UNIVERSITY OF
SOUTH CAROLINA

CSCE274 Robotic Applications and Design
Fall 2021
Robot Components
Actuators

Ioannis REKLEITIS, Ibrahim SALMAN

Computer Science and Engineering

University of South Carolina

yiannisr@cse.sc.edu

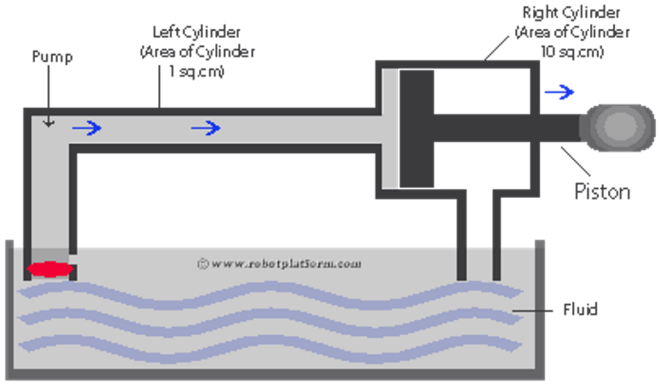
https://www.youtube.com/watch?v=74VZ7f4dsTU

Actuators

- Actuation require some form of energy
  - Active actuation: external energy transformed into mechanical energy
  - Passive actuation: Exploiting potential energy:
- Direction of motion
  - Rotation
  - Linear

Actuators

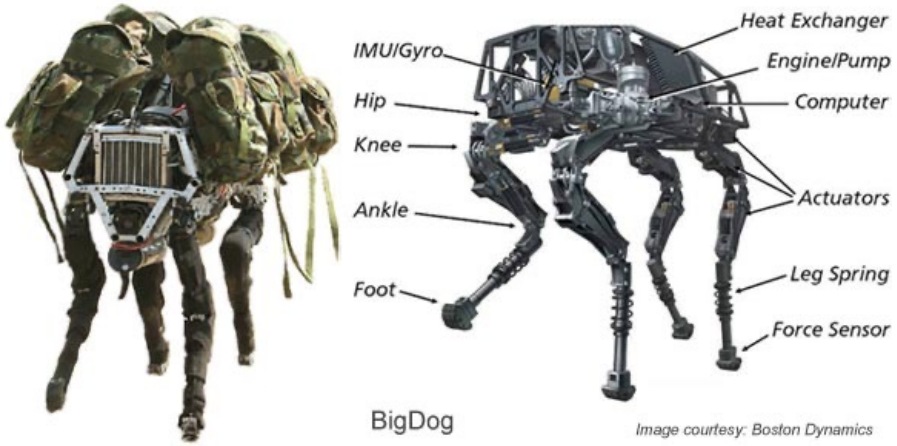
- Active actuation
  - Hydraulics
    - Pros
      - Powerful
      - Precise
      - Stiff
    - Cons
      - Large
      - Potentially dangerous
      - External pump



