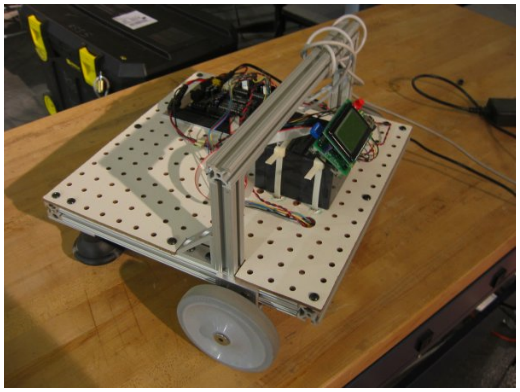
6.141J / 16.405J: Robotics Science and Systems Spring 2012

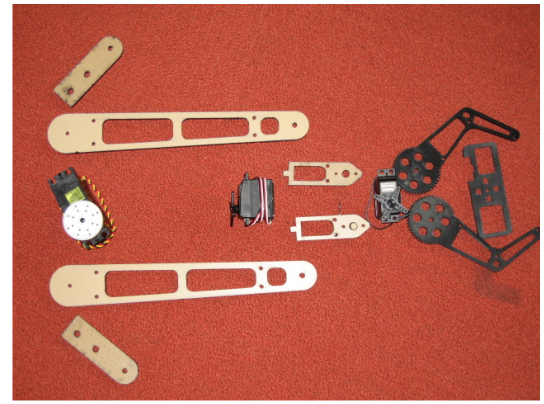


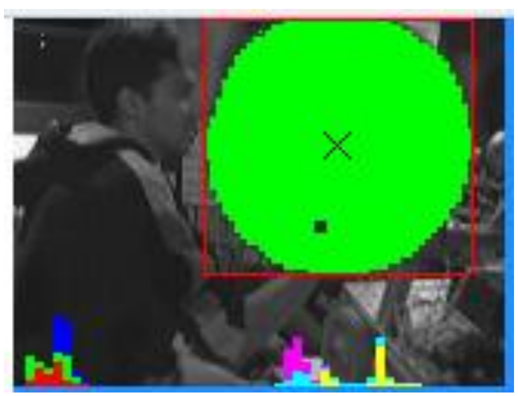
L1: Introduction

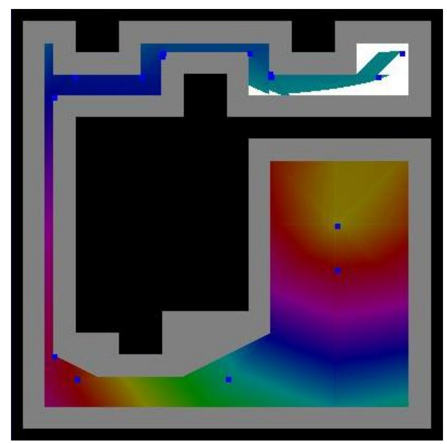
Wed 8 Feb 2012

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

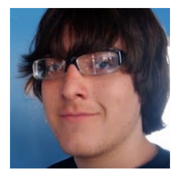
RSS Staff

- Instructors
  - Prof. Daniela Rus (EECS)
  - Prof. Seth Teller (EECS)

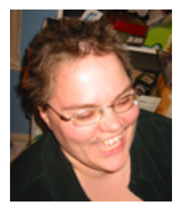

- CI-M Lecturers
  - Ms. Mary Caulfield
  - Ms. Jane Connor


- TA & Las
  - TA Jon Brookshire
  - LA Scott Bezek
  - LA Dylan Hadfield-Menel
  - LA Ed Mugica
  - LA: Sam Powers




- Class assistant & webmaster
  - Ms. Bryt Bradley (CSAIL)
  - Ms. Kathy Bates




Goals of RSS

- Intensive introduction to theory and practice
  - Hands-on application of fundamental ideas
- Experience with inherently interdisciplinary area
  - EE, CS, MechE, Aero/Astro: sensing, estimation, control, system architecture, implementation, validation…
- Communication
  - Verbal briefings; written reports; static & live graphics
  - Individual and team opportunities to communicate
  - Tackle real issues arising in team-based engineering
- Design and implementation challenge
  - Explore an area, collect raw materials, build structure

What will you learn?

- What are robots, what is the science and technology behind building robots and programming them ?
- Why is robotics hard ?
- Hands-on experience building a robot of your own

Syllabus for RSS

- Theory in lecture; practice in lab (in small teams)
  - Also demos and short “labtures” for each lab module
- Foundational material (weeks 1-9):
  - robot architectures, motor control, sensing and machine vision, navigation, motion planning, kinematics, grasping and manipulation
  - Complex system design, development and test
- Debates (weeks 11-12):
  - Students, in small teams, debate ethical issues in class
- Course challenge (weeks 1, 3, 7, 9, 10-14):
  - Introduced first day of class, revisited throughout term
  - Individual and team written design proposals
  - Design reviews (including dry runs) with course staff
  - Five weeks of team-based work, with regular checkpoints

