Lecture 1 - 1

Overview

From Teleoperation to Autonomy

Introduction to AI Robotics (Ch. 1)

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, Quizzes, Labs, Tech Support

- This is a **mobile robotics** course, not a programming class, although programming is required, you must be proficient enough to do this independently
- This course will focus on robotics history, theory, application and control
- Lab demonstrations will be due every Thursday in class
- Lab memos and code will be due on Angel every Thursday by midnight
- Quizzes will be every Monday and Tuesday (covers reading and lectures)
- Quizzes are closed book and closed notes
- For hardware issues, **do not take the robot apart**, take it to the parts room for repair

Objectives

Upon completion of this lecture the student should be able to:

- Define a robot
- List the three robotics primitives
- Describe the 3 robotic paradigms
- Describe the behaviors of one of the first robots
- Define the difference between teleoperation and semi-autonomous control
- List the seven main areas of artificial intelligence

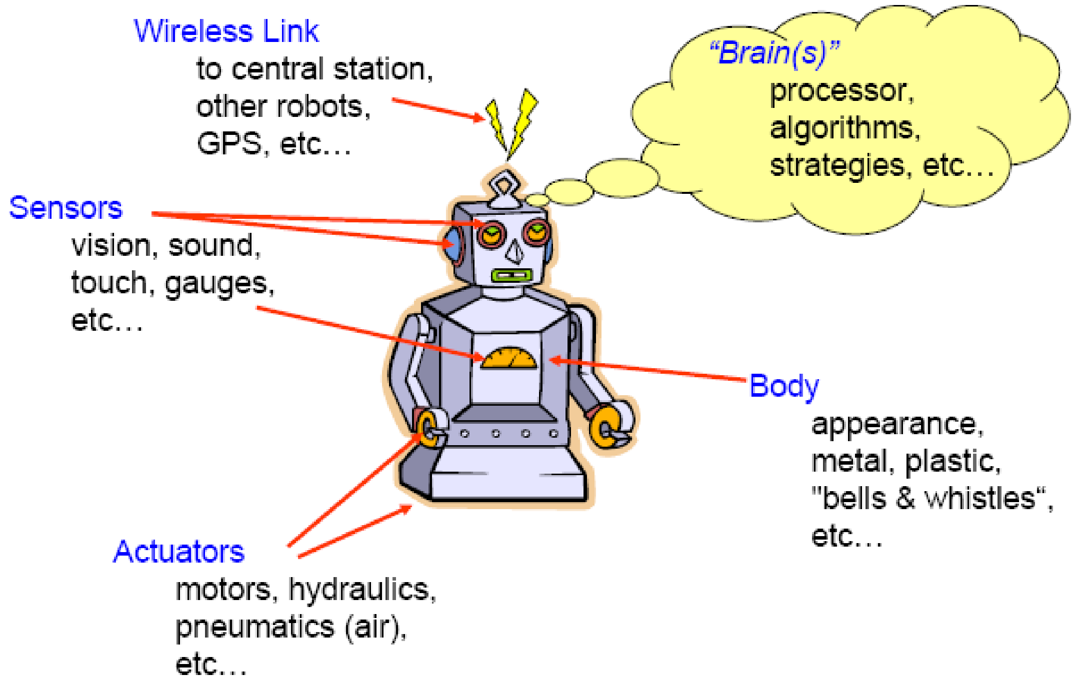
What is a robot?

*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**

Robot Components

- Body
- Sensors
- Effectors and Actuators
- Controller



Effectors and Actuators

- An ***effector*** is any device that has an effect on the environment
  - Equivalent to biological legs, arms, fingers
  - Body parts that do physical work
  - i.e. wheels, tracks, arms, grippers
- An ***actuator*** is the mechanism that enables an action or movement
  - Equivalent to biological muscles and tendons
  - i.e. electric motors, hydraulic or pneumatic cylinders

