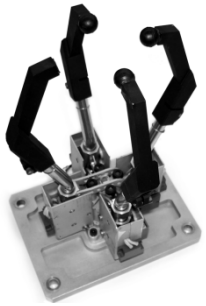
CISC 1003 – EXPLORING ROBOTICS

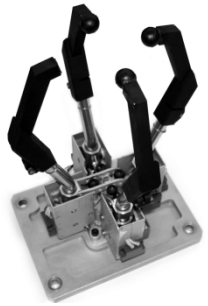
ROBOT CONSTRUCTION: EFFECTORS AND ACTUATORS

Arms, Legs, Wheels, Tracks and What Really Drives Them



https://www.robotshop.com/blog/en/how-do-i-choose-appropriate-actuators-6903

Effectors



- An ***effector:*** any device on a robot that has an effect (impact or influence) on the physical environment.
  - Wheels on a mobile robot
    - Or legs, wings, fins…
  - Whole body might push objects
  - Grippers on an assembly robot
    - Or welding gun, paint sprayer
  - Speaker, light, tracing-pen

http://www.wikiwand.com/en/Robot_end_effector

Replicating fossil paths with toilet roll [Prescott & Ibbotson (1997)]

- A spiral 'foraging' trail generated by the robot trace-maker.
  - Control combines thigmotaxis (stay near previous tracks) & phobotaxis (avoid crossing previous tracks)
    - Thigmotaxis: motion in response to a touch stimulus
    - Phobotaxis: change in the direction of locomotion in response to a given stimulus

Replicating fossil paths with toilet roll [Prescott & Ibbotson (1997)]

Actuators

- Actuator: the mechanism that enables the effector to execute an action or movement.
  - In animals and humans:
    - muscles and tendons are the actuators
    - make the arms and legs and the backs do their jobs.
  - In robots:
    - actuators include electric motors and various other technologies.
    - Connected via transmission:
      - System gears, brakes, valves, locks, springs…

Effectors and Actuators

- terms are often used interchangeably to mean: “whatever makes the robot take an action”
  - but they aren’t the same thing

Effectors and Actuators

- most simple actuators control one degree of freedom
  - i.e., a single motion
  - e.g., up-down; left-right; in-out

Effectors and Actuators

- how many degrees of freedom a robot has is very important in determining how it can affect its world, and therefor how well, if at all, it can accomplish its task
- More on D.O.F. later…

Passive vs. Active Actuation

- The action of actuators and effectors requires some form of energy to provide power.
- Some actuators use *passive actuation*

http://www.mdpi.com/1424-8220/15/11/28287/htm

Passive Actuation

- Utilizing potential energy (usually gravity) of the effector and its interaction with the environment
  - Instead of active power consumption.
- A glider is an example of this

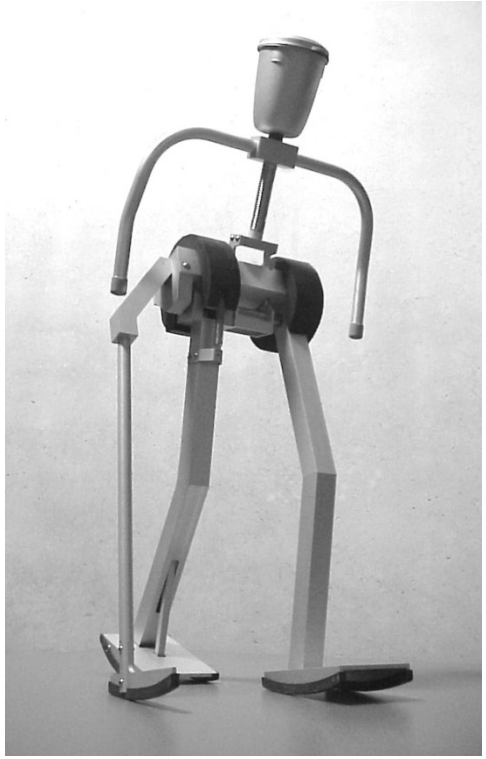
http://www.mdpi.com/1424-8220/15/11/28287/htm