Course Challenge

- Build a Shelter on Mars
  - Explore region, given uncertain prior map
  - Gather prefabricated materials dropped from orbit
  - Transport materials to a selected building site
  - Assemble them into a wall or structure
- Eight teams, four students per team
- Challenge described in more detail on the web and will be presented in class and lab
- Warm-up for Fall subject (6.142, RSS II), NASA Grand Challenge, other future efforts

Communication Aspects of RSS

- CI-M lectures typically on Fridays at 1pm

- Lab team wiki (brief answers, plots, videos etc.)
- Lab team briefings (to course staff)
- Lab checkpoints (in lab, rolling basis)
- Written challenge design document (individual)
- Written challenge design (team), revision
- Challenge design review (to staff), with dry runs
- Debates (in pair teams, with class)
- Challenge overview presentations (in lab, to class)
- Reflective report (individual, at end of term)

Requirements Satisfied by RSS

- Institute Lab
- 12-unit subject worth 12 EECS EDPs
- CI-M subject in EECS
- Can be petitioned for use in lieu of 6.UAP
- Department Lab in EECS (6-1, 6-2, and 6-3)
- Aero/Astro students can petition to use it as a PAS

Required Work

- Weekly
  - Lab assignments given in lab
  - Lab reports (oral and one written) by beginning of specified lab period
  - First lab today
- Debate participation
- End of term paper (due last day of classes)
- Team Project with Challenge Run and project presentation

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%

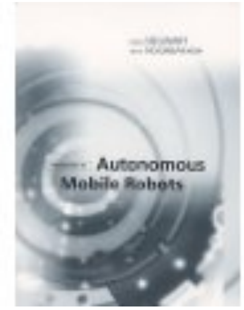
Team behavior, cooperation (qualitative factors)

Intermediate grade summaries Week 5, Week 10

Schedule

- Lecture **MWF 1-2p** in 32-155
  - Lectures start promptly at 105pm, end at 155pm
- Lab **MW 3-5pm**
  - 38-630
  - First lab is **this afternoon**
- Students expected to attend all lectures and labs
  - Very occasional absence OK; email staff beforehand
- Challenge Friday **May 6th**
  - Scheduled **3-5pm**; historically longer 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