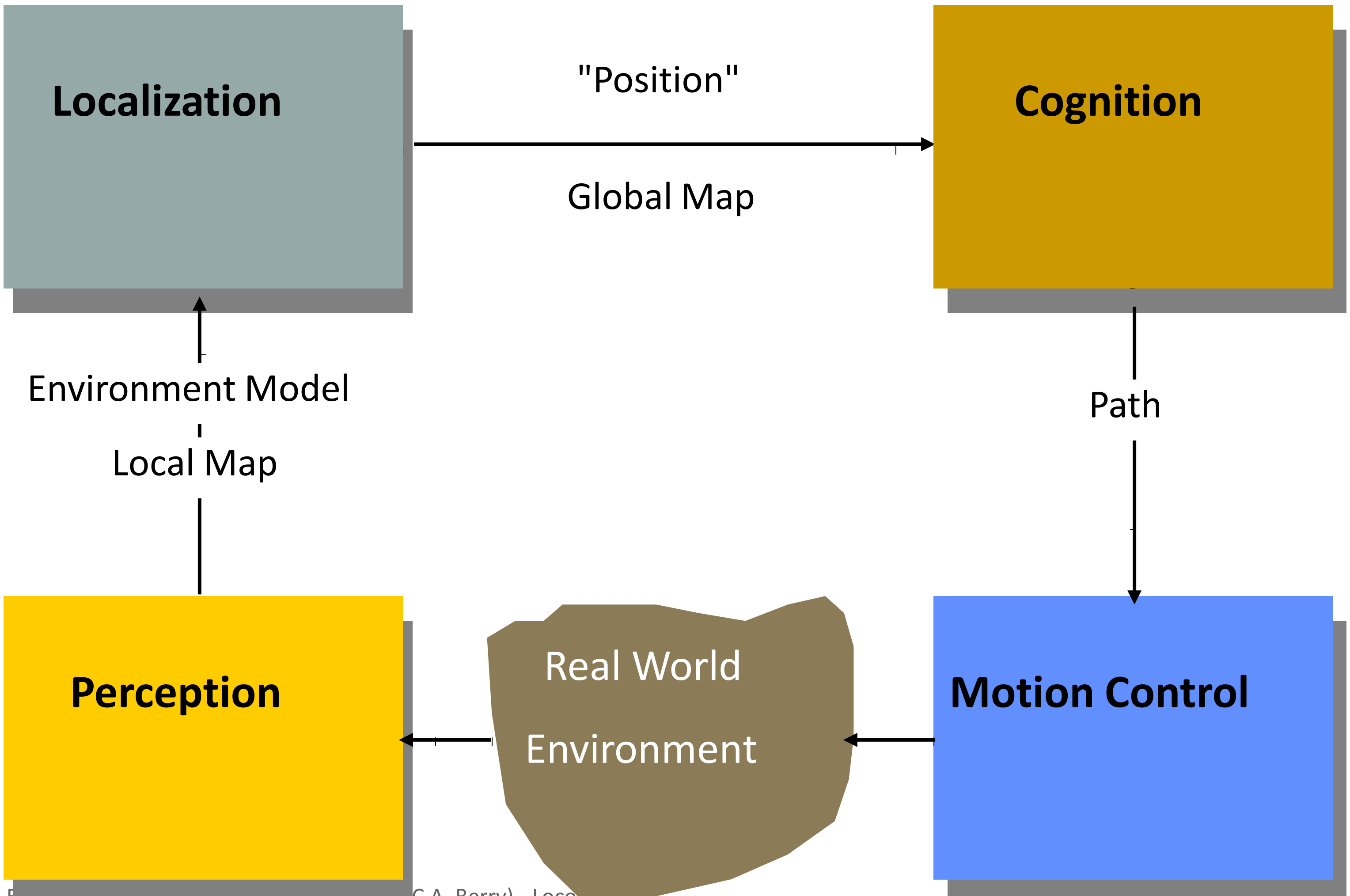
Locomotion

- ***Locomotion*** refers to the way that a robot moves from place to place
- In ***locomotion***, the environment is fixed and the robot moves by imparting force to the environment
- In ***manipulation***, the robot arm is fixed but moves objects by imparting force to the environment

Trajectory and Motion Planning

- Two concerns in locomotion
  - Getting the robot to a particular location (goal)
  - Having the robot follow a trajectory
- ***Navigation*** is concerned with getting to a goal
- ***Trajectory planning (motion/path planning)*** is more difficult than moving the robot to a particular location. This is related to forward and inverse kinematics.
- ***Optimal trajectory*** deals with finding the safest, shorts, or most efficient path