Hydraulic Actuator

Source: robotplatform.com

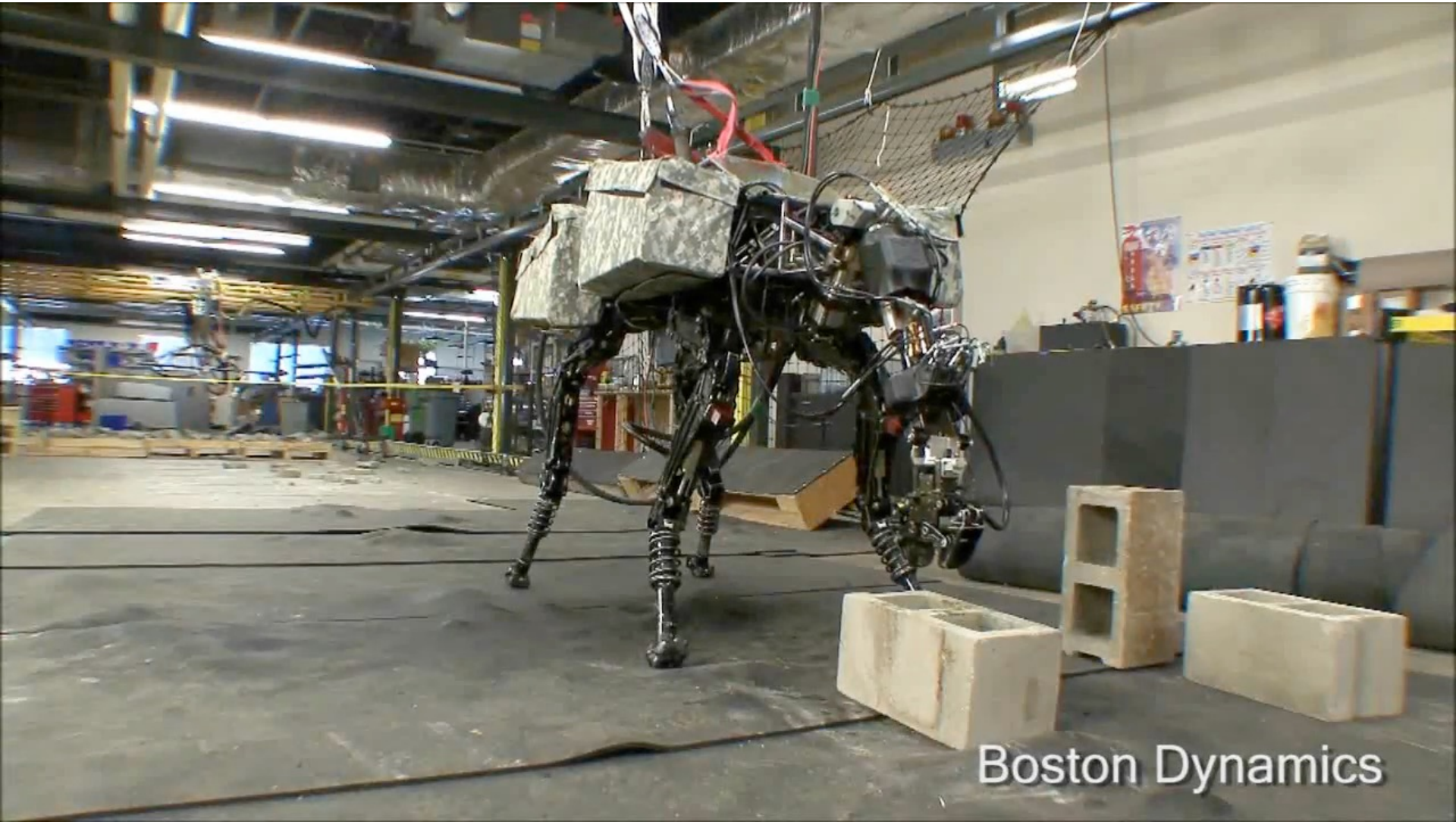
Big Dog from Boston Dynamics



Source: robotplatform.com

Big Dog

Big Dog



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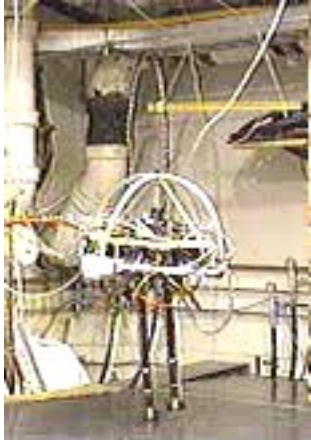
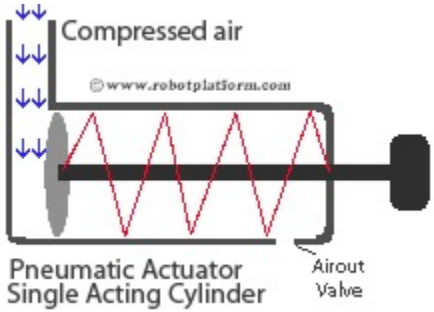
Actuators

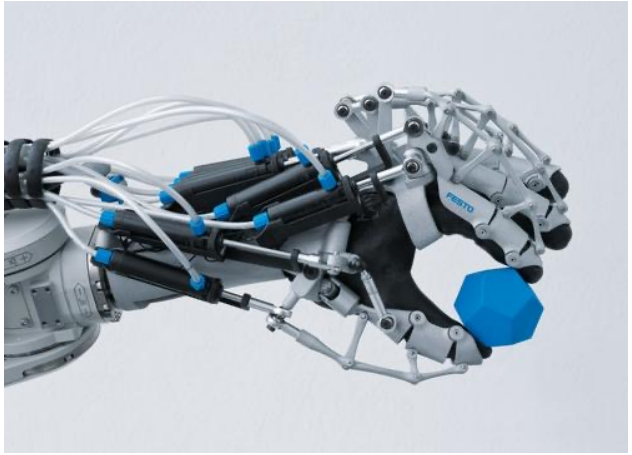


- Active actuation
  - Pneumatics
    - Pros
      - Powerful
      - Light
    - Cons
      - Soft/Compliant
      - Potentially dangerous



Source: robotplatform.com

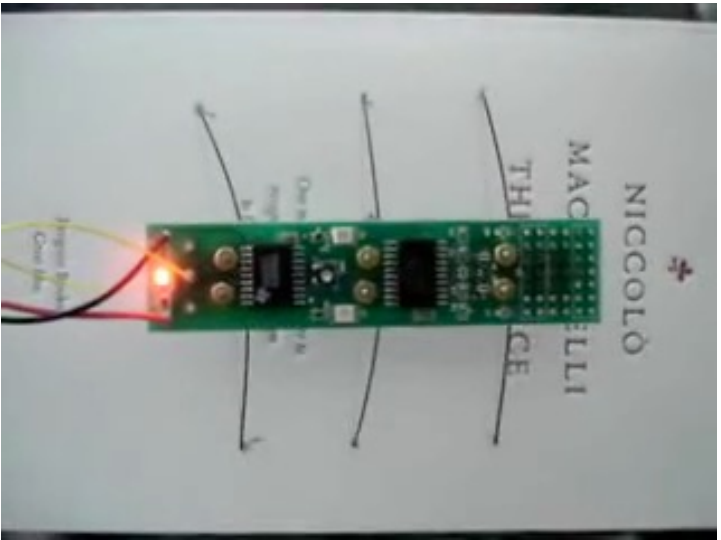
Festo's ExoHand

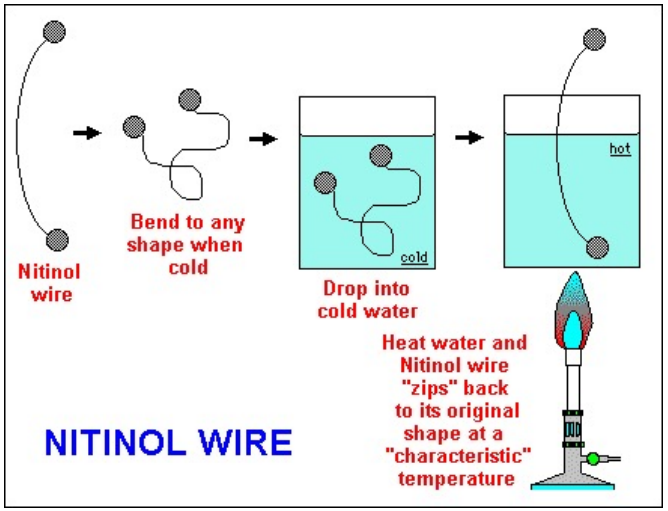


Source: designnews.com

Actuators

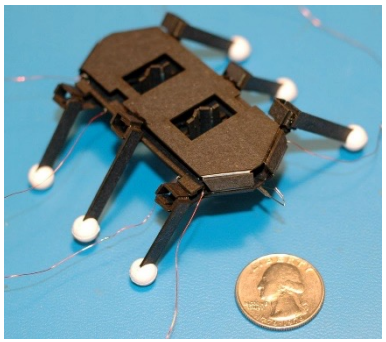
- Active actuation
  - Thermally reactive materials, e.g., Shape Memory Alloy Actuators
    - Pros
      - Light
    - Cons
      - Slow (cooling)





