## Robot Basics

The attribution problem in Cognitive Science
- If mind is caused by something inside of us, what exactly is it that one must assume is IN THERE in order to account for the organized behavior one can observe?

## Artificial Intelligence

- Internal models of the world
- Search through possible solutions (in a solution space)
- Planning and reasoning to solve problems
- Symbolic representation of information
- Hierarchical system organization
- Sequential program execution.

## A parting of the ways (1960s – 1990s)

- AI and information processing psychology became dominant in N. America.
- Other approaches based on cybernetics and control theory thrived in Europe, but were mostly ignored in N. America.
- Robotics grew slowly in N. America.

## A new synthesis (1990s – present)

- A shift from seeing cognition as a logical procedure to seeing cognition as a biological process... The embodiment of cognition
  - Challenges traditional AI
  - Opens the door for cybernetics again
  - Makes possible new links between robotics and cognitive science.

## What is a robot?

- A robot is an autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals.
- And the actions respond to (are contingent on) the sensory input.
Control Theory

- Control theory is the mathematical study of the properties of automated control systems ranging from steam engines to airplanes, and much in between.

The Watt Governor
(to control the speed of a steam engine)

Cybernetics

- Proponents of cybernetics studied biological systems, from the level of neurons (nerve cells) to the level of behavior, and tried to implement similar principles in simple robots, using methods from control theory. Thus, cybernetics was a study and comparison of communication and control processes in biological and artificial systems.

Braitenberg’s Vehicle 2

Vehicle #2 sensor state space

Cricket
Phonotaxis

The importance of sensor placement

Three tasks:
Tune, locate, locomote

No representations
No computations

A dynamic state space a lot like Vehicle #2
Caution!

- Do NOT assume that a pattern of behavior that can be accurately described by rules is generated by following rules.
- Rule described ≠ rule governed

The active body

- The computation that gets done in interaction of body and world, does not have to be done by the brain (or microprocessor) alone
- Walking taking advantage of the dynamics of the body. Thelen & Smith;
- Inhabit rather than control the body

Passive-Dynamic Walker

- http://www.youtube.com/watch?v=qwEWki9H0Ao

What is the brain doing?

- The brain is revealed not as an engine of reason or quiet deliberation, but as an organ of environmentally situated control. *(Mindware: 95)*

What sort of explanation do we want?

- Perception – computation – action loop?
- Well, what needs to be explained?
- The answer to that depends on where we place the boundaries of the unit of analysis.
  - Boundary at skin of the creature -> explain behavior in terms of brain processes
  - Boundary around creature/environment dynamical system -> explain powerful regularities in the behavior of the complex dynamical system composed of brain, body and world. *(Finger waggling, Infant stepping, e.g.)*

Principle of Ecological Balance

- Given a certain task environment there has to be a match between the complexities of the agent’s sensory, motor, and neural systems...
- There is a certain balance or task distribution between morphology, materials, control, and environment.
- *(Pfeifer and Bongard, 2007)*
Dynamical Cognitive Science

- Body and world (and hence time, movement, etc.) all matter and can play powerful roles in adaptive problem solving.
- Neural, bodily, and environmental elements are intimately intermingled in continuous mutual and reciprocal causality.
- The traditional “input – compute – act” cycle cannot explain such systems.

Types of Robot Control

- Deliberative Control (AI style)
  - Sense – Compute – Act
  - No longer used in robotics
- Reactive control
  - Sense -> Act
- Hybrid control
  - Reactive with a little bit of planning
- Behavior-based control

Analog, Discrete, and Digital Signals

- An analog signal is one that is continuous in time and amplitude (amount of wave oscillation, for example).
- A discrete signal is discontinuous in time and amplitude. It can assume a limited number of values.
- A digital signal is a two-value discrete signal. It is either ON or OFF, never any value in between.

The main components of a Robot

- A physical body, so it can exist and do work in the physical world
- Sensors, so it can sense/perceive its environment
- Effectors and actuators, so it can take actions
- A controller, so it can be autonomous.

Sensors and Sensor State

Effectors and Actuators

- An effector is any device on a robot that has an effect (impact or influence) on the environment. Effectors DO stuff.
  - A wheel is an effector
- An actuator is the mechanism that enables the effector to execute an action or movement.
  - An electric motor that turns a wheel is an actuator
DC Motor
(our most common actuator)
- Converts electrical energy into mechanical energy.
- Consumes power
- Spins really fast (9000 rpm)

Gears
- What to do with that fast spinning motor?
  - Gear reduction

Servo Motors
- Can turn their shaft to a particular position
- A servo is a DC motor plus
  - Gear reduction
  - Position sensor on the motor shaft
  - Controller operating on pulse-width modulation

Degrees of Freedom
- A degree of freedom (DoF) is any of the minimum number of coordinates required to completely specify the motion of a mechanical system.
- Rotational DoF: ways an object can rotate
- Translational DoF: ways an object can move without rotating

Six Degrees of Freedom
Three rotational, three translational

Controllable and Uncontrollable DoF
If a robot has an actuator for every DoF, then all of the DoF are controllable.
- The DoF that are not controllable are called uncontrollable DoF.
Three kinds of relations:
- Holonomic: Controllable DoF = Total DoF
- Nonholonomic: Controllable DoF < Total DoF
- Redundant: Controllable DoF > Total DoF
Static Stability

- A statically stable robot can stand still without falling over; it can be static and stable.
  - A robot will be statically stable if the center of gravity (CG) is above the polygon of support.

Dynamic Stability

- In dynamic stability, the body must actively balance or move to remain stable; it is therefore called dynamically stable.

Desirable properties of gaits in walking

- A gait is the particular way a robot (or a legged animal) moves
  - Stability: the robot does not fall over
  - Speed: the robot can move quickly
  - Energy efficiency: the robot does not use a great deal of energy to move
  - Robustness: the gait can recover from some types of failures
  - Simplicity: the controller for generating the gait is not unwieldy.

Wheeled Robots

- Tend to be statically stable
- Usually not holonomic
- This means that trajectory planning may be required
- Can use differential drive to steer the popular two-wheeled with a caster design

Design Advice

- Start simple
  - The KISS principle “Keep It Simple, Stupid.”
  - Add complexity gradually and only as needed.
- Degrees of Freedom!
  - Do what you can to reduce the total number of DoF.
  - For example, work on the ground rather than in the air.
- Stability:
  - Seek designs that are inherently stable.
  - Seek static stability where possible. Dynamic stability is hard to produce.

Your Robot Descriptions

- 10 of you proposed a wheeled robot that can navigate a space and locate some target objects.
- Jellyfish, snake, hiking hat, tea steeper, musical instrument,
- Machine translation
- Helicopter
A Robotics Shield Kit for Arduino

Earning points in the class

<table>
<thead>
<tr>
<th>ASSIGNMENT</th>
<th>POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robot Description</td>
<td>10</td>
</tr>
<tr>
<td>Design Considerations</td>
<td>20</td>
</tr>
<tr>
<td>Implementation</td>
<td>30</td>
</tr>
<tr>
<td>Behavior</td>
<td>40</td>
</tr>
<tr>
<td>Full Portfolio</td>
<td>50</td>
</tr>
<tr>
<td>Quiz 1</td>
<td>5</td>
</tr>
<tr>
<td>Quiz 2</td>
<td>5</td>
</tr>
<tr>
<td>Quiz 3</td>
<td>5</td>
</tr>
<tr>
<td>Quiz 4</td>
<td>5</td>
</tr>
<tr>
<td>Final Exam</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
</tr>
</tbody>
</table>