Locomotion Concepts: Path Planning



Mobile Robot Kinematics

- ***Mobile robot kinematics*** is the dynamic model of how a mobile robot behaves
- Kinematics is a description of mechanical behavior of the robot for design and control
- Mobile Robot Kinematics is used for:
  - Position estimation
  - Motion estimation
- Mobile robots move unbounded with respect to their environment
  - There is no direct way to measure robot position
  - Position must be integrated over time
  - The integration leads to inaccuracies in position and motion estimation

Odometry

- Odometry is a means of implementing ***Dead Reckoning***
- A way of determining a robot's position based upon previous known position information given a specific course heading and velocity
- Periodically requires error measurement to be 'fixed' or reset
- Meant for short distance measurements

Relative Positioning: Odometry and Kinematics

- Given wheel velocities at any given time, compute position/orientation for any future time
- Advantages
  - Self-contained
  - Can get positions anywhere along curved paths
  - Always provides an “estimate” of position
- Disadvantages
  - Requires accurate measurement of wheel velocities over time, including measuring acceleration and deceleration
  - Position error grows over time

Odometry errors

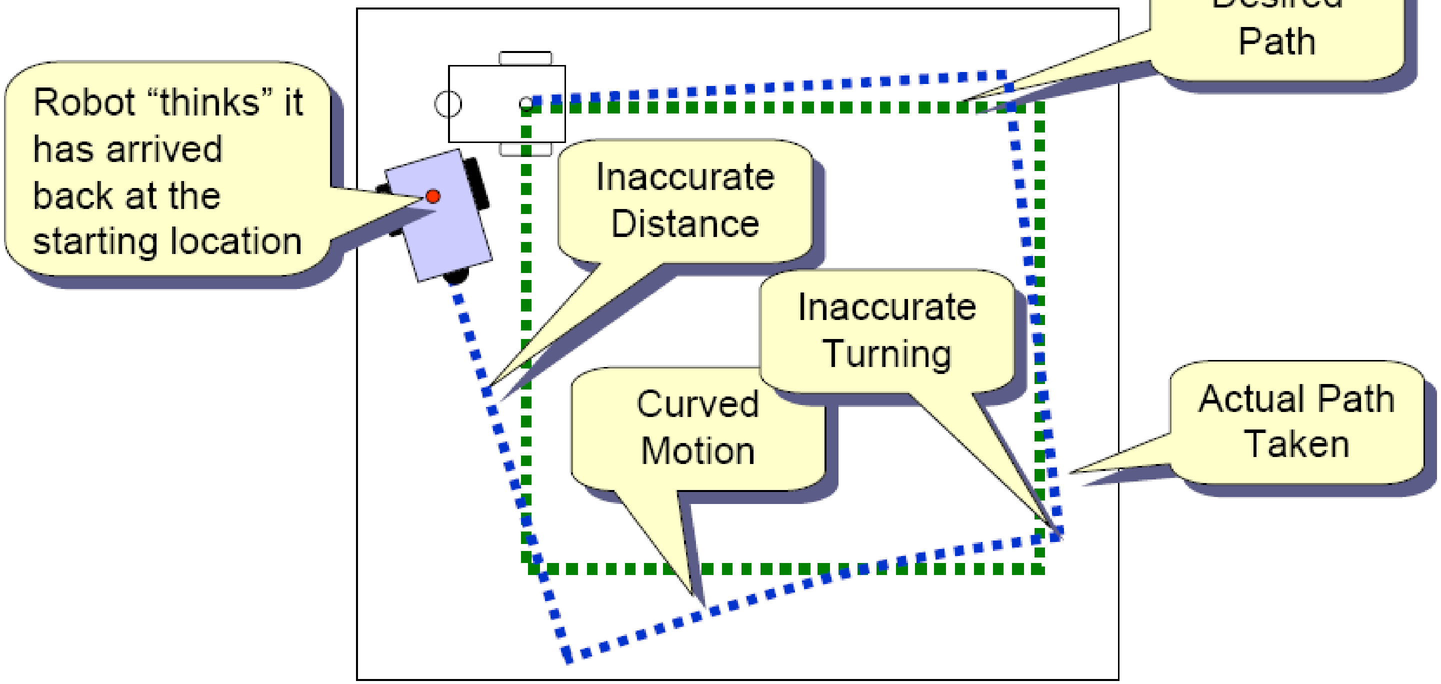
- Systematic
  - Unequal wheel diameters
  - Misalignment of wheels
  - Finite encoder resolution
  - Finite encoder sampling rate
- Non-systematic
  - Travel over uneven floors
  - Unexpected objects in the floor
  - Wheel slippage due to
    - Over acceleration
    - Slippery floor
    - skidding

