Robotic Actuators + Locomotion + Differential Drive

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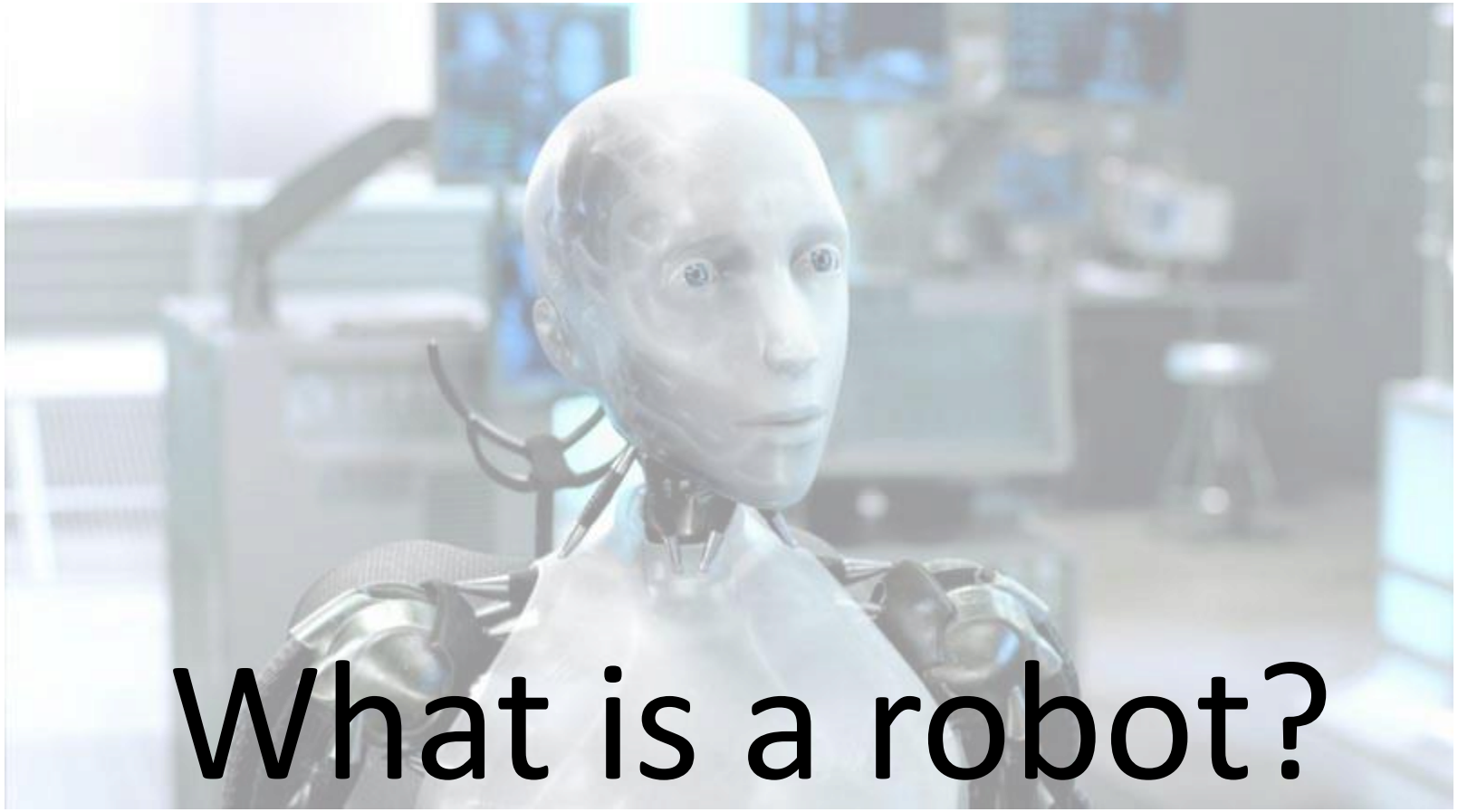
Summary

- What's a robot ?
- World of a robot
- Robotic examples
- Context: Generic Stuff
- Locomotion
- Motors & Actuators
- In depth study of some Motors and actuators
- Grippers
- Kinematics and Dynamics



What is a robot?

Robot – Definition

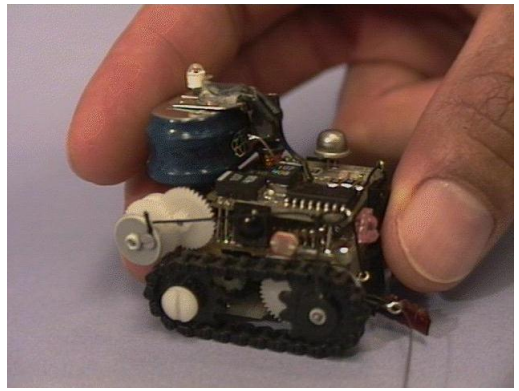
- What is an (autonomous) robot ?
  - Autonomy of decision
  - True “Helper”
  - Not so structured environment

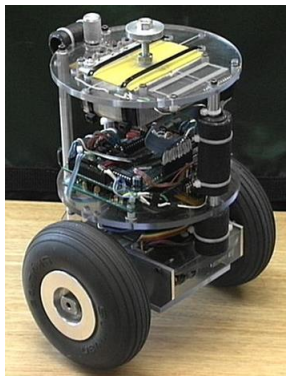
Robot – Definition

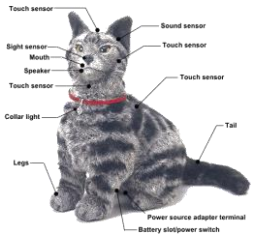
- Autonomous
- Mobile
- Intelligent
- Embodied
- Agent
- Robot

Not so autonomous…

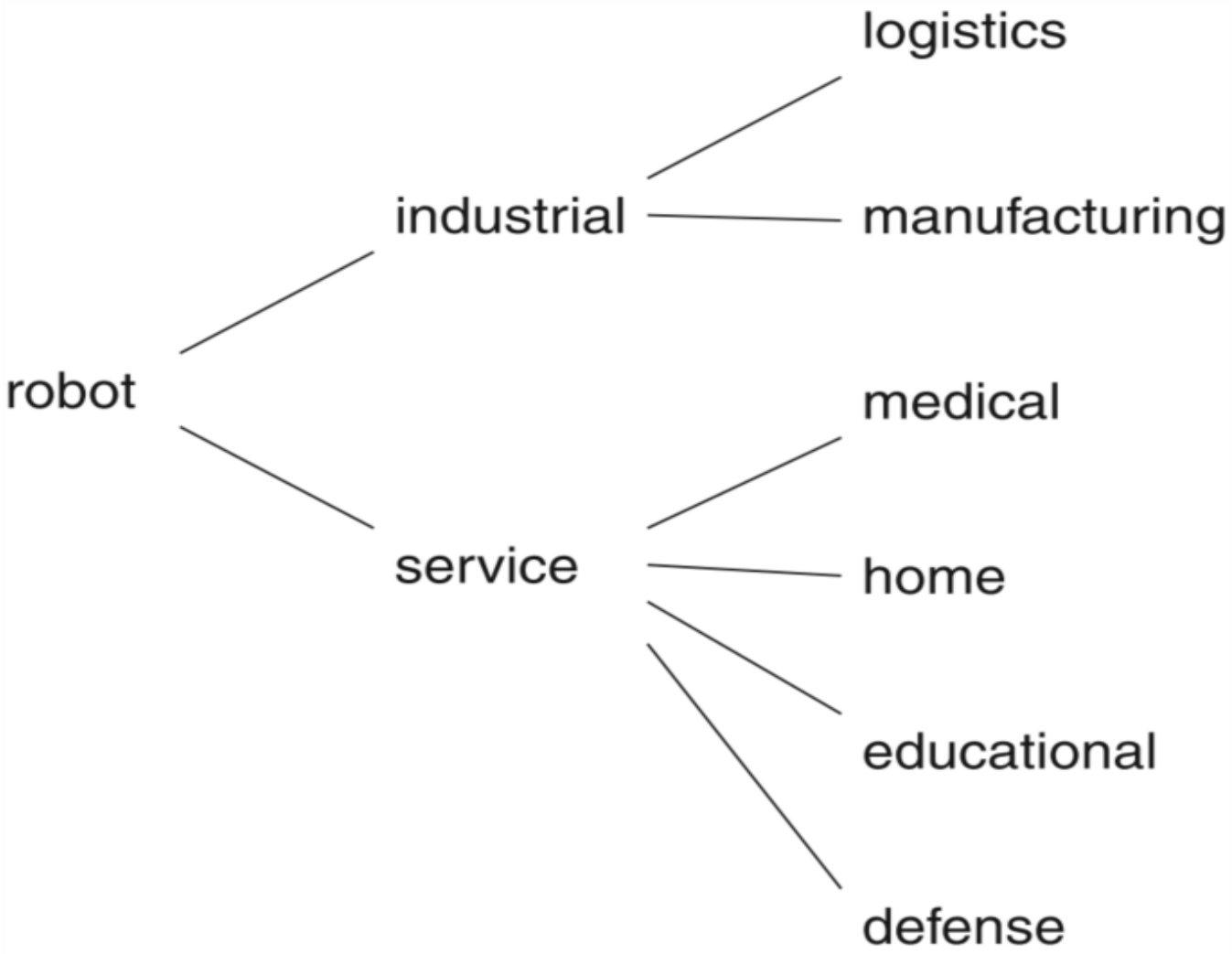
Tomorrow's robots of today

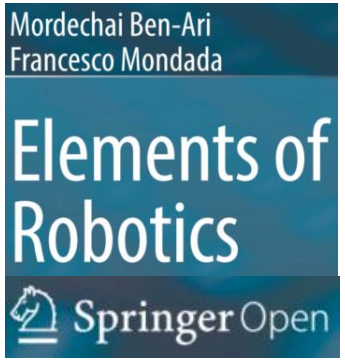






Robots - application field





https://doi.org/10.1007/978-3-319-62533-1
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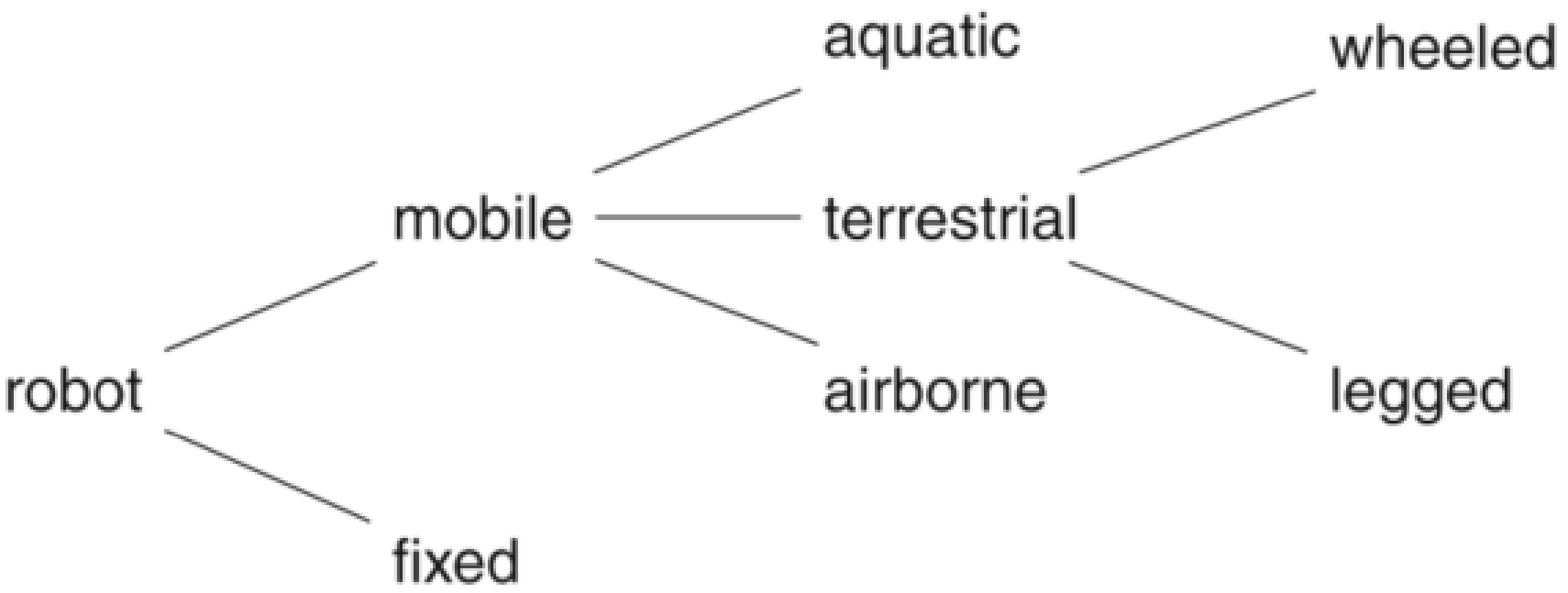
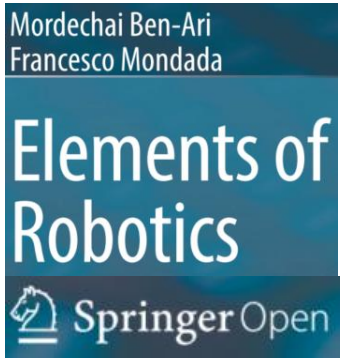
Robots - environment and mechanism of interaction





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Collaborative robot: COBOT

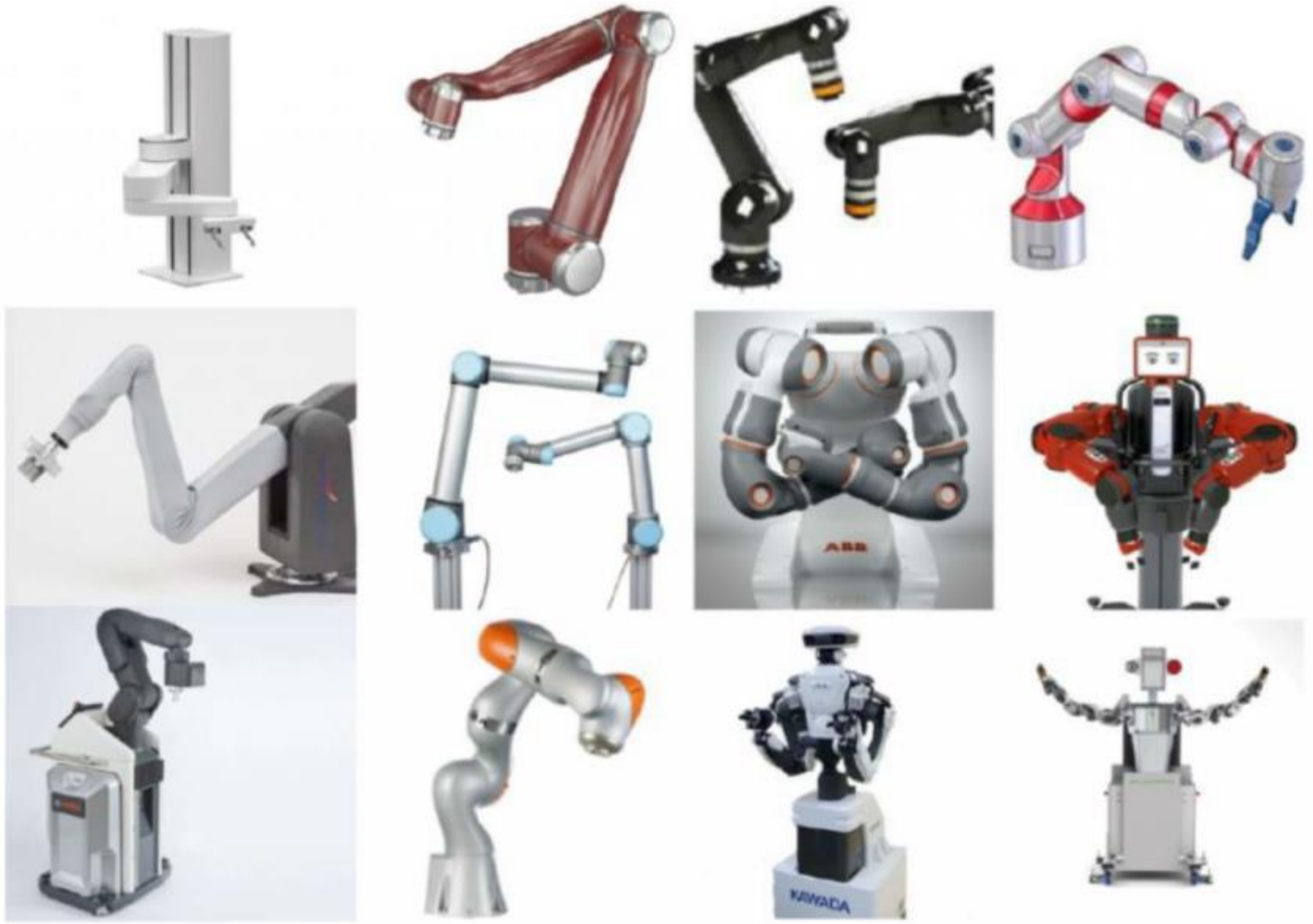
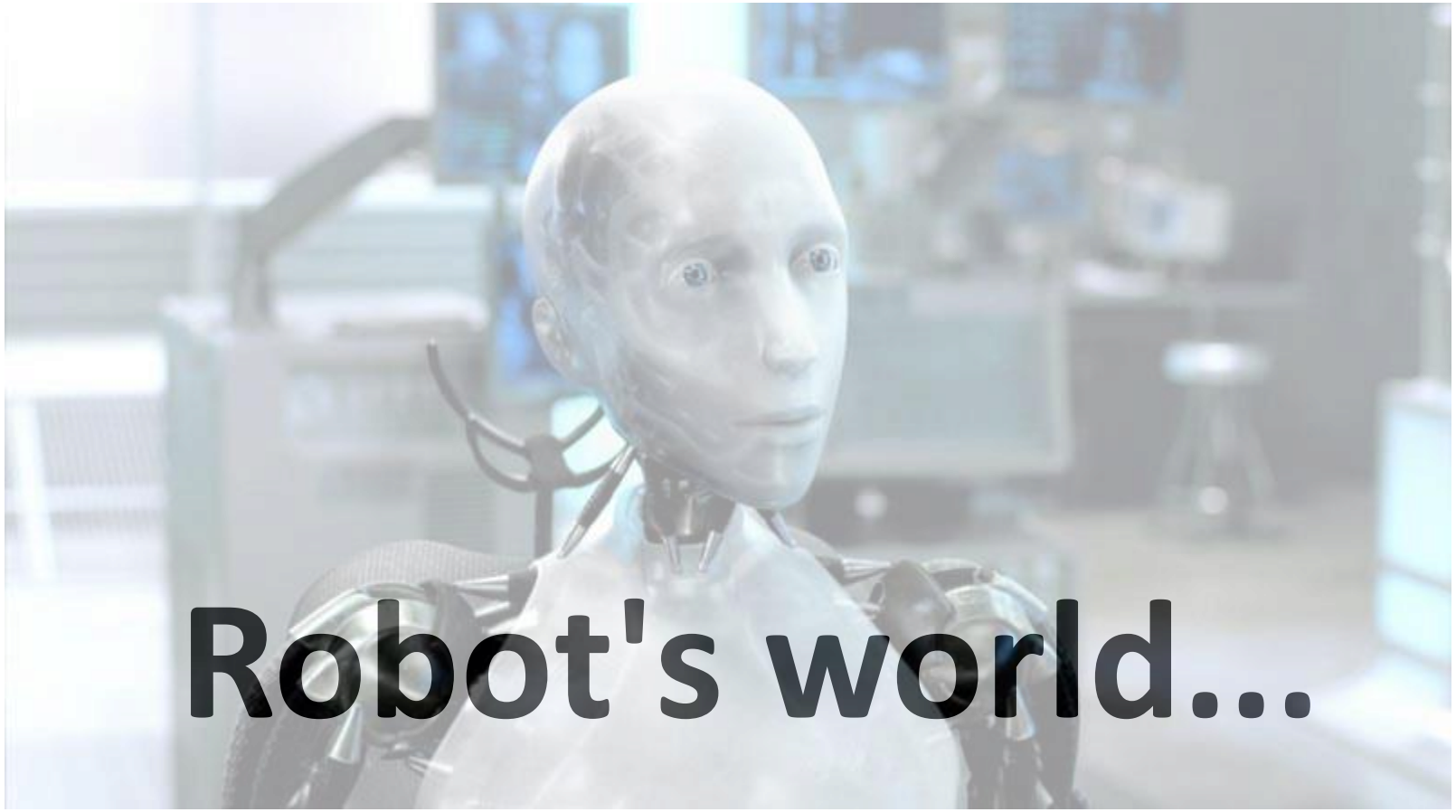


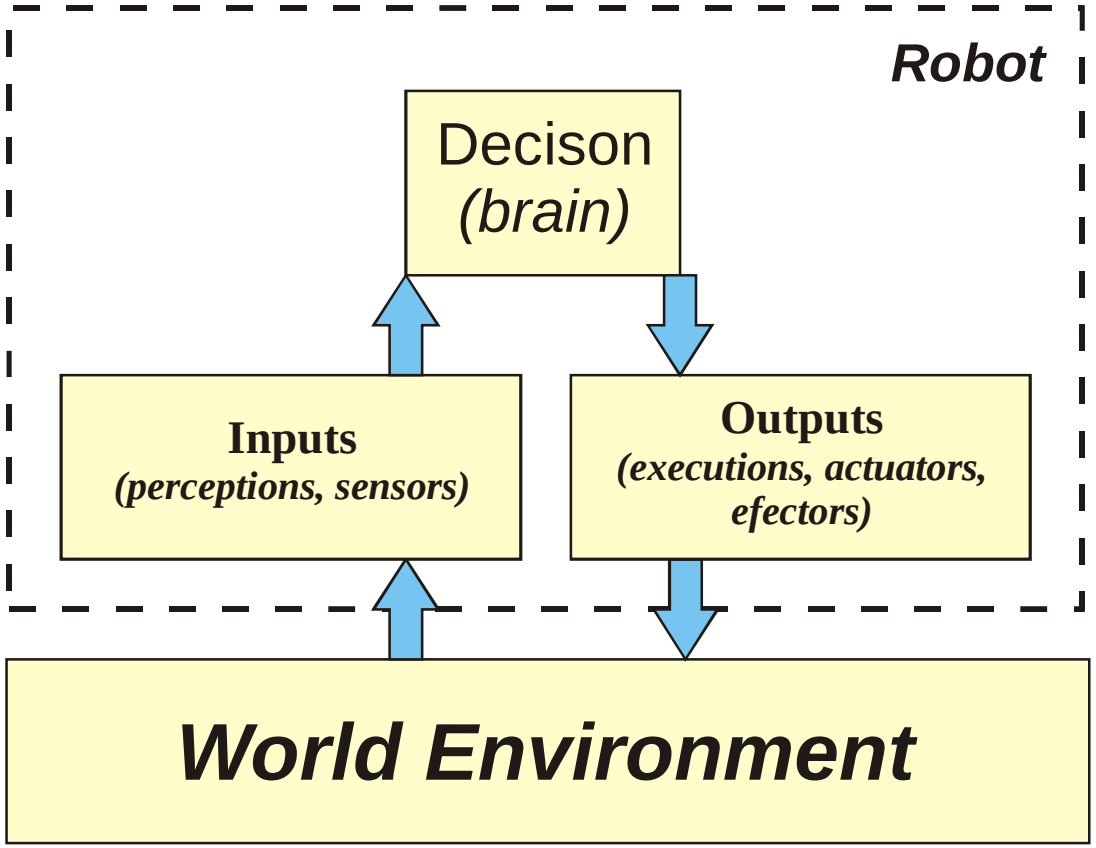
Figure 19: Example of Cobots

Cobots

- As all the technologies, cobots are designed not only to work with humans but also to improve the productivity and efficiency. There are five characteristics a cobot should has:
- 1) Safety: The first essential characteristic is to be safe around human. It is realized by the collaborative features according to the standards which will be discussed later.
- 2) Light weight: The second one is to be relatively light weight, so that they can be portable. In such a way that one cobot is suitable for multi tasks.
- 3) Simplicity: The third one is to be simple, which means operators do not need and background knowledge about programming to teach and work with them. Anyone, especially blue collar can easily work with a cobot.
- 4) Low expenses: The fourth one is to be cheaper for both acquirement of the cobot and the cost of maintenance and management than the traditional robots.
- 5) Flexibility: Last one is to be dexterous and flexible, with the innovation of new technologies, it allows cobot to have up to 7 dof, one more than what was strictly necessary. It is this plus one dof provides better configuration.

