Lecture 1 - 1

Defining Robotics

History of Robotics

The Robotics Primer (Ch. 1, 2)

Quote of the Week

"Don't tell people how to do things. Tell them what to do and let them surprise you with their results."

George Patton

Syllabus, Lab, Grader, Tech Support

- Labs will be due every Thursday by midnight starting 3/19/09
- Quizzes will be every Monday and Tuesday starting tomorrow (covers reading and lectures)
- Jon Nibert is the grader
- His office hours will be Wednesdays, 7 – 8 in D219
- Email him for help outside of office hours (nibert@rose)
- For hardware issues **Do not take the robot apart**, take it to the parts room for Jon or Matt to fix

What is a robot?

An autonomous system which exists in the physical world, can sense its environment and can act on it to achieve some goals

- **Autonomous** means it can make decisions and is not controlled by human (not teleoperation!)
- It must exist in the **physical world**
- It must have sensors for **perceiving** information from the world
- It must be capable of **acting on** the environment
- It must act on the environment to **achieve some goals**

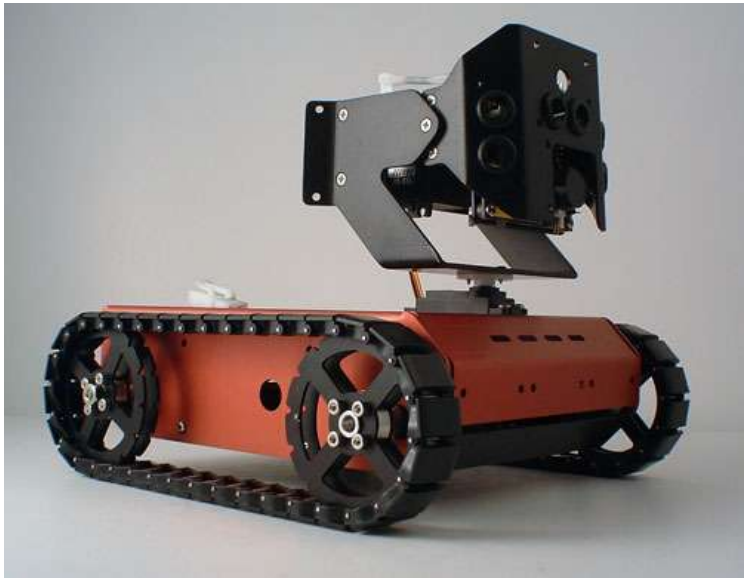
What is robotics?

Robotics is the study of robots interacting with the physical world

The study of the autonomous systems purposeful

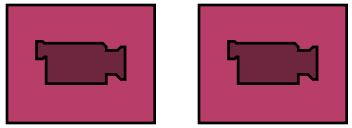
- *perception*
- interaction, and
- *action*

in the physical world.



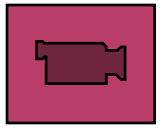
Teleoperation

- In hostile or unsafe environments, human operators can ***teleoperate*** a mobile robot. The human performs localization and cognition, the robot provides motion control.
- The human controls the robot
- The human views the environment through the robot's eyes
- There is no need for artificial intelligence (AI)
- Suited for tasks that are unstructured and not repetitive
- Task requires dexterous manipulation, and hand-eye coordination
- Task requires object recognition or situational awareness
- Display technology does not exceed limitations of the communication link (bandwidth or time delays)
- No constraints on the availability of trained personnel



Autonomy

- In **semi-autonomous** robots, the human may control the robot sometimes. The robot is viewed as a peer or partner in the workspace with the human
- In **supervisory control**, the human is involved but routine or safe tasks are handled autonomously by the robot
- In **shared control**, the human provides the robot with the task but may interrupt the robot with feedback or perceptual inputs or interrupt execution if necessary
- In **fully autonomous control**, the human initiates the task but does not interact after execution. Some robots share space with humans and their ***autonomy*** allows the robot to maintain a sense of position and navigate without human intervention



