Actuators

Drive system???

- Links of the Robot move about the prescribed axis by receiving the power through the drive system (actuator).
- The movements produced may be
- Rotory or Translatory

How Do I Choose an Actuator?

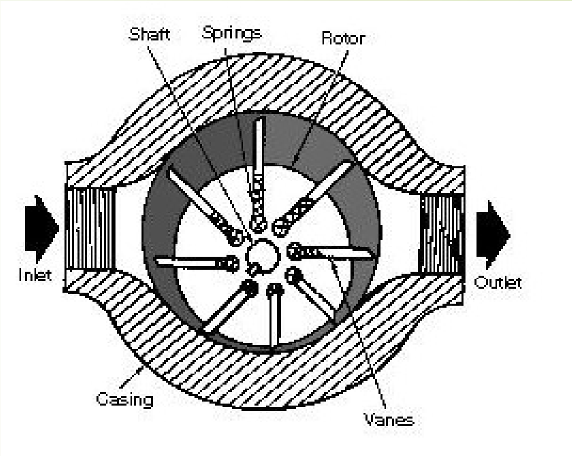
- Is the drive system being used to propel or drive a wheeled robot?
- Is the drive system being used to lift or turn a heavy weight?
- Is the range of motion limited to 0 to 180 degrees?
- Does the angle need to be very precise?
- Is the motion in a straight line?

HYDRAULIC ACTUATORS

- A **Hydraulic Actuator** is a mechanical actuator that is used to give a unidirectional force through a unidirectional stroke.
- Early industrial robots were driven by hydraulic actuators.
- Pump supplies high-pressure fluid (typically oil) to a linear cylinders, rotary vane actuator or a hydraulic motor at the joint!
- Large force capabilities.
- Large power-weight ratio
- Control is by means of on/off solenoid valves or servo-valves controlled electronically.
- The entire system consisting of Electric motor, pump, accumulator, cylinders etc. is bulky and often expensive – Limited to ‘big’ robots.

Hydraulic Motors

- Consist of , Casing, Rotor, Vanes, Shaft
- Power output P= $\frac{D*e*V*p}{1000}$
- D= Outermost dia of the vane
- e= eccentricity
- V = linear speed of rotation =(2*pi*N*R/(60)) m/sec
- N= revolution per minute
- R=D/2
- ***P***= pressure of the oil supplied to the motor
- (Torque)T= 60000P/(2*PI*N) k-Nm



Hydraulic –Linear actuator

- Single Acting Hydraulic cylinder

- P (Power)= p*Q/(1000)

