Explore Robotics – CISC 1003

Introduction to Autonomous Robots
and autonomous robotics

Autonomous Robotics

- We will focus on autonomous robotics
- Reminder - What is a robot?
  - “A robot is defined as a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks.” [Robot Institute of America, 1979]
  - “a robot is an automatic device that performs functions normally ascribed to humans or a machine in the form of a human.” [Webster dictionary]

Autonomous Robotics

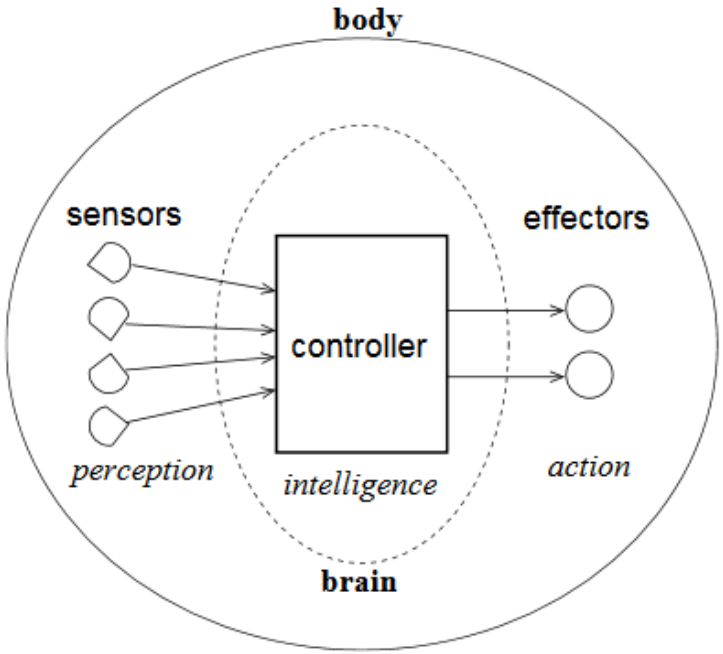
- What is an agent?
  - In artificial intelligence, an **intelligent agent** (**IA**) is an autonomous entity which observes through sensors and acts upon an environment using actuators (i.e. it is an agent) and directs its activity towards achieving goals (i.e. it is "rational", as defined in economics) [Russel & Norvig, 2003]

Autonomous Robotics

- What is Autonomy?
  - No remote control!
  - An agent makes decisions on its own, guided by feedback from its sensors; but you write the program that tells the agent how to make its decisions environment.

Our definition of a robot

- Robot = autonomous embodied agent
- Has a *body* and a *brain*
- Exists in the physical world (rather than the virtual or simulated world).
- Is a mechanical device



our canonical agent

Robot definition (cont.)

- Contains *sensors* to perceive its own state
- Contains *sensors* to perceive surrounding environment
- Has *effectors* that perform actions
- Has a *controller* that takes input from the sensors, makes *intelligent* decisions about actions to take, and performs these actions by sending commands to motor

Robot components

- All have five common components:
  - Control:
    - Human: Brain, central nervous system
    - Function: the brain makes decisions based on sensory input , nervous system sends signals to muscles
    - What is the equivalent in Robots?
      - Usually the brain is a computer of some kind, wires send signals
  - Effectors (body/structure):
    - Human: Bones and muscles - legs, arms, wrists, neck, etc.
    - Function: Allows movement
    - What is the equivalent in Robots?
      - Motors allow movement, wheels

Robot components

- All have five common components (cont.):
  - Perception (sensors):
    - Humans: 5 senses detected by our body (what are they?)
      - Touch, Smell, Sight, Hearing, Taste
    - Robots: Touch sensor notifies robot of contact with another object, sound sensor allows robot to perceive audio.
  - Power source:
    - Humans: food and digestive system
    - Function: provide energy
    - Robots: usually batteries of some kind

Robot components

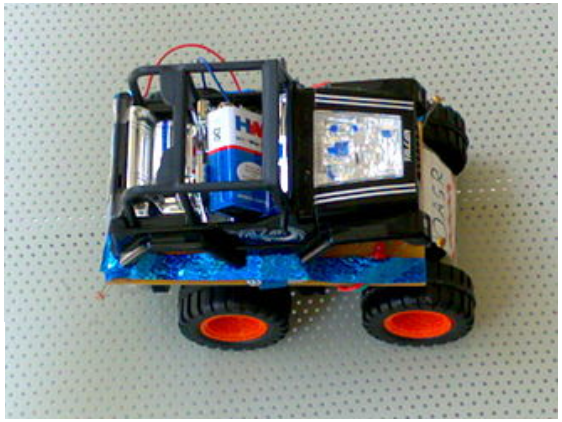
- Communications:
  - Humans: voice, gesture, hearing
  - Function: communication with outside world
  - Robots: input/output functionality, expressions, wireless signals