Passive Actuation

- Utilizing potential energy (usually gravity) of the effector and its interaction with the environment
  - Instead of active power consumption.
- Advantage:
  - No need for extra weight required by energy source (battery, gasoline, etc) and complicated actuators.
- Disadvantage:
  - Dependence on a motivating source that may be transient.
    - For example, weather may affect glider movement

http://www.mdpi.com/1424-8220/15/11/28287/htm

Movement



A passive walker: a robot that uses gravity and clever mechanics to balance and walk without any motors.*

*The robotics primer, Mataric

Types of Actuators

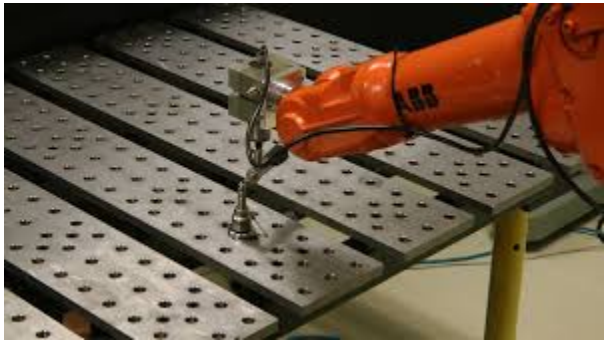
- Electric motors
  - speed proportional to voltage
    - voltage varied (by pulse width modulation)
- Hydraulics
  - Pressurized liquid
- Pneumatics
  - Pressurized air

Types of Actuators

- Others, including:
  - Photo-reactive materials
  - Chemically reactive materials
  - Thermally reactive materials
  - Piezoelectric materials
    - Crystals create a charge when pushed or pressed.

Variables Affecting Actuators Choice

- Load (e.g. torque to overcome own inertia)
- Speed (fast enough but not too fast)
- Accuracy (will it move to where you want?)
- Resolution (can you specify exactly where?)



http://www.payper.com/palletizer-robots, https://www.dreamstime.com/stock-illustration-robot-running-high-speed-clipping-path-included-image49547946, , https://www.youtube.com/watch?v=niKo_-EgdJ0

Variables Affecting Actuators Choice

- Repeatability (will it do this every time?)
- Reliability (mean time between failures)
- Power consumption (how to feed it)
- Energy supply & its weight

www.photonics.com/a42575/Robotic_Automation_for_Solar_Cell_Manufacturing, https://www.dreamstime.com/stock-images-robot energy-charge-image22373104

Robot Motion

- Fundamental question:
  - Where is the robot located?
- ***Configuration***: a specification of the position of all points of a robot