Source: talkingelectronics.com

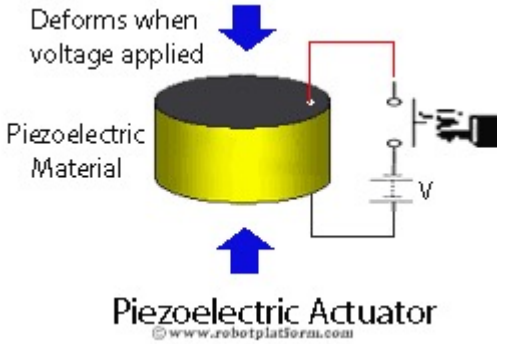
Folded millirobots (2008)



Source: robotics.eecs.berkeley.edu/~ronf

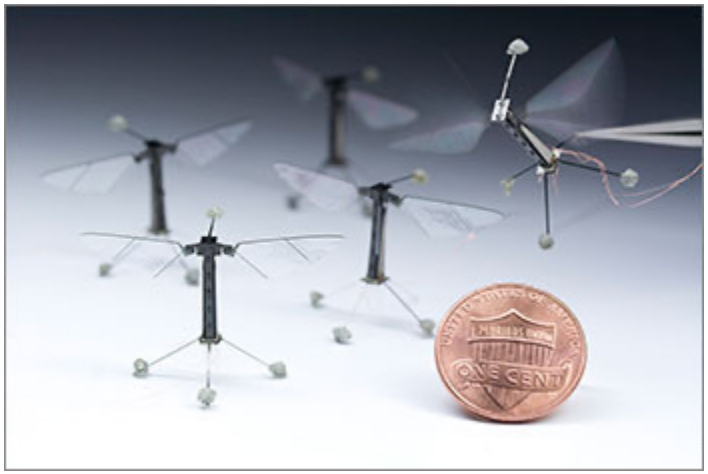
Actuators

- Active actuation
  - Piezoelectric materials
    - Pros
      - Very small motions possible at high speeds
      - Low-powered
    - Cons
      - Short actuation
      - High voltages
      - Expensive
      - Fragile



Source: robotplatform.com

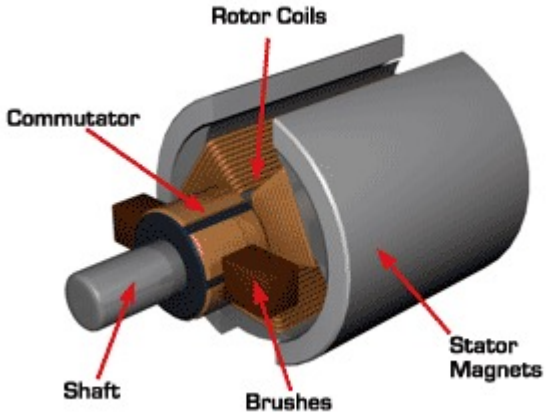
RoboBee – Harvard



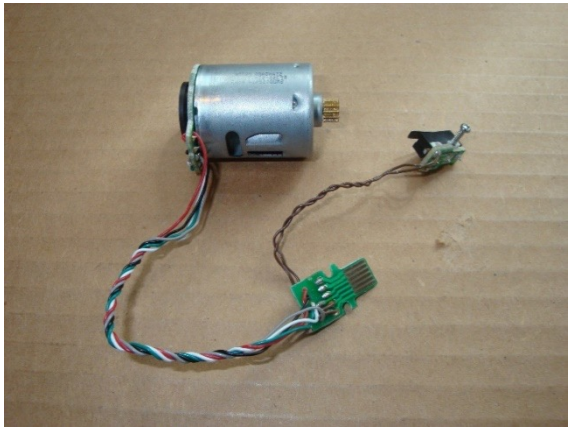
Source: Wikipedia.com

Actuators

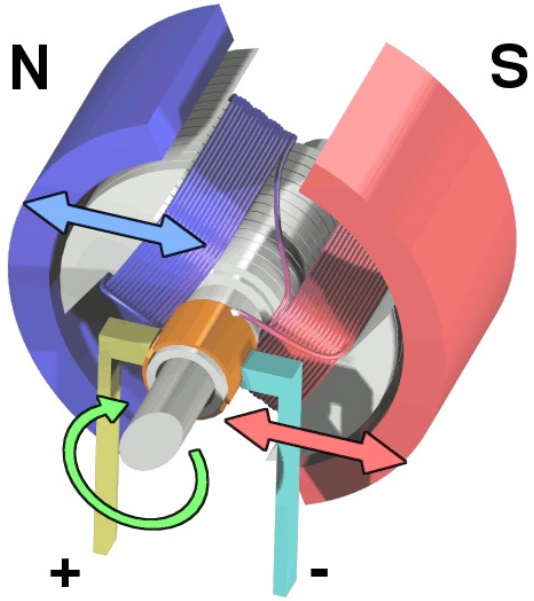
- Active actuation
  - Electric motors, e.g., Direct-Current (DC) motors
    - Pros
      - Better position precision
      - Inexpensive
      - Well understood
    - Cons
      - Heavy
      - Cooling issue