Effectors

- Any device that affects the environment
  - Include legs, wheels, arms, etc.
- Actuator:
  - The mechanism that allows the effector to execute the action
  - Converts software commands into physical movements
    - Through electronic or hydraulic signals
- Specific categories:
  - Manipulators: Industrial robot arms, capable of picking and placing objects, mimicking human
  - Mobile/humanoid robots: effectors enables moving around

Mobile Robots

- Classified by manner of locomotion:
  - Wheeled
  - Legged
- Stability is important
  - Static stability
  - Dynamic stability



https://en.wikipedia.org/wiki/Mobile_robot
https://nodna.de/H20-Wireless-Humanoid-Mobile-Robot-with-Dual-Arms_1
https://en.wikipedia.org/wiki/Roomba

Industrial Robots

- Robot system used for manufacturing
  - Automated and programmable
  - Typically stationary, include jointed arm and gripper
    - Typically no legs or wheels
    - Attached to a fixed surface

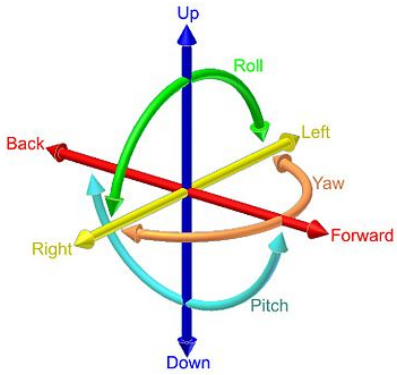
https://en.wikipedia.org/wiki/Industrial_robot

Robot Motion

- Fundamental question:
  - Where is the robot located?
- Configuration: a specification of the position of all points of a robot
- Robot has a rigid body
  - So configuration can be described by the positions of the ends of the robot
- Degrees of freedom : the dimension of the space of all configuration

Degrees of Freedom

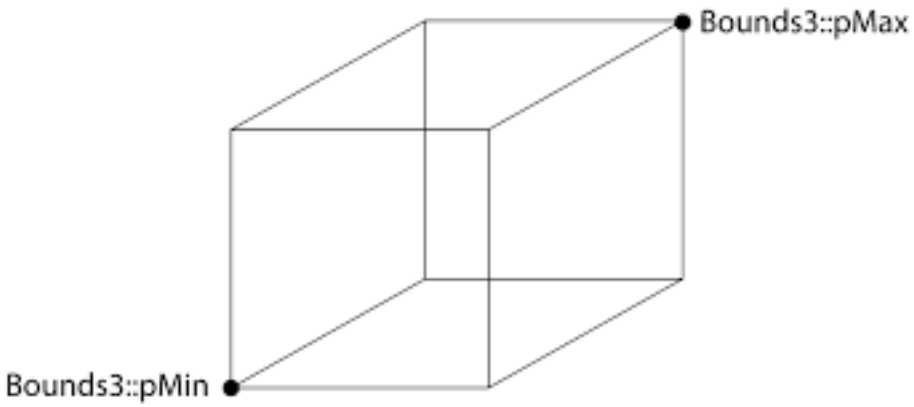
- Number of directions in which robot motion can be controlled
- Free body in space has 6 degrees of freedom:
  - Three for position (x,y,z)
  - Three for orientation (roll, pitch, yaw)



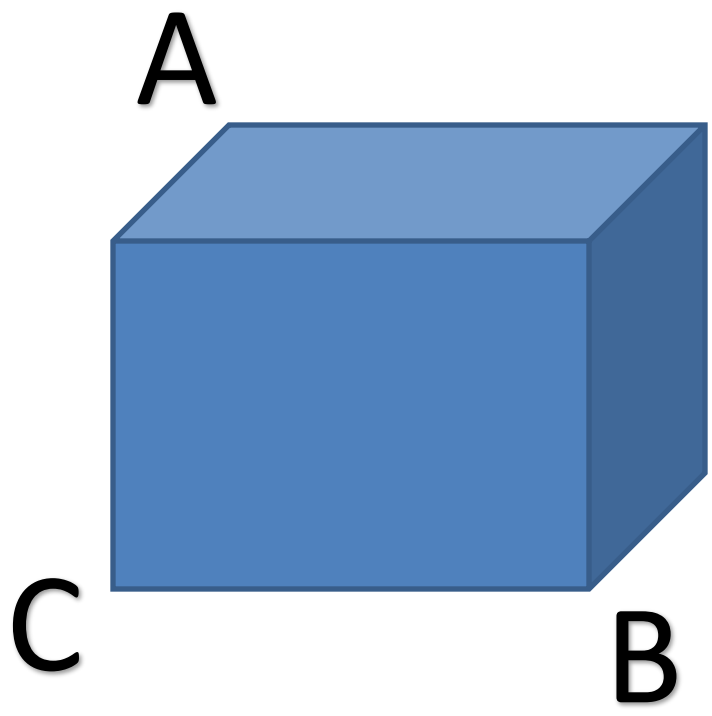
https://en.wikipedia.org/wiki/Six_degrees_of_freedom