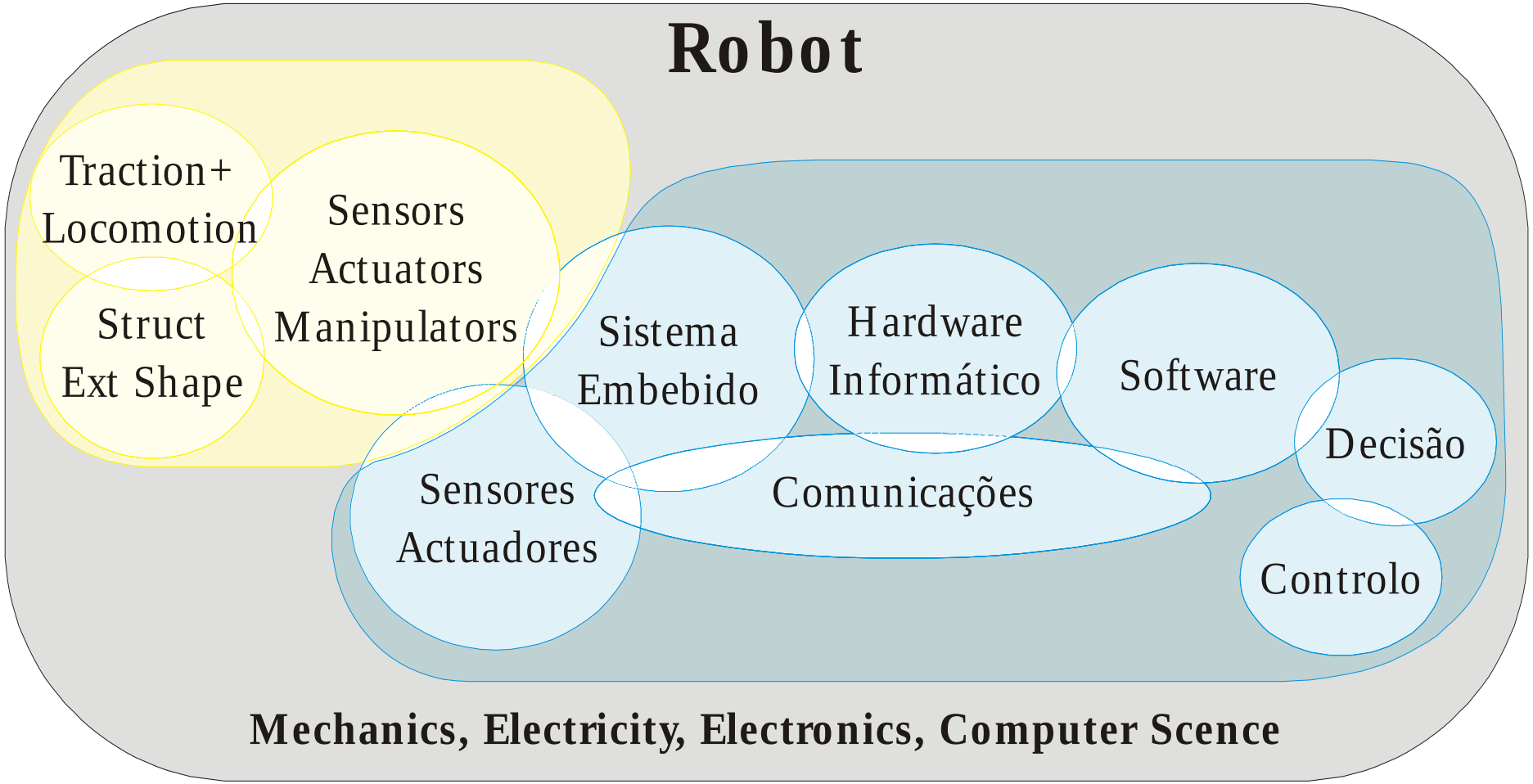

Robot's world...

World & Robotics

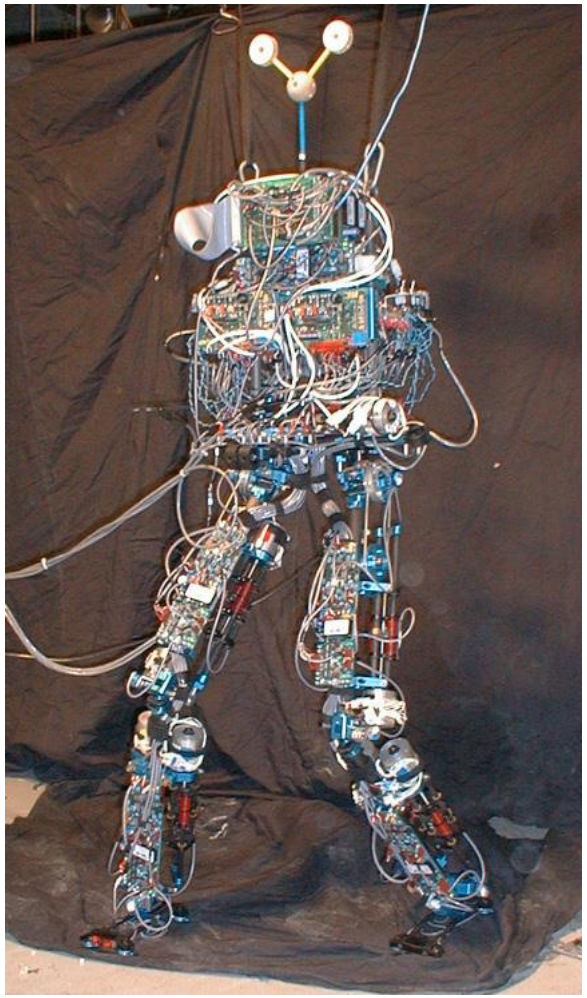


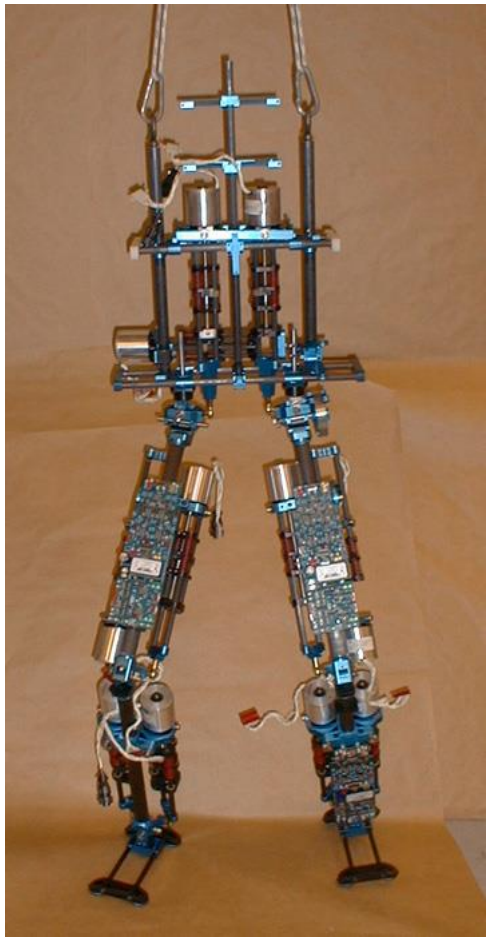
Everybody knows what closed loop means, right ?

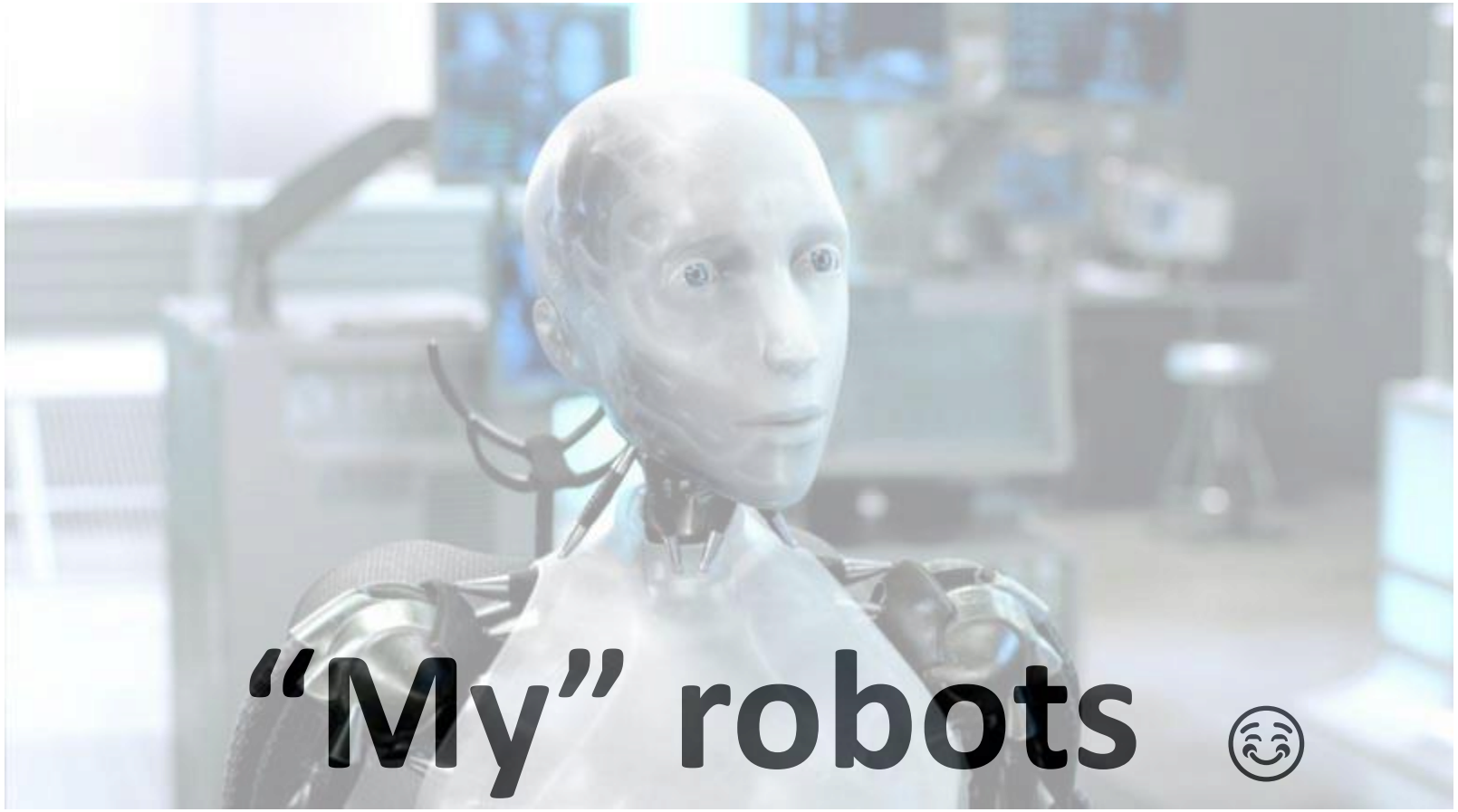
Robotics


Robot
Traction+
Locomotion
Struct
Ext Shape
Sensors
Actuators
Manipulators
Sistema
Embebido
Hardware
Informático
Software
Decisão
Sensores
Actuadores
Comunicações
Controlo
Mechanics, Electricity, Electronics, Computer Scence

Mechatronics






“My” robots 😊

Robotic Soccer & RoboCup Federation

- Soccer:
  - Cooperative
  - Competitive
  - Real Time
  - *Interesting...*

- RoboCup:
  - Largest Federation
  - Standard Test Bench
  - Annual challenge
  - Global engineering challenge
  - Fully autonomous

- Several Leagues
  - Different focuses
- Annual change in rules to foster C&T achievements

Robotic Soccer & RoboCup Federation

RoboCupSoccer Leagues

Humanoid

Standard Platform

Middle Size

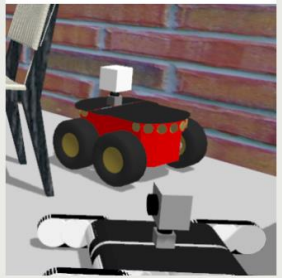
Small Size

Simulation

RoboCupRescue Leagues

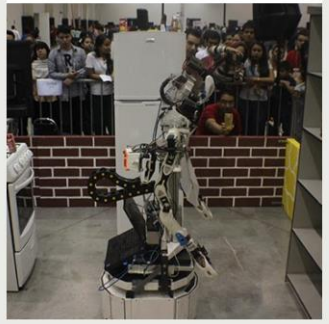
Robot

Simulation



RoboCup@Home Leagues

Open Platform



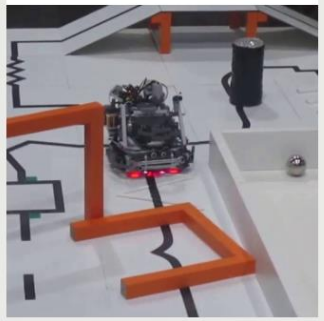
Domestic Standard Platform

Social Standard Platform

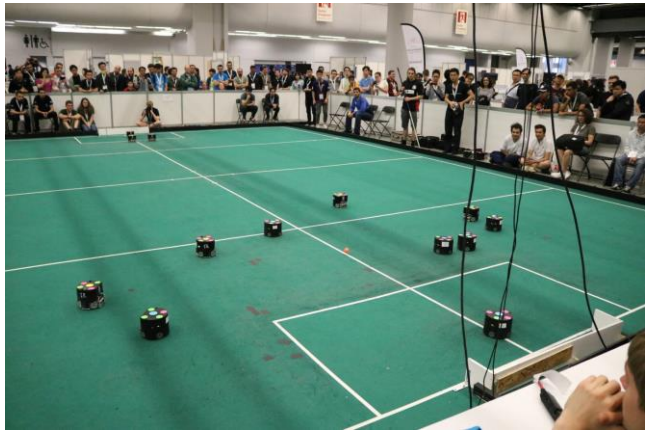
RoboCupJunior Leagues

Soccer

Rescue



OnStage



RoboCupIndustrial Leagues

@Work

Logistics

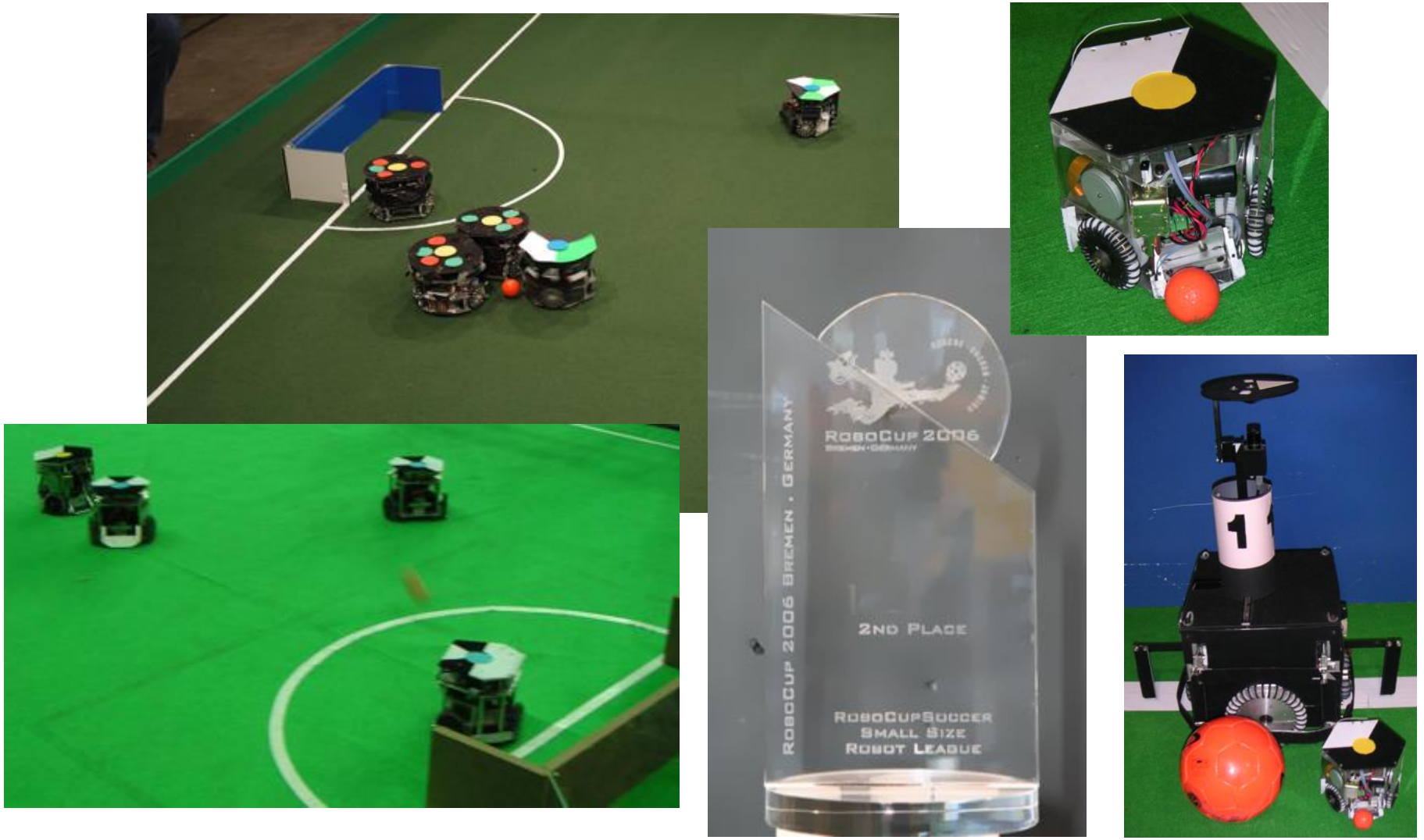
https://2021.robocup.org/leagues

RoboCup Soccer: Small Size League

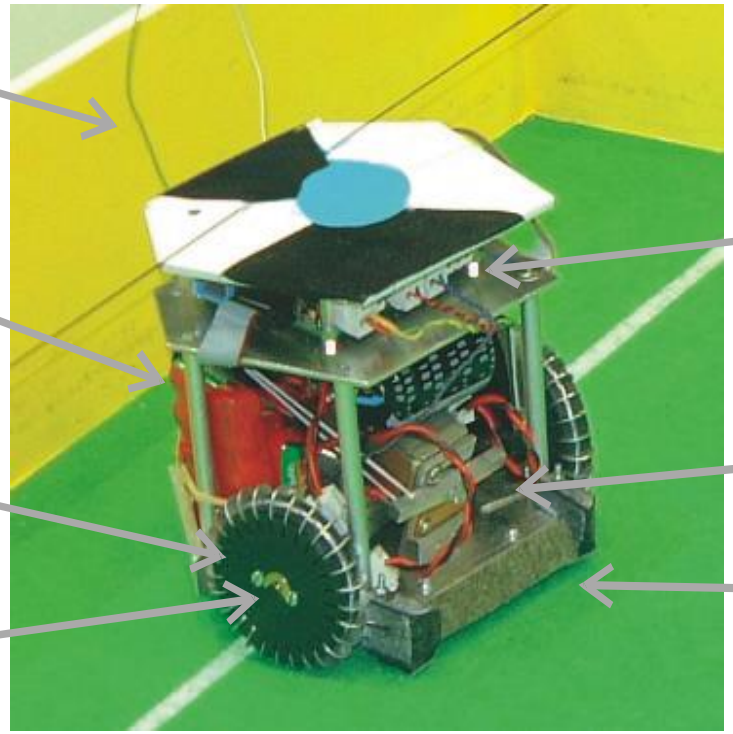
Small Size League - History

5dpo team from FEUP is Vice Champion of the world !!!

