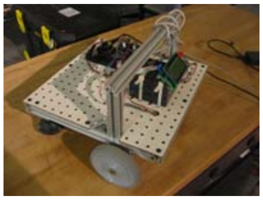
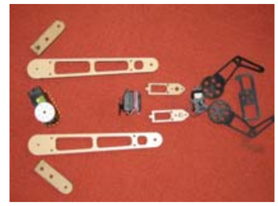
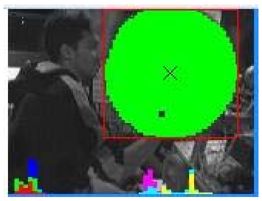
6.141J / 16.405J: Robotics Science and Systems Spring 2013

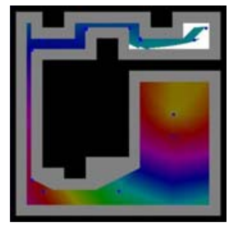


L1: Introduction
Wed 6 Feb 2013

Prof. Seth Teller
Prof. Daniela Rus*
EECS / CSAIL / MIT







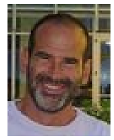
http://courses.csail.mit.edu/6.141/

Today

- Introductions of course staff
- Goals and structure of the class
- Administrative items
- Technical introduction to robotics

RSS Staff

- Instructor
  - Prof. Seth Teller (EECS / CSAIL)



Prof. Daniela Rus
(EECS / CSAIL)

- Writing Program staff
  - Ms. Jane Connor

- TA & LAs
  - TA Sudeep Pillai (EECS)
  - LA Chelsea Finn (EECS)
  - LA Alec Poitzsch (EECS)

- Class secretary & webmaster
  - Ms. Bryt Bradley (CSAIL)

Goals of RSS

- Intensive introduction to theory and practice
  - Hands-on application of fundamental ideas
- Experience with inherently interdisciplinary area
  - CS, EE, MechE, Aero/Astro: sensing, estimation, planning, control, system architecture, implementation, validation…
  - Occasionally, students from Courses 4, 7, 8, 9, 18 …
  - We urge you to become *generalists*, not specialists
- Improved technical communication ability
  - Verbal briefings; written reports; static & live visualization
  - Individual / team opportunities to communicate, persuade
  - Tackle real issues arising in team-based engineering
- Open-ended design and implementation challenge
  - Explore area, collect raw materials, build structure

Structure of RSS

- Theory in lecture; practice in lab (in small teams)
  - Also demos and short “labtures” for each lab module
- Foundational material (weeks 1-9):
  - Lectures and intensive labs covering motor control, robot architectures, sensing and machine vision, navigation, motion planning, kinematics, grasping and manipulation
  - Complex system design, development and test
- Debates (weeks 10-12):
  - Students, in small teams, debate ethical issues in class
- Course challenge (weeks 1, 3, 6, 9-14):
  - Individual and team-written design exercise, proposal
  - Six weeks of team-based work, with checkpoints in lab
  - Final Challenge runs in week 14, with public audience
- Communication threads through all aspects

Debates

- Argue a stance on an ethical-technical issue
  - All robots must obey Asimov’s three laws
  - Robots will eventually have civil rights
  - Robots should be allowed to use lethal force, autonomously
  - Etc.
- Instruction from an expert on rhetoric

Communication Aspects of RSS

- CI-M “Forum” on Fridays at 1pm (not every Friday)
  - Concrete strategies for effective writing, design, reporting
- Challenge Design Exercise (individual)
- Team wiki (brief answers, plots, images, videos &c.)
- Team briefings (to course staff) for each lab
- Lab checkpoints (in lab, rolling basis)
- Written challenge design (indiv. + team), revision
- Debates (in small groups, with class as audience)
- Reflective report (individual, at end of term)

Requirements Satisfied by RSS

- Institute Lab
- 12-unit subject worth 12 EDPs in EECS
- CI-M subject in EECS for 6-1, 6-2, or 6-3
- Department Lab in EECS for 6-1 or 6-2
- Can petition for use in lieu of 6.UAP (not guaranteed)
- Aero/Astro students can petition to use it as a PAS

Prerequisites – some mix of:

- Relevant coursework from a variety of Departments
- Familiarity with Java (or C or C++)
- Bench skills (EE, machine shop, etc.)
- Independent experience (UROPs, competitions etc.)