Degrees of Freedom

- How can we see this?
- Let’s say we have a square object



Degrees of Freedom



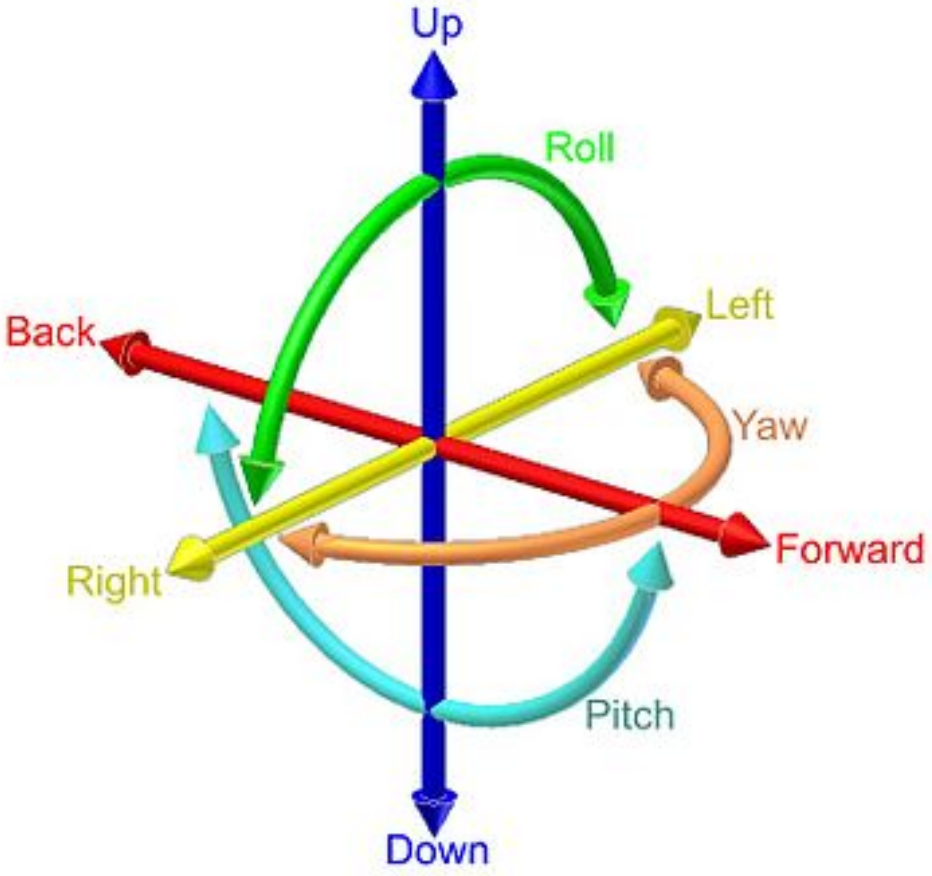
Degrees of Freedom

- Point A can have 3 values (x,y,z)
- Once point A is set, we want to fix point B
- However, the length between A and B is constant
  - So only two angles can be fixed
- Once A and B are fixed, only one angle is possible for point C
  - One additional degree of freedom

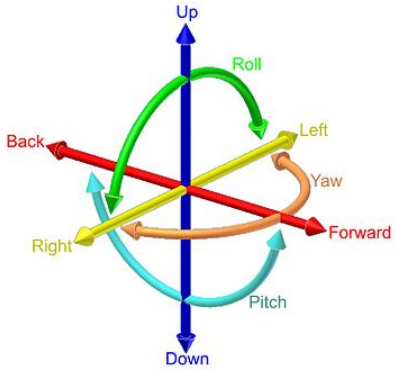
Degrees of Freedom

- How many degrees of freedom are for an object on a linear space?
  - I.e., a car
- 3 degrees of freedom
  - 2 on the linear space
  - One is the angle