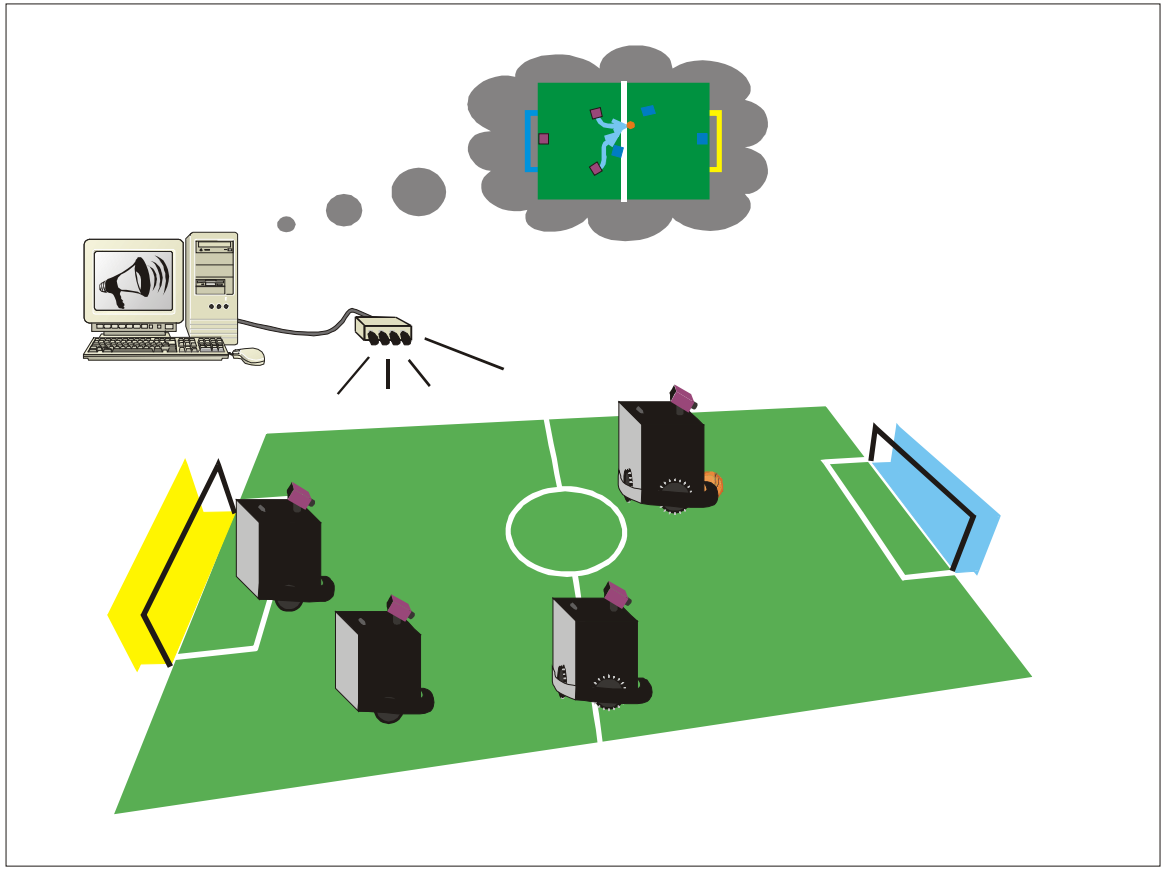
Small Size Looks



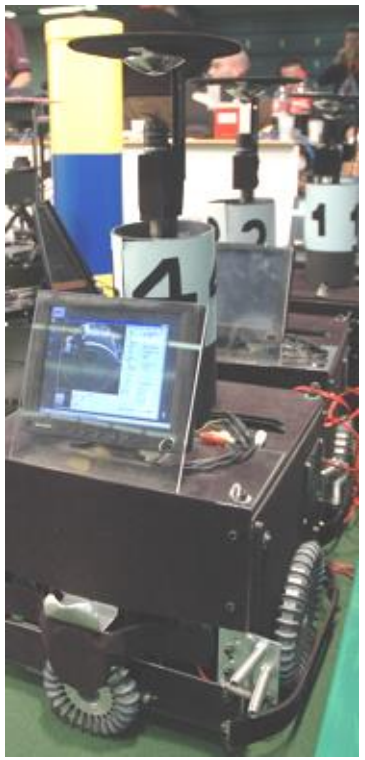
Small Size Briefing

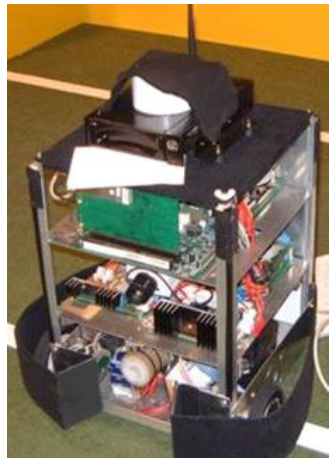


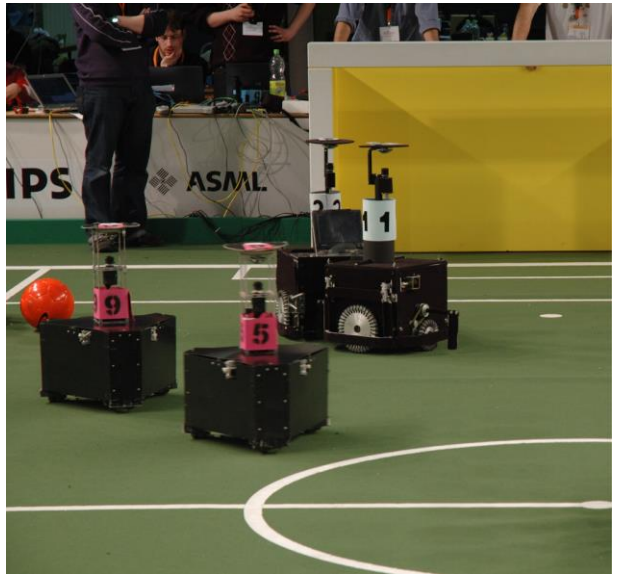
RoboCup Soccer: Medium Size League



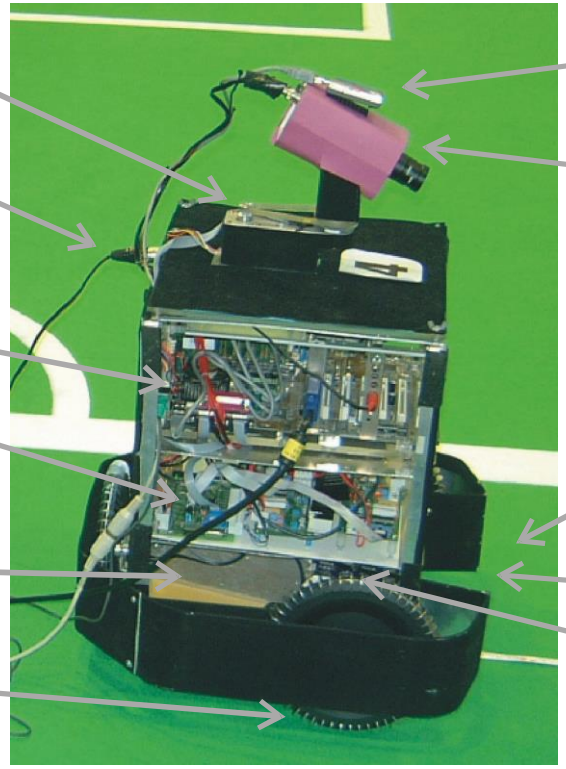
Medium Size Looks & History







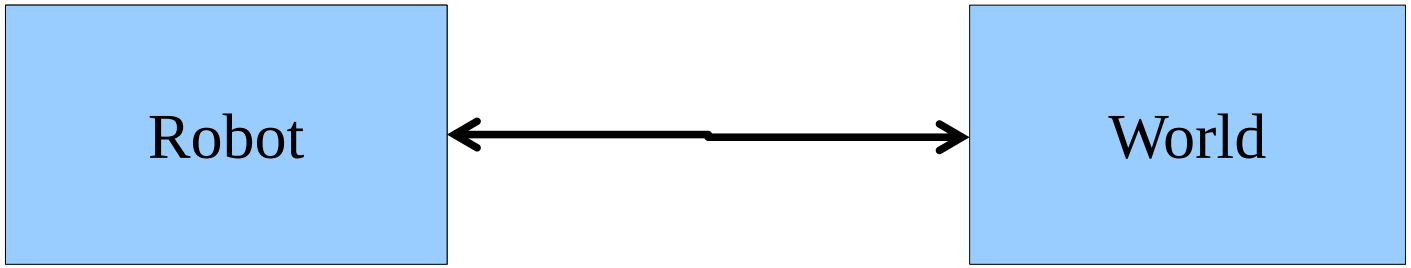
Middle sizy robot briefing




General stuff...

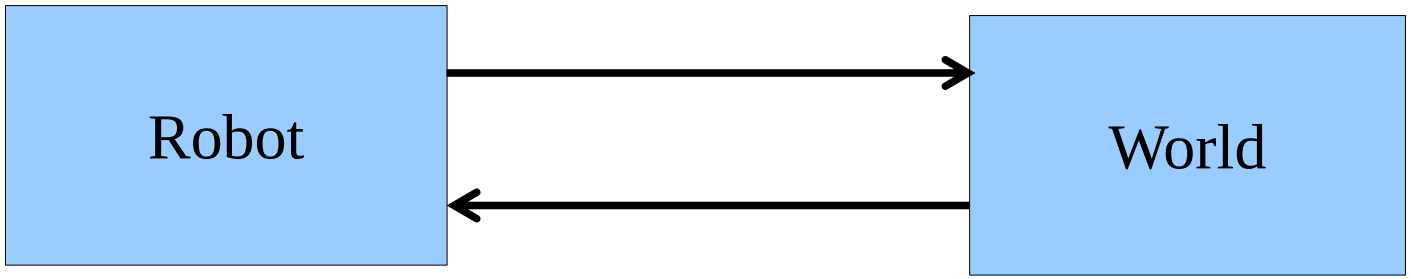
Robot & World

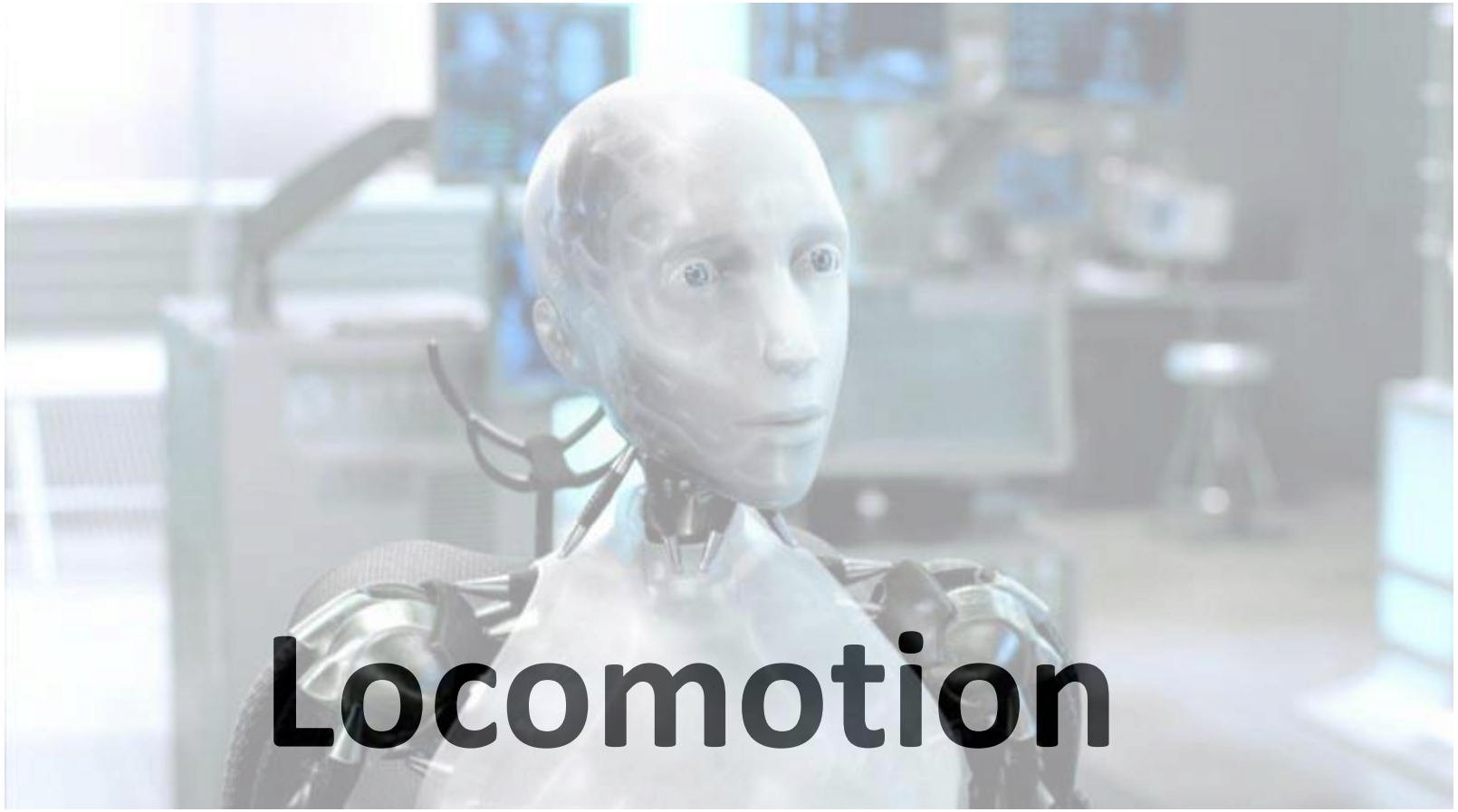
- The robot exchanges energy
  - Discover the world
  - Change it
- How ?
  - By using transducers that change energy forms



Sensors & Actuators

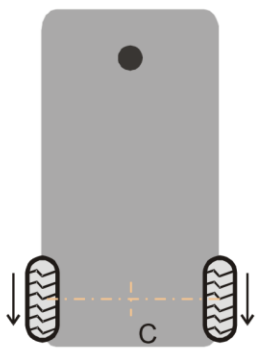
- Efeito de carga / Load Effect ?
  - Does sensing change anything ???
- What is the **efficiency** of the change in the world ?
- How much energy is available ?
- Safety for the world *(humans!)* and the robot itself!



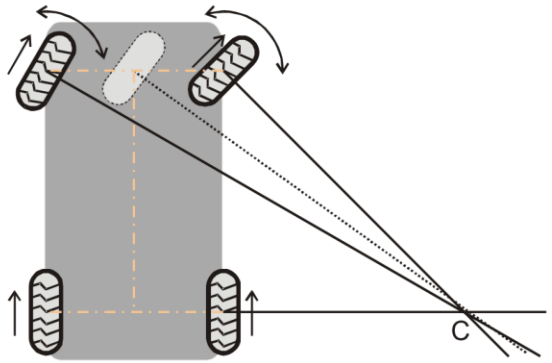


Locomotion

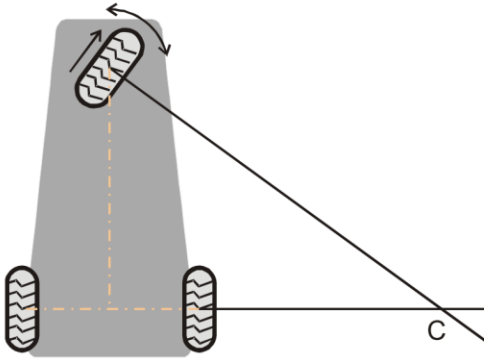
Locomotion (i) - Wheels



Differential drive
(wheelchair)

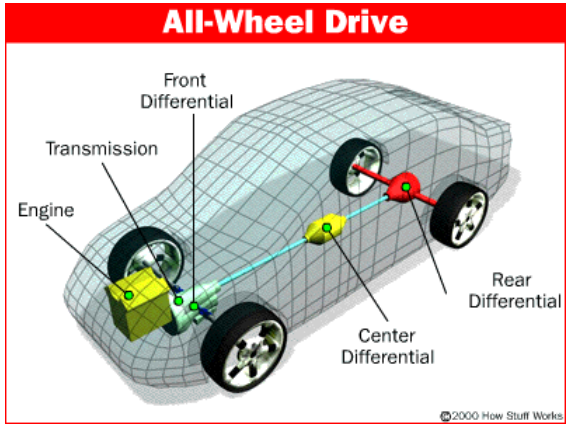


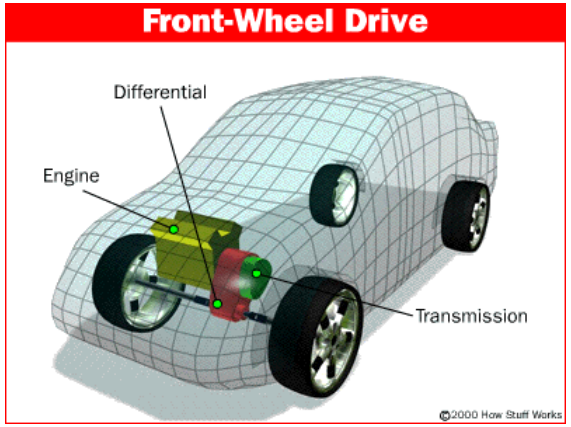
Ackerman
(normal car drive)

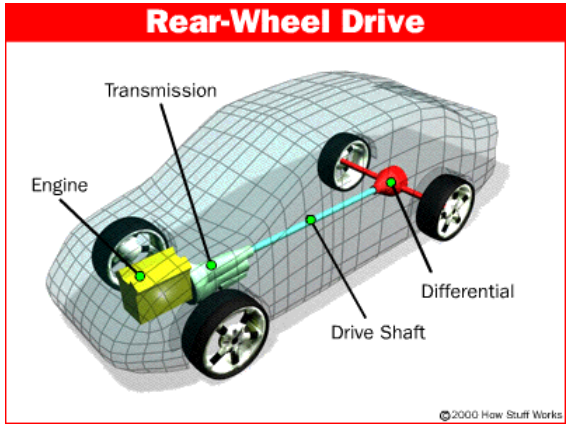


Tricycle

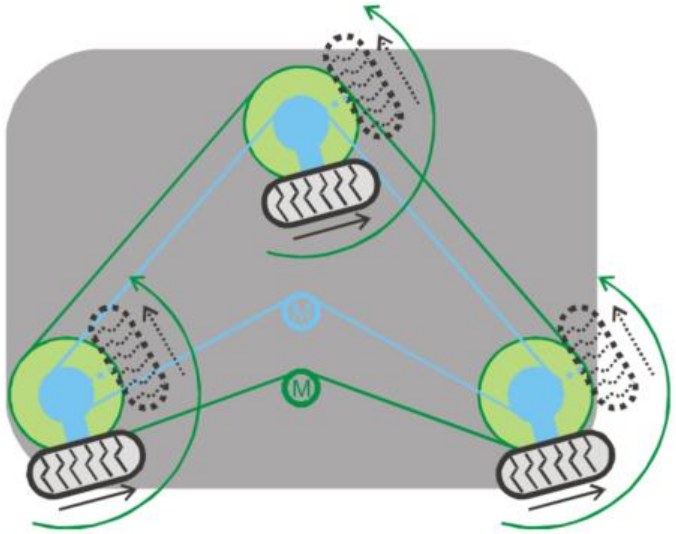
Ackerman
(normal car drive)





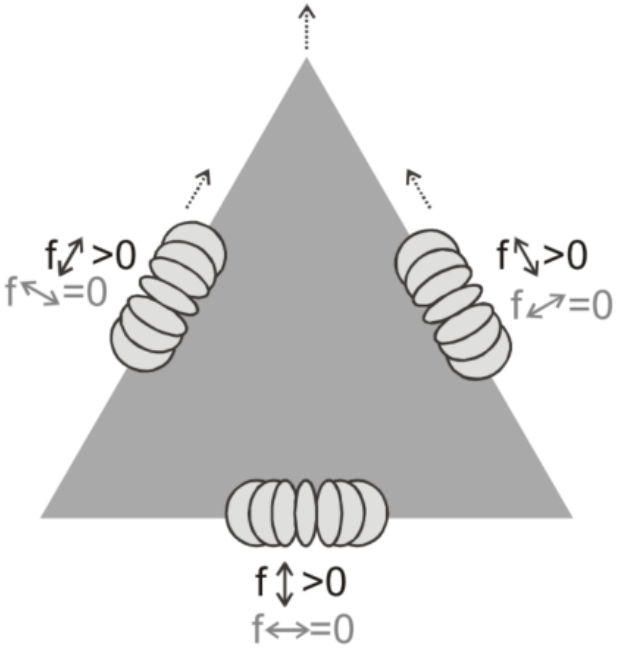


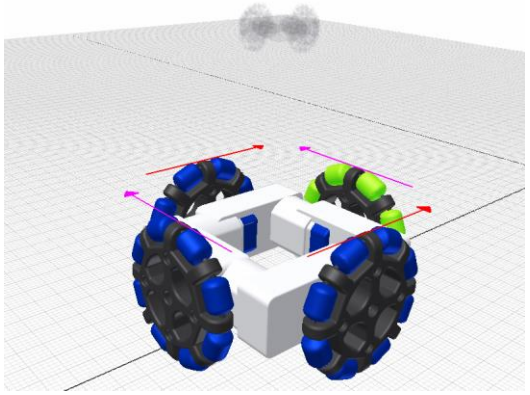
Locomotion (ii) – Omni / Omniwheels



Synchronous
(Quasi omnidrive)

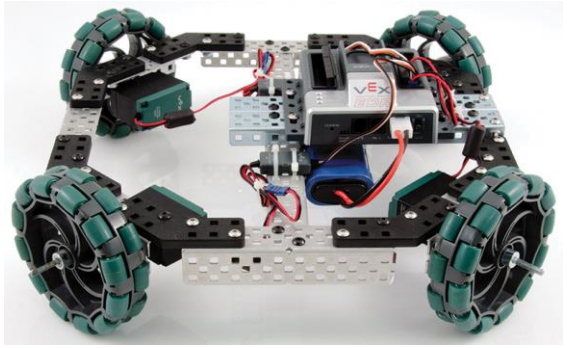
Locomotion (iii) – Omni / Omniwheels

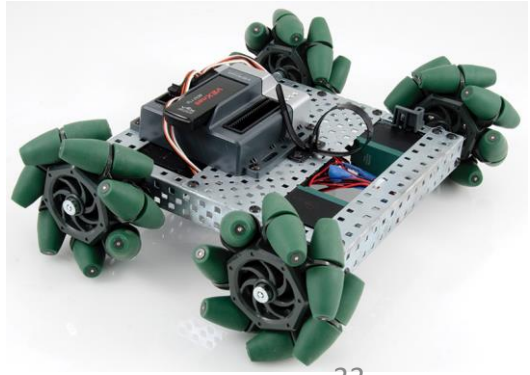




Omni Wheels Holonomic Drive

Mecanum Wheel





https://www.servomagazine.com/magazine/article/a-look-at-holonomic-locomotion

https://www.vicenzathunders.com/products

Mecannum (Omni) Wheels

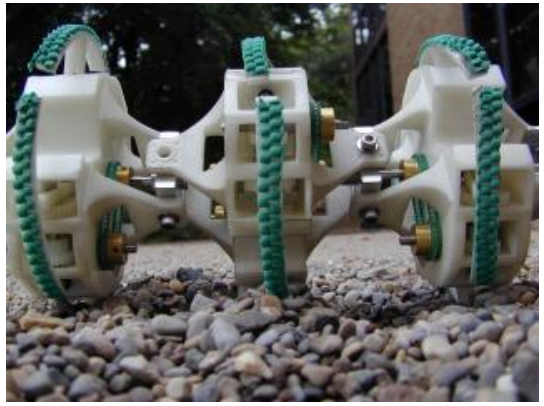
- http://youtu.be/o-j9TReI1aQ
- http://youtu.be/Yng7JB6swuI
- http://youtu.be/TXTo16KKm8Q
- Omni Lifter Airtrax Cobra - http://youtu.be/IlmKcohyXG0
- Lego Omni Wheel - http://youtu.be/7fevklHUaIk

Locomotion (iv)

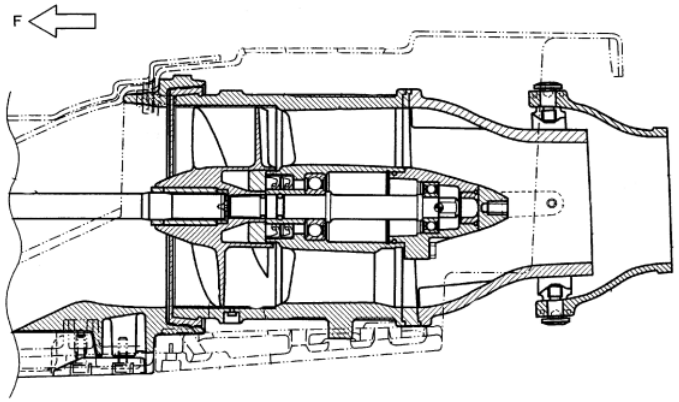
Nbot / segway

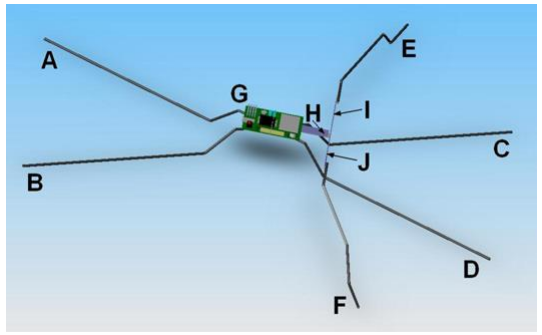
Track Drive
(military tank like)

Soryu

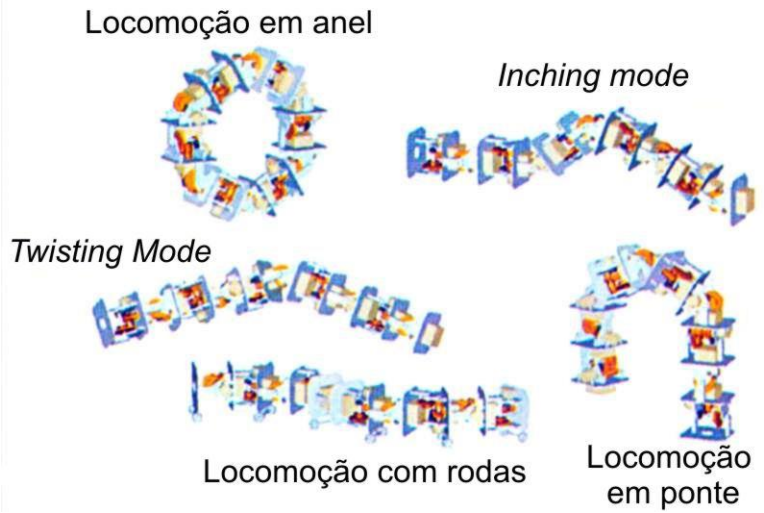


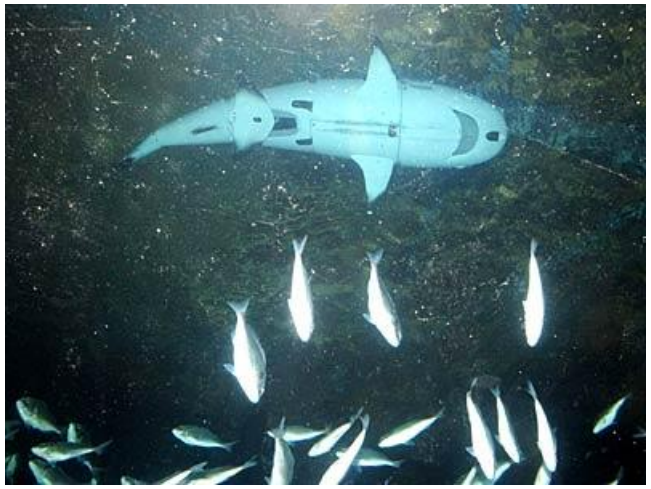
Locomotion (v) – water related



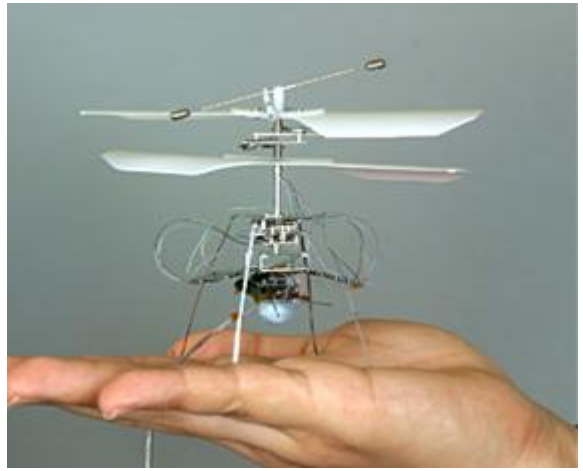


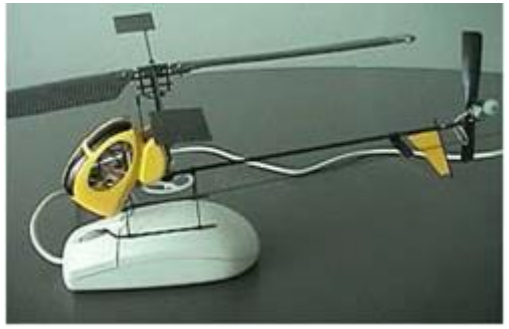
Locomotion (vi)





Locomotion (vii) – Heli, Jet, Mars, other…





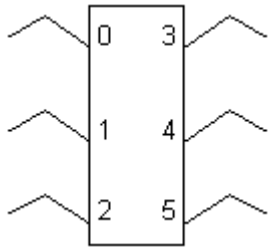
Other motion principles

- Jet / Propellers (air/water)
  - Dynamic (ruder, plane wings - *pressure difference*)
  - Helicopter
  - Wings / directive fins / rudders (air/water)
- Rocket / Solar Wind / Ion Thrusters
- Wind...
- ...
- Keep a sharp eye –
  many, MANY other options !!!