Grading

- Lab quality, wikis, and briefings 35%

- Team challenge design and proposal 10%
- Challenge implementation 30%

- Debate performance 10%
- Participation in lecture and lab 5%
- Initial ideas and reflective report 10%

Team behavior, cooperation (qualitative factors)

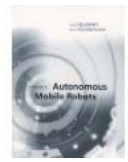
Intermediate grade summary in Week 11 (by drop date)

Schedule

- Lectures **MW 1-2p** here in 32-155
  - Lectures start promptly at 105pm, end at 155pm
- Forums **F 1-2pm** here in 32-155 (but not every Friday)
  - Focus on communications aspect of class
- Both Lectures and Forums are **essential parts** of 6.141

- Lab **MW 3-5pm**
  - In 38-630 (accessible via 38-500 or 38-600)
  - Open M-R 9am-1145pm; F 9am-5pm; Sun 1pm-1145pm
  - First lab is **this afternoon**
- Students are expected to attend all lectures, forums & labs
  - Very occasional absence OK; email staff beforehand
- Challenge dry runs on **M May 6th,** final runs on **W May 8th**
  - Scheduled from **3-5pm**; historically run later than 5pm

Text and Other Resources



- Textbook: Siegwart and Nourbakhsh,
  Introduction to Autonomous Mobile Robots
  (Intelligent Robotics and Autonomous Agents)
- Web Site:
  http://courses.csail.mit.edu/6.141
- Course staff:
  - Lecturers, TA, and LAs hold scheduled hours in lab
- Help after hours:
  Email rss-help@csail.mit.edu

Lecture / Lab Etiquette

- We're all adults here…
  - Laptop use only for RSS note-taking, browsing
  - No texting, music, email- or newspaper-reading, …

- Life is short
  - Lectures will start promptly at 105pm and end at 155pm
- Staff members observe the same courtesy

Enrollment is Limited

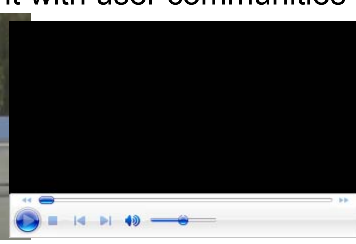
- As many as we have room and supplies for
- Fill out questionnaire & **hand it in as you leave**
  - Your course and year
  - Relevant background (formal, independent etc.)
  - Whether you've previously tried to register for RSS
- Come to (and do!) the first lab starting at **330pm**
- We will email with slots no later than 6pm today
  - You must reply with your acceptance by 8pm
- We will make rolling waitlist offers starting at 8pm
  - Check email frequently over the next few days

My Research Focus

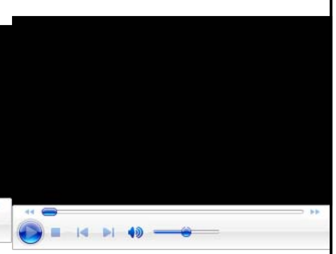
- **Machine situational awareness**
  - Integrating experience, models of the environment, and sensor data to plan and carry out useful behaviors
- **Natural interfaces** involving speech, gesture
  - References to shared surroundings
- **Fielded robots** for real-world utility
  - Engagement with user communities

DRC 2012-14

DARPA Urban Challenge: Self-driving passenger vehicle



Agile Robotics for Logistics: Gesture-commandable forklift



Voice-commandable autonomous wheelchair

Motivation

Robots: people have long sought to build them. Why? And what exactly is a robot?


Robots: Precursors and Conceptions

3000BC	Anubis
1000BC	Talos
100AD	Early automata
1500s	Leonardo da Vinci
1580s	Rabbi Loew: Golem
1700s	Pierre Jaquet-Droz
1738	Jacques de Vaucanson
1816	Mary Shelley
1833	Babbage’s difference engines
1926	Metropolis’s Maria
1961	George Devol’s Unimate


Anubis

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Talos (Τάλως)

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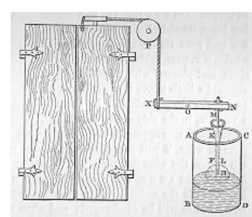

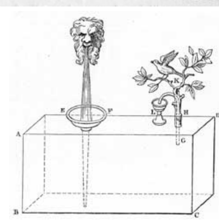

Hero of Alexandria

Robots: Conceptions and Precursors

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Developed mechanical principles of automata
Built mechanical lion to entertain King Louis XII

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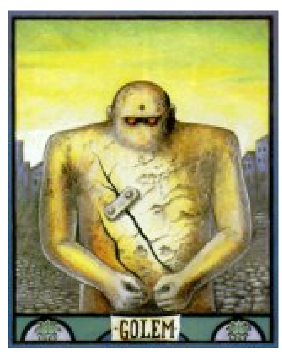