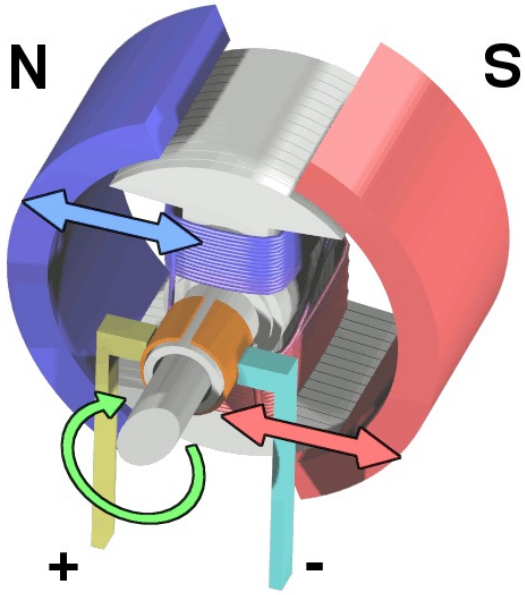


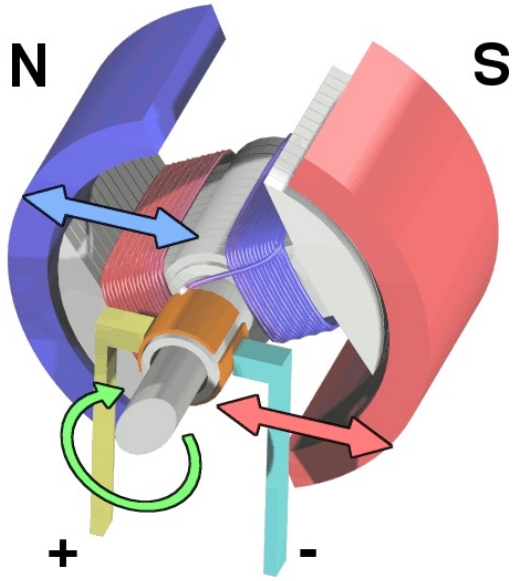
Source: electrical4u.com



Operation: Brushed DC motor



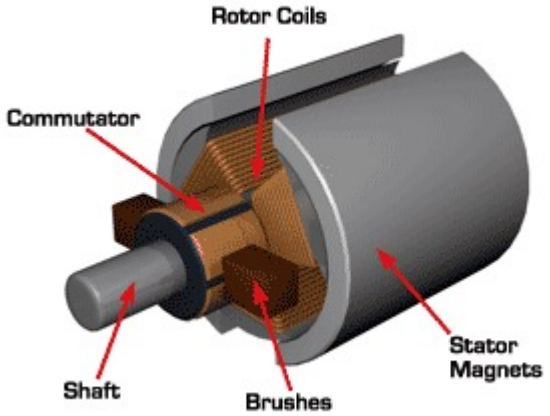




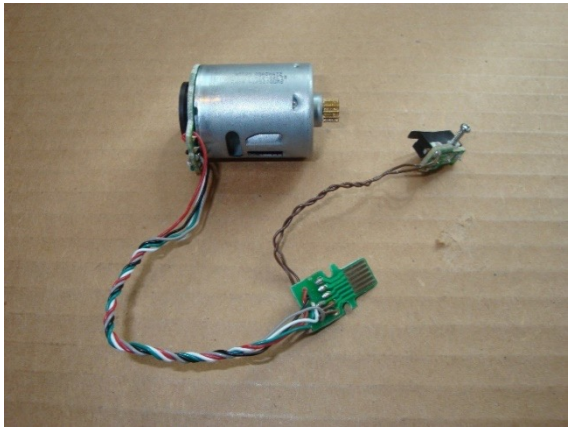
Source: Wikipedia.org

DC motors

- Input: Voltage
  - "Right range" -> current drawn ~ work
  - work = force * distance
- $power_{out}$ ~ torque * v_{rot}
  Free running/stalled: p=0
- Speed: 3K-9K rpm (50-150rps)

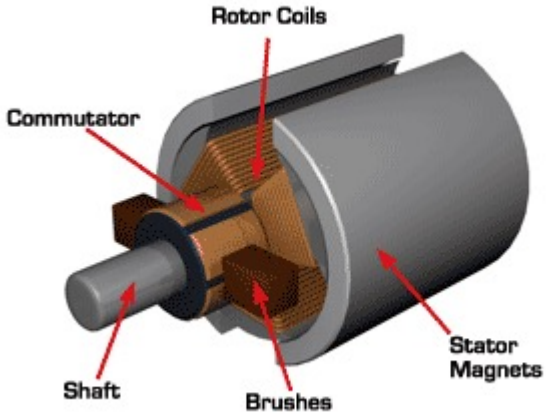


Source: electrical4u.com

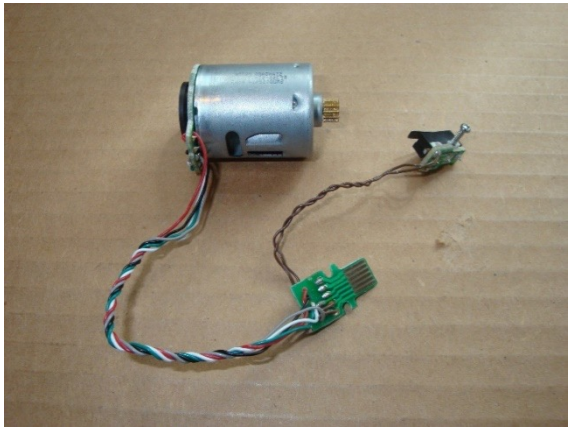


DC motors

- When there is no resistance to its motion, the motor draws the least amount of current
- When the robot pushes against an obstacle motors drain more current
- If the resistance becomes very high the motor stalls and draws the maximum amount of current (stall current) at its specified voltage

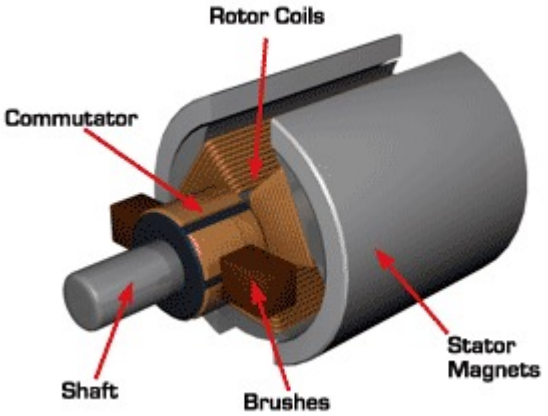


Source: electrical4u.com



DC motors

- Change the torque output of motors
- Tradeoff between high speed and more torque
- Wheels: $torque_{out}$ ~ $torque_{in}$/radius
- To increase torque use gears