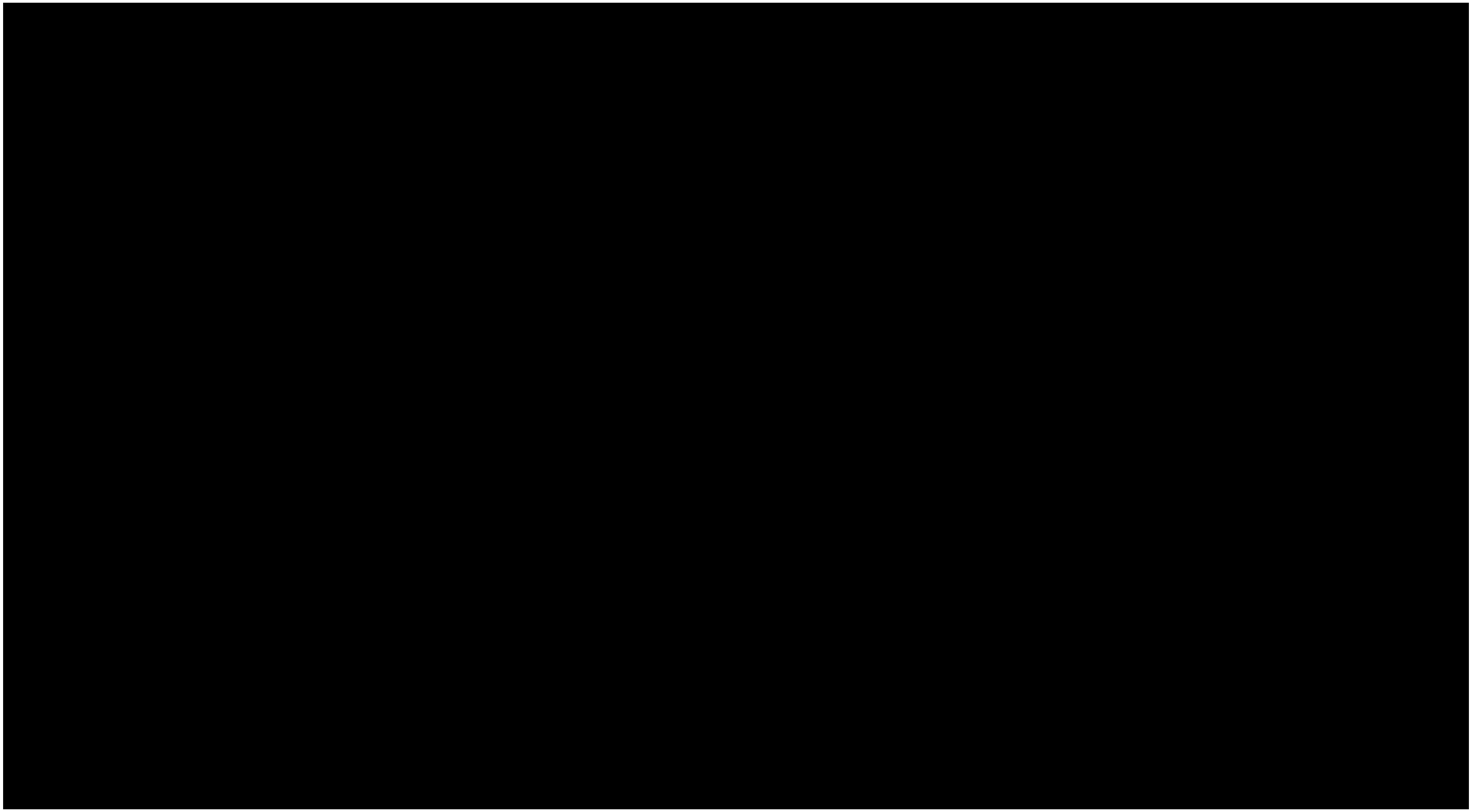
Lecture / Lab Etiquette

- Laptop use only for RSS note-taking
- Please: no texting, music, email- or newspaper-reading, …
- All lectures start at 1:05pm (and end at 1:55pm)
- Please be on time for all activities: lectures, lab lectures, project presentations, etc.

Enrollment is Limited

- As many as we have room and supplies for
- Fill out questionnaire & **hand it to LA when it is done**
  - Your course and year
  - Relevant background (formal, independent etc.)
  - Whether you've previously tried to register for RSS
- We will email between 3pm - 3:30pm and post class list on lab door (38-630)
  - You must reply with your acceptance by 4pm
- We will make waitlist offers after 4pm

Movie: 50 years of Robotics (thanks to Prof. Khatib, Stanford)



6.141:
Robotics systems and science
Lecture1: what is a robot?

Outline

- A Brief History of Robots
- What is a Robot?
- Current Robot Trends
- Robot Methodology

1921: Karel Capek

Rossum Universal Robots

Robota = Hard, Repetitive Labor

Fear

Excitement

Robotics is…

- **A dream to build a machine in our own image**
- Building platforms for studying life and intelligence
- Intelligent connection of perception and action
- Outcome of visionaries with energy, resources
- **The next disruptive technology that will bring intelligent machines in our lives**