Odometry errors

- Imprecise measurements
  - Discrepancy with actual speed and turn angles
- Inaccurate control model
  - Tracks/Wheels/Motors are not perfectly aligned or do not make contact at a single point
- Immeasurable physical characteristics
  - Friction
  - Wobbling wheels
  - Surface is not perfectly smooth and hard
  - Sliding

Dead Reckoning

- As a result of these error factors, a simple path cannot be traversed accurately.



Open Loop Control

- **Open Loop Control** does not use sensory feedback, and the robot state is not fed back into the system
- **Feed-forward control**
  - The command signal is a function of some parameters measured in advance
- Feed-forward systems **are effective** only if
  - They are well calibrated
  - The environment is predictable and does not change

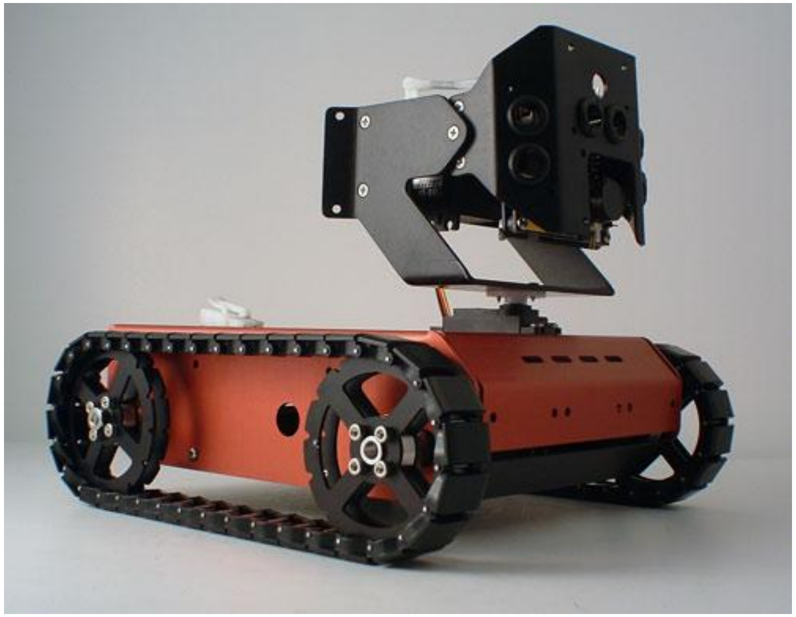
What is robotics?

Robotics is the study of robots interacting with the physical world

The study of the autonomous systems purposeful

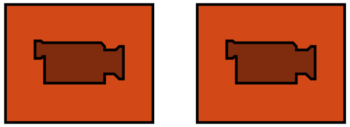
- *perception*
- interaction, and
- *action*

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

Mobile Robotics

- ***Mobile robotics*** studies robots that move around on the ground but also in the air or water (i.e. Mars rover)

- ***Manipulator robotics*** is concerned with robot arms (i.e. industrial robots)

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)

Control Theory and Cybernetics

- **<u>Control theory</u>** 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.
- **<u>Feedback control</u>** is a key concept in robotics that governs the electrical and mechanical behavior or systems
- **<u>Cybernetics</u>** 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