Golem (גלמ)

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Writing automaton

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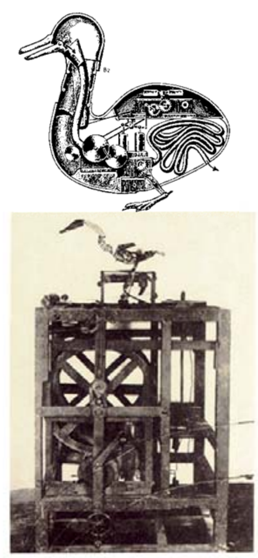
Duck automaton

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Frankenstein's Monster

The Turk

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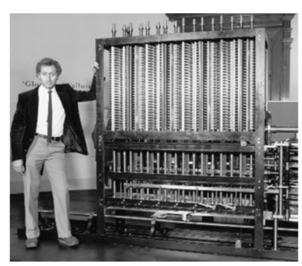

Difference engine models

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Maria

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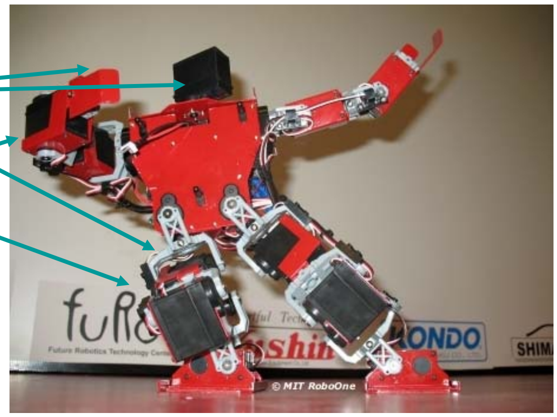
Unimate
(note controller!)

What is a Robot?

- A "programmable mechanical device that can exert forces" ?

- Essential ingredients:
  - Sensors
  - Computation
  - Actuators
    - Mobility
    - Manipulation
  - State (memory)
- Difference from an automaton?



- RSS focuses on autonomous mobile navigation & manipulation

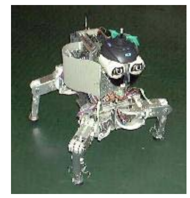
Other Workable Definitions

- An intelligent robot is a machine able to extract information from its environment and use knowledge about its world to move safely in a meaningful and purposeful manner (Typical Dictionary Entry)
- A robot is a system which exists in the physical world and autonomously senses its environment and acts in it (USC)
- A robot is a reprogrammable, multi-functional manipulator designed to move material, parts, or specialized devices though variable programmed motions for the performance of a task (Robotics Industry Association)
- Robotics is the intelligent connection of perception to action (Mike Brady)

Current Robots and Applications

- Manipulators
- Mobile robots
- Humanoid robots
- Bio-inspired robots

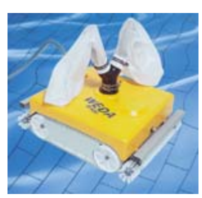





Inspection, Surveillance (Field), Transportation, Construction, Health Care, Agriculture, Manufacturing, Entertainment, …


Adept Flexfeeder


Fanuc Palletizer


Pool cleaner (SWE)


Electrolux (SWE)


Fujitsu (JAP)


Honda Asimo


Automated Highways integrated with IT

From Industrial Robotics to Service Robotics

From PCs (Personal Computers) to PRs (Personal Robots)

Service Robotics

Robots find applications in tasks which are:
- Dull
- Dangerous
- Dirty
- Dumb

Not just manufacturing tasks!

Service robots
- Health care
- Entertainment
- Security
- Personal assistance
- Construction
- Cleaning

Autonomous Mower (SWE)

Swisslog (GER)

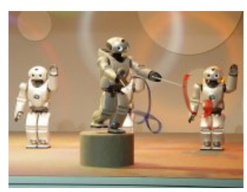
Window cleaner (GER)

Refueling station

Roomba (iRobot)

Personal Robots

Education / Hobbyist Robots
Entertainment Robots
Smart Toys
Robotics Pets
Automated Home
'Partner' Robots



"We strongly believe that after the Gold Rush of the Internet and cyberspace, people will eagerly seek real objects to play with and touch. Robot Entertainment provides tangible physical agents and an unquestionable sense of reality." - Sony internal document

Assistive Robotics

Help people in both private and public settings:

- Drug delivery & reminders
- Object fetching
- Surgery
- Exoskeleton
- Rescue
- Ordnance disposal
- Disaster relief!