From Technological Marvels

ANUBIS: 3000BC

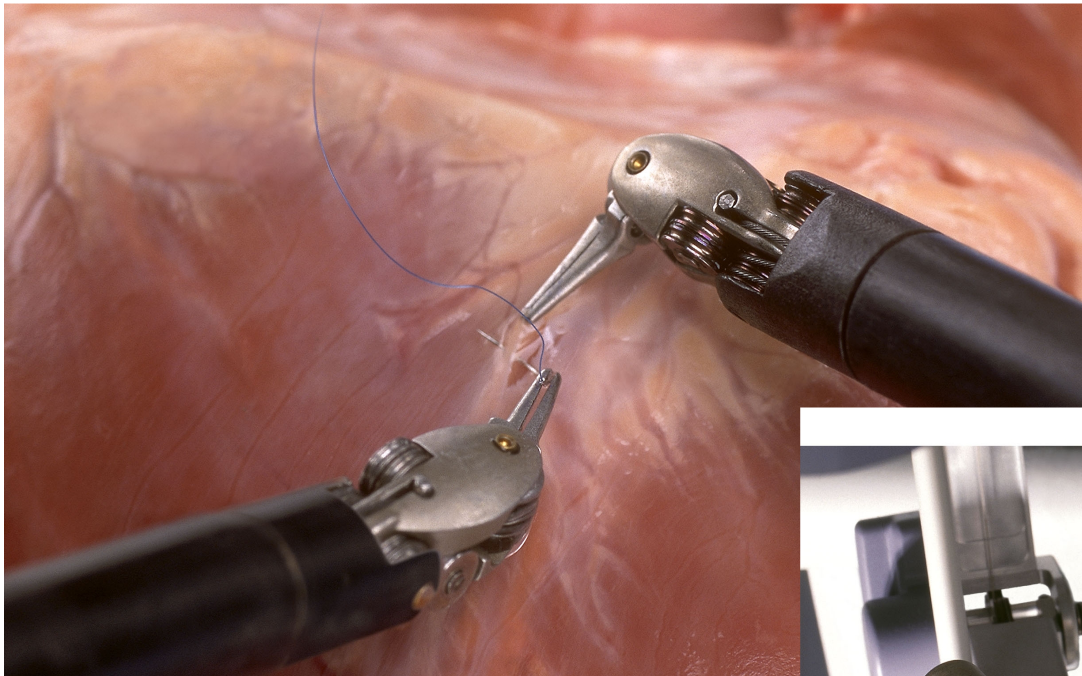
MECHANICAL WRITER: 1700s

To Science Fiction

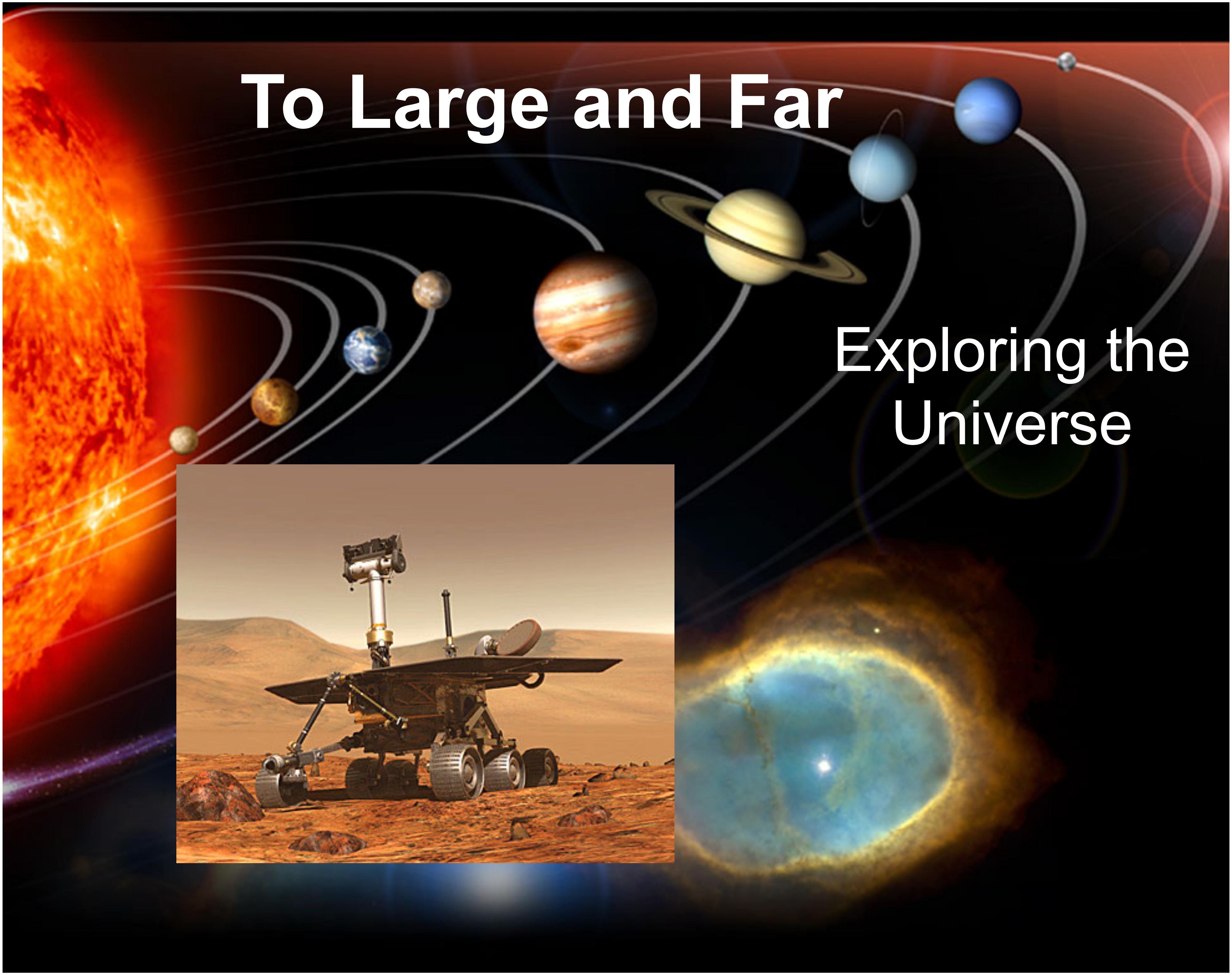