Legged Locomotion Example: 6 legs

Forward Sequence:

- Lift legs 0, 2 and 4.
- Pull back legs 1, 3 and 5 to push robot forwards.
- Lower legs 0, 2 and 4.
- Lift legs 1, 3 and 5.
- Move legs 1, 3 and 5 forward to reset them.
- Pull back legs 0, 2 and 4 to push robot forwards.
- Lower legs 1, 3 and 5.
- Lift legs 0, 2 and 4.
- Move legs 0, 2 and 4 forward to reset them.
- Lower legs 0, 2 and 4.

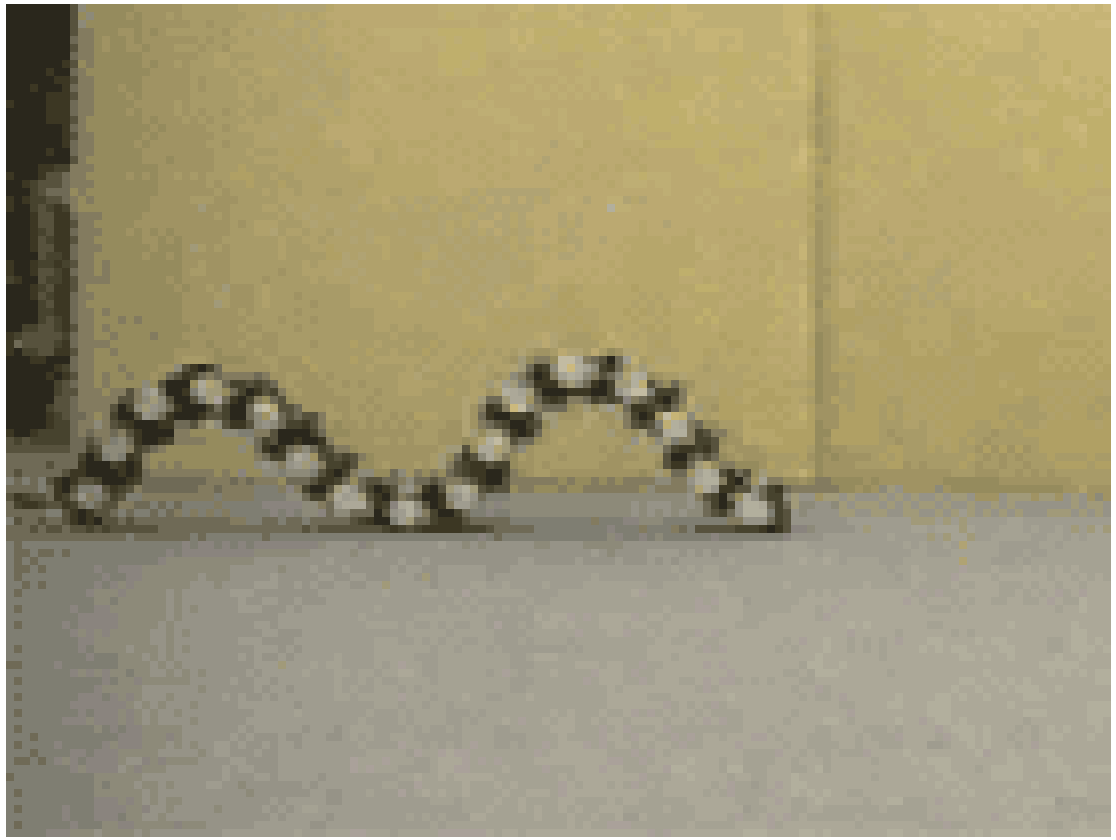


Turn Right Sequence:

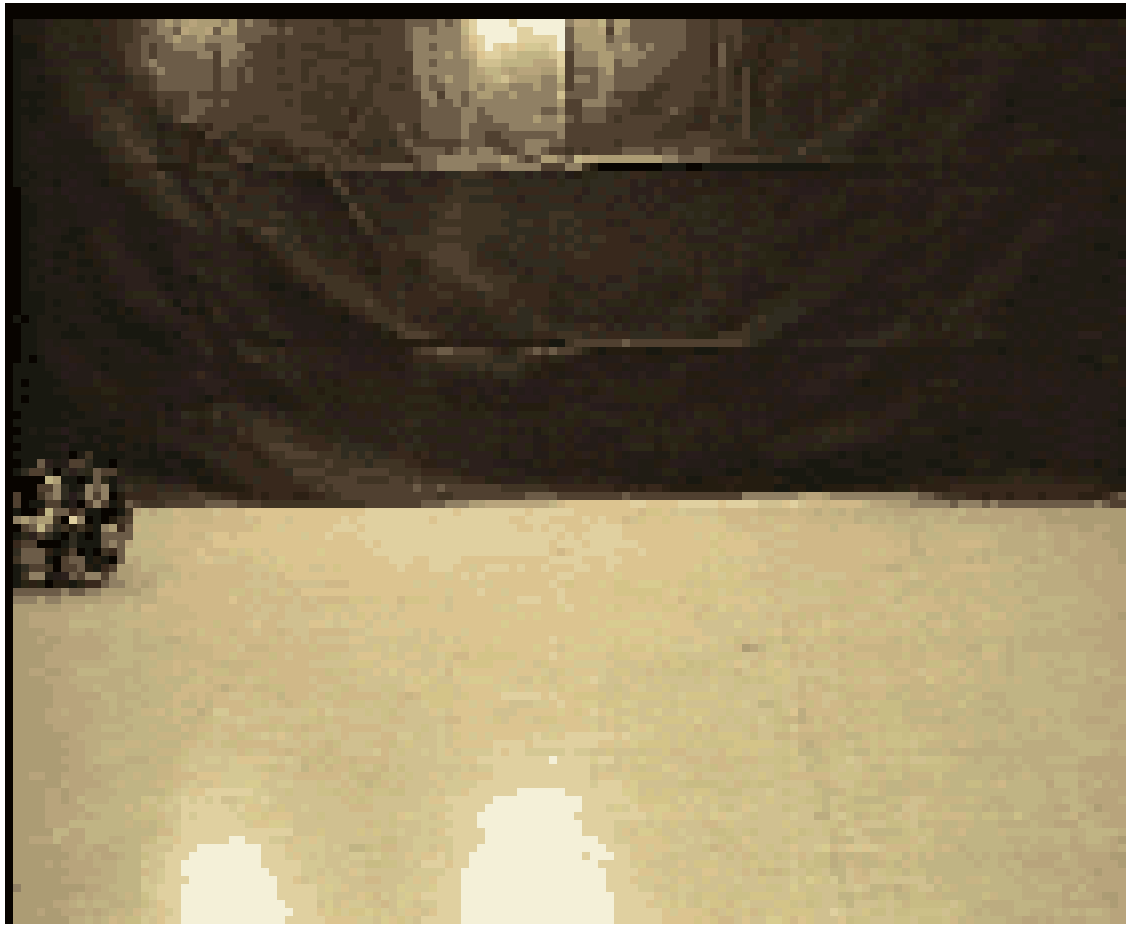
- Lift legs 1, 3 and 5.
- Push back legs 0 and 2 to turn robot.
- Lower legs 1, 3 and 5.
- Lift legs 0 and 2.
- Move legs 0 and 2 forward to reset them.
- Lower legs 0 and 2.

http://www.mcdonald.org.uk/andrew/archive/robot/comp/movement.htm
http://www.youtube.com/watch?v=ZhB4nFN_mRI
http://youtu.be/-Soq9qpK5Ac

Locomotion animations

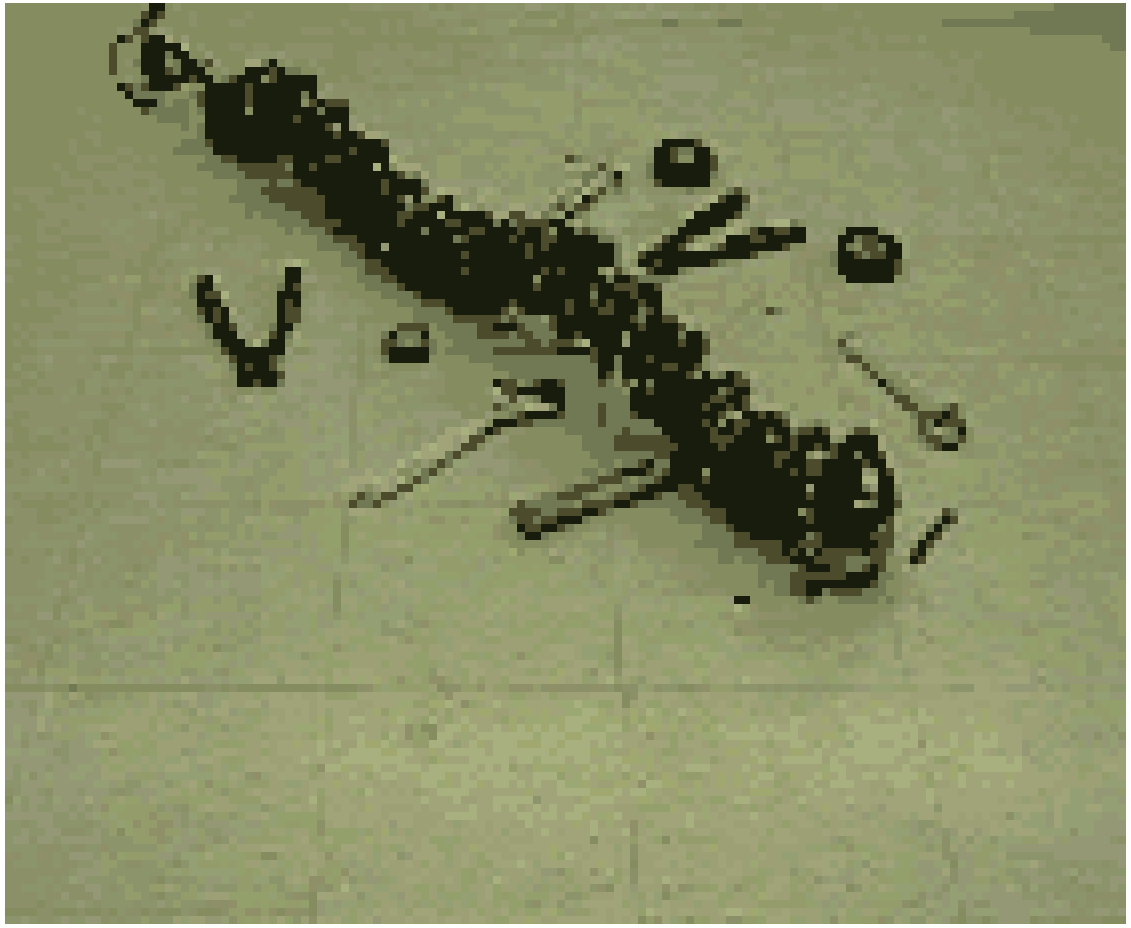


Locomotion animations (ii)



Locomotion animations (iii)

Locomotion animations (iv)



Locomotion animations (v) - caterpillar

http://www.youtube.com/watch?v=vfw4nduVU_E

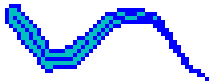
Locomotion animations (vi) - rolling

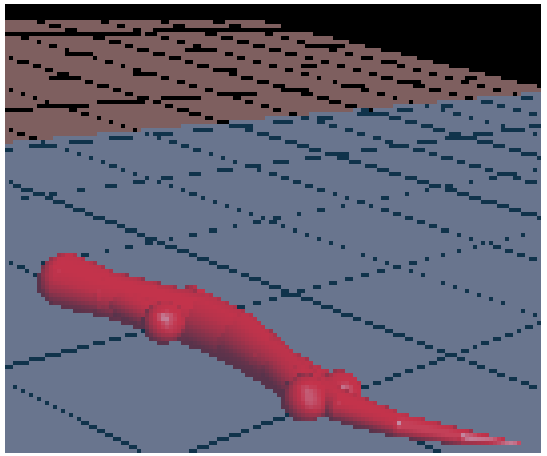
http://www.youtube.com/watch?v=f3rr1lcFe3Q&feature=related

Snake Morphing Adapt Locomotion…

http://youtu.be/v6W-sEpJEqY

Locomotion animations – Biology inspired



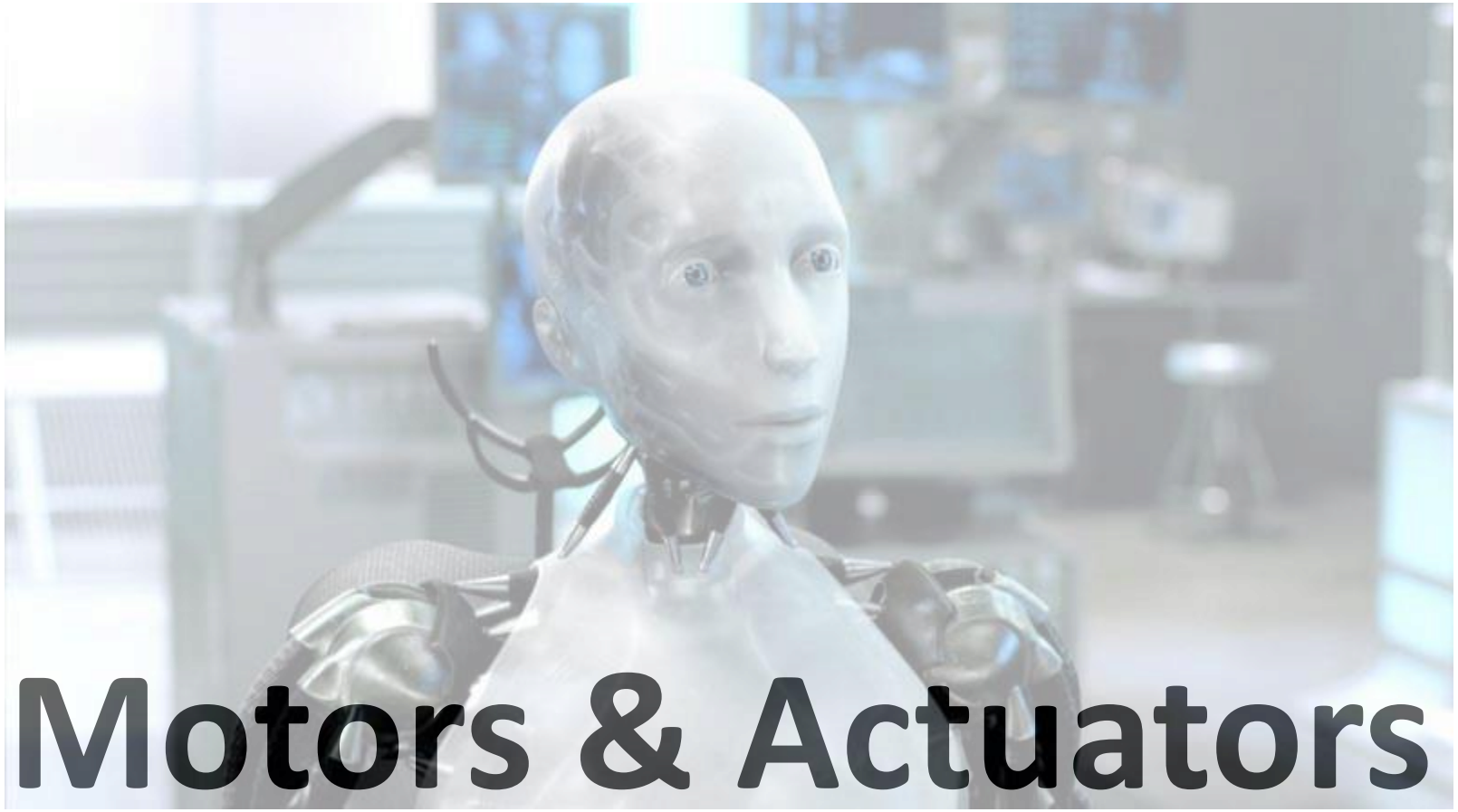


Mtran Modular robot:
http://www.youtube.com/watch?v=4oSavAHf0dg
http://unit.aist.go.jp/is/frrg/dsysd/mtran3/mtran3.htm

Robotic Chair (reassembles itself):
http://youtu.be/t5pvZoZwzh0

LS3 - Legged Squad Support System (“dog”):
http://youtu.be/R7ezXBEBE6U
http://youtu.be/cNZPRsrwumQ

Ibot Robotic Wheel chair (climbs stairs):
http://youtu.be/O7otewMk9pc



Motors & Actuators

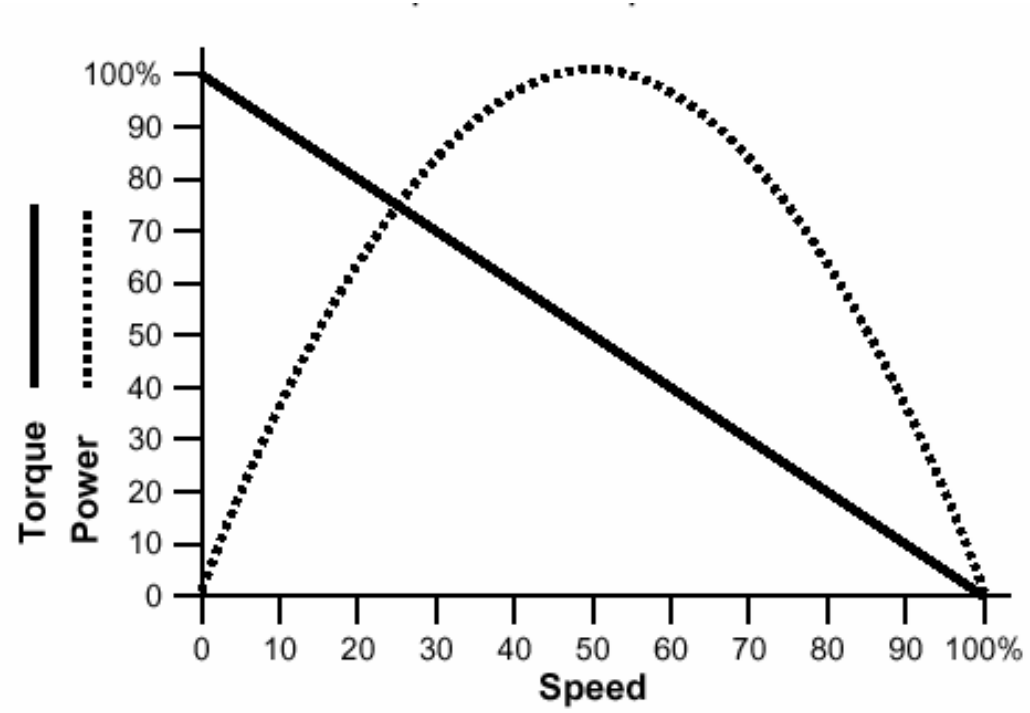
Principle of workings

- Actuators + Motors are transducers
  - Rotative (torque)
  - Linear (force)

- Physics of producing torque / force
  - Electromagnetic (current + magnetic field)
  - Pneumatic + Hydraulic (pressure difference)
  - Piezoelectric+Ultra Sonic Motor (Shape Shifting Materials)
  - Internal Combustion (Diesel/Gasoline!) :(

Mechanics

- Start
- Stall
- Nominal
- Max mechanical
- Above nominal ?
- Life cycle
- Thermal
- Zero speed ?!