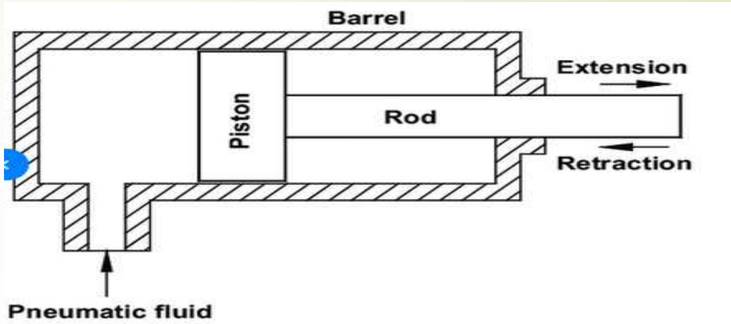
  $F=P(pi/4)*D^2$

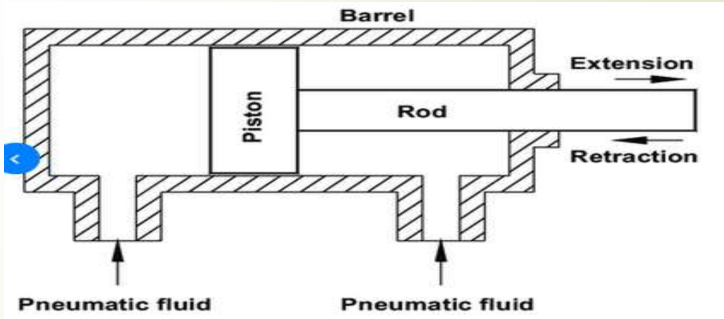
- Speed of motion

  $V\_e= 4*Q/(pi*D^2)$

- Speed Retraction

  $V\_r= 4*Q/(pi(D_p^2-D_r^2))$





Pneumatic Actuator

- A **pneumatic actuator** converts energy (typically in the form of compressed air) into mechanical motion. The motion can be rotary or linear, depending on the type of actuator.
- Similar to hydraulic actuators, air is supplied from a compressor to cylinders and flow of air is controlled by solenoid or servo controlled valves.
- Less force and power capabilities.
- Less expensive than hydraulic drives.
- Chosen where electric drives are discouraged or for safety or environmental reasons such as in pharmaceutical and food packaging industries.
- Closed-loop servo-controlled manipulators have been developed for many applications.

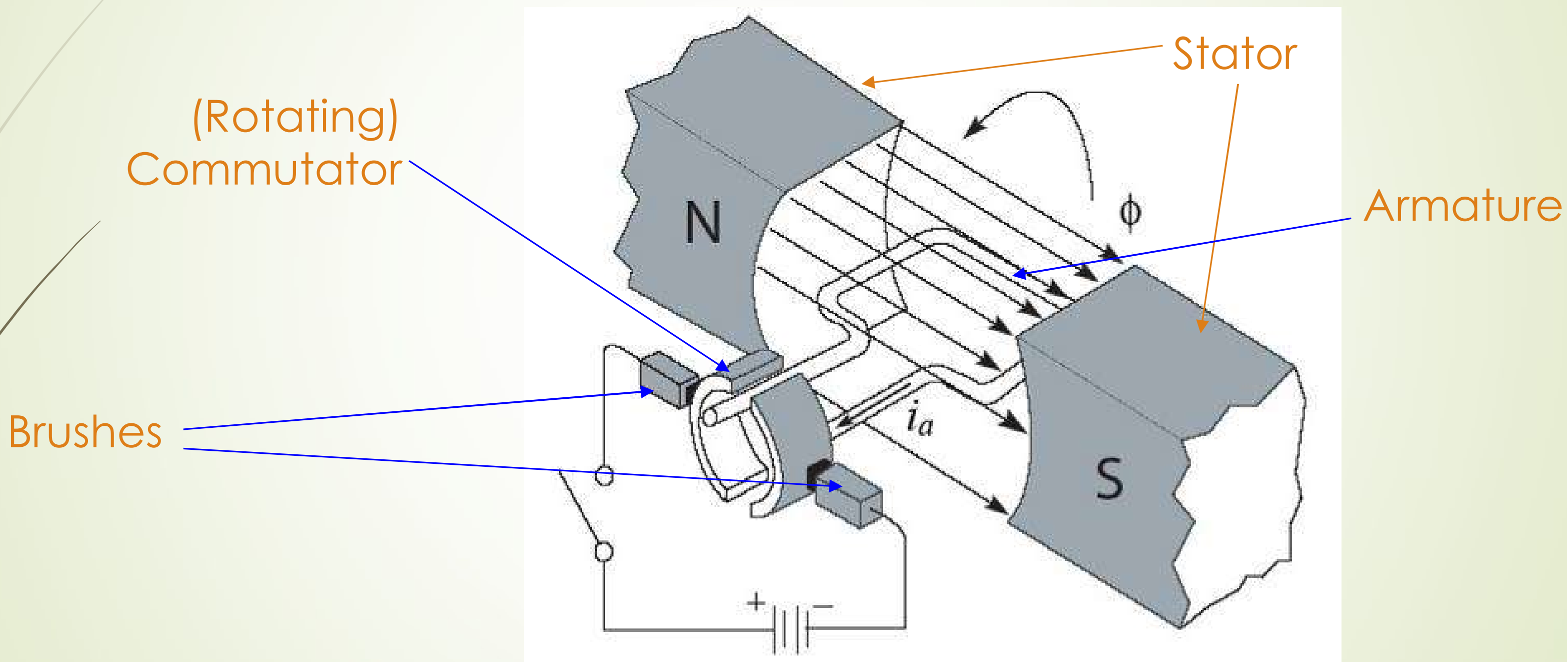
Electric Actuators

- **Electric motors**, the most common actuators in mobile robots, used both to provide location by powering wheels or legs, and for manipulation by actuating robot arms
- Electric or electromagnetic actuators are widely used in robots.
- Available in wide variety of shape, sizes, power and torque range.
- Very easily mounted and/or connected with transmission elements such as gears, belts and timing chains.
- Amendable to modern day digital control.