To Today's Personal Robots

… becoming More Life-Like

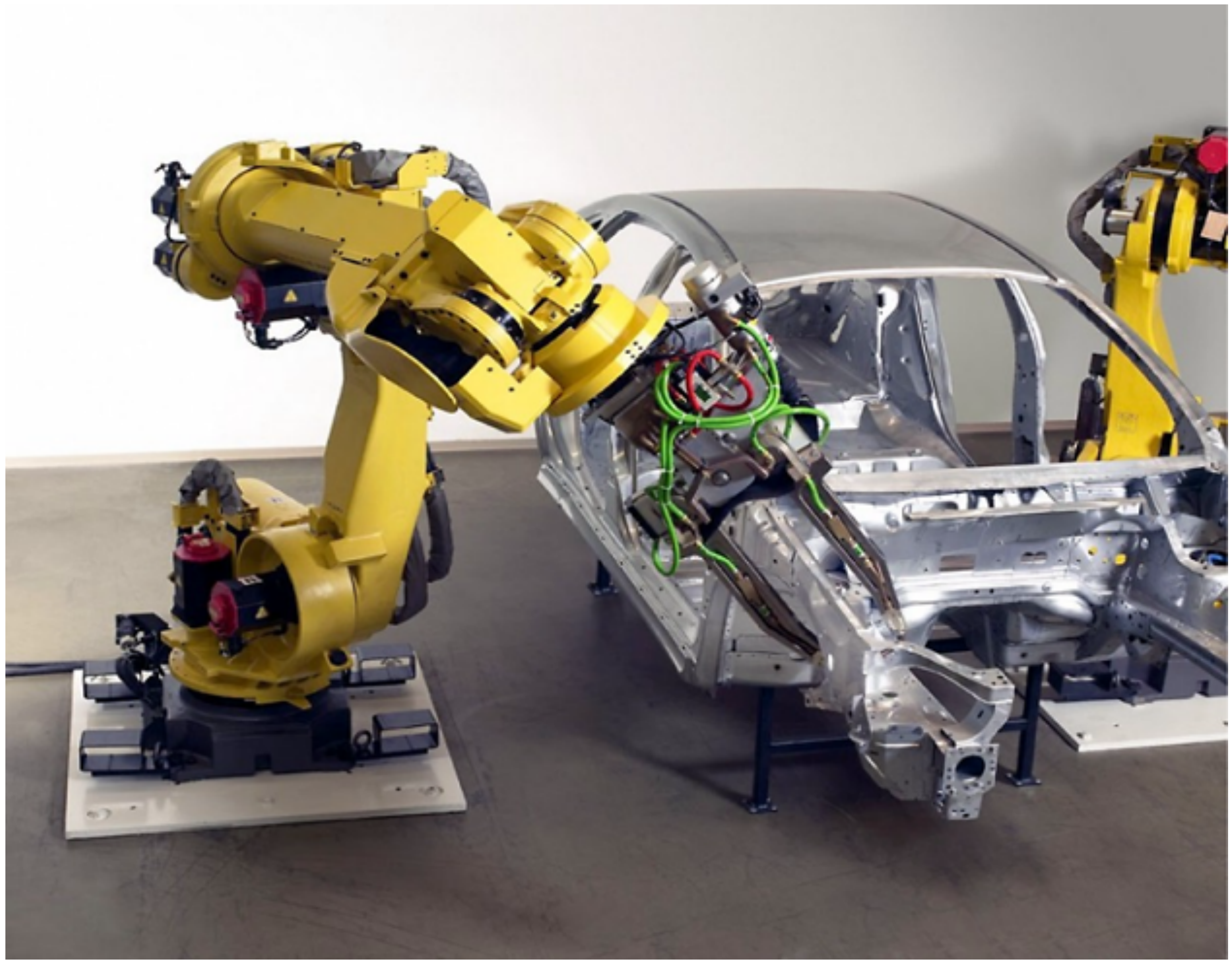
From Small and Near



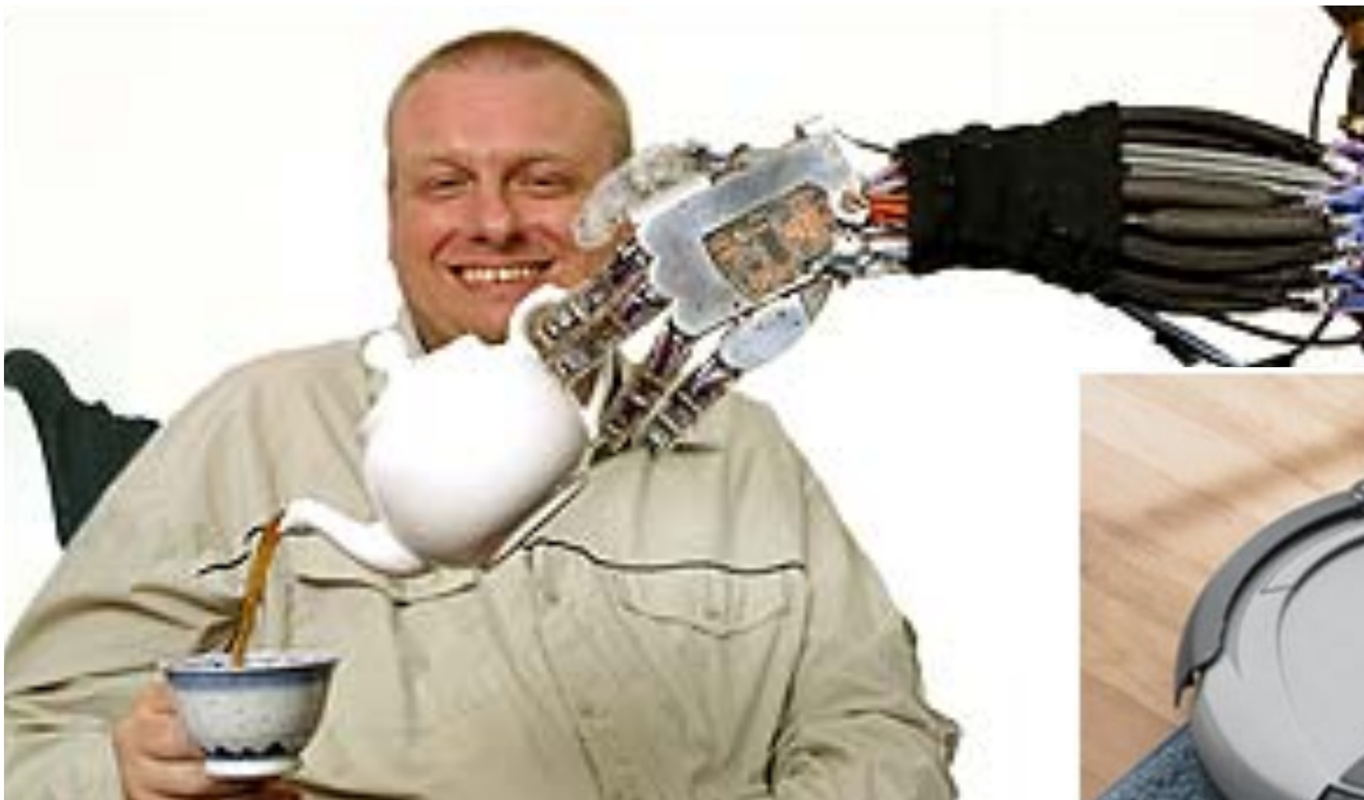
Robot Assisted Surgery (A. Okamura)