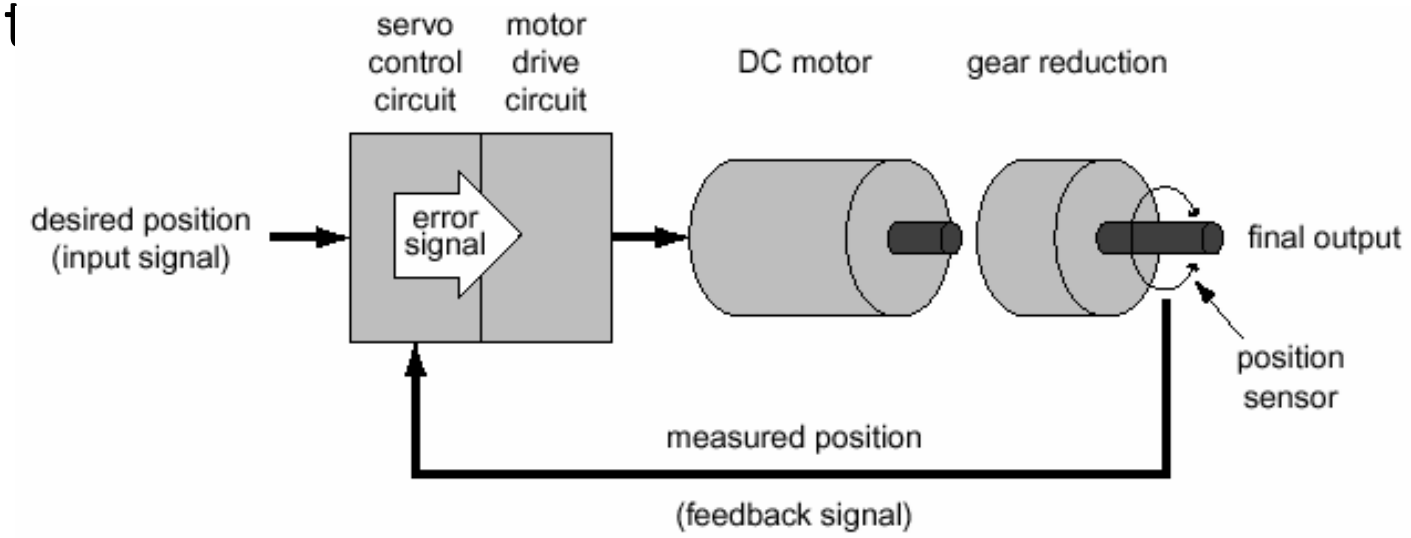


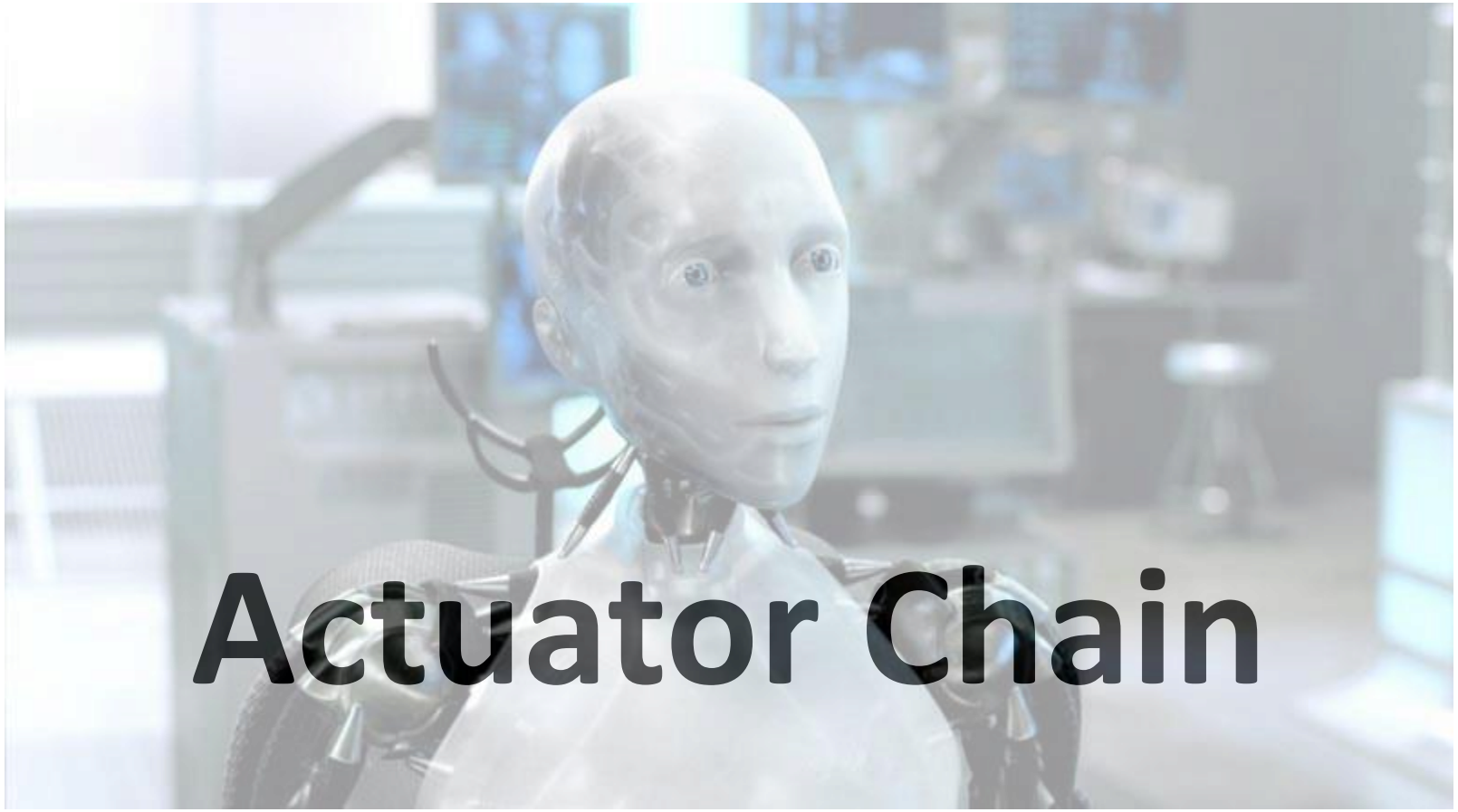
General Considerations

- Each has different characteristics
  - Efficiency / size / safety / life cycle / max speed + max force
  - Start-Up + stall – start-up currents + *f.c.e.m.*
  - Electricity is nice for input, force / torque is output
  - Static / viscous / non-linear friction
  - Dead Zone / non linear
- Point of work of actuator is the interception of actuator curve and load curve – probably not very simple
  - Stable or dynamic point of working
- Actuators are mechanically complex
  - Throughout the actuator chain, several limitations will apply, all are dangerous
- Broken actuators are typically expensive and time consuming!!!

Servo Motor

- A complex actuator that includes closed loop control
- Generally power and signal separated
- External behaviour similar to ideal actuator
  - Linear, fast, safe, reliable, “intelligent” (?!), “smart” (?!), ...
- Position controllers have extra complexity so servo position actuators are frequent

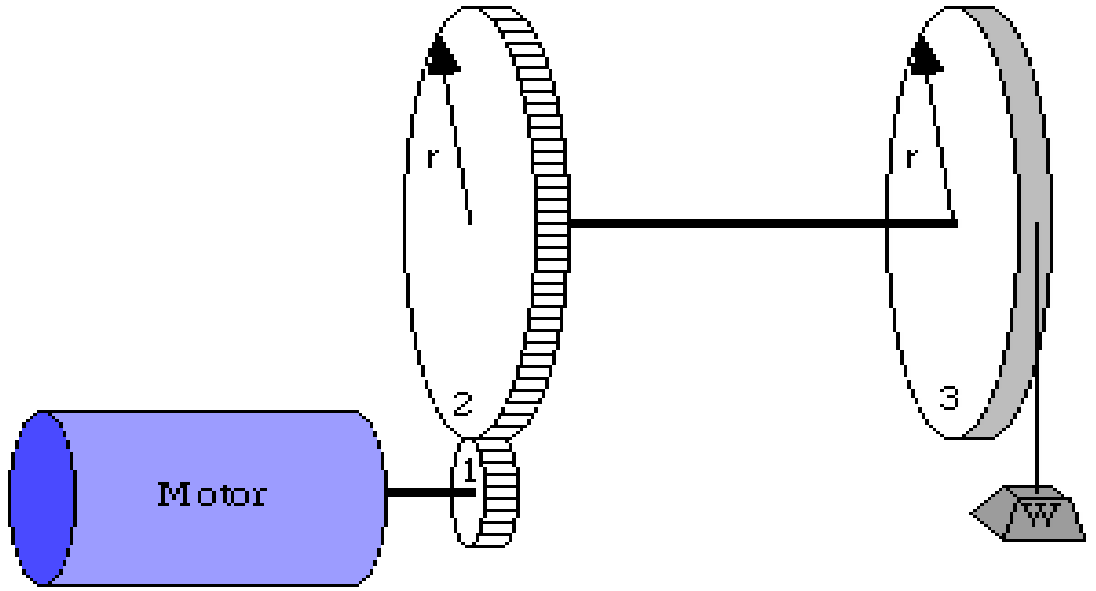




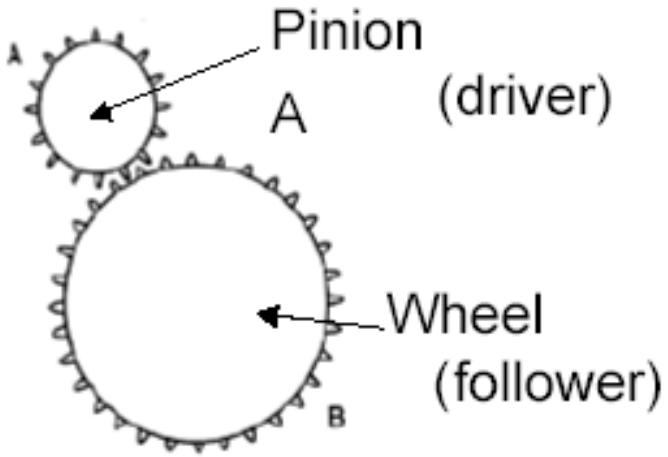
Actuator Chain

Gears

- What for ? Exchange Speed for Torque
  - $T_{output} = T_{input} \times r_{output} / r_{input}$ *(reduce speed to get larger torque)*
- Types:
  - Spur, Bevel, Worm Gear, Rack and pinion, planetary ...
  - http://www.societyofrobots.com/mechanics_gears.shtml



Gear Math

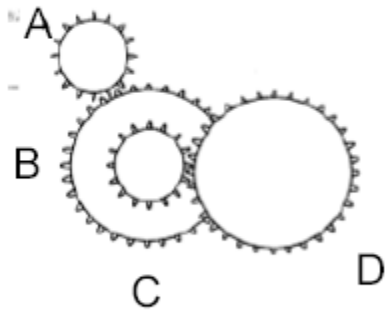


- Gear ratio

  $R = \#\ teeth_w / \#teeth_p$
- $T_w = e(T_p\ R)$
- $\omega_w = e(\omega_p / R)$

Spur Gear Reduction

A is attached to motor

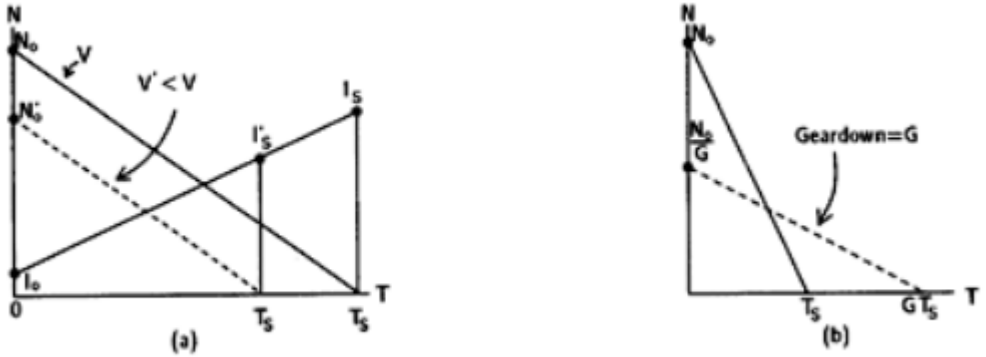


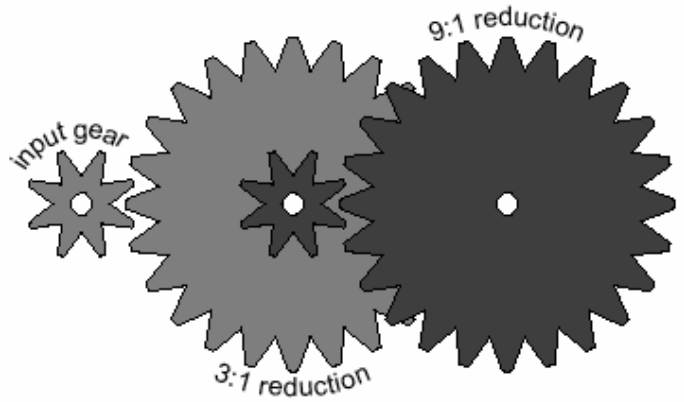
$\omega_{out} = (A/B)\ (C/D)\ \omega_{in}$

C is a pinion attached to B's output shaft
D is on output shaft

Gear math (ii)

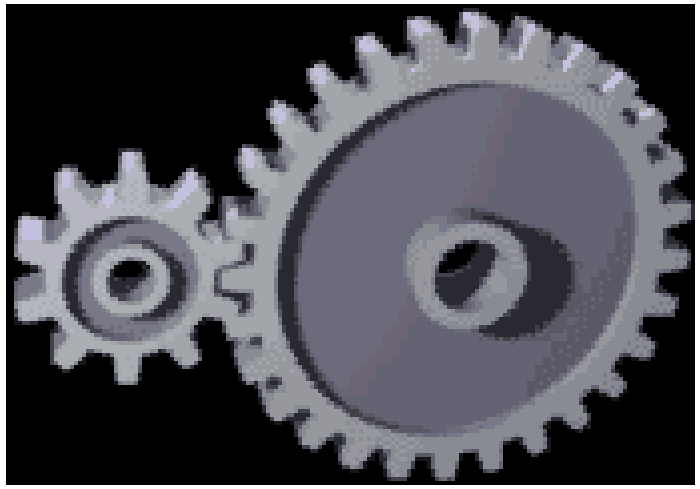
- Exchange speed for torque

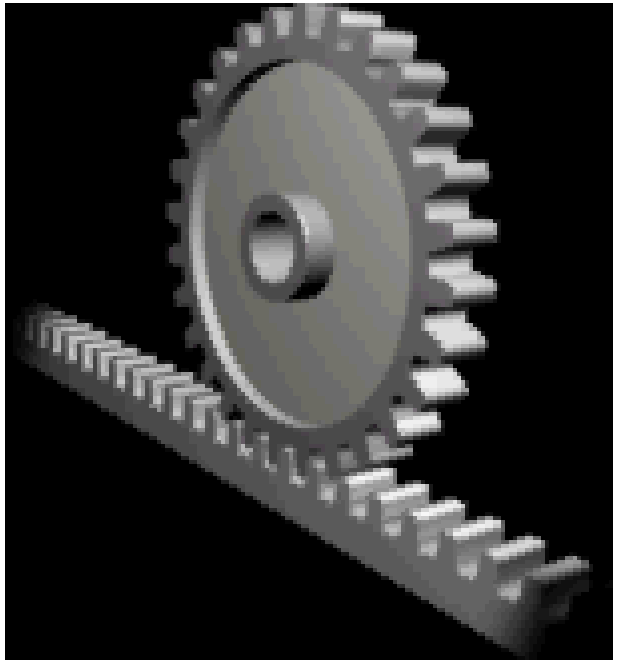




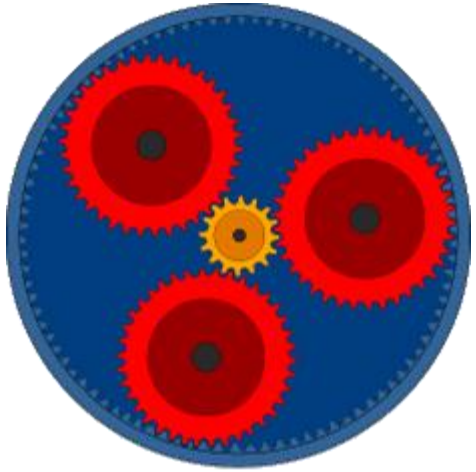
8-tooth gear on left; 24-tooth gear on right

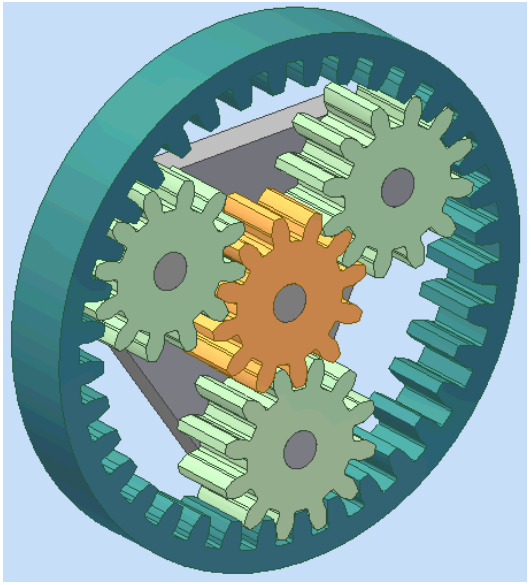
Spur Gear / Rack pinion





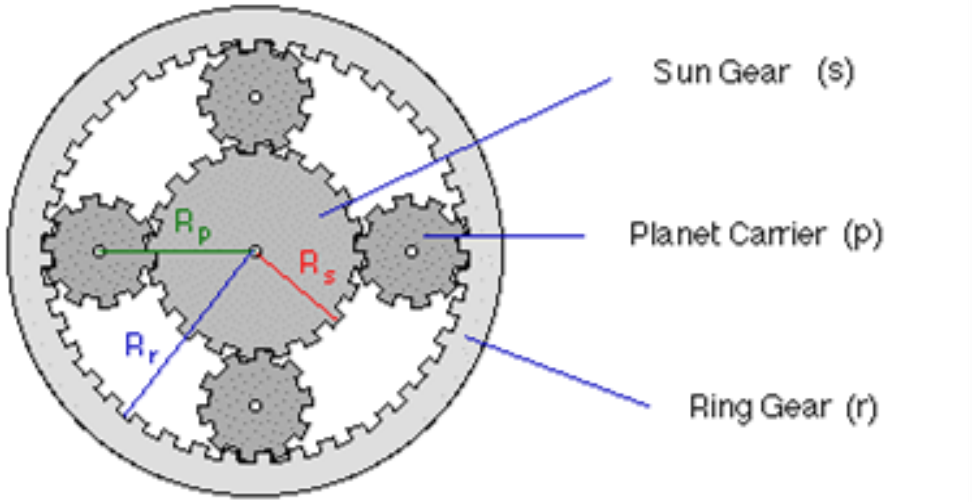
Planetary Gear





3D Printed example (video):

https://www.youtube.com/watch?v=P-Obt-9tZVo



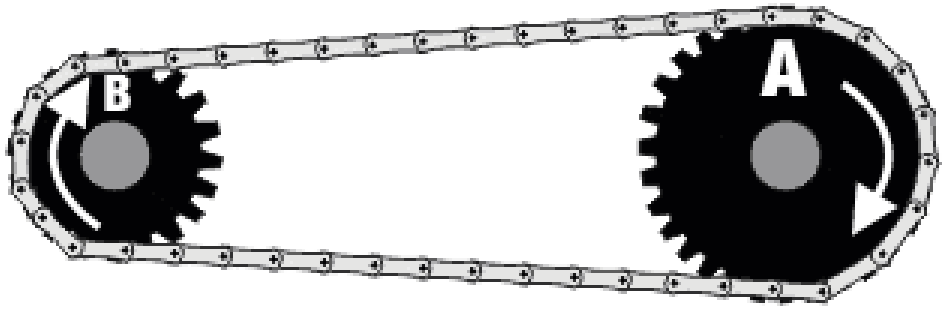
$$2R_p\omega_p = R_s\omega_s + R_r\omega_r$$

where R: Radius
ω: Angular Velocity

Gears

- Differential Gear:
  - http://www.youtube.com/watch?v=vBm-SzO3ggE
  - http://youtu.be/gIGvhvOhLHU
- Planetary Gear:
  - http://www.youtube.com/watch?v=ECljAo1q1RQ
  - http://www.youtube.com/watch?v=acXiebKExQM
  - http://www.youtube.com/watch?v=50uQriU1mCs
- Spur Gear:
  - http://www.youtube.com/watch?v=5QCvONWi4mk
  - http://www.youtube.com/watch?v=H1cfbv7iqsY
- Worm Gear:
  - http://www.youtube.com/watch?v=S3XAeMCeZr0&NR=1

Gear-chain / belt



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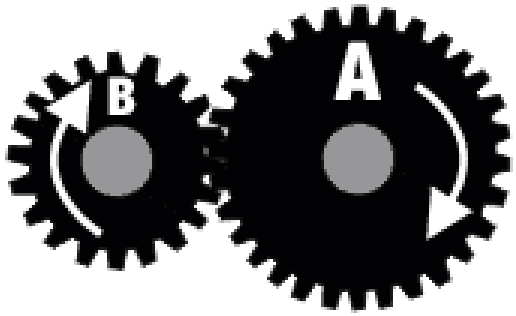


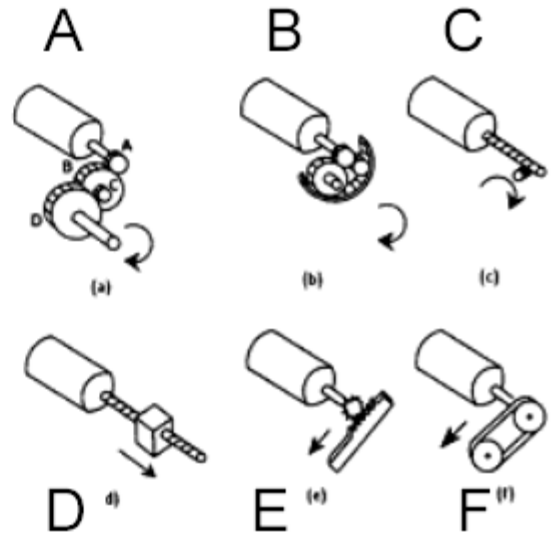
Example Actuator Chain: windshield wiper

https://youtu.be/D_KIOr_TpcM - Taha Emara

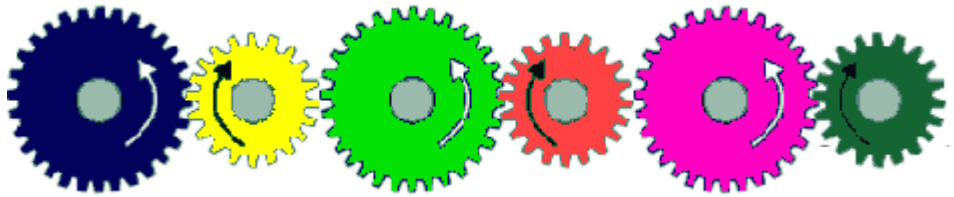
Example Actuator Chain (ii)

Actuator Chain (iii)

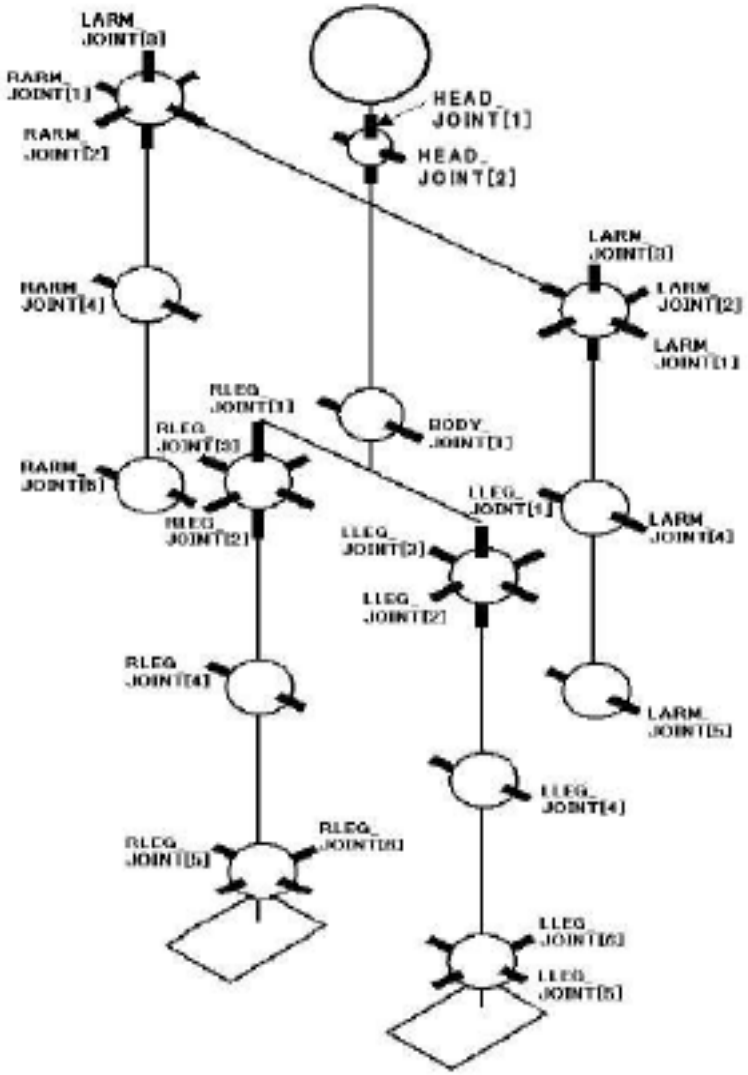
- Can change angle of rotation or direction of rotation: e.g. c
- Can convert rotational motion to linear motion (eg E)
- Can change location of rotational motion (eg a)

