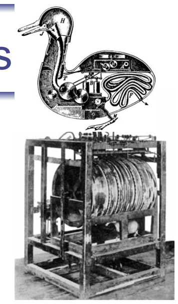
COMP 102: Computers and Computing
Lecture: Robotics

Guest lecturer: Joelle Pineau (jpineau@cs.mcgill.ca)

What is a robot?

- The word "robot" is popularized by the Czech playwright Karel Capek in his 1921 play Rossum's Universal Robots (R.U.R.).
- Webster dictionary: An automatic device that performs functions normally ascribed to humans, or a machine in the form of a human.
- A robot is a system which exists in the *physical world* and *autonomously* senses its environment and *acts* in it.
- Robotics is the intelligent connection of perception to action.
- Robotics has evolved together with AI, but is a separate field.

Precursors to modern robotics



~ 350 B.C: The Greek mathematician Archytas of Tarentum builds a mechanical bird dubbed "the Pigeon" that is propelled by steam.

~ 322 B.C. From Aristotle:

http://www.youtube.com/v/jfeNC28vpYo

"If every tool, when ordered, or even of its own accord, could do the work that befits it... then there would be no need either of apprentices for the master workers or of slaves for the lords."

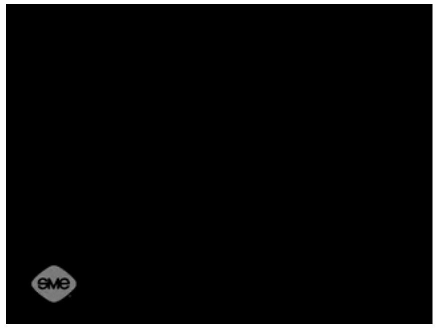
1700-1800's Clockmakers in Europe begin building automata.

Why are robots useful?

- Manufacturing, precise, repetitive tasks
- Hazardous environments
- Autonomous vehicles
- Telepresence and virtual reality
- Enhancing human abilities
- Fun and games (e.g. Lego robots)

Manufacturing

- Primarily robotic arms, doing repeatable actions.
  - Part sorting.
  - Painting.
  - Welding.

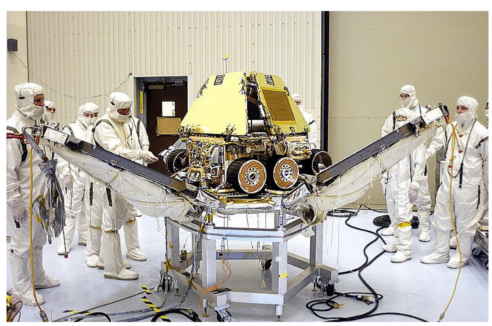


www.youtube.com/v/DkNVhtOCcrE

- Very precise motion control.
- Brittle to changes in environment.

Space exploration

- Many robotic probes launched in the last 2 decades.
- Also some rovers, with abilities for ground navigation.
  - Spirit (inactive), Opportunity (2003 - ??), Curiosity (2011 - ??)



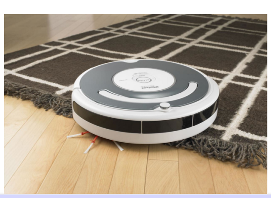
Emergency response

- Dante II exploring a volcano (1994).
- Search-and-rescue robots deployed at the World Trade Center (2001).

The Urbie robot fits in spaces too small for rescue workers with bulky equipment.

Home robots

- Large commercial success:
  Roomba vaccum cleaner
- Many other examples of domestic robots in Japan and elsewhere.
  - Surveillance.
  - Pool cleaners.
  - Companions (eldercare / childcare).
  - Pancake flipping robot.



www.youtube.com/v/W_gxLKSsSIE

Research / hobby

- Great variety of platforms, abilities, applications.

www.youtube.com/v/RerTewzPzfY

www.youtube.com/v/9KjohL2ZWOo

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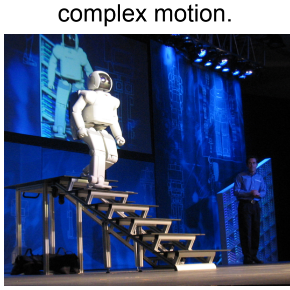
Humanoid robots

- Mostly research platforms, some built by major companies.
- Many challenges to achieve control, balance, complex motion.