Main types of electric actuators:

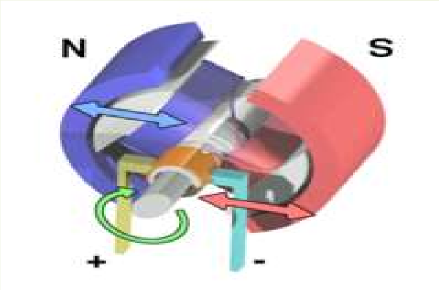
- Stepper motors
- Permanent magnet DC servo-motor
- Brushless motors

Components Of An Electric Motor

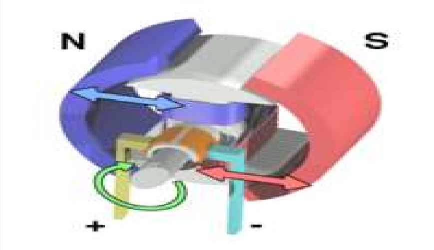


Working of dc servomotor

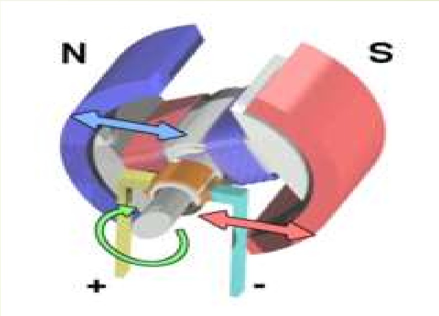
A simple DC electric motor: when the coil is powered, a magnetic field is generated around the armature. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation



The armature continues to rotate

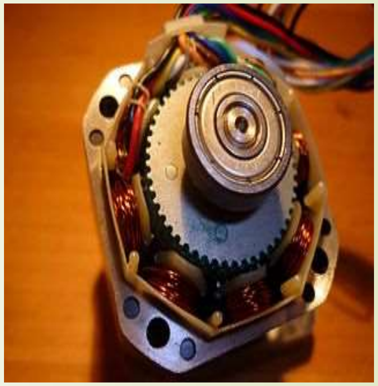


When the armature becomes horizontally aligned, the commutator reverses the direction of current through the coil, reversing the magnetic field. The process then repeats.

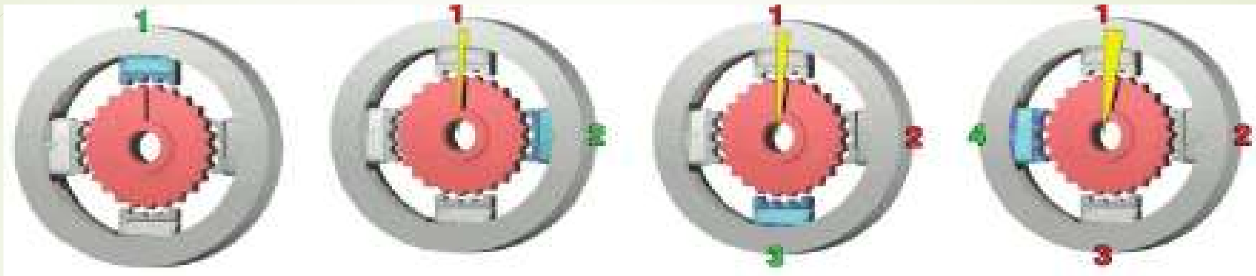


Stepper Motor

- A **stepper motor** (or **step motor**) is a brushless DC electric motor that divides a full rotation into a number of equal steps.
- Used in ‘small’ robots with small payload and “low” speeds.
- Stepper motors are of permanent magnet, hybrid or variable reluctance type.
- Actuated by a sequence of pulses .
- Typical step size is $1{:}8^\circ$ or $0{:}9^\circ$.
- Speed and direction can be controlled by frequency of pulses.
- Can be used in open-loop as *cumulative error* and maximum error is one step!
- Micro-stepping possible with closed-loop feedback control.