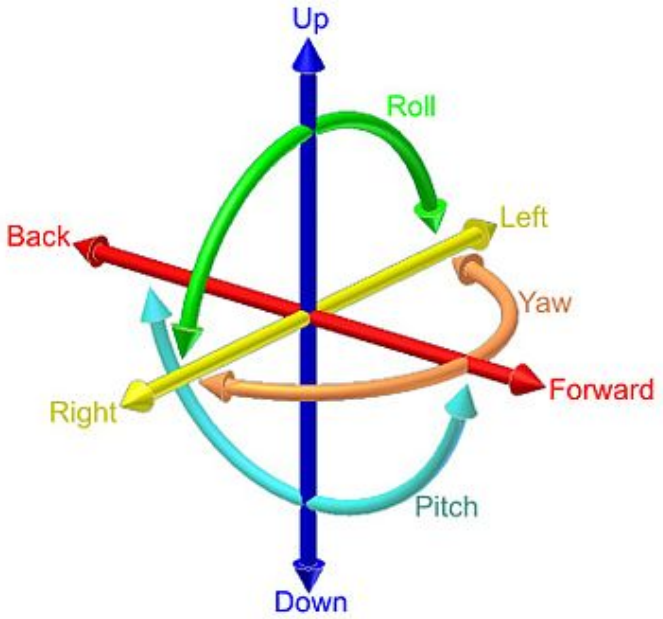
Robot Motion

- 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

Robot Motion

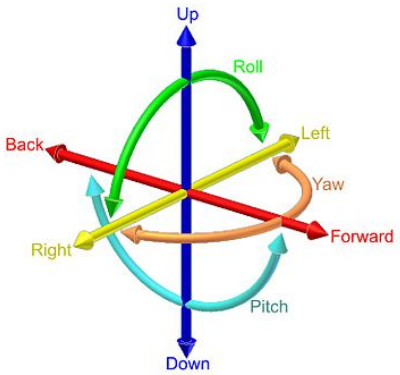
- Fundamental question:
  - Where is the robot located?
- ***Configuration***: a specification of the position of all points of a robot
- ***C-Space***: the space of all configurations
- ***Degrees of Freedom*** : the dimension of the space of all configuration

DEGREES OF FREEDOM



Degrees of Freedom

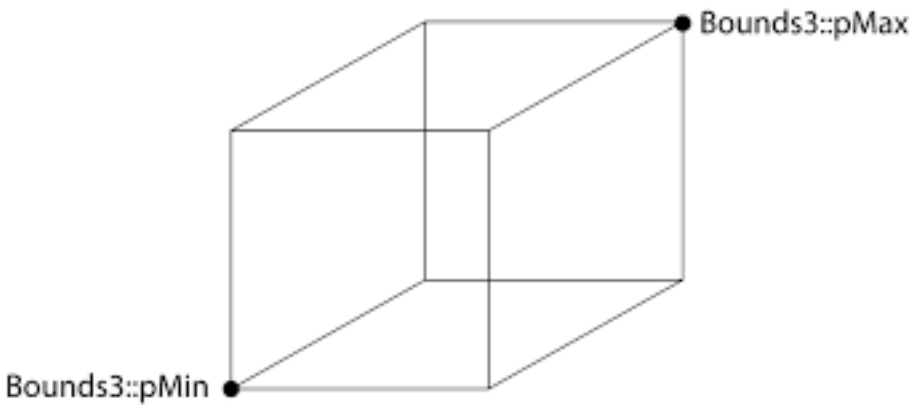
- Number of directions in which robot motion can be controlled
- Free body in space has 6 degrees of freedom:
  - Three for position (x,y,z)
  - Three for orientation (roll, pitch, yaw)



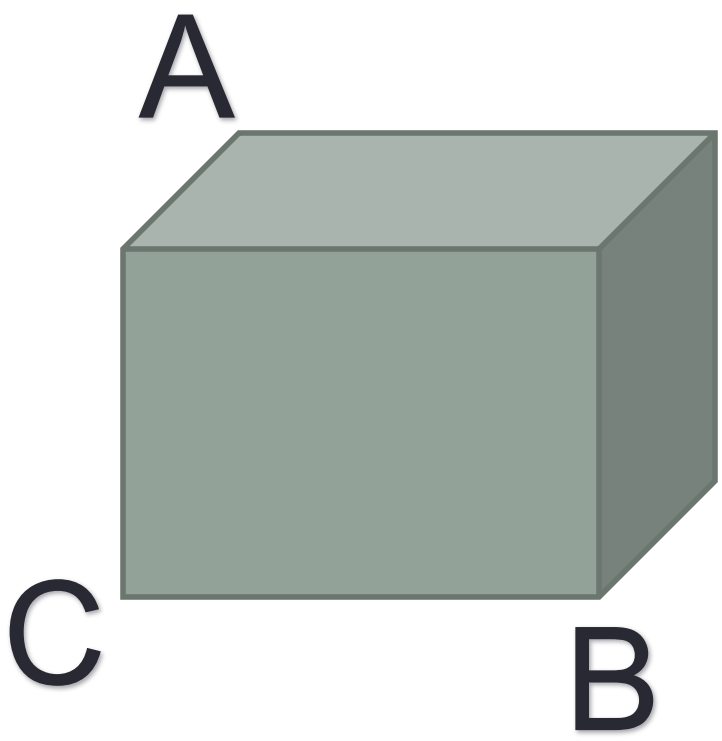
https://en.wikipedia.org/wiki/Six_degrees_of_freedom

