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?

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
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)

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 (a sensed voltage, 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 Electric Motor**  
(our most common actuator)
- Converts electrical energy into mechanical energy.
- Consumes power
- Spins really fast (9000 rpm)

**Electric Motor**

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

**Inside our servo motor**

**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

**Hydraulic Effector (leg)**
Big Dog Bot

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

Asimo’s Degrees of Freedom

Azimo climbs stairs
Stable:

- 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.

Diego San with Javier Movellan

Big Dog Walking

Diego San in Action
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.

A Robotics Shield Kit for Arduino