WORKING OF STEPPER MOTOR



- Electro-magnet **1** is activated Rotor rotates up such that nearest teeth line up.
- 2) Electro-magnet **1** is deactivated and **2** is turned on Rotor rotates such that nearest teeth line up –rotation is by a ***step*** (designed amount) of typically **1.8 or 0.9 degrees**.
- 3) Electro-magnet **2** is deactivated and **3** is turned on Rotor rotates by another step.
- 4) Electro-magnet **3** is deactivated and **4** is turned on and cycle repeated.

ELECTRIC ACTUATORS – SERVO MOTORS

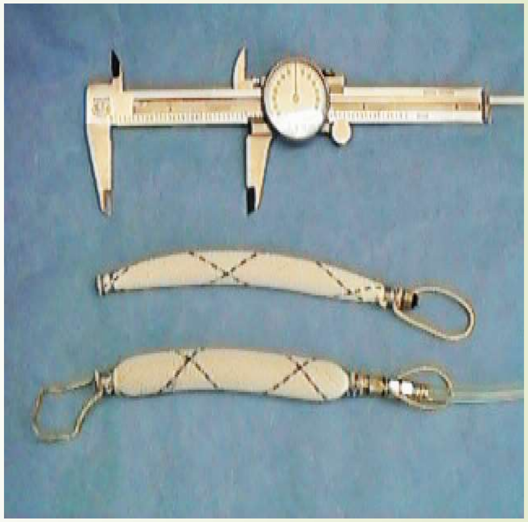
- A **servomotor** is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback.
- Rotor is a permanent magnet and stator is a coil.
- Permanent magnets, can provide large magnetic fields and hence high torques.
- Widely available in large range of shape, sizes, power and torque range and low cost.
- Easy to control with optical encoder/tacho-generators mounted in-line with rotor.
- Brushless AC and DC servo-motors have low friction, low maintenance, low cost and are robust.

Artificial Muscles

- During the past forty years a number of attempts have been made to build artificial muscles.
- Muscles contract when activated, since they are attached to bones on two sides of a joint, the longitudinal shortening produces joint rotation.
- Bilateral motion requires pairs of muscles attached on opposite sides of a joint are required to produce joint rotation.

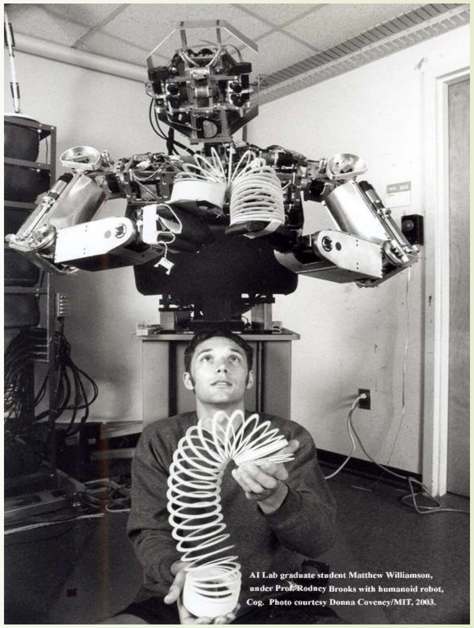
Artificial Muscles: McKibben Type

- The McKibben muscle was the earliest attempt at constructing an artificial muscle.
- This device consisted of a rubber bladder surrounded by a sleeve made of nylon fibers in a helical weave.
- When activated by pressurized air, the sleeve prevented it from expanding lengthwise, and thus the device shortened like living muscles.



Artificial Muscles: McKibben Type

- Since the 1960s there has been several other attempts to develop improved McKibben type artificial muscles:
  - (Brooks, 1977) developed an artificial muscle for control of the arms of the humanoid torso Cog
  - (Pratt and Williamson 1995) developed artificial muscles for control of leg movements in a biped walking robot
- However, it is fair to say that no artificial muscles developed to date can match the properties of animal muscles


AI Lab graduate student Matthew Williamson, under Prof. Rodney Brooks with humanoid robot, Cog. Photo courtesy Donna Coveney/MIT, 2003.