Degrees of Freedom

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



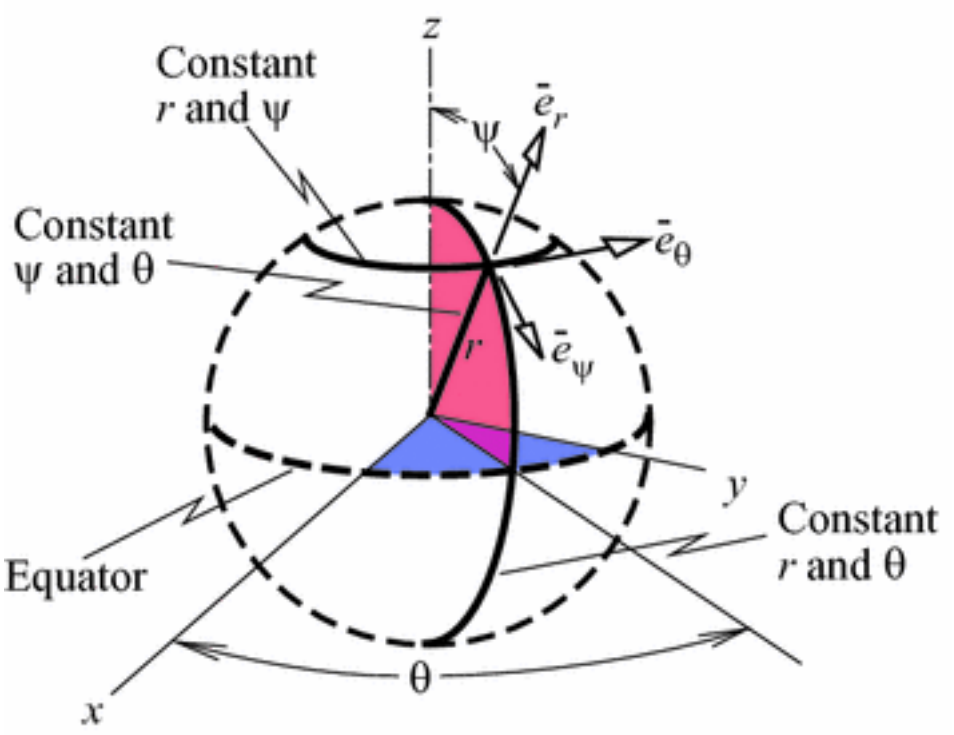
Degrees of Freedom



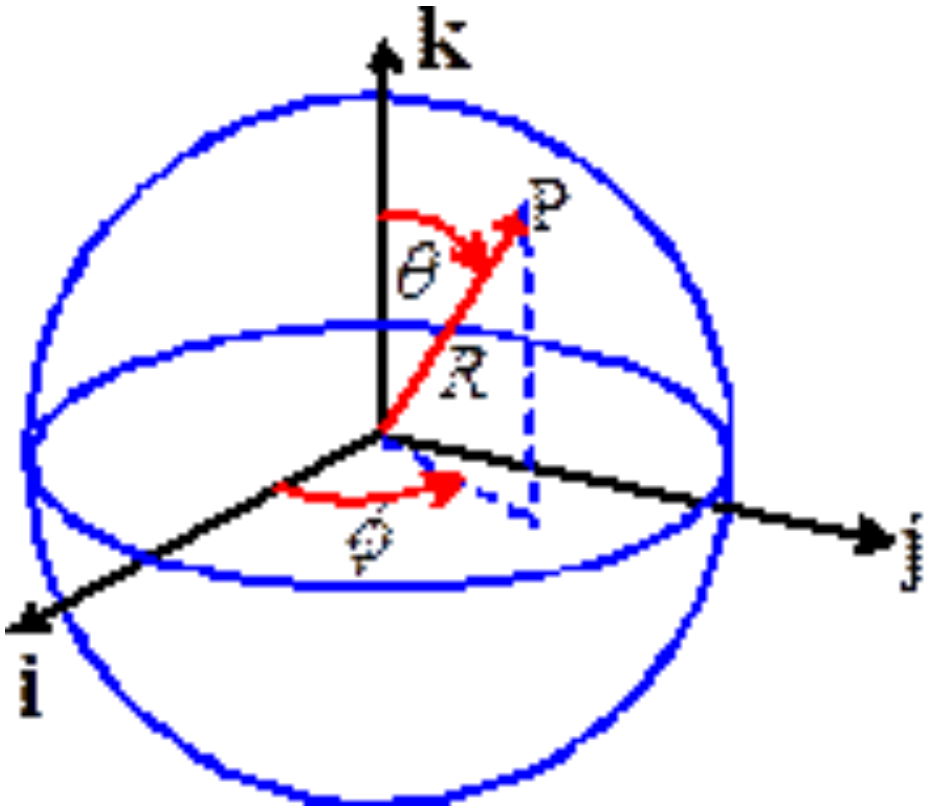
Degrees of Freedom

- 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
    - We have one constrain on the location of B
  - What is the constraint on B?
    - B can be located on a sphere
      - The sphere radios is the length between A and B