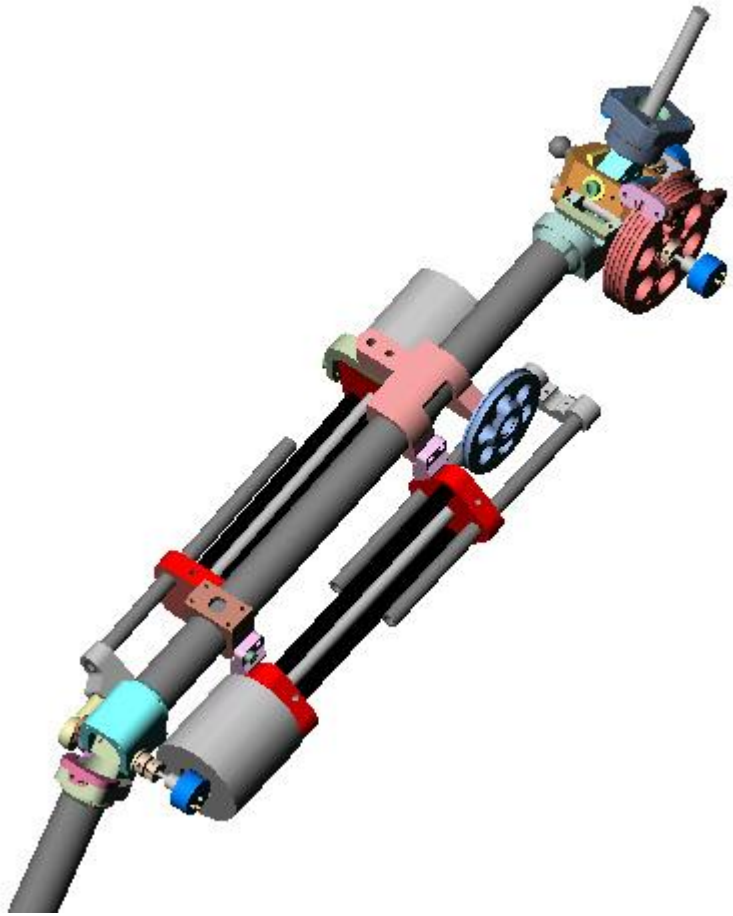


A: spur gear
B: Planetary gears
C: Worm gear
D: Ball screw
E: rack and pinion
F: belt and pulley



Actuator Chain - humanoid

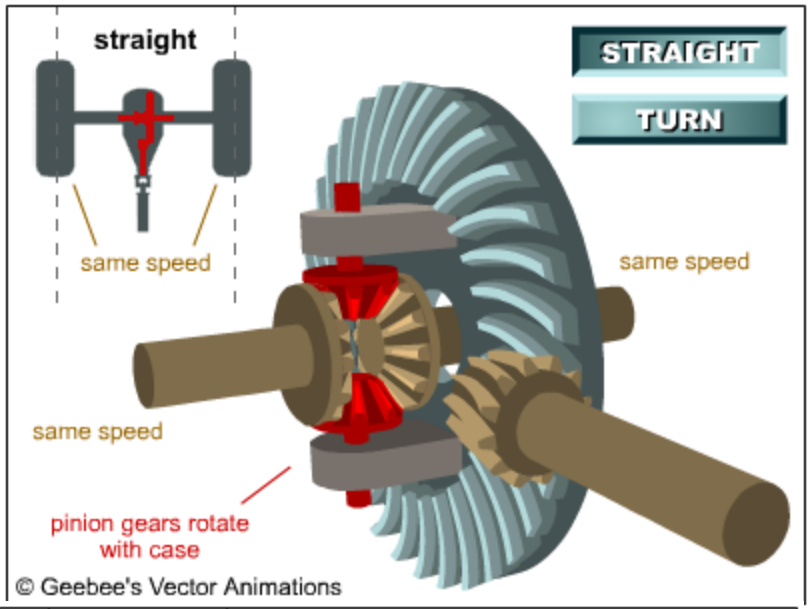


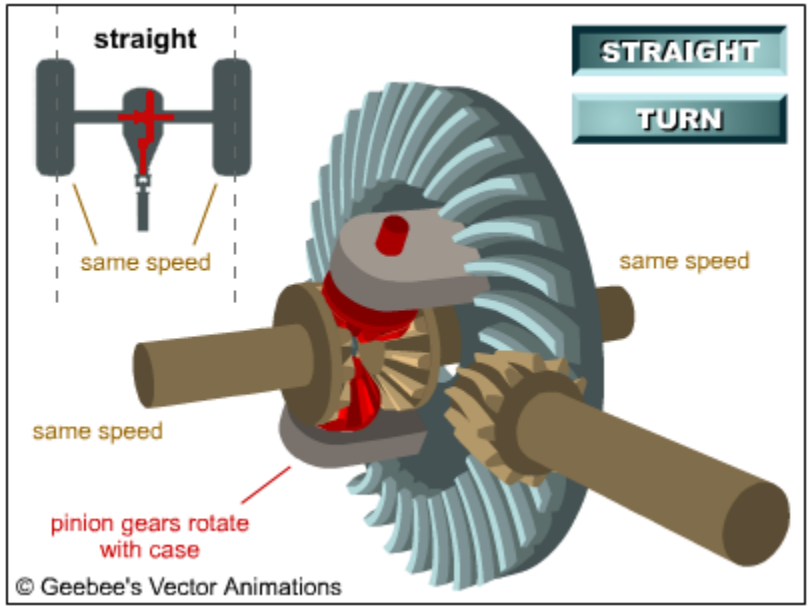


Gear Knowlegde

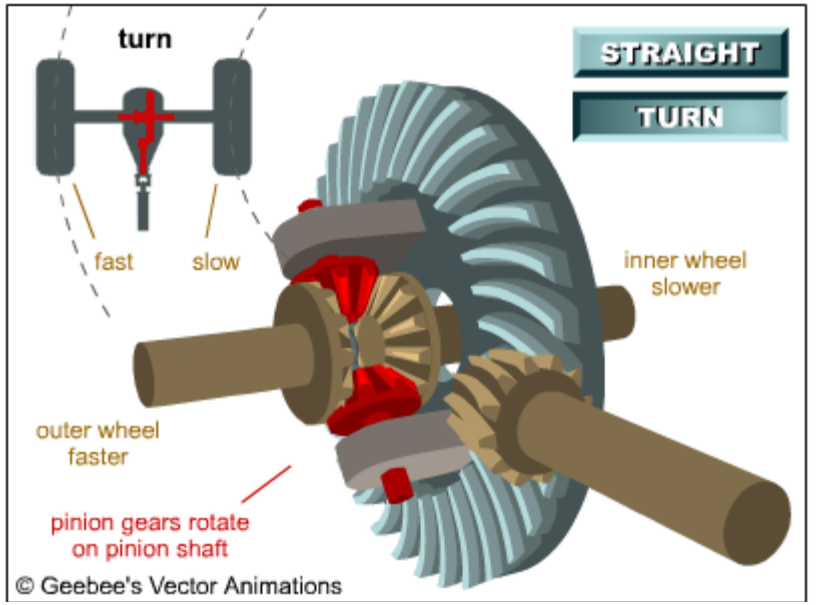
- Backlash
  - Amount of space between an engaging tooth and the tooth space of the mating gear
  - Proportional to lubricant flow (high is good)
  - Inverse to efficiency – heat generation (low is good)
  - Backlash is a non linearity in control (low is good)
- Other project considerations
  - Noise
  - Durability (life cycle time)
  - Breakdown
  - Friction

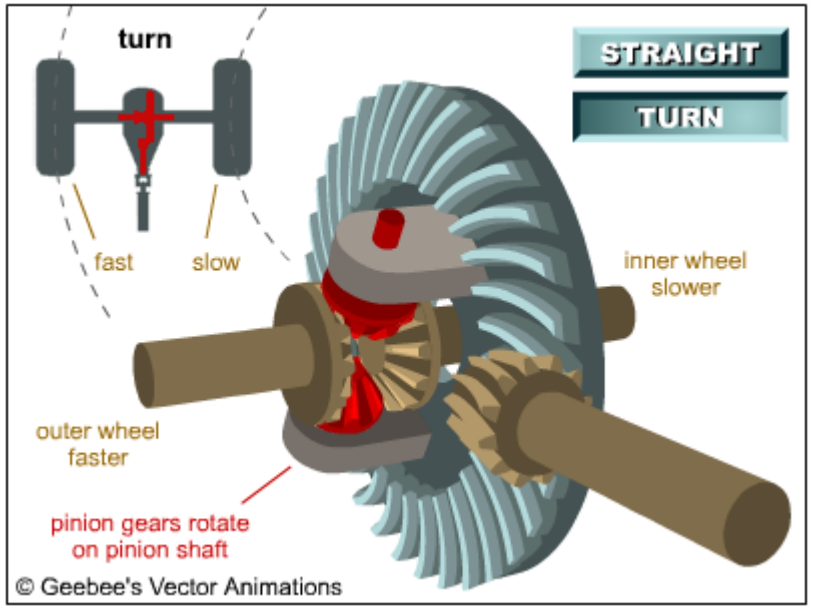
Differential – mechanical power trading





http://auto.howstuffworks.com/differential3.htm



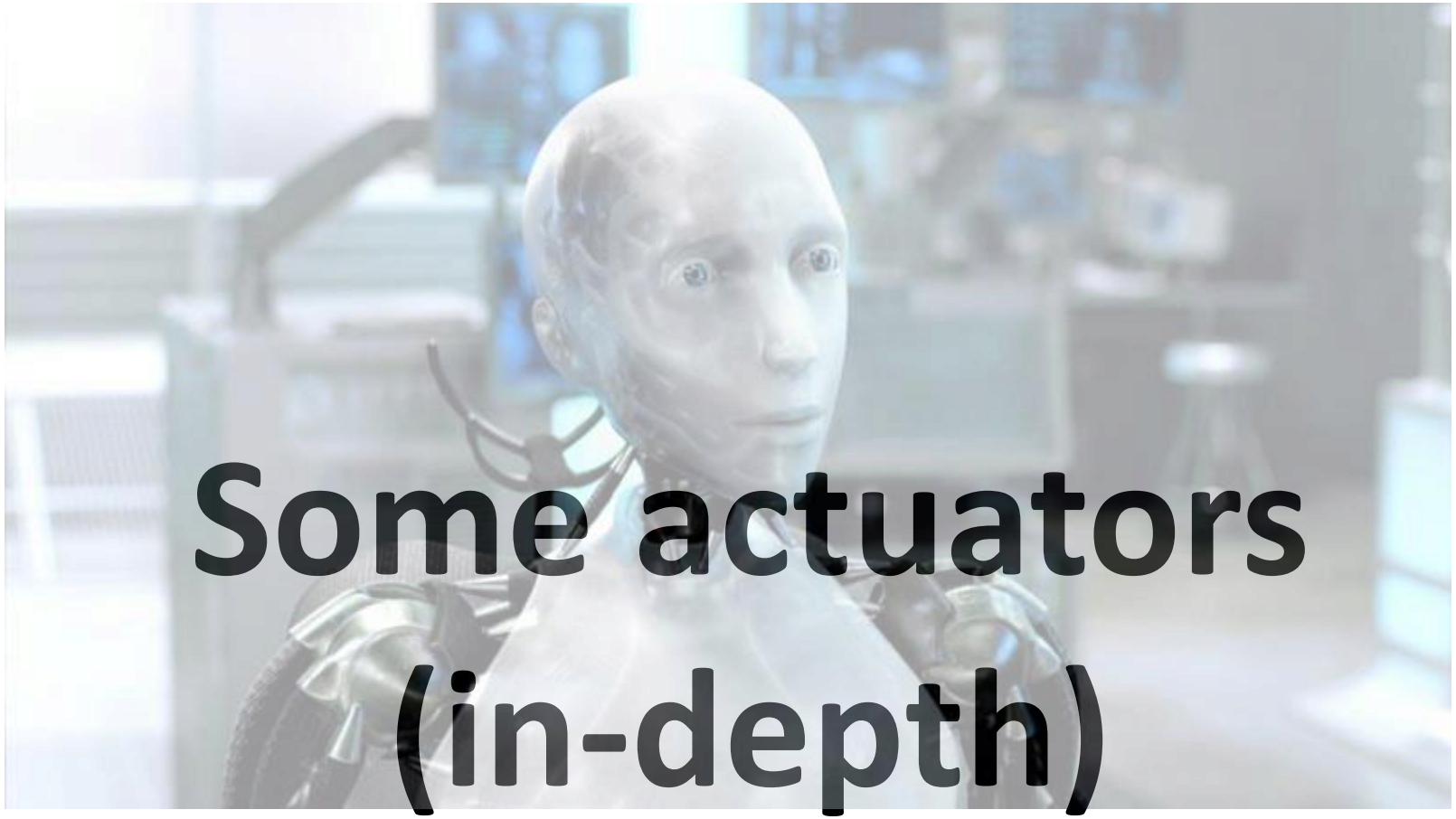


Cardan & Joints

http://www.youtube.com/watch?v=Dh5C4e4exhM

http://www.youtube.com/watch?v=TGvKS4bHgTk&feature=

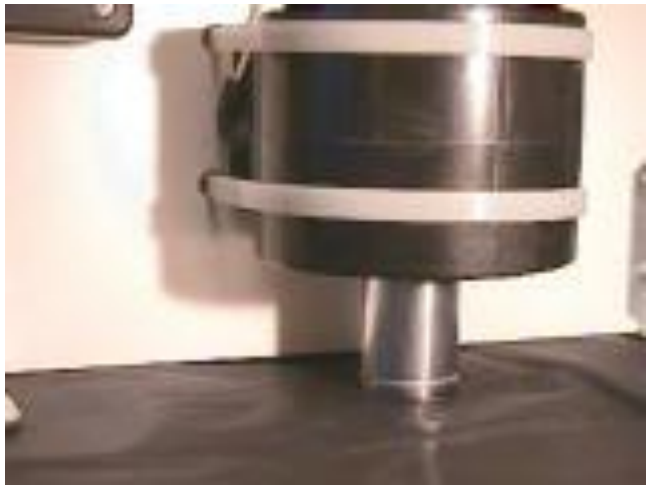
http://www.youtube.com/watch?v=R-NzQ21i-98

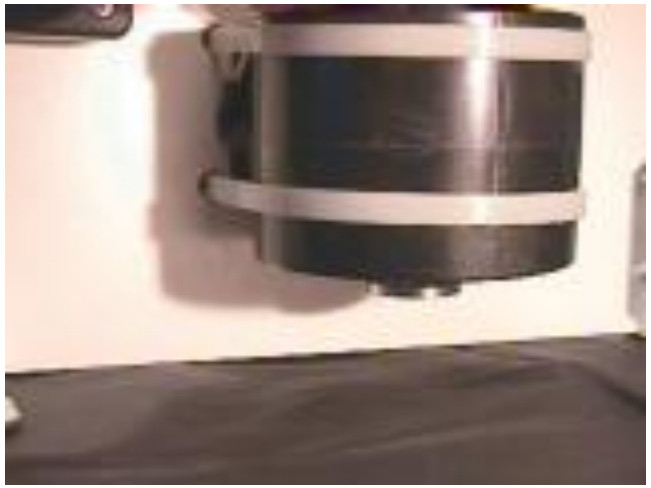


Some actuators (in-depth)

Solenoid Actuator

- Solenoid – electro magnet with air core
  - Simplest electric actuator
  - When energized, tends to minimize magnetic reluctance
  - Drop (off) / pull (on) - *and 50 % of the time on (PWM) ???*
  - Example: Kicker in robotic soccer

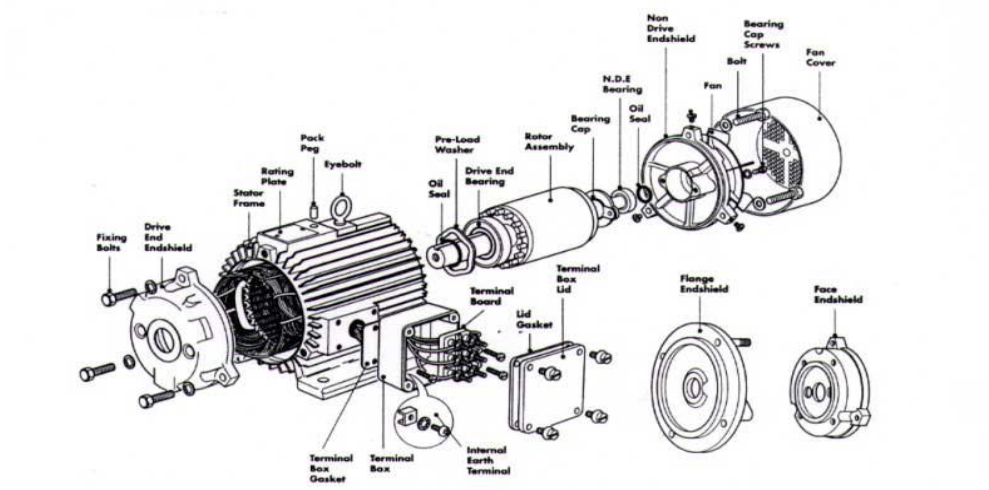


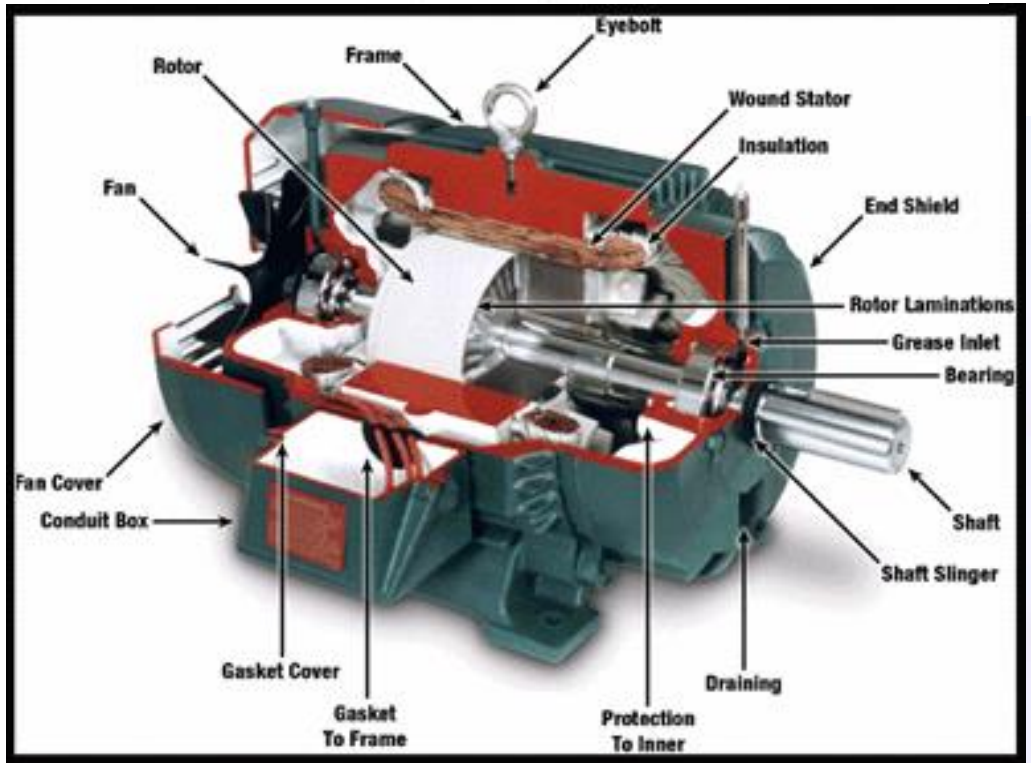


Motor Technologies

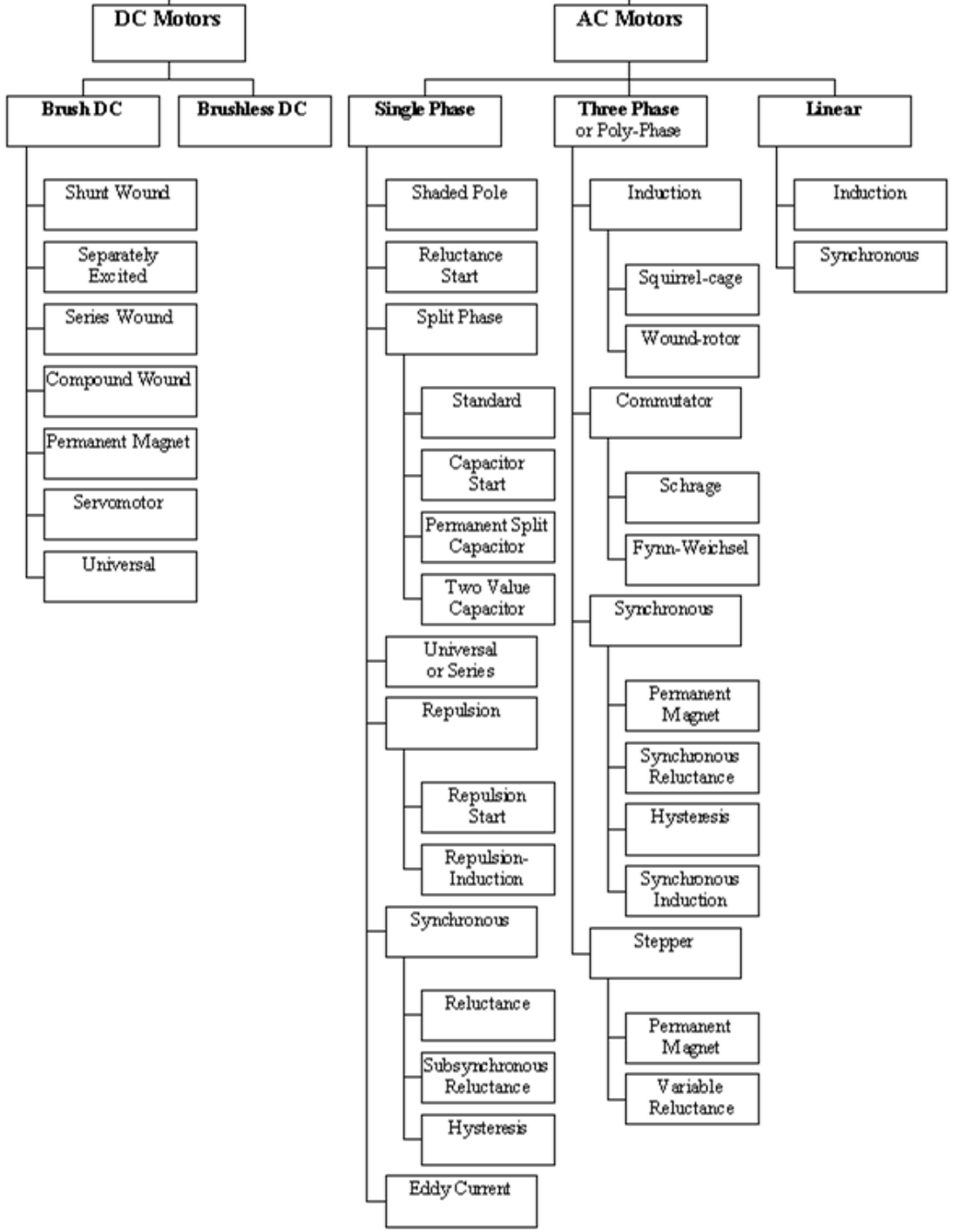
- AC Motors
  - synchronous, induction 1,3 phase, ...
- DC Motors
  - Perm Magnet/winding, brushless DC Motors
  - Piezo/Ultra Sonic Motors
- Stepper Motors

“World of electrical motors”



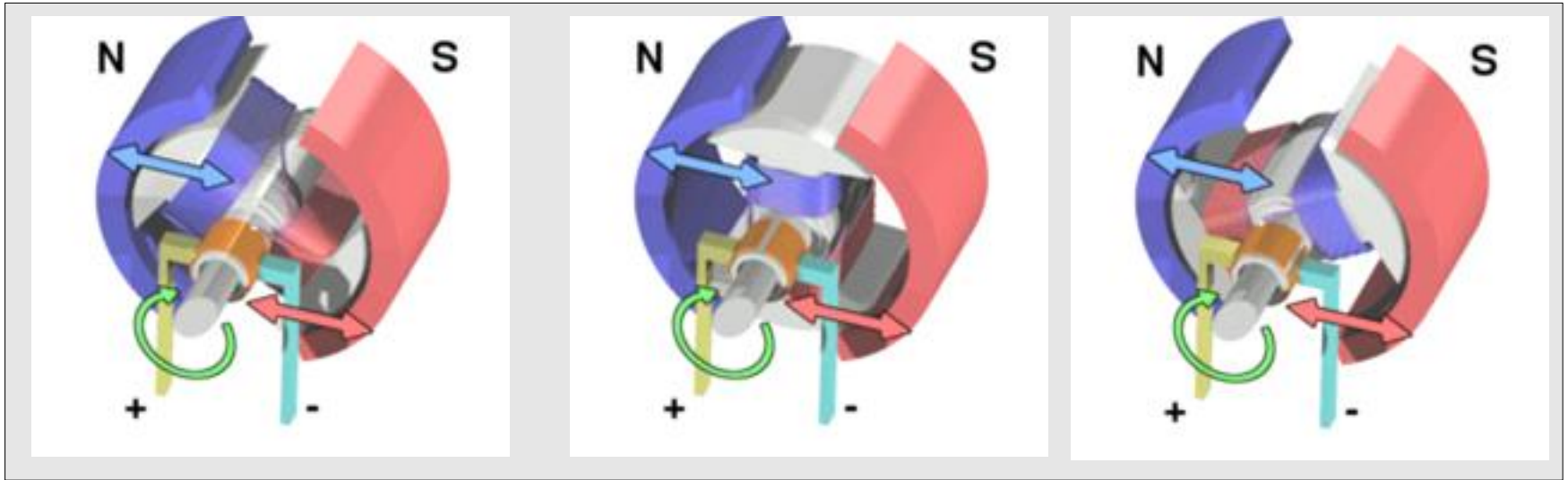


“World of electrical motors”