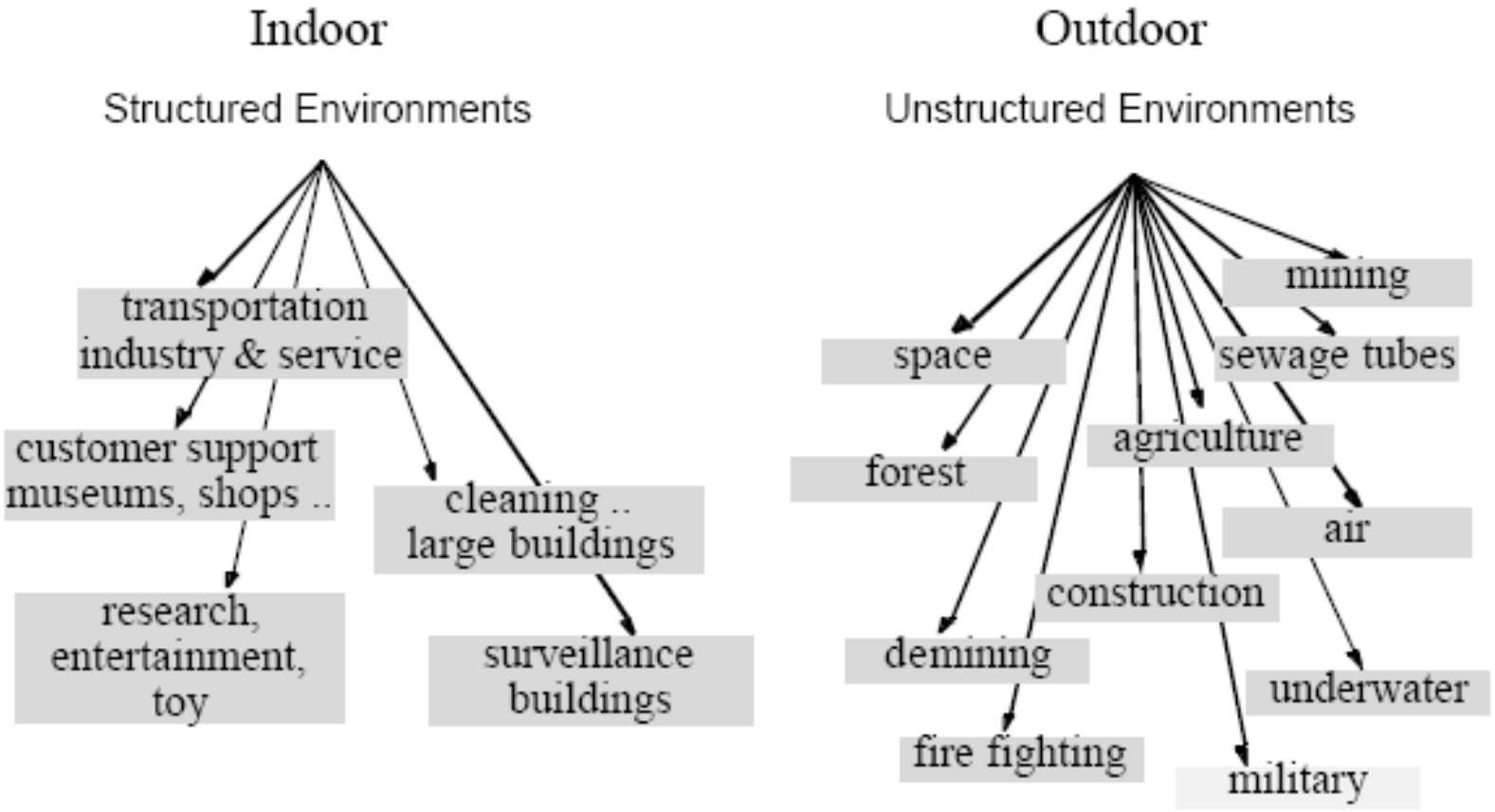
Autonomous Mobile Robotics

How can a robot move unsupervised through real-world environments to fulfill its tasks?