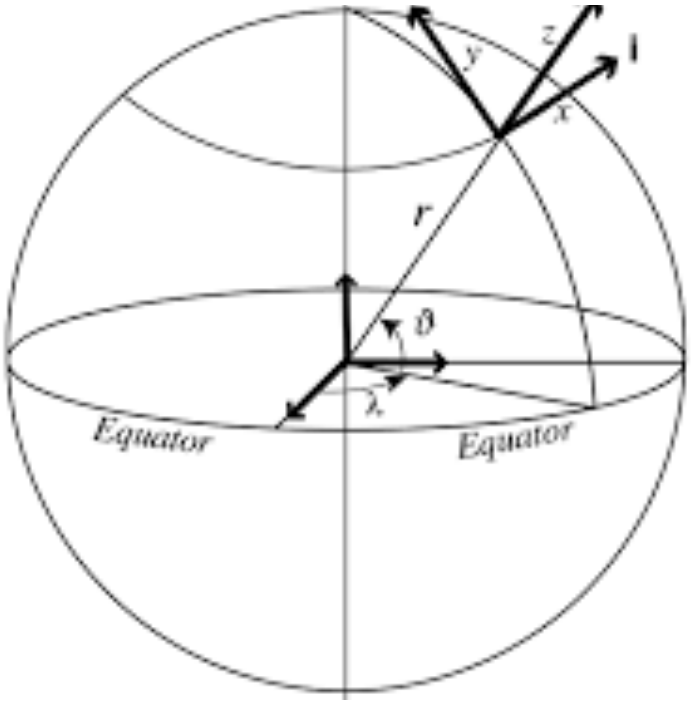
Degrees of Freedom



Degrees of Freedom



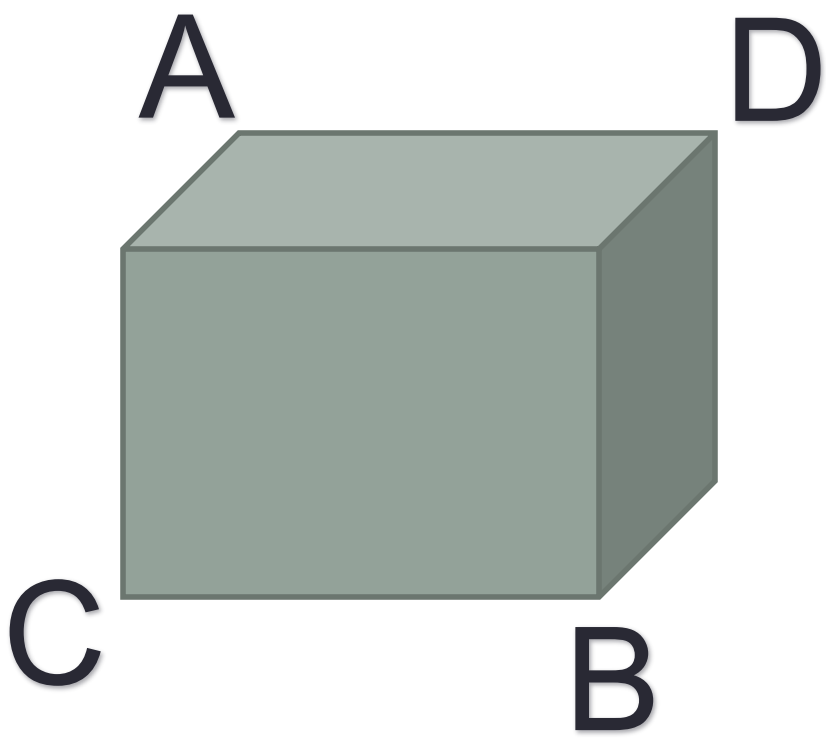
Degrees of Freedom



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
    - We have one constrain on the location of B
- Once A and B are fixed, only one angle is possible for point C
  - One additional degree of freedom
    - We have two constraints on the location of C

Degrees of Freedom



Degrees of Freedom

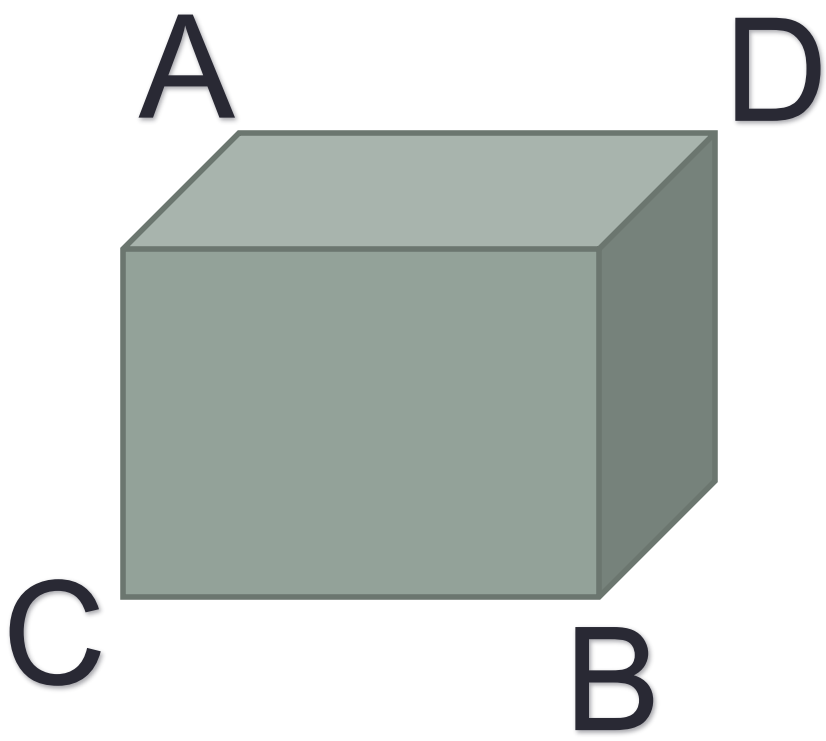
- How many possibilities for point D?
  - Zero D.O.F. – only one possible location

Degrees of Freedom

- $\#\ of\ D.O.F. = \sum (Freedom\ of\ Points) - \#\ of\ independent\ constraints$

- Since robot is made of rigid bodies:
- $\#\ of\ D.O.F. = \sum (Freedom\ of\ bodies) - \#\ of\ independent\ constraints$

Degrees of Freedom



Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	?	?	
B			
C			
D			

Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	3	0	?
B			
C			
D			

Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	3	0	3
B	?	?	
C			
D			

Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	3	0	3
B	3	1	?
C			
D			

Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	3	0	3
B	3	1	2
C	?	?	
D			

Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	3	0	3
B	3	1	2
C	3	2	?
D	?	?	