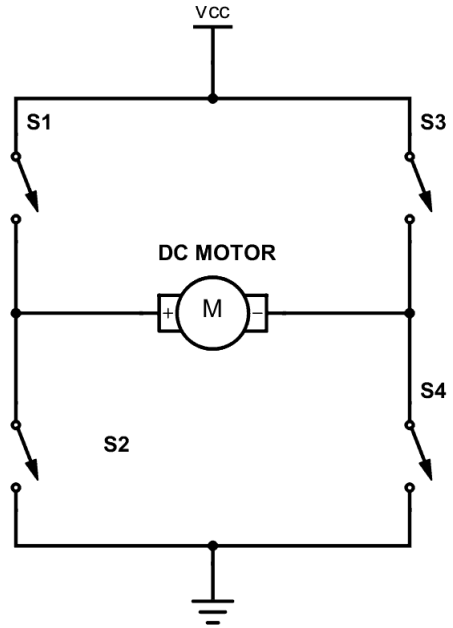
DC Motor

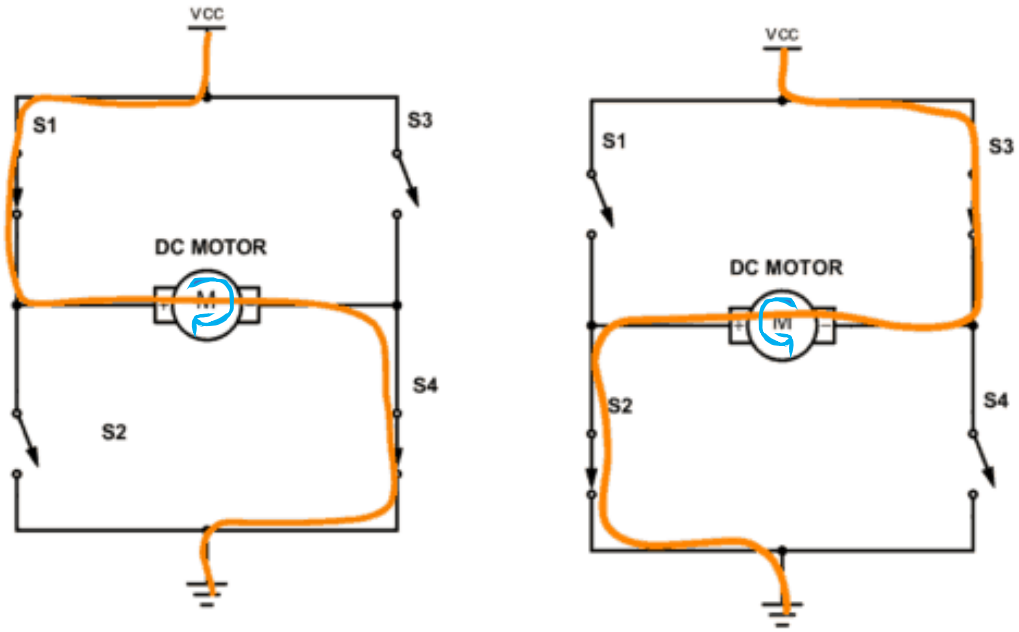
- Conventional brushed DC motor
  - Permanent magnets on the stator
  - Mechanical brushes on the rotor
  - Currents on the rotor drive the shaft to always rotate
- Brushless DC Motor
  - Rotor has permanent magnets
  - Stator windings are commutated by external electronics to keep motion
  - For perfect drive, needs position sensing in the shaft
  - (has same points in common with stepper motors)



Drive Electronics – H Bridge

- H-brigde
  - PWM (AC or DC)
  - 2 way
  - …
- S1..S4 are very high speed electronic switches
- PWM ~ 20 kHz
- Input for a servo drive simply direction and analogue speed

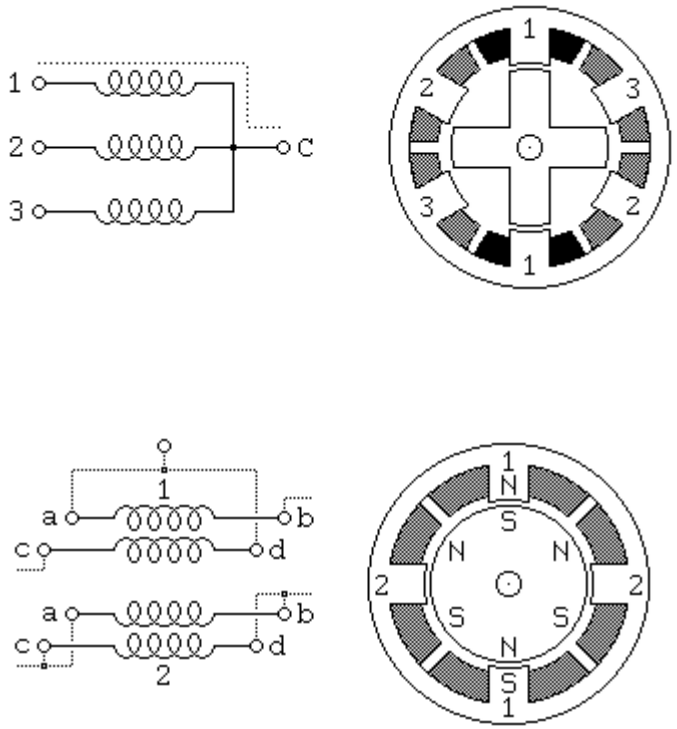




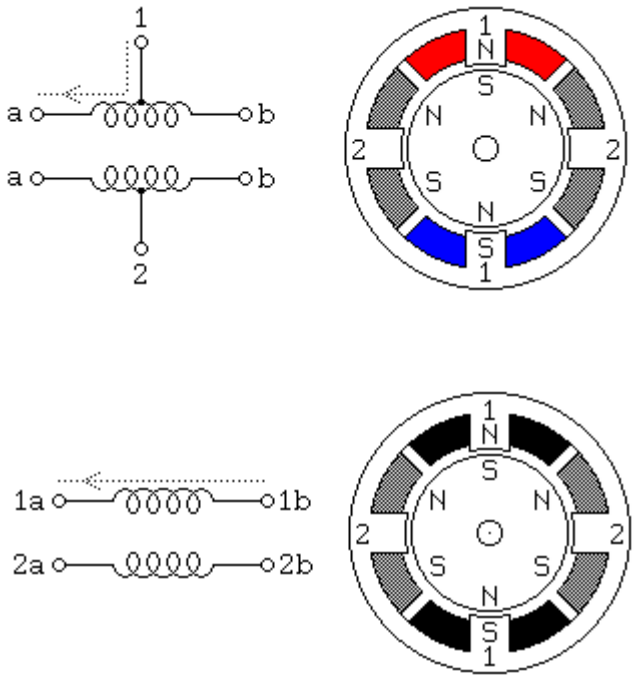
https://www.build-electronic-circuits.com/h-bridge/