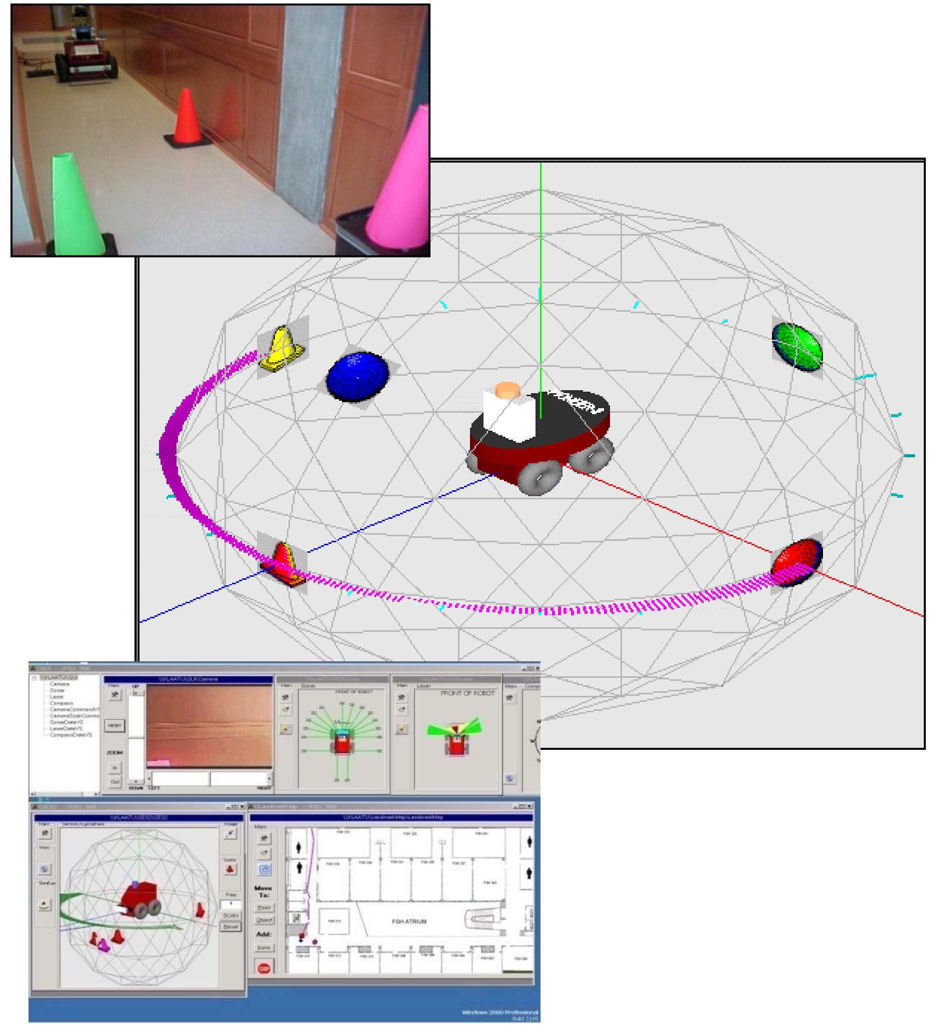
What is Artificial Intelligence (AI)?