Degrees of Freedom

Point	Coordinates	Indep. constraints	# Actual freedoms
A	3	0	3
B	3	1	2
C	3	2	1
D	3	3	0

Degrees of Freedom

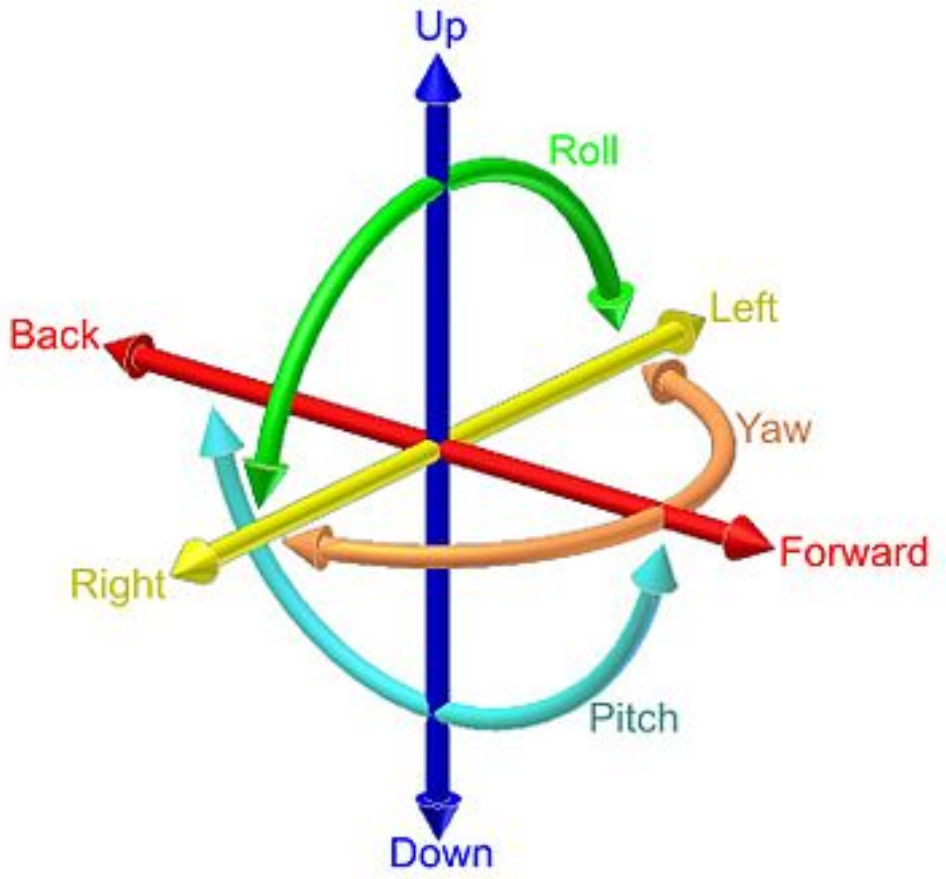
- $\#\ of\ D.O.F. = \sum (Freedom\ of\ Points) - \#\ of\ independent\ constraints$

- Since robot is made of rigid bodies:
- $\#\ of\ D.O.F. = \sum (Freedom\ of\ bodies) - \#\ of\ independent\ constraints$