To Large and Far
Exploring the Universe

From Manufacturing



To Homes



Robots …

Contribute to Knowledge & Science

Make the World a Better Place

Da Vinci

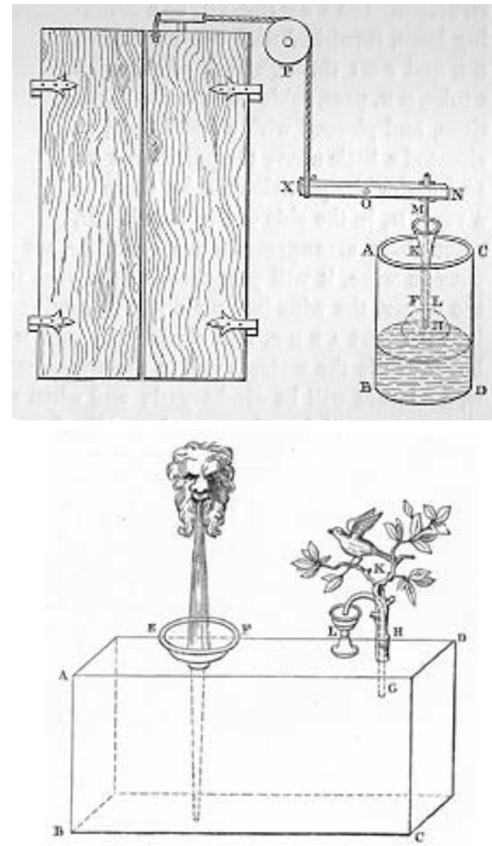
Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol's Unimate

Anubis

Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol's Unimate



Hero of Alexandria

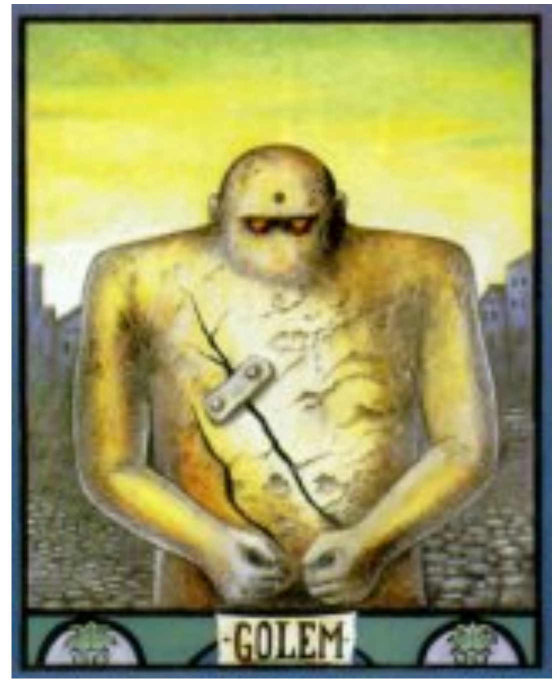
Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol's Unimate

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

Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol’s Unimate



Golem (גלמ)

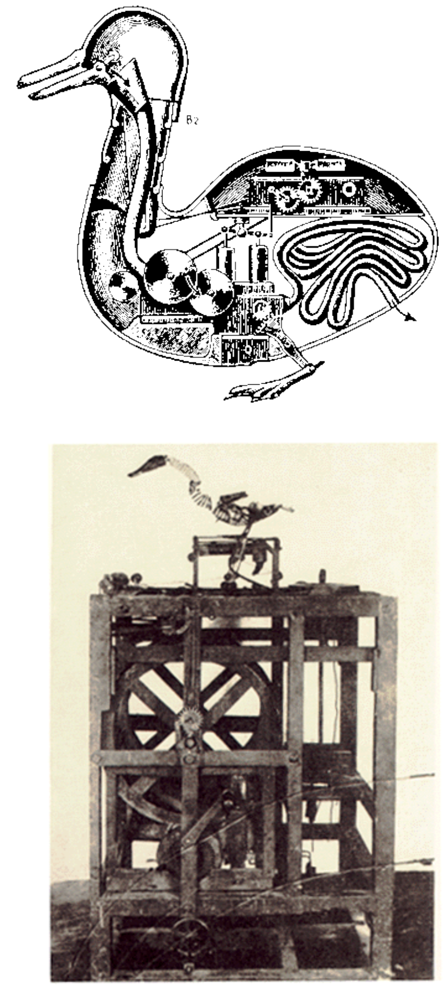
Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol's Unimate