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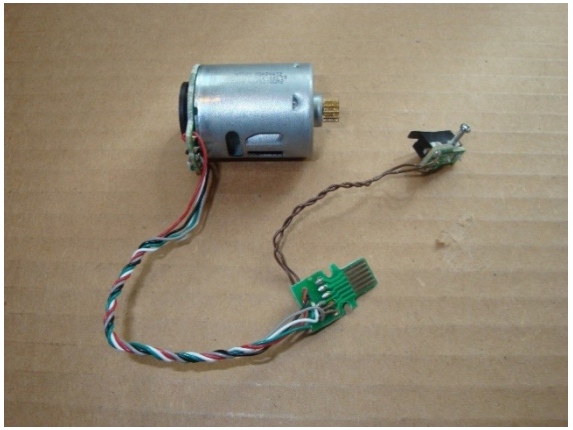
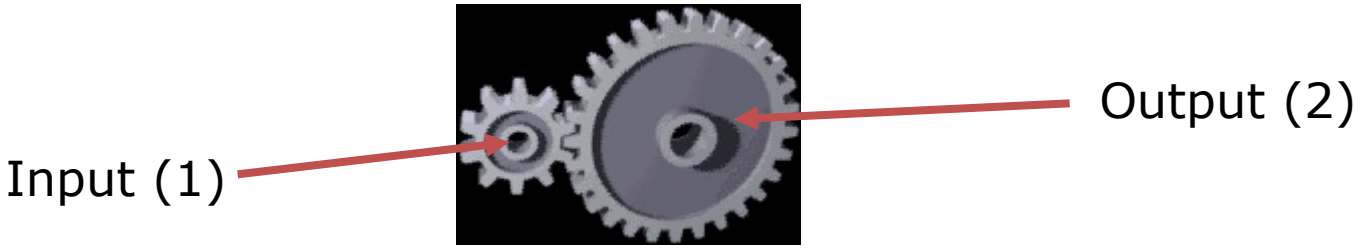


Gearing

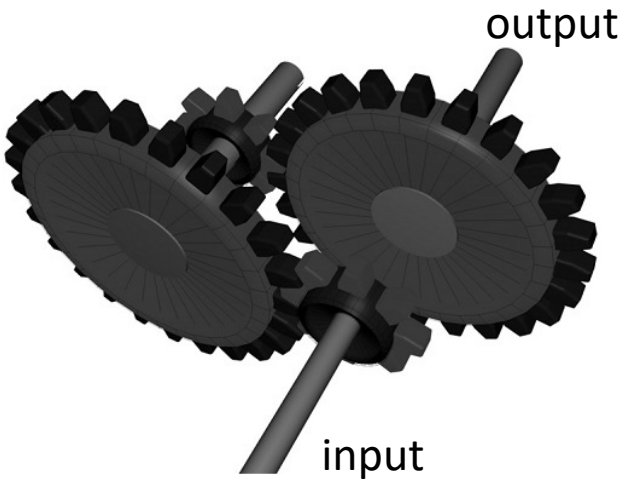


3:1 gear reduction

- Const ≡ power ~ torque * v_{rot}
- $V_{rot,2} = v_{rot,1}/3$ ➔ $torque_2 = torque_1 * 3$

Gearing

- How to achieve 9:1 gear reduction?
  - Use larger gears
  - Use multiple gears
- Designing gear teeth:
  - Reduced backlash
  - Tight meshing
  - Proportionally sized gears