Questions to answer:

- Where am I? (Perception, Localization)
- Where am I going? (Planning)
- How do I get there? (Motion Generation)

Applications of Mobile Robots



Control Theory and Cybernetics

- **Control theory** is a foundation of engineering that studies concepts that govern mechanical systems and how to control them for a certain behavior. This is the mathematics of controlling machines.
- **Feedback control** is a key concept in robotics that governs the electrical and mechanical behavior or systems
- **Cybernetics** uses control theory to study communication and control process in biological and artificial systems. It looked for common properties in animals and machines. It is a combination of robotics and artificial intelligence. Cybernetics combined "sensing", "thinking", "acting" and the interaction in the environment

W. Grey Walter's Tortoise: First Robot

- W. Grey Walter (1910 – 1977) was a neurophysiologist who was interested in how the brain works
- He was studied brain function by building and analyzing machines with animal like behavior
- A **biomimetic** machine is one with properties similar to those of biological systems
- His tortoises, Elmer and Elsie, were electro mechanical robots that were light sensitive
- It had 3 wheels in a tricycle design with front wheel steering and back wheel driving
- He called the robots "a machine that thinks" and a "machine that can learn" (in Latin)

Grey Walter's Tortoises (Elmer and Elsie)

Lego version of the Tortoise

W. Grey Walter's Tortoise: Components and Behaviors

- Components:
  - One photocell to sense light levels
  - One bump sensor
  - One rechargeable battery
  - Three motors for 3 wheels
  - One analog electronic circuit which connects the bump sensor and photocell to the wheels
- Behaviors
  - Find the light
  - Head toward the light
  - Back way from bright light
  - Turn and push to avoid obstacles
  - Recharge the battery

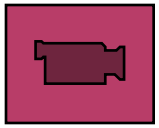
W. Grey Walter's Tortoise: Control System

- Reactive Control:
  - Controls a robot using a collection of prioritized reflexes
  - This system of reflexes resulted in an animal-like behavior
- Emergent Behavior
  - Unexpected behavior that a robot creates that is not explicitly defined in the system

Braitenberg Vehicles

- Valentino Braitenberg wrote a book on how to design simple robots that produce behaviors that appear animal like and life-like.
- These robots had sensors directly connected to their motors that produced photophilic, photophobic, excitatory and inhibitory connections

- Braitenberg described how these mechanisms can be used to store information, build a memory and achieve robot learning.

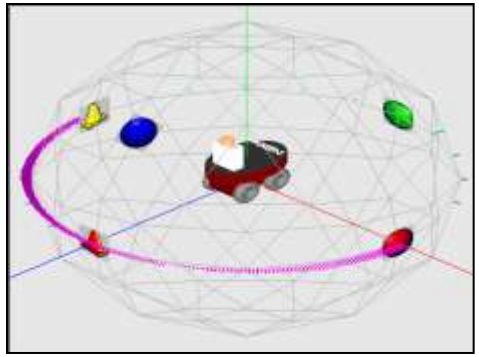


What is Artificial Intelligence (AI)?

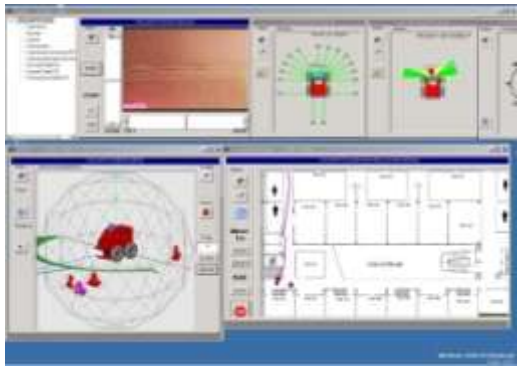
the scientific understanding of the mechanisms underlying thought and intelligent behavior and their embodiment in machines

How intelligent a robot appears is strongly dependent on **how much** and **how fast** it can sense its environment and apply that information to tasks.

AI is the mechanism for planning and reasoning.