www.youtube.com/v/EzjkBwZtxp4



www.youtube.com/v/uluRc1r_N34

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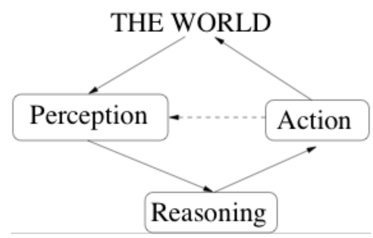
Robot parts

- Sensors: tactile, visual, thermal
- Effectors/actuators: locomotion vs. manipulation
- On-board computer system: ensures control of sensors/actuators

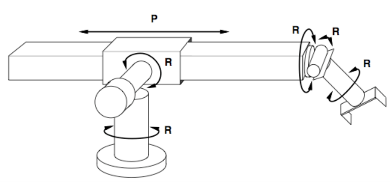
These affect the kinds of tasks

that a robot can do.



Effectors and actuators

- An *effector* is any device that affects the environment, e.g. wheels, arms, fingers
- An *actuator* is the actual mechanism that enables the effector to execute an action, e.g. motors
- Two basic ways of using effectors:
  - To move the robot around: **locomotion** (= legs or wheels)
  - To move other objects around: **manipulation** (= arms and hands)



Sensors

- Physical devices that measure physical quantities, such as:
  - Contact (e.g. bump, switch)
  - Distance (e.g. ultrasound, radar, infrared)
  - Light level (e.g. photo cells, cameras)
  - Sound level (e.g. microphones)
  - Strain (e.g. straing gauges)
  - Rotation (e.g. encoders)
  - Magnetism (e.g. compasses)
  - Smell (e.g. artificial noses)
  - Temperature (e.g. thermal, infrared)
  - Inclination (e.g. inclinometers, gyroscopes)
  - Pressure (e.g. pressure gauges)
  - Altitude (e.g. altimeters)
  - And others…

Sensors (cont' d)

- They represent the perceptual system of the robot.
  What a robot can do depends on what it can sense!
- The raw sensory information is of very little use! We need to process it in order to detect interesting things.
- Sometimes more than one sensor conveys the same information - sensor fusion enables more reliable readings.
- Choose appropriate sensors for the task at hand!

www.youtube.com/v/aiNX-vpDhMo

www.youtube.com/v/A52FqfOi0Ek

Robotic reasoning and control

- Refers to the way in which the sensing and action of a robot are coordinated.
- There are MANY different methods, but they all fall into four different categories:
  - Reactive control: Don't think, (re-)act.
  - Deliberative control: Think hard, act later.
  - Hybrid control: Think and act independently, in parallel.
  - Behavior-based control: Think the way you act.

Robot control

- Few actuators = easy to control.
- Many actuators = Many degrees-of-freedom to control.
- Many applications of machine learning to learn control rules.

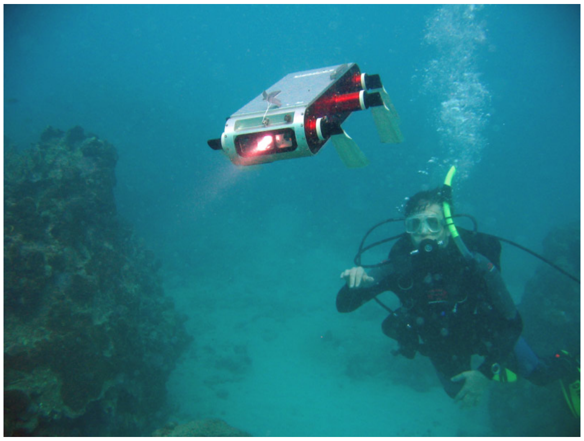
http://www.youtube.com/v/ppILwXwsMng

www.youtube.com/v/W1czBcnX1Ww

www.youtube.com/v/VCdxqn0fcnE

The Aqua Underwater Robot (McGill)

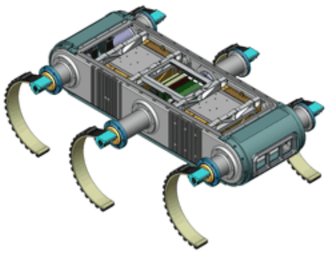
- Project lead by Prof. Greg Dudek of the Mobile Robotics Lab.



http://epitome.cim.mcgill.ca:8080/AQUA/index_html

Robot components

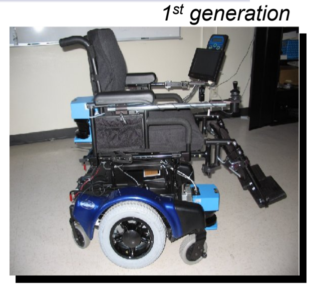
- Actuators: 6 legs, individually controlled.
  - Flippers for swimming and walking on beach, rubber-treaded legs for walking.
- Sensors:
  - Rear- and forward-facing video camera.
  - Acoustic sensors for localization.
- Programming:
  - C++ libraries for robot control.