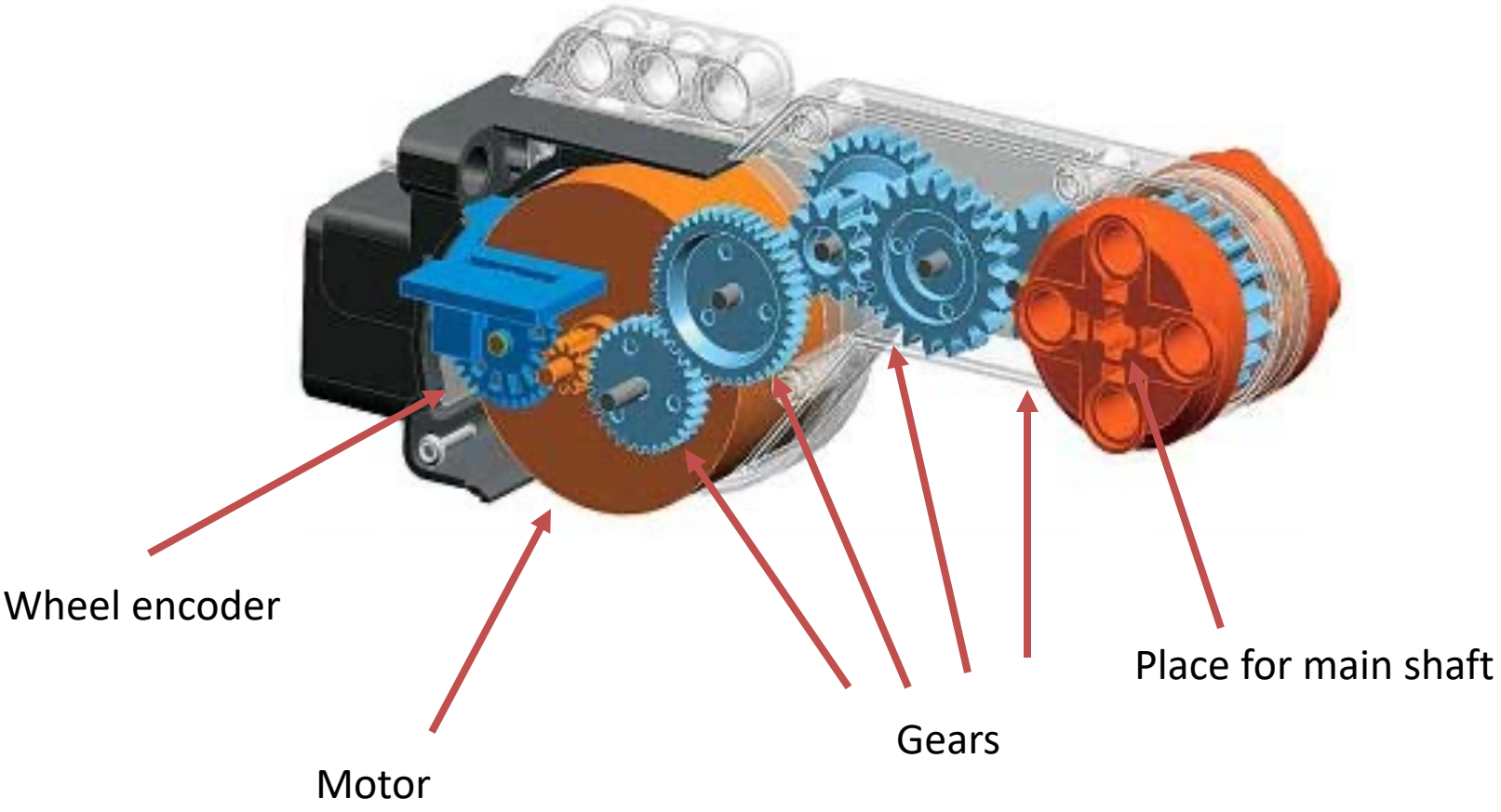


9:1 gear reduction with ganged gears

Servo motor

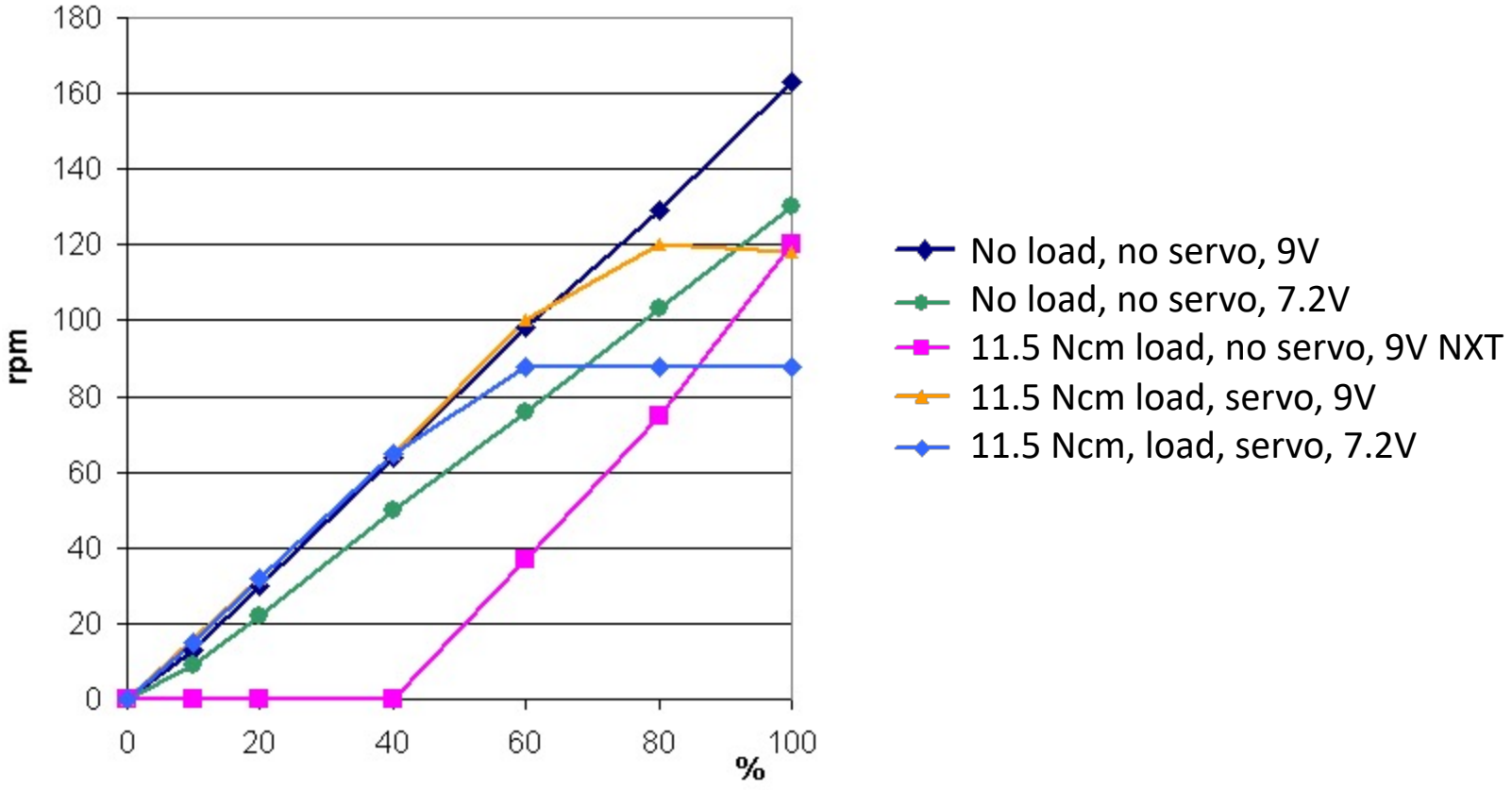
- Servo (Motors): instead of continuously rotating, move to a given position
- Components
  - DC Motor
  - Gear reduction
  - Position sensor
  - Controller
- Input signal: pulse-width modulated
- Position control (stiff) vs. torque control (less stiff)

Servo motor



Source: http://www.philohome.com/nxtmotor/nxtmotor.htm

NXT Motor: Servo Function



Target RPM (% of max RPM)