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

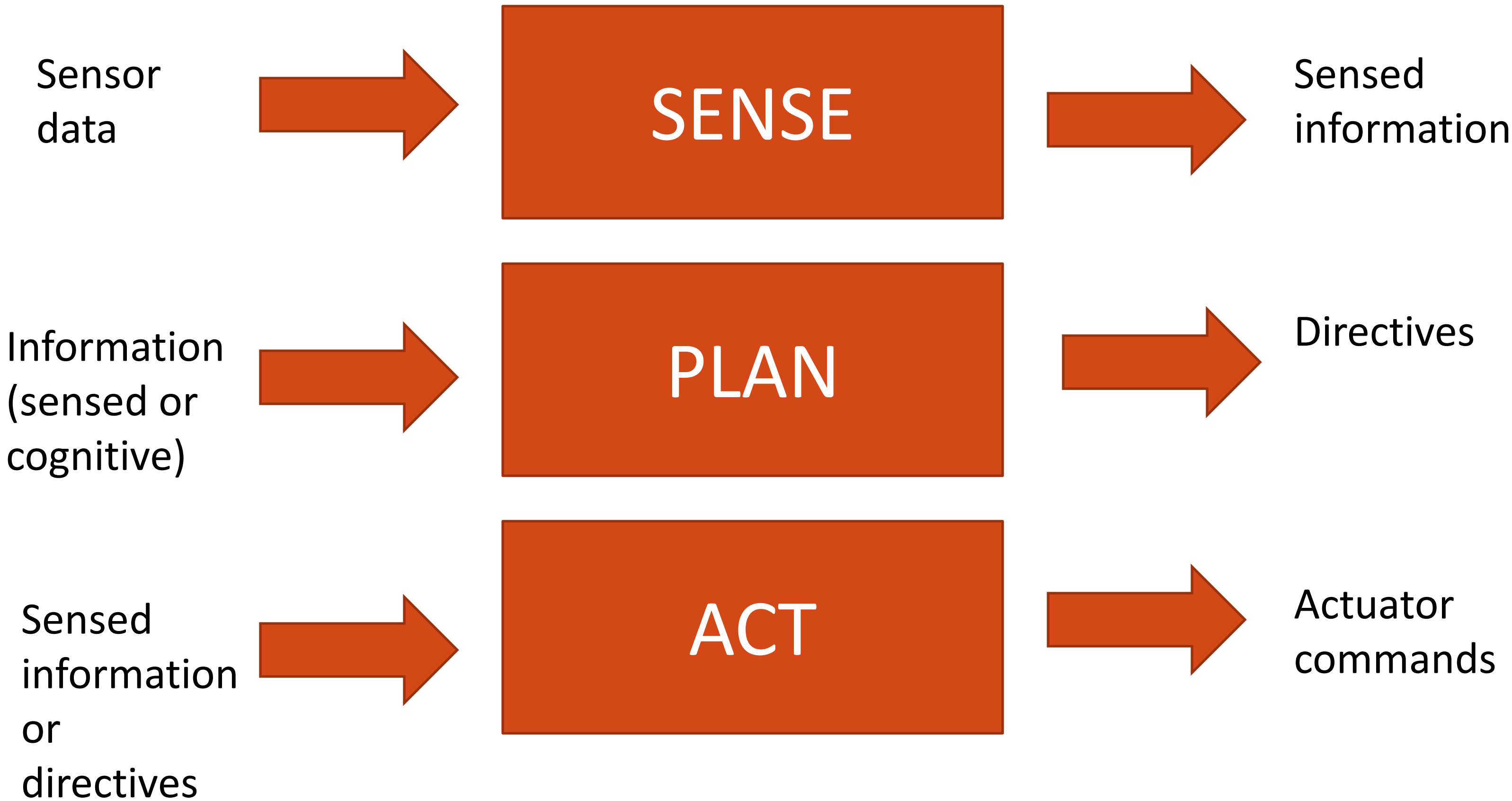


Types of Robot Control:

3 paradigms for organizing robot intelligence

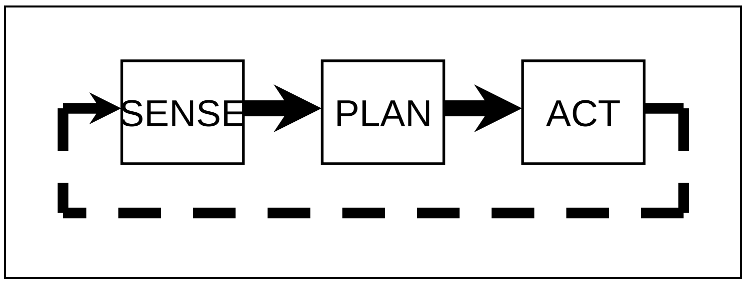
- Originally, Artificial Intelligence (60s & 70s) used
  - **Deliberative control**
- In the 1980s, this type of control was replaced with
  - **Reactive control (behavior-based control)**
  - **Hybrid (deliberative/reactive) control**