IE-I (Georgia Tech)


Extremity (UC Berkeley)


Da Vinci


Tokyo Fire Department


Envoy (MIT)

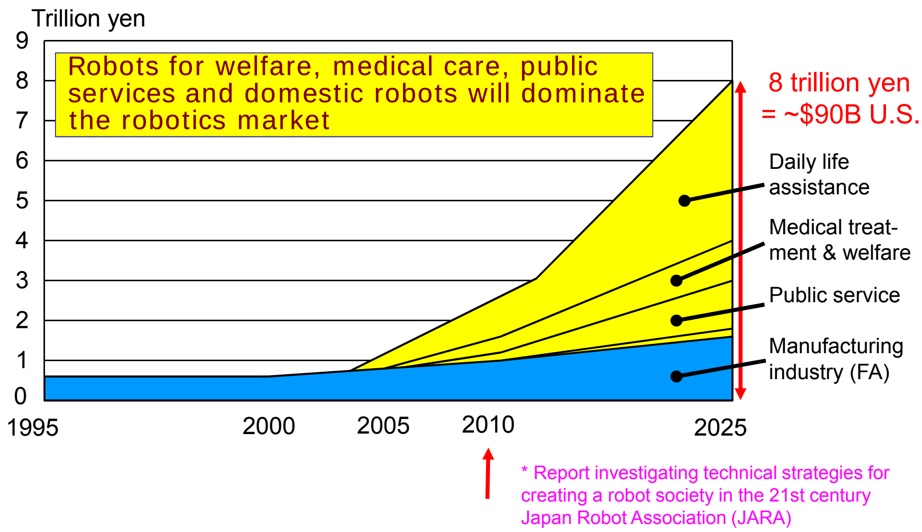
Drivers of Advances in Robotics

- Mission-oriented agencies (e.g., DoD, NASA, DHS, VA) in U.S.
  - Air Force Vision 2020
  - DARPA Robotic Vision 2020
  - NASA Robotic and Human Exploration of Mars
  - DARPA Grand Challenges, Urban Challenges, Robotic Challenges
  - Homeland Security (e.g. port monitoring, ship inspection)
- Economic, social, demographic factors in Europe and Japan

Honda ASIMO project (1986 -)

ZMP: Nuvo humanoid robots (domestic companions)

Market for Service Robots



Why is Robotics Difficult?

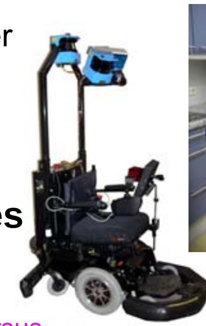
- Actions in the world must be coordinated with perception of, and models of, the world
- Physical world is continuous, dynamic, and accessible only through sensing
- Sensors and actuators are uncertain; they exhibit noise, and are subject to error
- Communication of intent often requires rich existing knowledge of the world
- To be useful in human-occupied environments, robots must be tolerated by the people there

Research and Development Challenges

INDUSTRIAL

- Manipulation
- Perception
  - Visual, haptic, aural
  - Rich world models
- Development
  - Design, packaging, power
  - Safety
  - Product cost
- **Mobile manipulation**
- **Human-robot interfaces**
- **Task-level autonomy**






PERSONAL and PERVASIVE

Structured / prepared (known) versus unstructured / unprepared (unknown) environments

Reactive vs. Deliberative Architectures

- Reactive: Connect sensing directly to action

Sense → Primitive response → (Re)Act

- … examples from biology?

- Deliberative: Incorporate state (memory), prediction

Sense → Learn, Think → Act

- … examples from biology?

- Differences? Is this a hard distinction?

Course Challenge

- Build a Shelter on Mars
  - Explore a region, given an uncertain prior map
  - Gather prefabricated materials dropped from orbit
  - Transport materials to a selected building site
  - Assemble them purposefully into a wall or structure
- Eight teams, 4-5 students per team
- Challenge described in more detail on RSS web page, and will be discussed both in class and lab

What's Next

- Lab today **(starting at 330pm)** in 38-630
  - Introduction to μORC board (used in MASlab, RSS)
  - Multimeters, oscilloscopes, battery safety
  - Admission decisions in lab & via email this evening
- Communication Forum on Friday at 1pm
  - Expectations for technical briefings, collaboration
- Individually written Challenge Design Exercise
  - Due this **Sunday evening at 1159pm**, turnin TBD
- Lecture Monday at 1pm
  - Motor Control
- Lab Monday at 3pm
  - Motor characterization and control