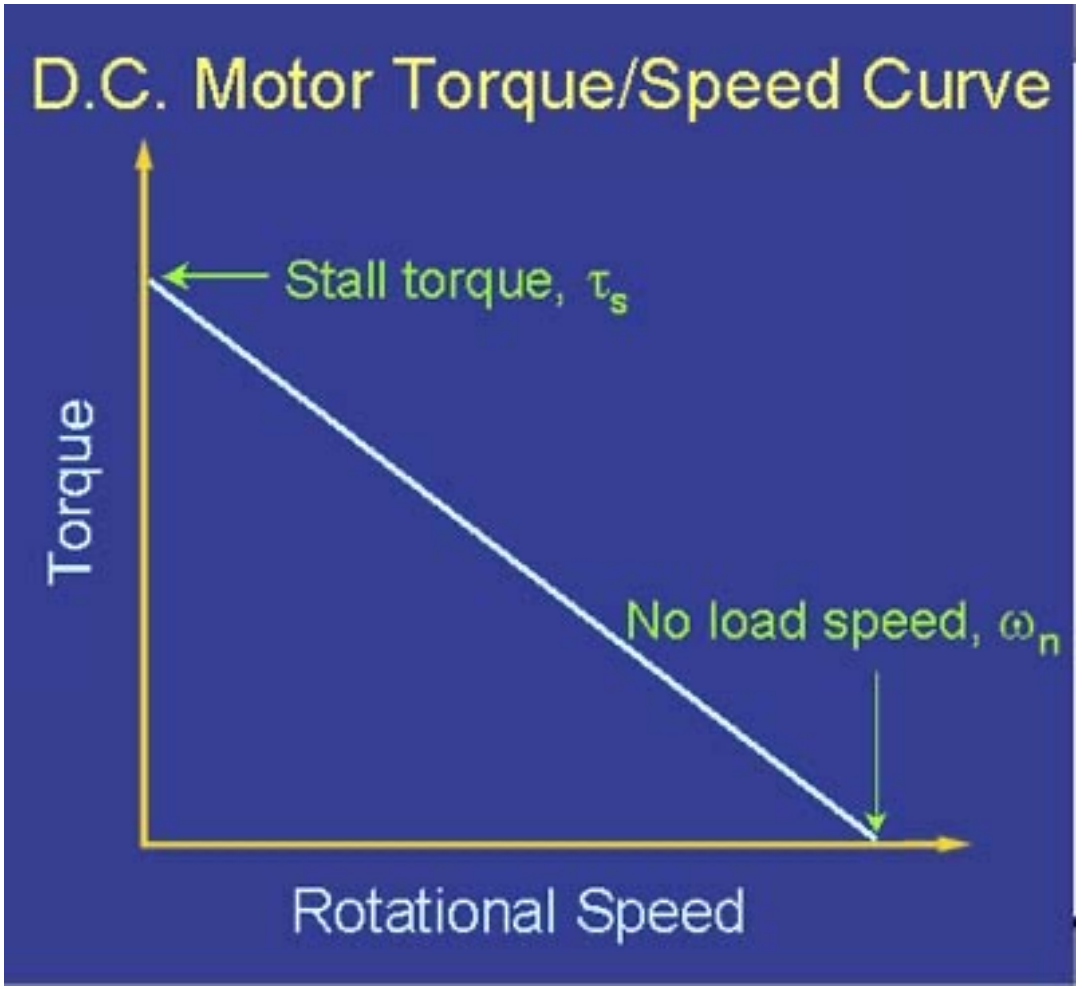
Source: http://www.philohome.com/nxtmotor/nxtmotor.htm

DC motor torque τ

$\tau = \text{torque}$

$I = \text{current}$

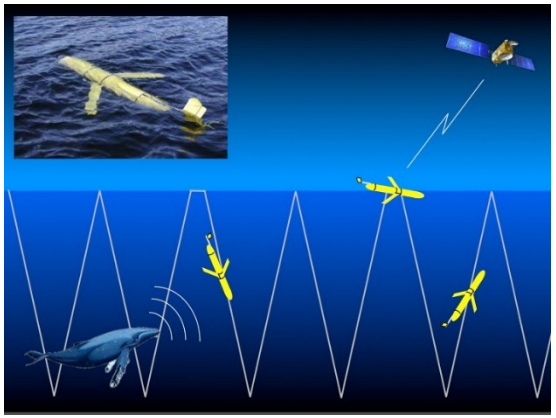
$$\tau \propto I$$



Actuators

- Passive actuation
  - Utilizes potential energy in the mechanics of the effector and its interaction with the environment instead of active power consumption