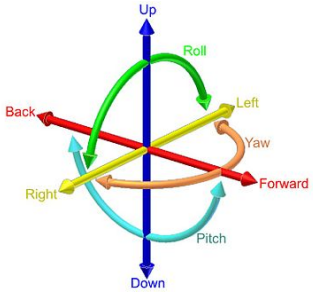
Degrees of Freedom

- 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

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Degrees of Freedom

- DegreesofFreedom

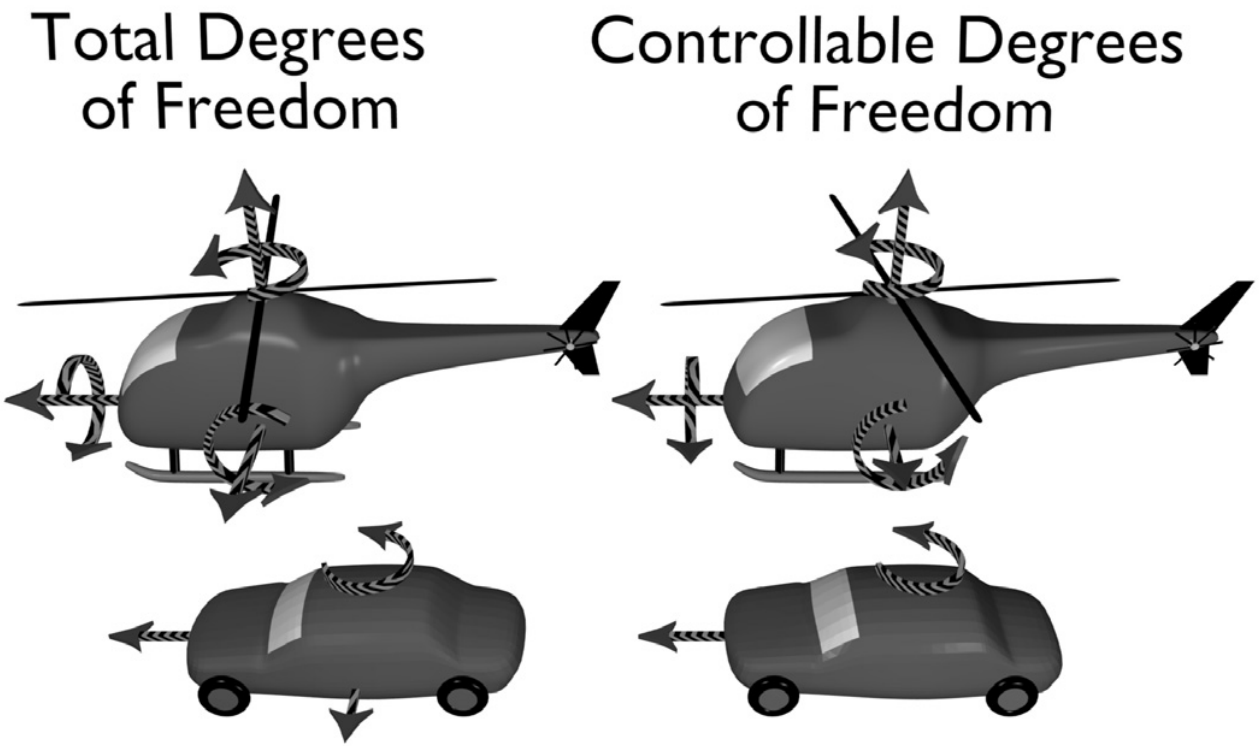
Degrees of Freedom

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

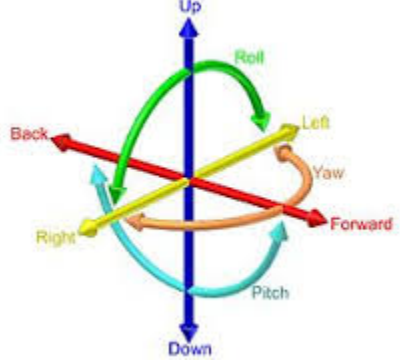
Degrees of Freedom

- 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
- How many are controllable?
  - 2: straight and turn
    - Can not drive sideways

Degrees of freedom (D.O.F.)



Robot's Variables Affecting D.O.F.



- Number of joints/articulations/moving parts
  - If parts are linked, fewer parameters needed to specify them.
- Number of Individually controlled moving part
  - Need parameters for each to define configuration
  - Often described as 'controllable degrees of freedom'
  - But some may be *redundent*
    - Two movements may be in the same axis

Locomotion and Manipulations

- Choice of effectors and actuators sets the limits on what the robot can do
- Usually categorized as locomotion or manipulation
  - ***Locomotion***: vehicle moving itself
  - ***Manipulation***: An arm moving things
- In both cases can consider the *degrees of freedom* in the design

Lab time!

- Let’s work with our robots!