Writing automaton

Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol’s Unimate



Duck automaton

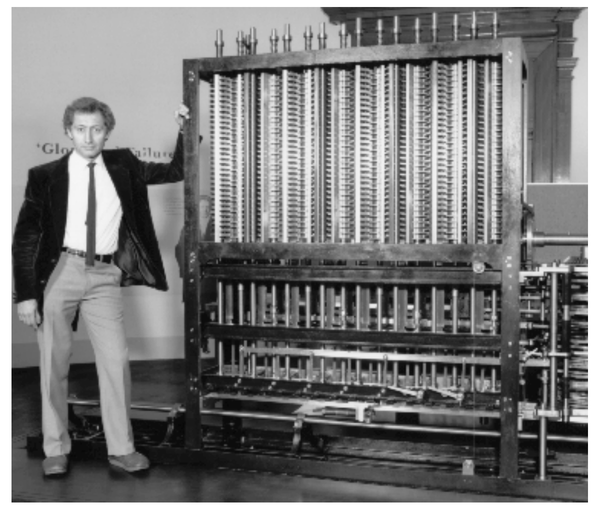
Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol's Unimate

Frankenstein's Monster

Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol’s Unimate



Difference engine models

Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol’s Unimate

Maria

Robots: Conceptions and Precursors

3000BC	Anubis
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
1960	George Davol's Unimate

Unimate
(note controller!)

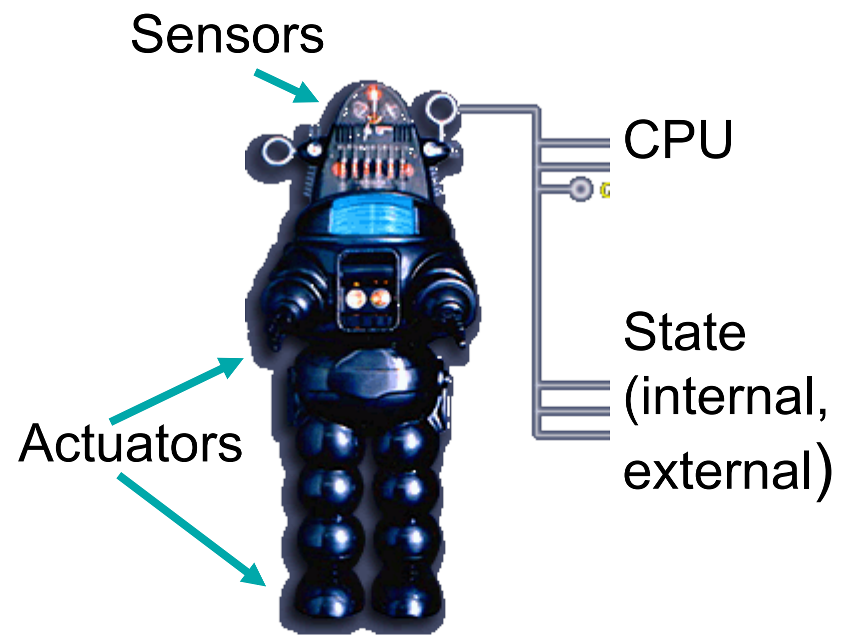
What is a robot?

- Science fiction robots make autonomous decisions
- Automata are hard coded and do not
- Robot:

What is a robot?

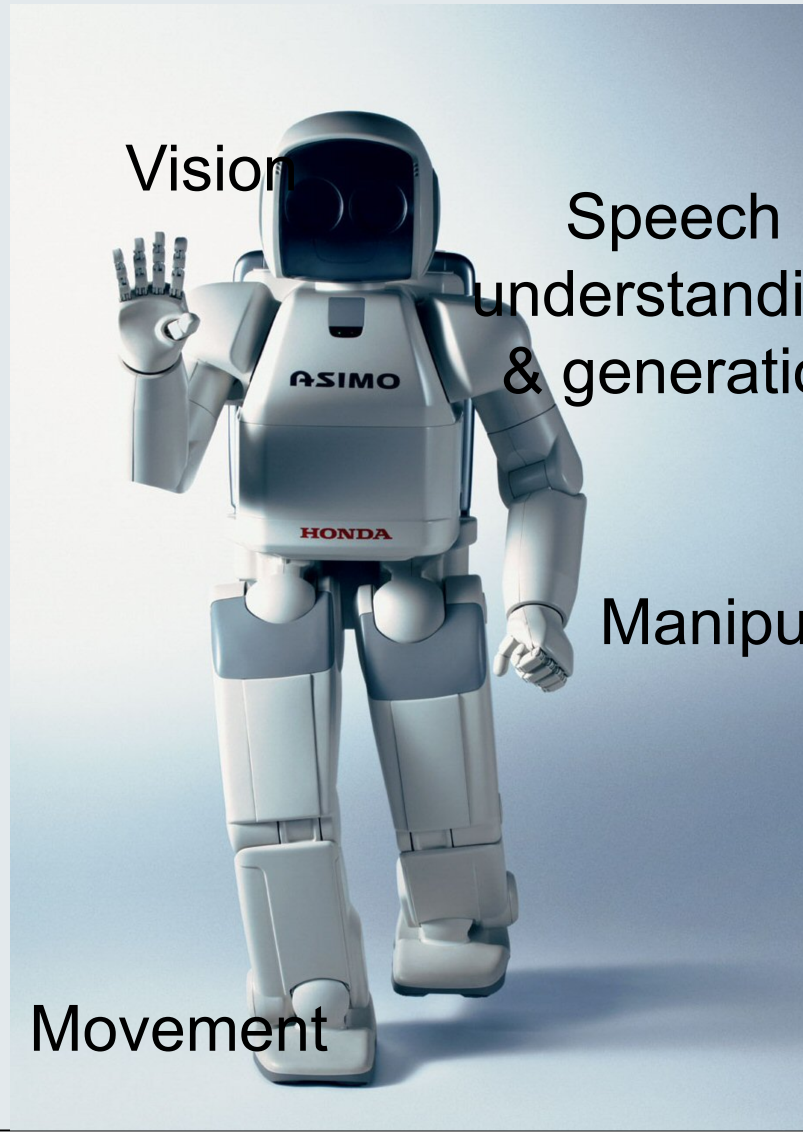
- Science fiction robots make autonomous decisions
- Automata are hard coded and do not
- Robot: programmable mechanical device that can exert forces