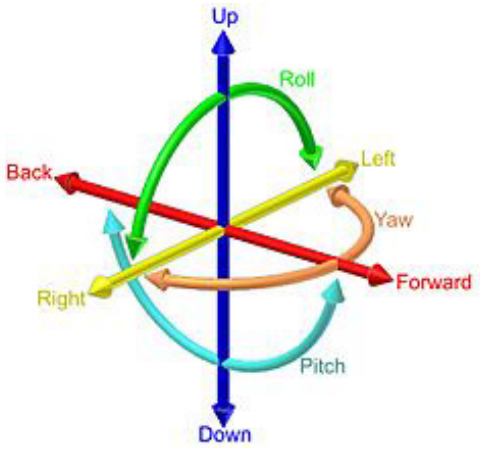
Slocum glider



Source: whoi.edu

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

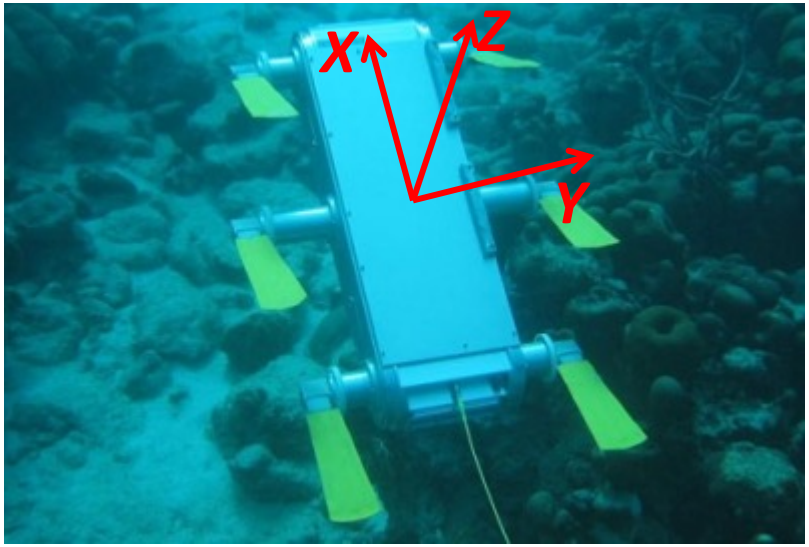


Source: Wikipedia.com

Translational DoF

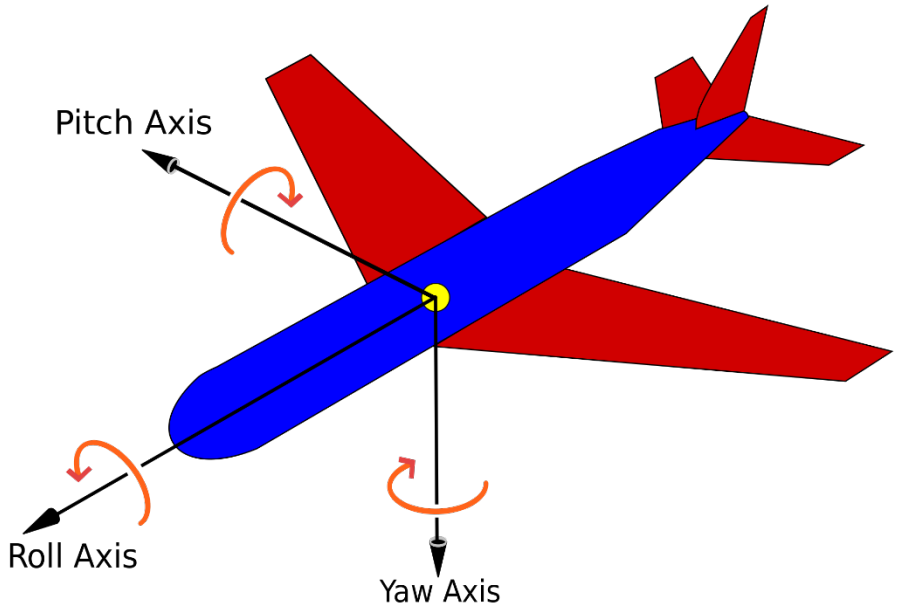
- The body can translate, without turning on:

  x, y, z



Rotational DoF

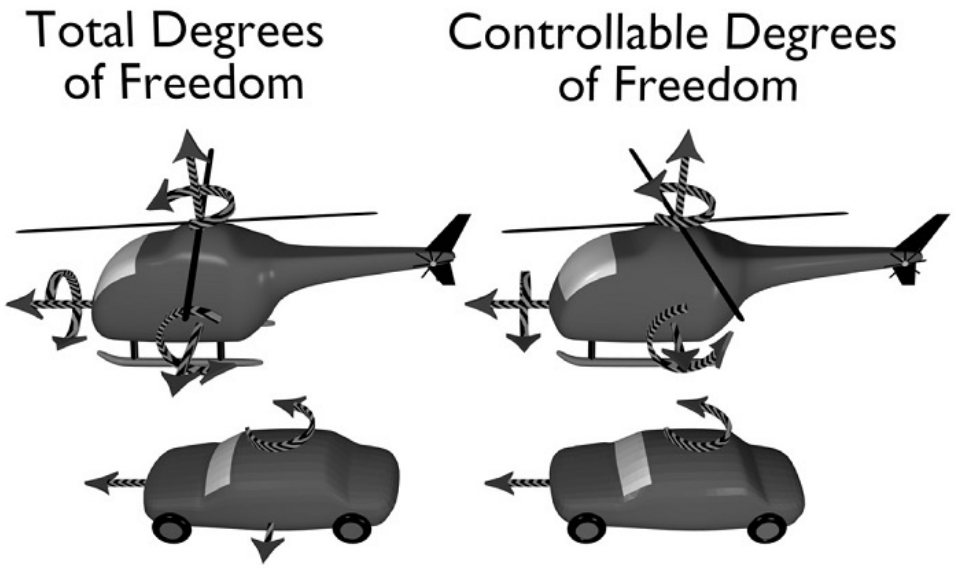
- They allow the body to rotate
  - Roll, pitch, yaw



Source: Wikipedia.org

DoF: controllable vs. uncontrollable

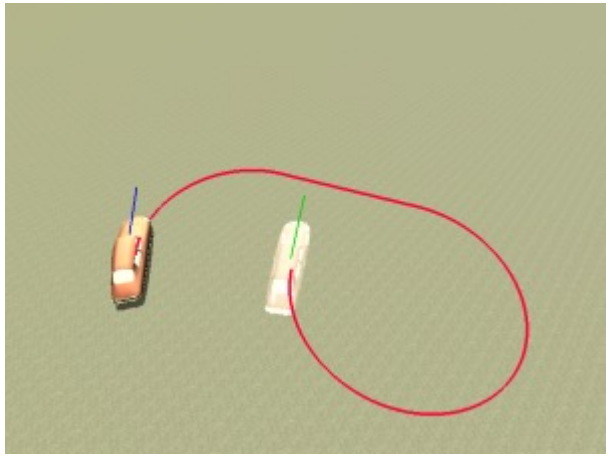
- Controllable DoF
  - If robot has an actuator for every DoF
- Uncontrollable DoF



Trajectory

- Although one single move cannot be enough, platform could get to any position by following a possibly complicated trajectory

Dubin's vehicle



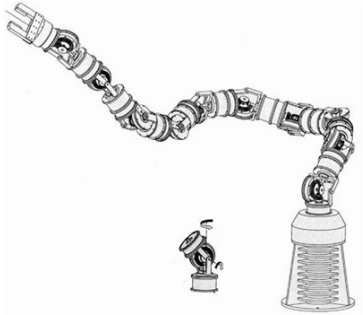
Source: gieseanw.wordpress.com

Robot type

- Holonomic: the total number of controllable DoF is equal to the total number of DoF on a robot

- Nonholonomic: the total number of controllable DOF is less than the total number of DoF on a robot

- Redundant: when the number of controllable DoF is larger than the total DoF



Source: imdl.gatech.edu/haihong