.

Control tradeoffs

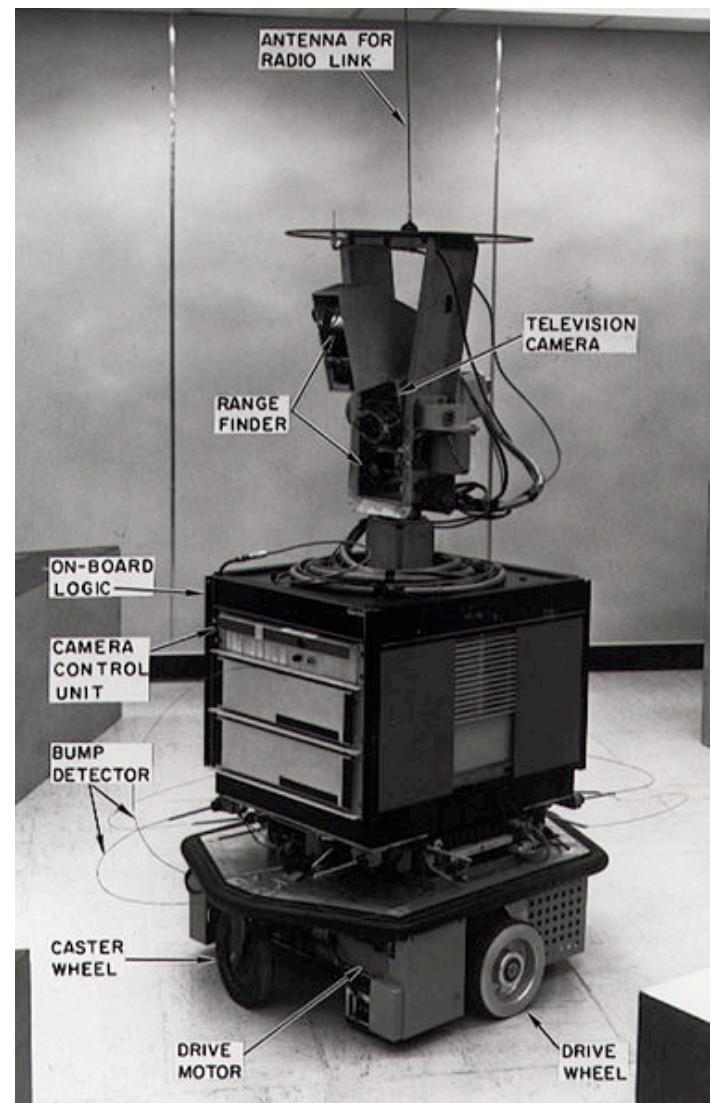
- ◆ Thinking is slow
- ◆ Reaction must be fast
- ◆ Thinking enables looking ahead (planning) to avoid bad solutions
- ◆ Thinking too long can be dangerous (e.g., falling off a cliff, being run over)
- ◆ To think, the robot needs (a lot of) accurate information => world models.

A historical note: reactive beginnings

<https://www.youtube.com/watch?v=1LULR1mXkKo>

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=qXdn6ynwpil>



Where we are today

- ◆ Boston Dynamics – leading robot firm
 - ❖ Specializes in “humanoid” and similar
- ◆ <https://www.youtube.com/watch?v=fRj34o4hN4I>

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
(<http://www.theroboticschallenge.org/>)

Self driving cars



How many players?