3 Robotic Primitives

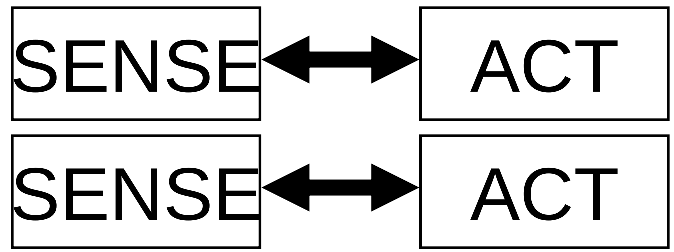


Robotic Paradigms in terms of Primitives

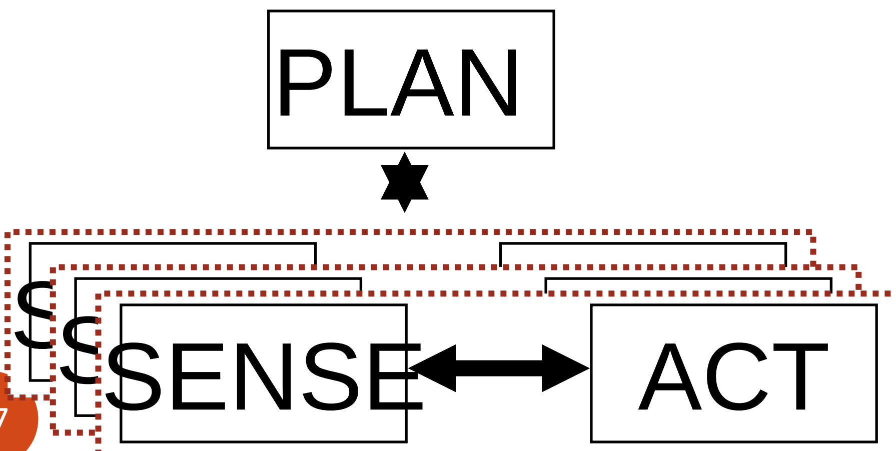
The 3 paradigms are described by the relationships between the 3 primitives



Hierarchical (1967) – very slow



Reactive (1986) – no planning

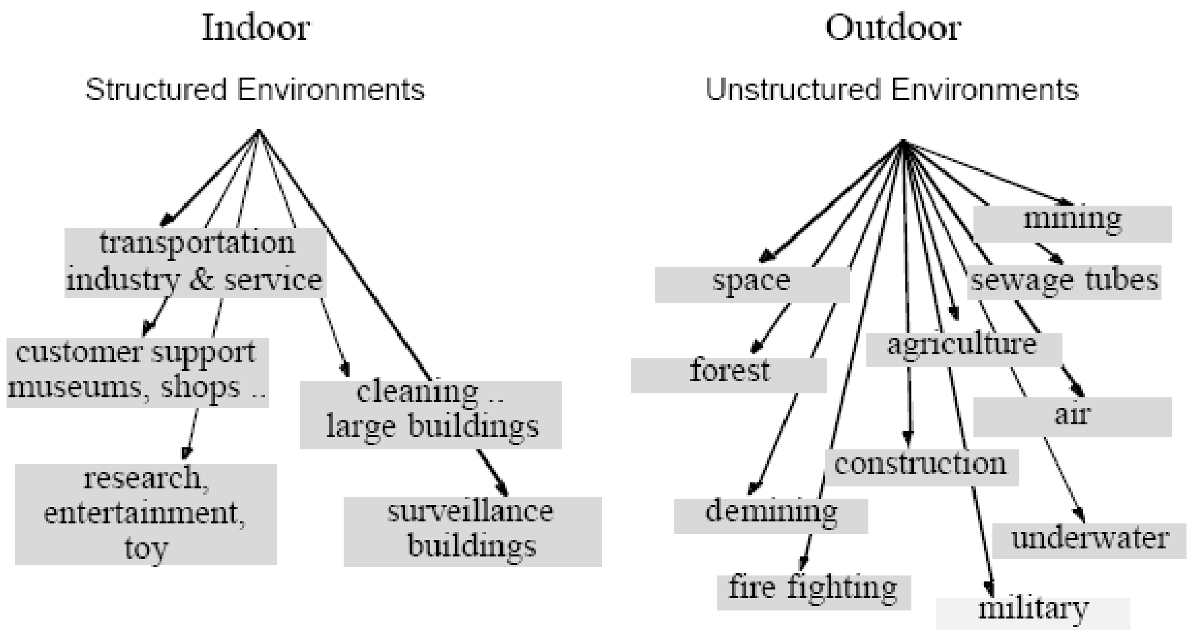


Hybrid Deliberative/Reactive (1990)

Applications of Mobile Robots

Robots are ideal for jobs (tasks) that are:

- Dirty
- Dangerous or
- Dull



W. Grey Walter's Tortoise: First Robot

- W. Grey Walter (1910 – 1977) was a neurophysiologist who was interested in how the brain works
- He 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)

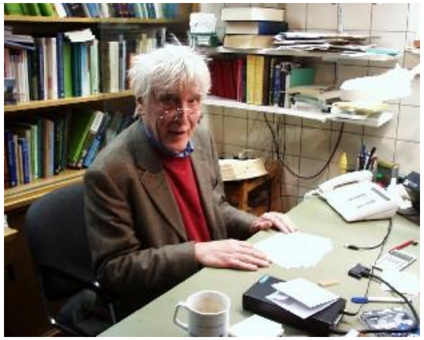
W. Grey Walter's Tortoise: Components and Behaviors

- 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.

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

Challenges in Robotics cont.

- 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 in Robotics 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