Input from sensors
Effects with actuators



Robot Challenges: Bodies and Brains

Planning, Sensing, Actuation



Other 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.
- 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 re-programmable, 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 (M. Brady)

Current Robots and Applications

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

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

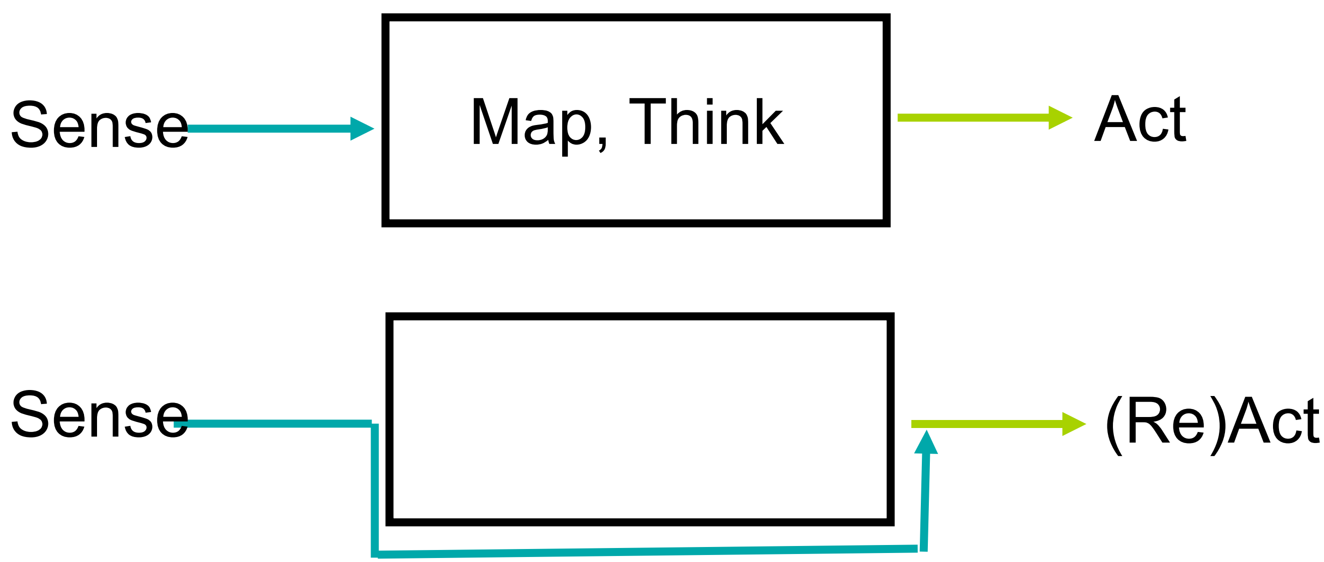
Why is Robotics Difficult?

Why is Robotics Difficult?

- Actions in the world must be coordinated with perceptions (and models) of the world
- Physical world is continuous, dynamic, and accessible only through sensing
- Sensors and actuators are uncertain, noisy, and subject to error
- Communication of intent requires rich existing knowledge of the world

Motion Planning

- How do we command the robot to move from A to B despite complications?



How does a robot sense?

- Depends on the sensors on the robot
- The robot exists in its perceptual space
- Robot sensors are very different from biological ones
- We have to imagine the world in the robot's sensor space

The Robot State

- A description of the system in terms of what is known internally and externally about the robot
- 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, centered)
  - Continuous (e.g., 25 km/hour)

Internal and External 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.: maps, paths, velocity, mood
- The robot's state is a combination of its external and internal state.
- State Space: all possible states for the robot

How does a robot move?

- 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)
  - manipulation (handling objects)
- This divides robotics into two areas
  - mobile robotics
  - manipulator robotics
- Control: coordination of sensing and action

Questions:

- Is HAL a robot?
- Are Battlebots robots?
- Are exo-skeletons robots?
- Are internet crawlers robots?
- Is Stanley a robot?

Next in 6.141:

- Lab today at 4pm
  - Introduction to μORC board (used in MASlab, RSS)
  - Multimeters, oscilloscopes, battery safety
  - Admission decisions in lab, via email by early evening
- Lecture Friday at 1pm
  - Electric Motors
- Lecture Monday at 1pm
  - Motor Control
- Lab Monday at 3pm
  - Building and Controlling the Chassis
- CI-M Lecture Wednesday at 1pm
  - Expectations for wiki materials, technical briefings