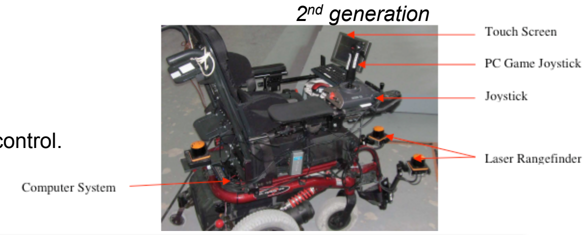
The SmartWheeler robot (McGill)

- Actuators:
  - Motors in wheels.
  - Speech synthesis.
  - Screen display.
- Sensors:
  - Rear- and forward-facing lasers.
  - Wheel encoders.
  - Speech recognition.
  - Touchscreen.
- Programming:
  - CARMEN toolkit for robot control.

1st generation



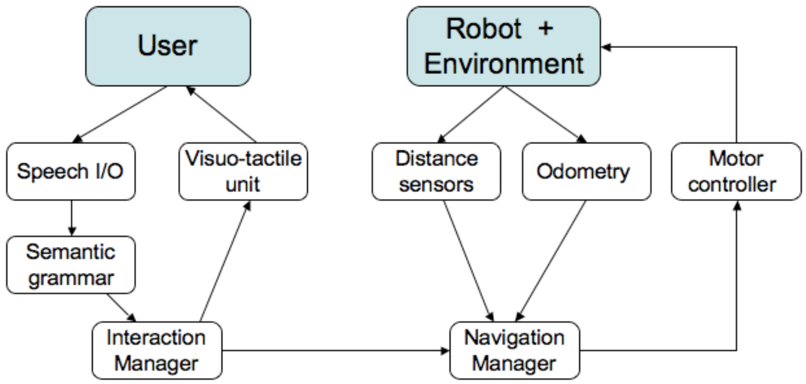
2nd generation



Objectives of the project

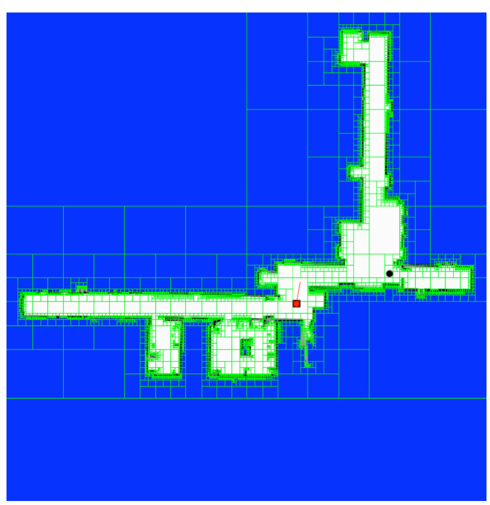
- Autonomous navigation within natural interior environments; maneuvering in constrained spaces.
- Natural interaction between robot and user; ability for robot to robustly pick actions in response to natural speech.
- Integration onboard commercial motorized wheelchair; testing and validation in realistic task domains with the target population.

Software architecture



Two primary components of AI system:
Interaction Manager and **Navigation Manager**

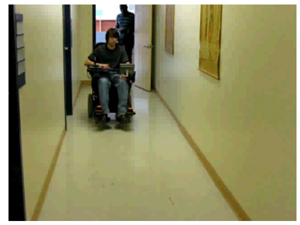
Robot navigation and mapping



The Wheelchair Skills Test (WST)

Kirby et al. Arch.Phys. Med. Rehabil. 2004.

- The test covers 32 skills.
- Each task is graded for ***Performance*** and ***Safety*** on a Pass/Fail scale by a human rater.



Why is robotics hard?

- Environment is dynamic (changing over time).
- Environment is full of potentially-useful information.
- Sensor information is now plentiful, but hard to process.
- Some state of the environment are still only partially observable.
- Effectors are still somewhat limited and crude.
- Artificial intelligence and machine learning techniques can help us deal with these issues.