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



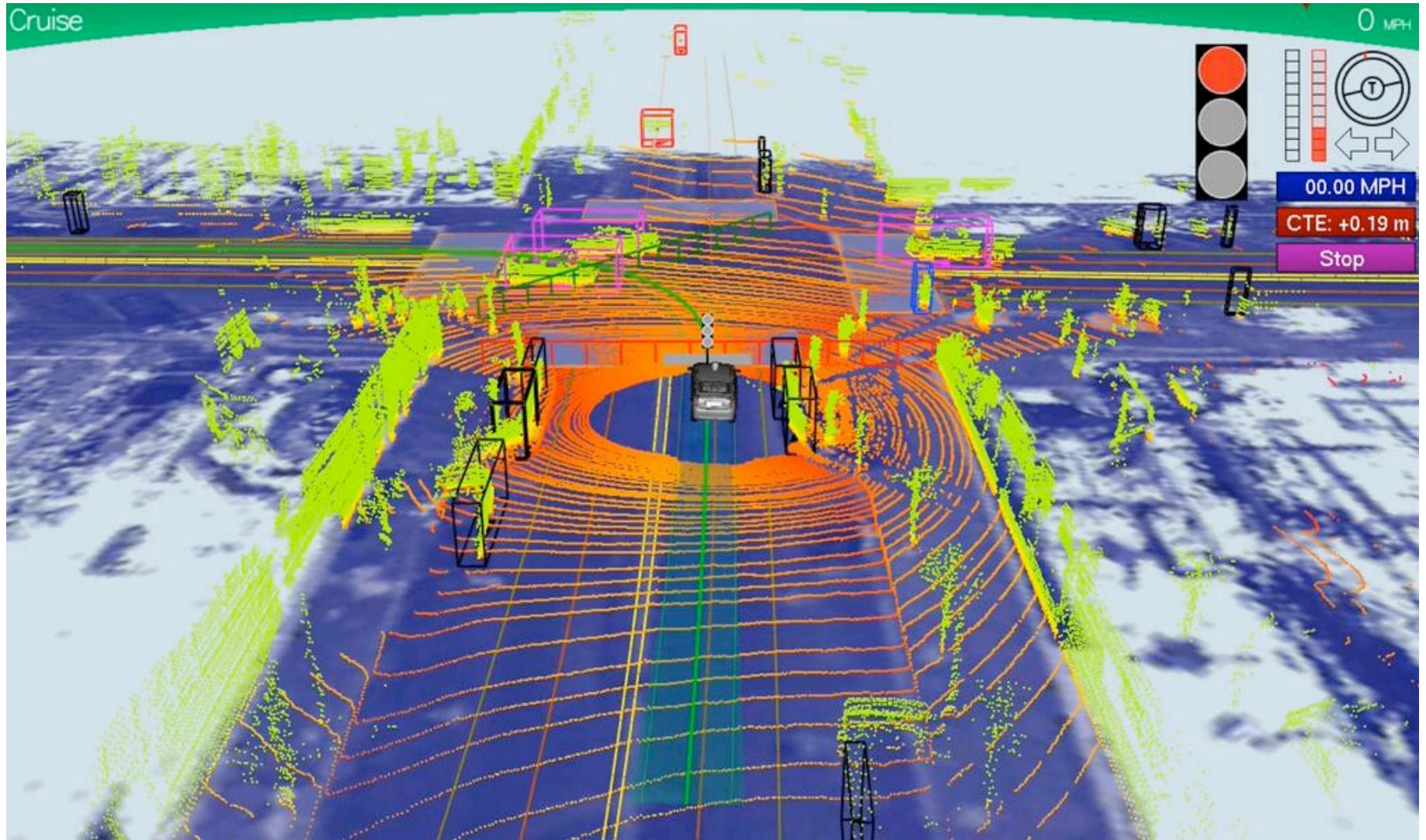
Sensing on a self-driving car

- ◆ 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)

Next week: final review + quiz

Date	Topic		Assigned	Due	Quizzes/Midterm/Final
21-Aug	Introduction	What is computing, how did computers come to be?			
28-Aug	Computer architecture	How is a modern computer built? Basic architecture and assembly	HW1		
4-Sep	Labor day				
11-Sep	Data structures	Why organize data? Basic structures for organizing data		HW1	
12-Sep		Last day to drop a Monday-only class without a mark of "W" and receive a refund or change to Pass/No Pass or Audit for Session 001			
18-Sep	Data structures	Trees, Graphs and Traversals	HW2		Quiz 1 on material taught in class 8/21-8/28
25-Sep	More Algorithms/Data Structures	Recursion and run-time			
2-Oct	Complexity and combinatorics	How "long" does it take to run an algorithm.		HW2	Quiz 2 on material taught in class 9/11-9/25
6-Oct		Last day to drop a course without a mark of "W" on the transcript			
9-Oct	Algorithms and programming	(Somewhat) More complicated algorithms and simple programming constructs			Quiz 3 on material taught in class 10/2
16-Oct	Operating systems	What is an OS? Why do you need one?	HW3		Quiz 4 on material taught in class 10/9
23-Oct	Midterm	Midterm			Midterm on all material taught so far.
30-Oct	Computer networks	How are networks organized? How is the Internet organized?		HW3	
6-Nov	Artificial intelligence	What is AI? Search, planning and a quick introduction to machine learning			Quiz 5 on material taught in class 10/30
10-Nov		Last day to drop a class with a mark of "W" for Session 001			
13-Nov	The limits of computation	What can (and can't) be computed?	HW4		Quiz 6 on material taught in class 11/6
20-Nov	Robotics	Robotics: background and modern systems (e.g., self-driving cars)			Quiz 7 on material taught in class 11/13
27-Nov	Summary, recap, review	Summary, recap, review for final		HW4	Quiz 8 on material taught in class 11/20
8-Dec		Final exam 11 am - 1 pm in SAL 101			Final on all material covered in the semester



Quiz #7

- ◆ <http://bit.ly/2zSZ3mR>