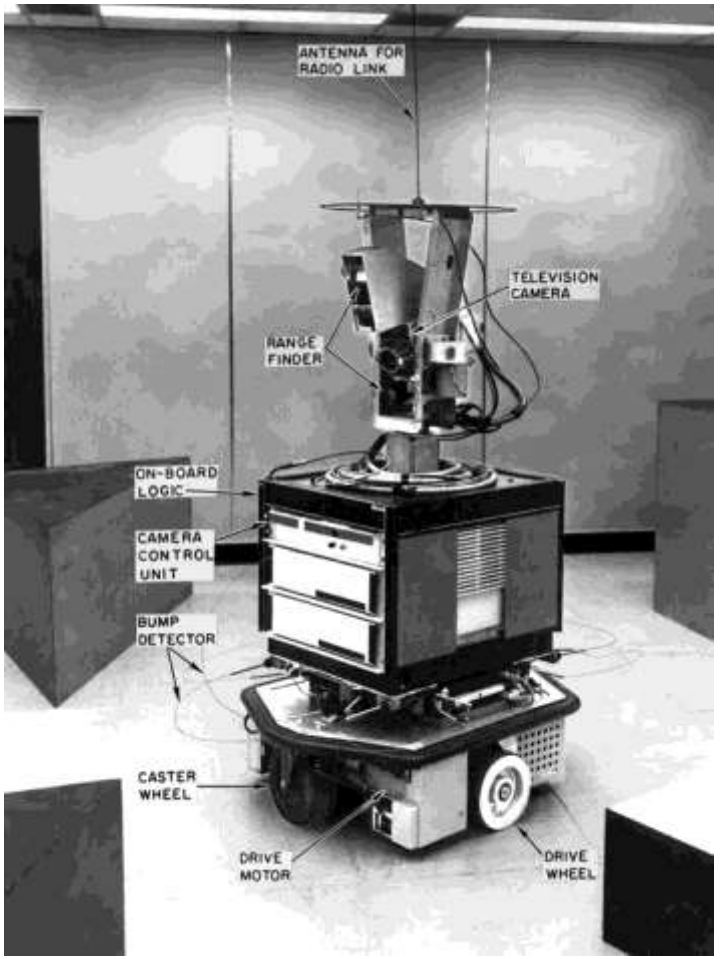


- Internal models of the world
- Knowledge Representation
- Understanding natural language
- Learning
- Planning and reasoning for problem solving
- Inference
- Search through possible solutions
- Hierarchical system organization
- Sequential program execution



Shakey (AI-Inspired robot)

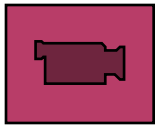
- Shakey was built at the Stanford Research Institute in 1970
- First mobile robot to use AI techniques
- It shook when it executed plans to move in the world thus the name.
- Controlled by a large computer
- Used spatial data from camera and laser range measurements to recognize objects
- Created a path to the object
- Pushed the objects (blocks) over when found

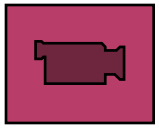


Other AI-Inspired Robots

- The Stanford CART developed in 1977 by Hans Moravec used vision-based navigation
- This robot was a cart on bicycle wheels
- It moved slowly because of the difficulty of processing data from vision and computer processors

- The CMU Rover developed in 1983 by Hans Moravec used a camera and ultrasound sensing for navigation





Types of Robot Control

- Artificial Intelligence used
  - Purely deliberative control
- In the 1980s, this type of control was replaced with
  - Reactive control
  - Hybrid control
  - Behavior-based control

Multidisciplinary Robotics

- **Mechanical Engineers** study robot shape, mechanics, payload limit, materials, walking, climbing, flexing, building
- **Electrical and Computer Engineers** study sensor/actuator design, wireless communications, board design, computer interfacing)
- **Computer scientists** study navigation, motion planning, behaviors, machine vision, cooperation and learning strategies
- **Cognitive scientists** study artificial intelligence, humanoids, neural networks, language processing, learning and memory
- **Chemists** study nano-sized robots and chemical engineering for motors

Challenges in Robotics

- Physical/Mechanical/Electrical issues
  - Sensors are prone to errors and bad readings
  - Sensors have limited range and resolution
  - Sensors are subject to noise and break
  - Sensor input requires lots of processing power
  - Actuators drain batteries and are not small or powerful enough
  - Actuators are unpredictable because of noise, wear and tear and mechanical failure
- Knowledge Representation & Retrieval
  - How to represent the real world in a robot's memory
  - How to extract relevant information from large amounts of sensor data
  - How does the robot adapt to a dynamically changing and unpredictable environment

Challenges cont.

- Uncertainty
  - There is an enormous amount of uncertainty in a robot's environment
  - The robot's internal model of the environment is approximate
  - Algorithms are approximate in order to be real-time
  - Robot's have to act on the environment using the insufficient information from sensors and inaccurate internal model
  - The robot cannot make decisions with complete certainty