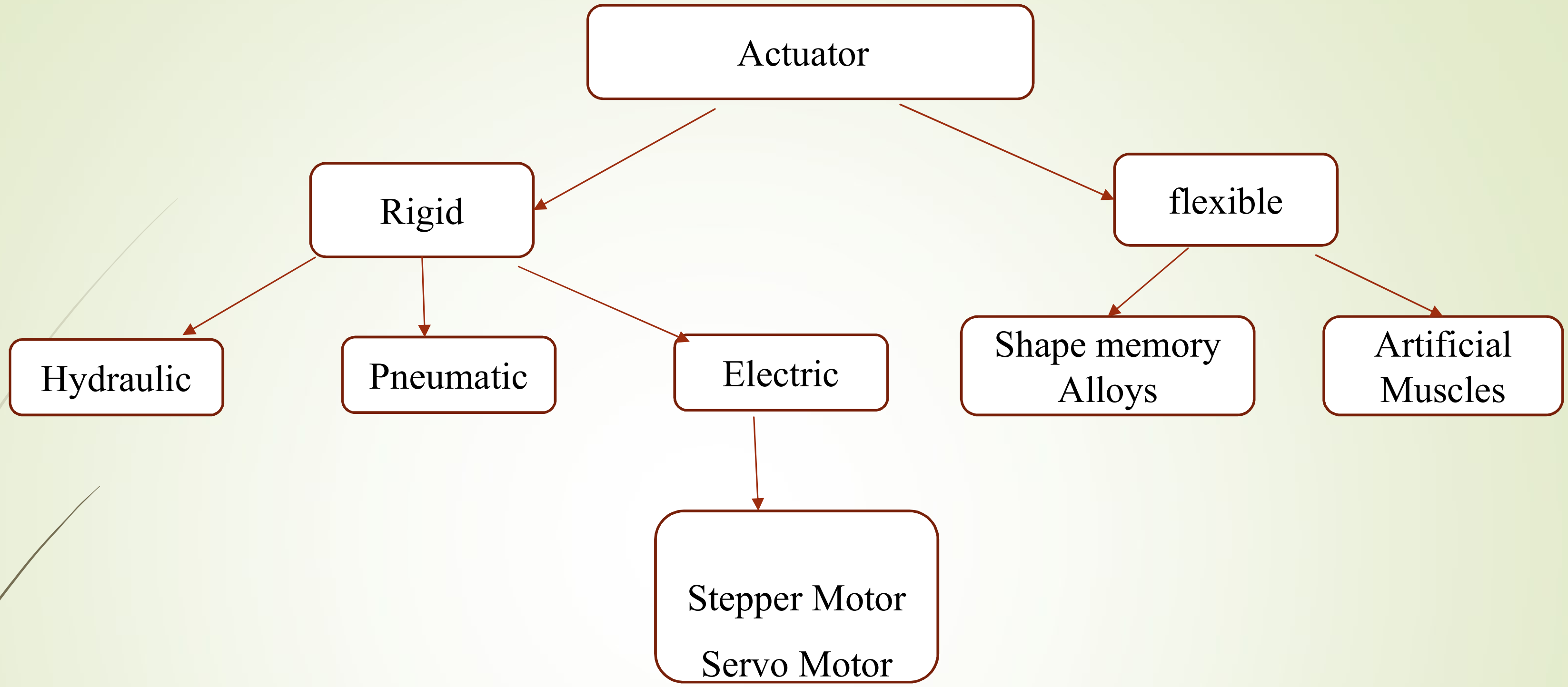
Northeastern University's Robot Lobster

- A robot lobster developed at Northeastern University used SMAs very cleverly
  - The force levels required for the lobster's legs are not excessive for SMAs
  - Because the robot is used underwater cooling is supplied naturally by seawater
- Cu-Al-Ni, Cu-Ti

Artificial Muscles: Electroactive Polymers

- Like SMAs, Electro active Polymers (EAPs) also change their shape when electrically stimulated
- The advantages of EAPs for robotics are that they are able to emulate biological muscles with a high degree of toughness, large actuation strain, and inherent vibration damping
- Unfortunately, the force actuation and mechanical energy density of EAPs are relatively low

Robotic face developed by a group led by David Hanson.


Actuator
Rigid
flexible
Hydraulic
Pneumatic
Electric
Shape memory Alloys
Artificial Muscles
Stepper Motor
Servo Motor