Degrees of Freedom



Degrees of Freedom



- Roll, pitch, yaw:
  - Degrees of freedom used for orientation:
  - *Yaw* refers to the direction in which the body is facing
    - i.e., its orientation within the xy plane
  - *Roll* refers to whether the body is upside-down or not
    - i.e., its orientation within the yz plane
  - *Pitch* refers to whether the body is tilted
    - i.e., its orientation within the xz plane

https://en.wikipedia.org/wiki/Six_degrees_of_freedom

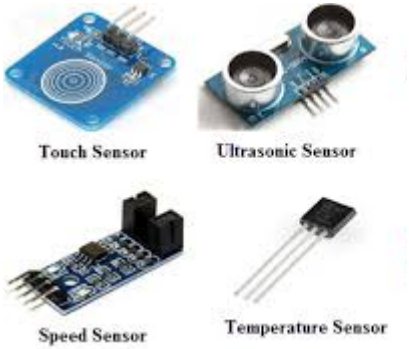
Degrees of Freedom

- DegreesofFreedom

Degrees of Freedom

- If there is an actuator for every degree of freedom, then all degrees of freedom are controllable => holonomic
- Most robots are non-holonomic

Sensors



- Provide perception
  - *Proprioceptive*: measure robot's internal values
    - know where you joints/sensors are
      - Motor speed, wheel load, battery status
  - Exteroceptive: Information from the environment
    - know where you are
      - Distance from objects, intensity of ambient light, etc.
- Function: to convert a physical property into an electronic signal which can be interpreted by the robot in a useful way

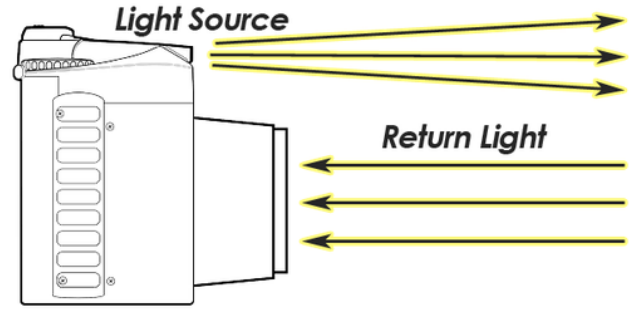
http://www.efxkits.com/blog/various-types-of-sensors-applications/

Sensors

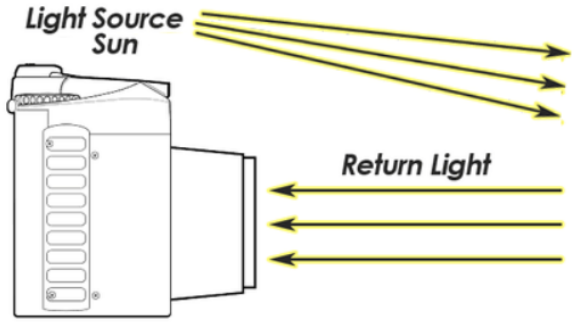
- Property sensed and sensors:
  - Sound Level:
    - Microphone, sound sensor
  - Light:
    - Camera, photo cell, light sensor
  - Distance:
    - Ultrasound, radar, infra-red®
  - Contact:
    - Bump/switch, touch sensor
  - Inclination:
    - Gyroscope
  - Others:
    - Smell sensor (chemical), temperature (thermal), altitude (altimeter)

Sensors (cont.)

- Operation:
  - Passive: read a property of the environment
    - Cameras when not using flash
      - Using naturally emitted light from the sun
  - Active: act on the environment and read the result
    - Camera when using flash
      - Illuminates its target and measures the energy reflected back



Active Remote Sensing Camera Example



Passive remote sensing camera example

Sensors (cont.)

- Are sensors always accurate?
  - Noise may interfere with measurements
    - Internal: from inside the robot
    - External: from the Robot's environment
    - Calibration: can help eliminate/reduce noise

Environment

- *Accessible* vs. *inaccessile*
  - Does the robot have access to all the information required to make decisions?
- *Deterministic* vs. *non-deterministic*
  - Does any action that the robot undertakes have only one possible outcome?
- *Static* vs. *dynamic*
  - Does the environment changes only due to robot actions, or does it also change by itself?
- *Discrete* vs. *continuous*
  - *Do sensors and actions have a discrete set of values?*

https://www.sdl.com/about/corporate-citizenship/environment/

State

- Knowledge about oneself and one's environment
- Kinematics == study of correspondence between actuator mechanisms and resulting motion
  - Relationship between robot dimensions, position and resulting velocity and acceleration
    - Rotary or linear motion
- Combines sensing and acting
  - Did I go as far as I intended?
- But environment is full of information
  - For an agent, need to pick relevant input

Why Robots?

- Can perform dirty, dangerous or dull tasks
- Where can we replace humans with robots?
  - Home
    - Roomba
  - Industry
    - Manipulator robot for building cars
  - Medical
    - Surgical robots
  - War
    - Bigdog (hw assignment next week)
  - Other places?

Questions?

Lab time!

- Let’s work with our robots!