Stepper

- Unipolar

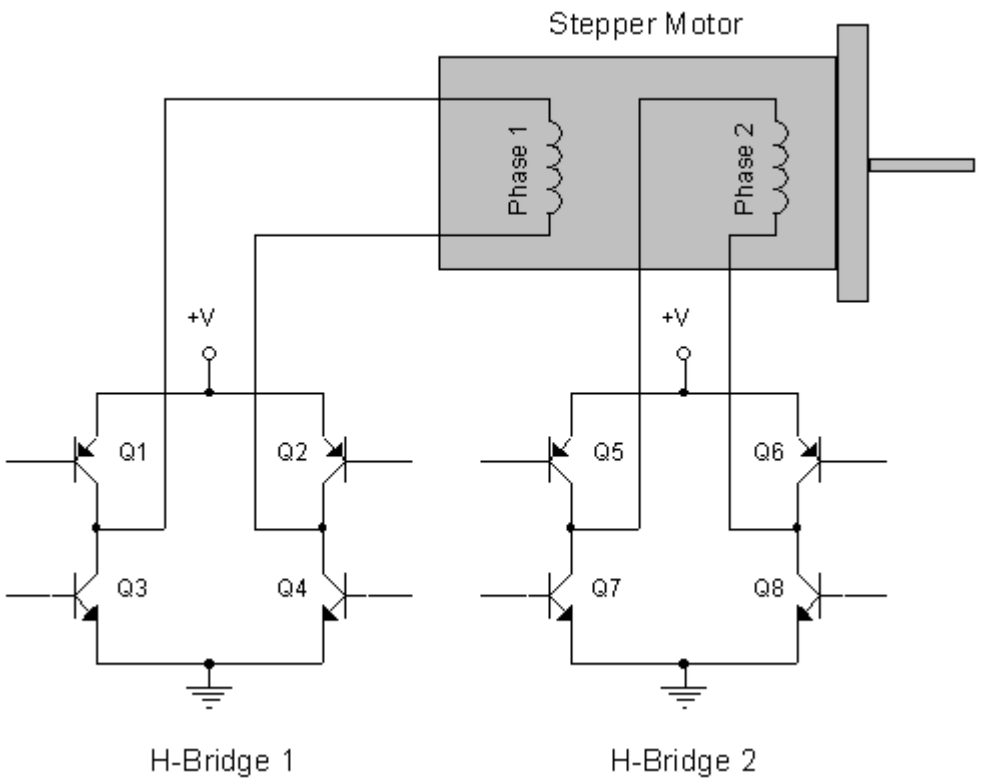


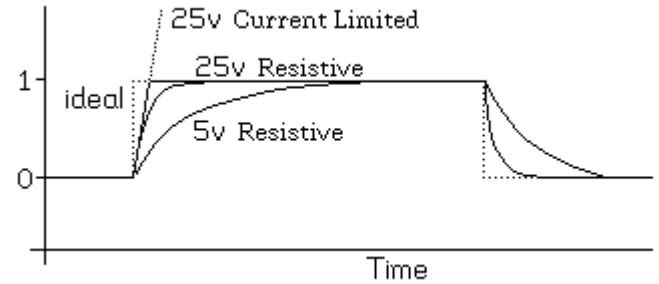
- Bipolar

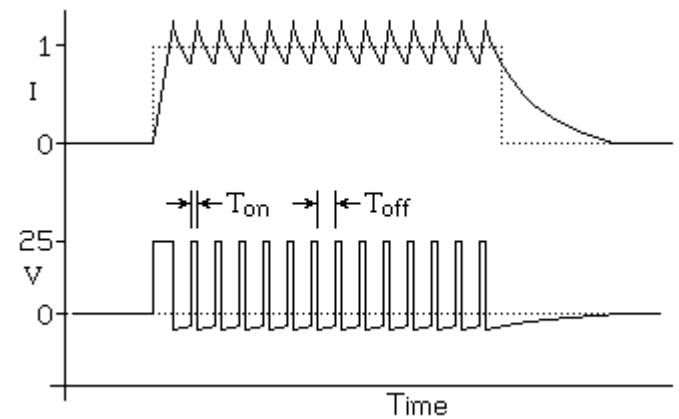


http://www.cs.uiowa.edu/~jones/step/

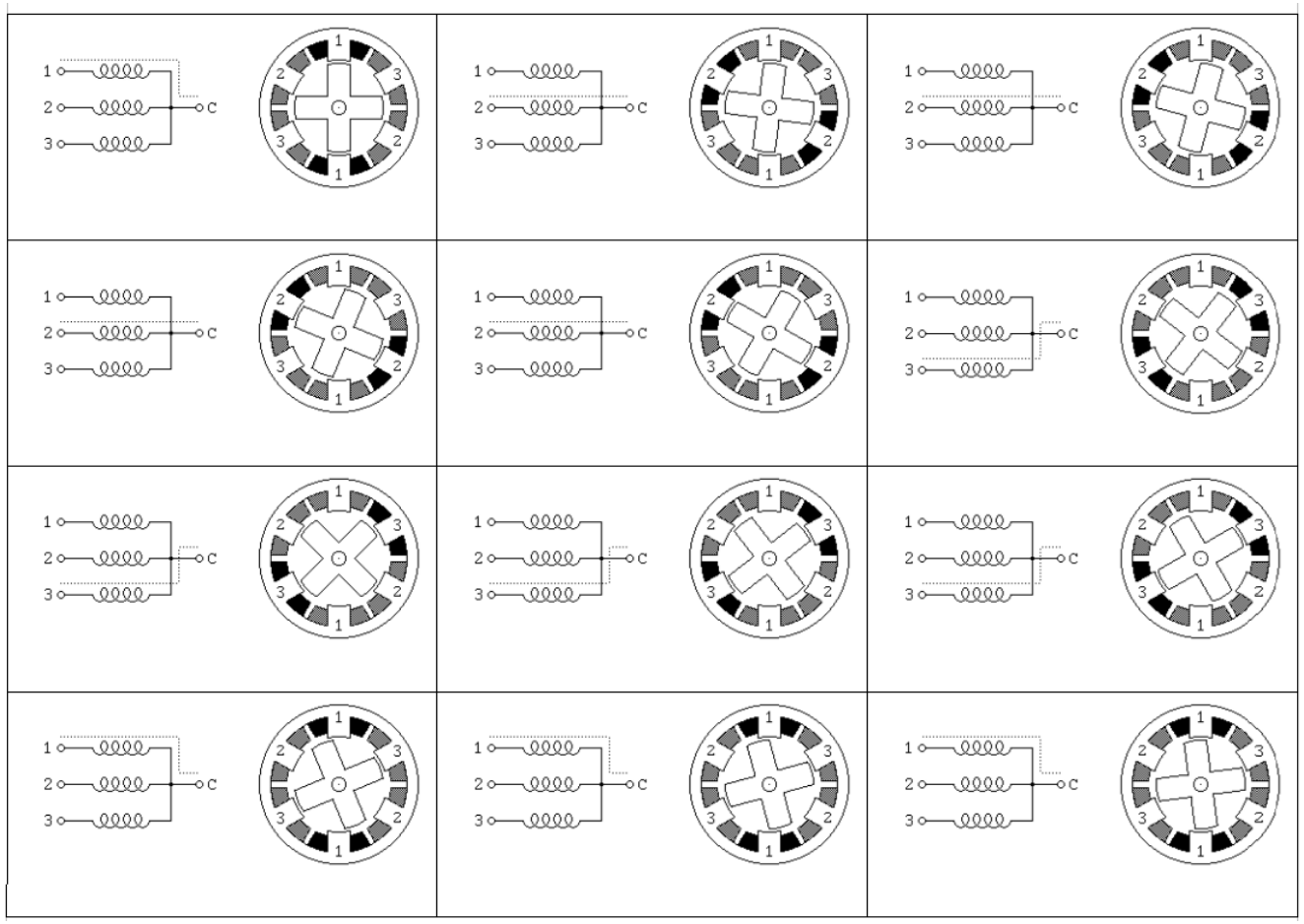
Stepper (ii) - electronics





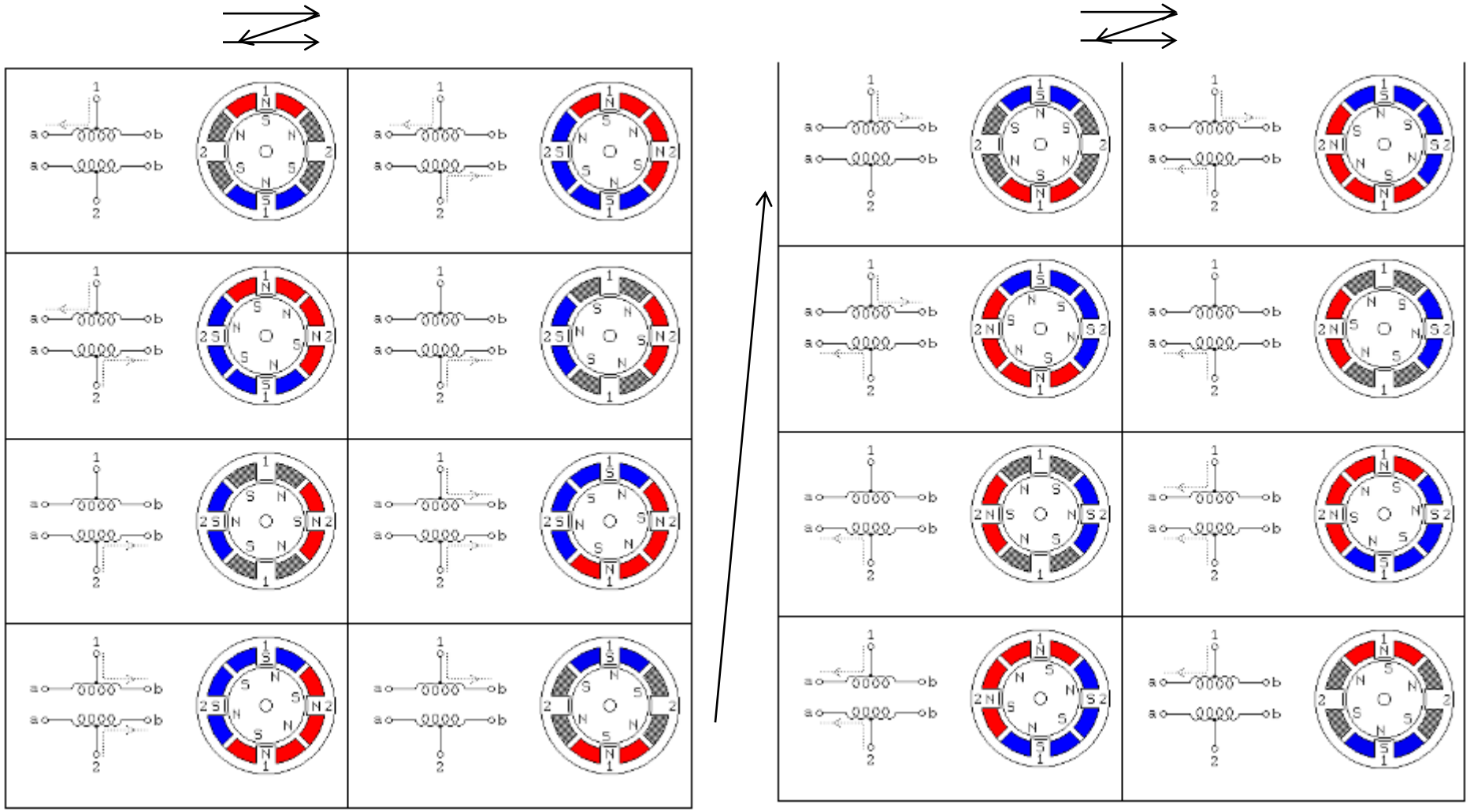


Stepper (iii) – unipolar sequence



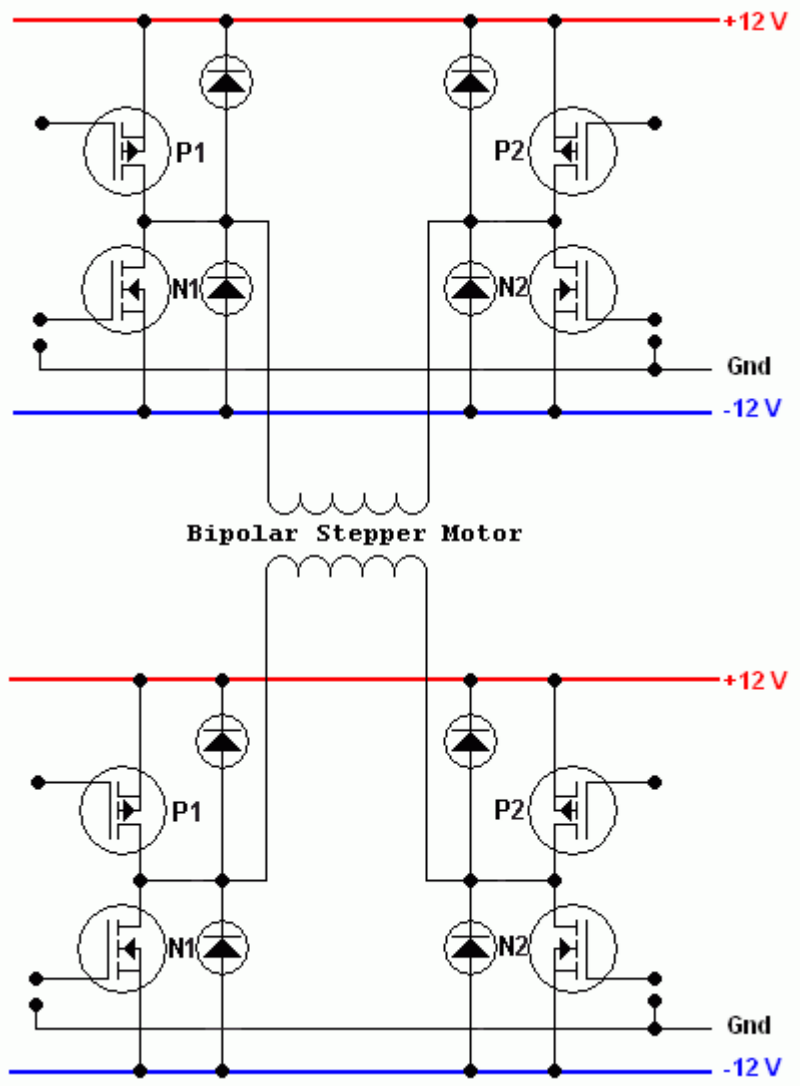
http://www.cs.uiowa.edu/~jones/step/

Stepper (iv) – bipolar sequence



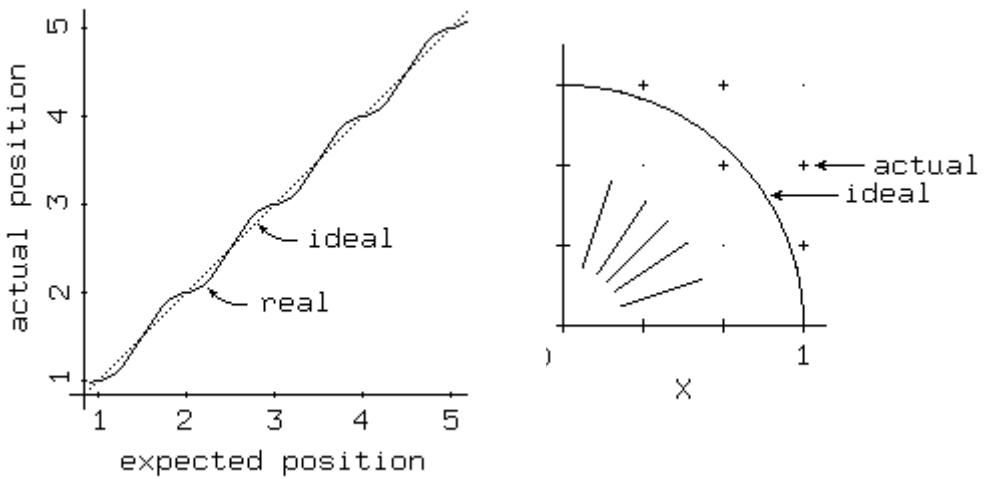
http://www.cs.uiowa.edu/~jones/step/

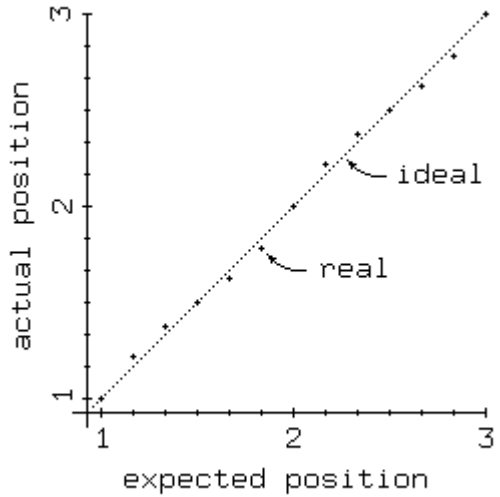
Driving a bipolar Stepper Motor



Microstepping

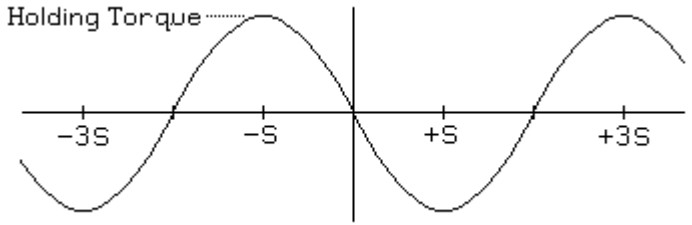
MicroStep

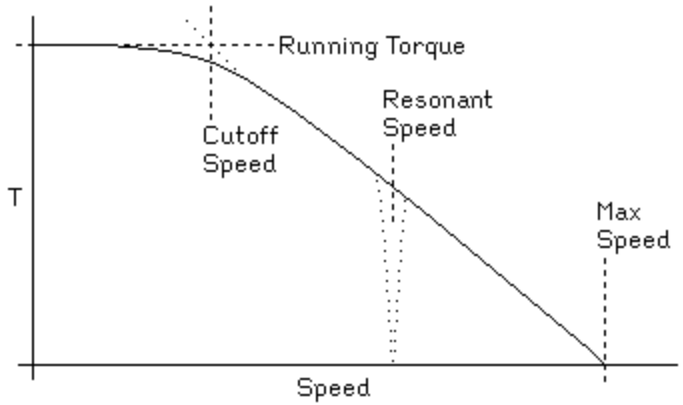


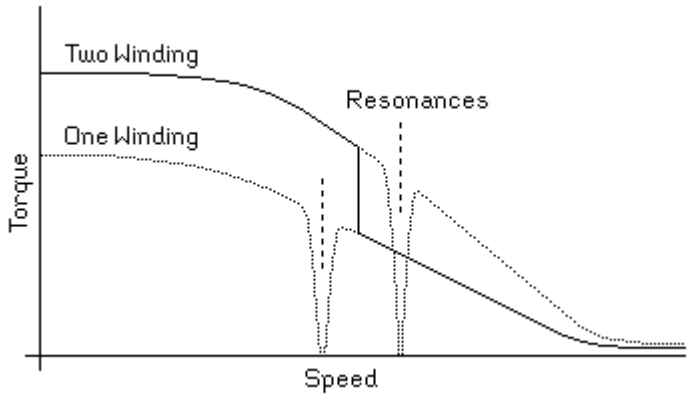


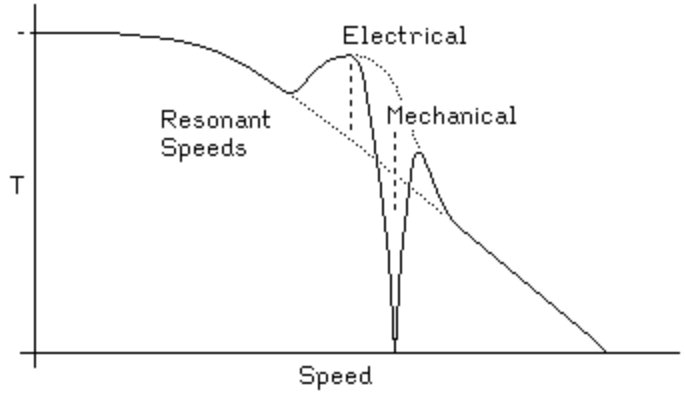
Stepper dynamics

- Poles & Static force & Dynamics...



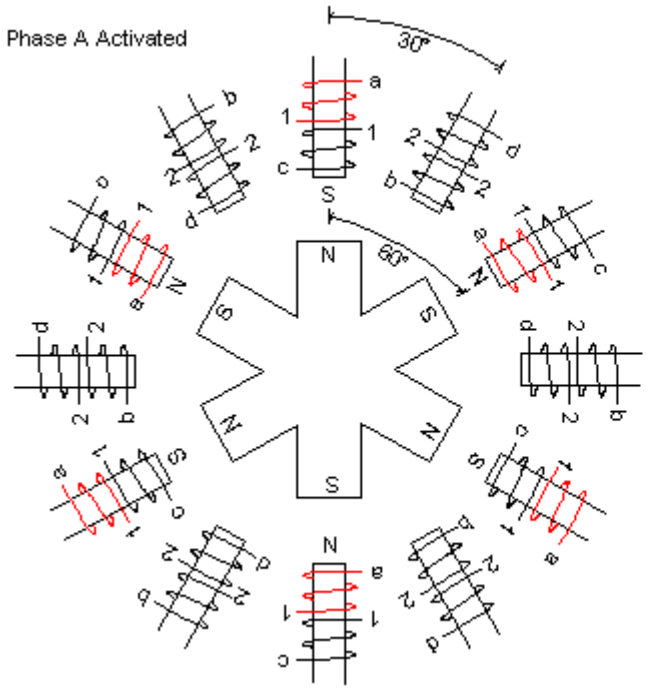


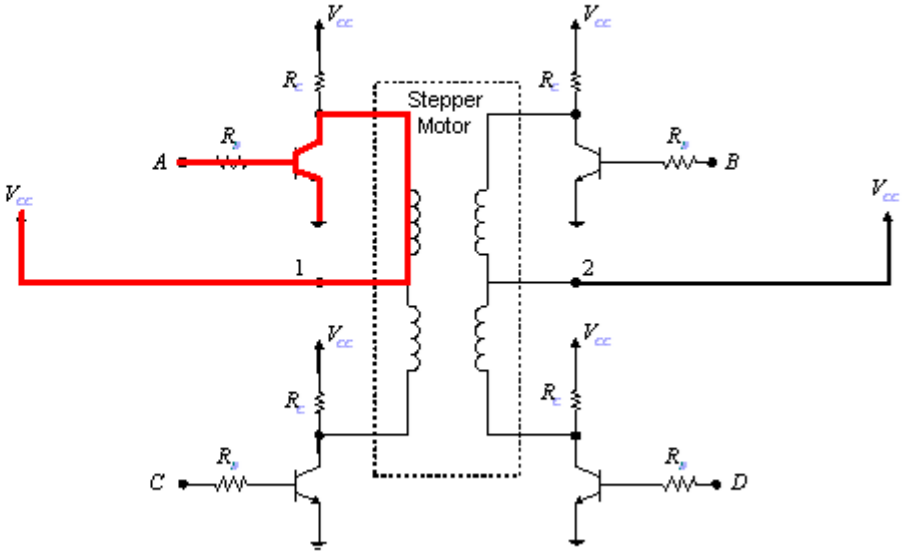




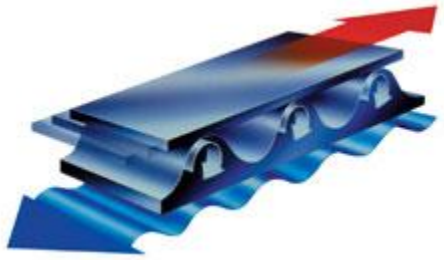
Stepper (animation)

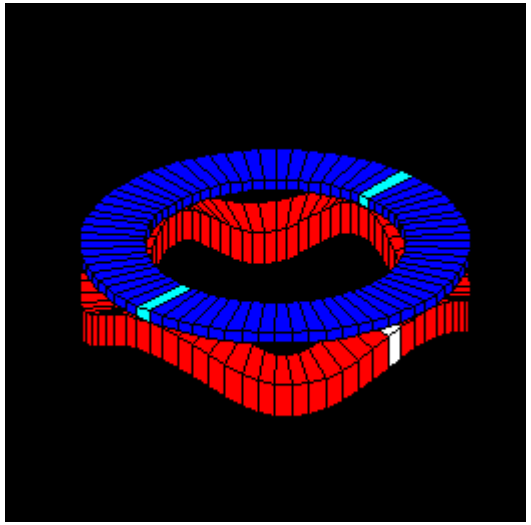
http://www.electric-motors-price.info/images/stepper-motor.jpg





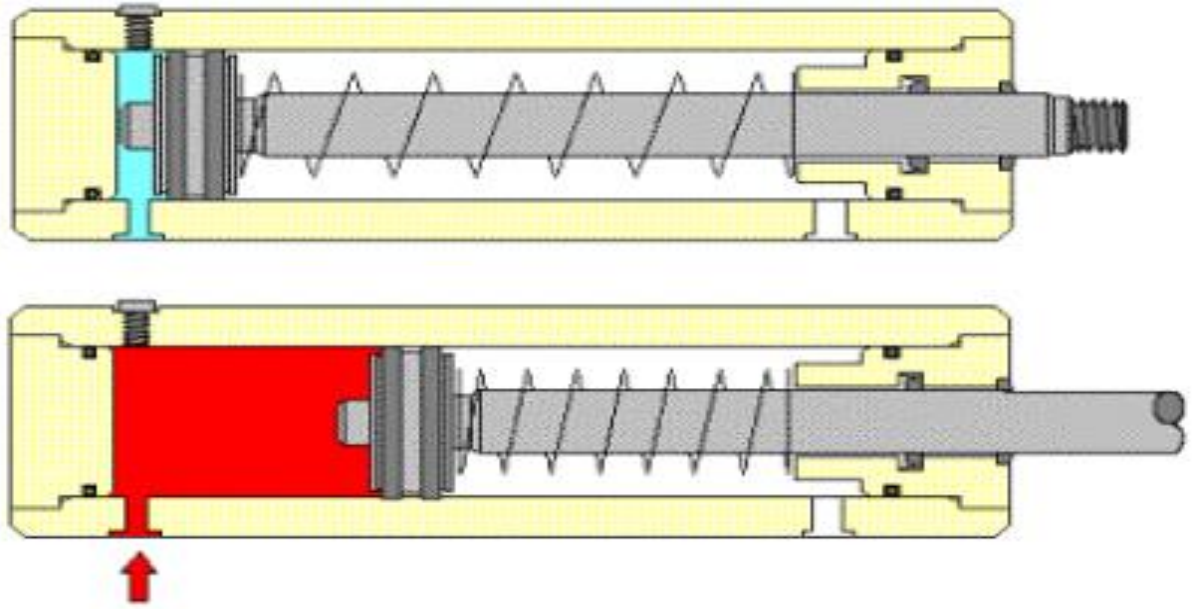
Ultra Sonic Motor (*piezo*)





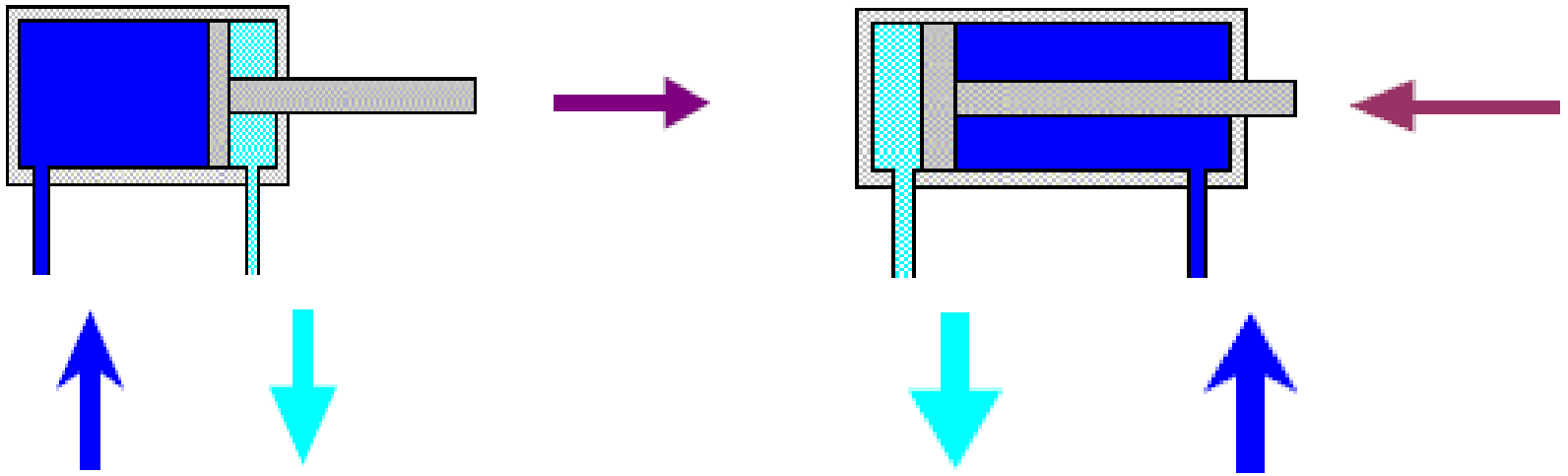
Pneumatic / Hydraulic Linear Actuator

- Single effect (+ spring)

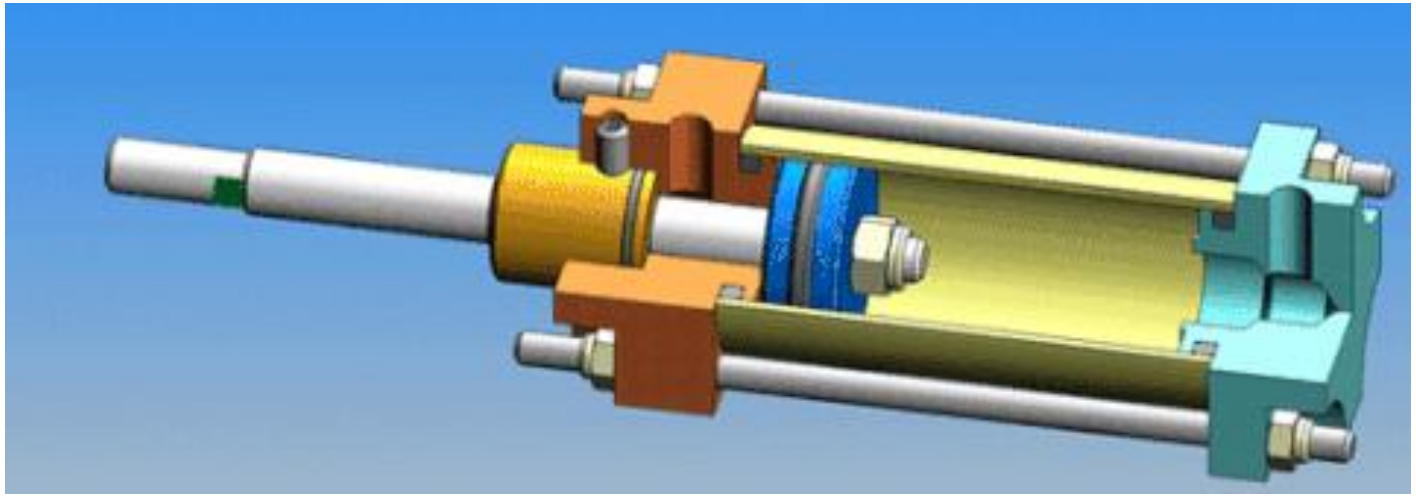


Pneumatic / Hydraulic Linear Actuator (ii)

- Double Effect



Pneumatic / Hydraulic Linear Actuator (iii)

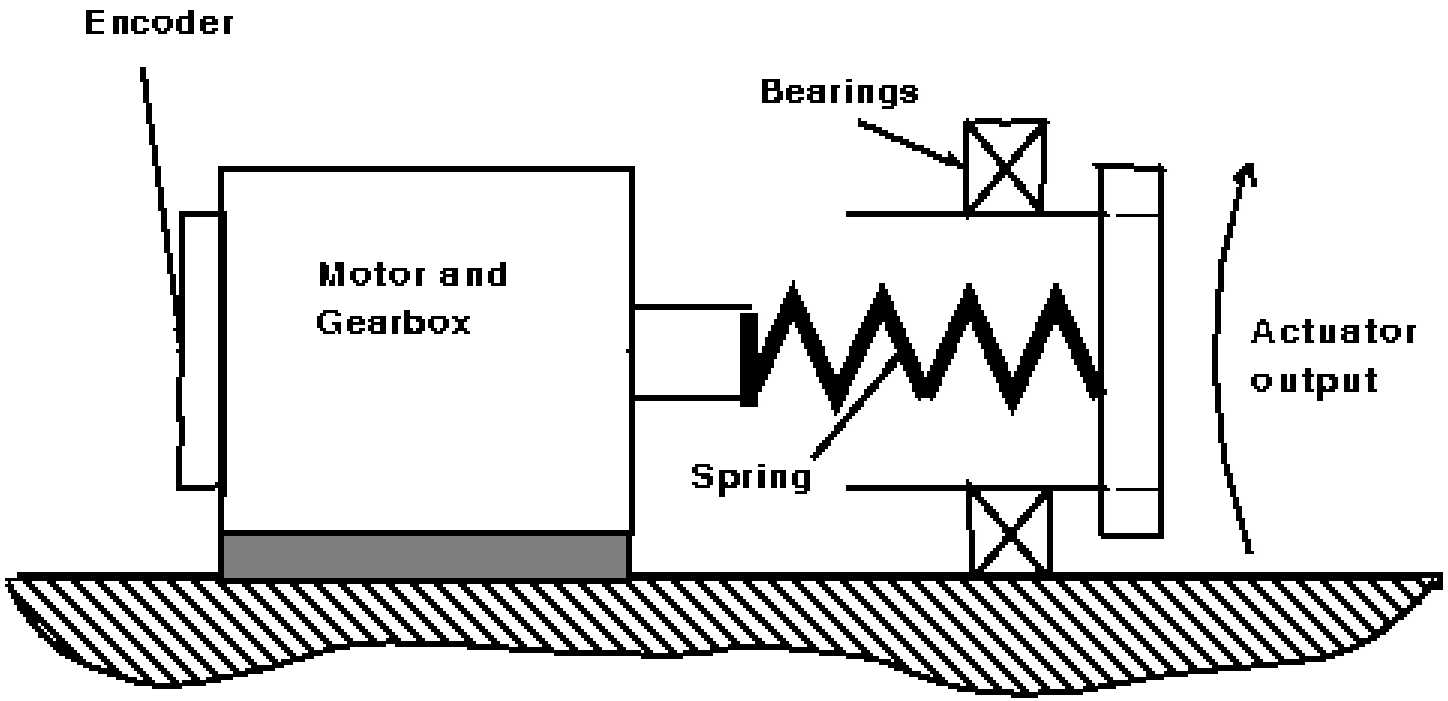


https://gifer.com/en/Ls6U

Why Pneumatic/Hidraulic ?

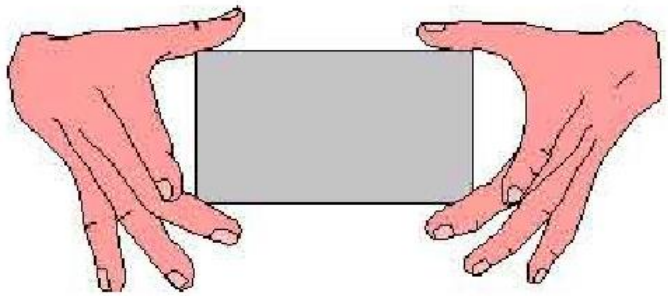
- Hydraulic
  - High stress (20 MPa) / High power density (600 W/Kg)
  - Moderate-high speeds (although inefficient at high speeds)
- Pneumatic
  - Moderate stress (0.7 MPa) / High power density (200 W/Kg)
  - High efficiency (~90%)
  - Fast but settling time (compressible gas, control difficulty)
- Both:
  - Bilateral actuation,
  - High instantaneous power delivery
  - Constant force advancements
  - …

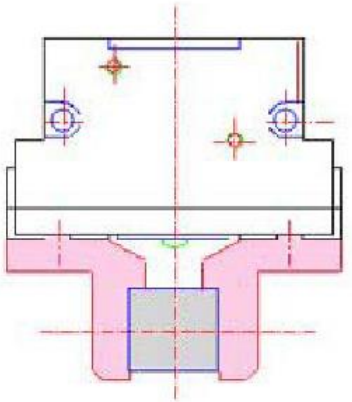
Series elastic actuactor

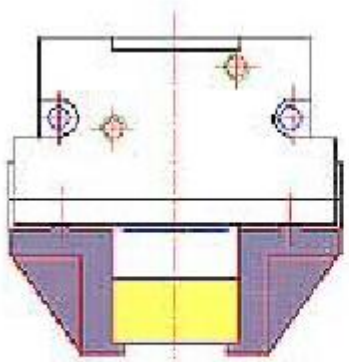


End Effectors

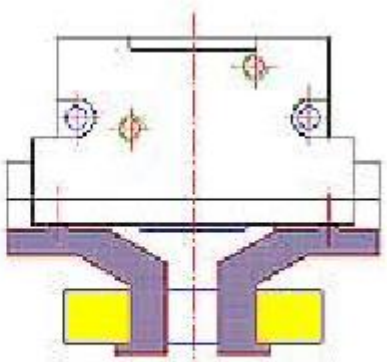
Grippers are also chain(s) of actuator(s)



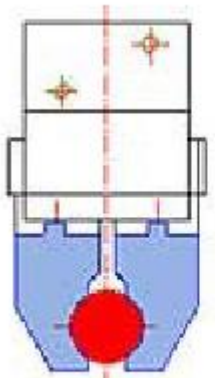




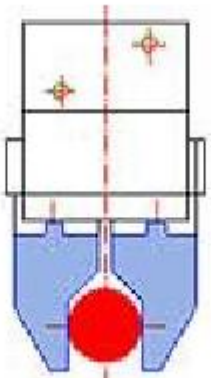
External Grip
(Closed)



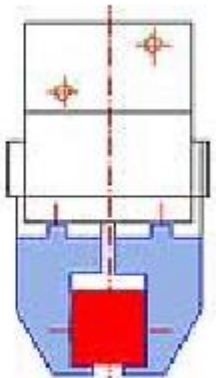
Internal Grip
(open)



Encompassing



Friction



Retention

“Effector” – arm – complex actuator chain

Fig. 6: One of *Pneuman’s* robotic arms.

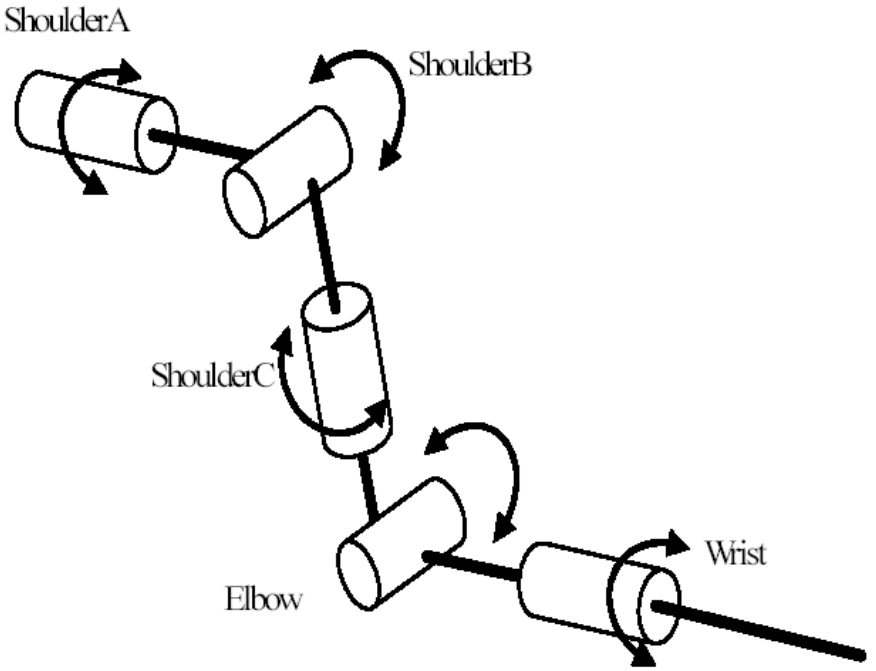
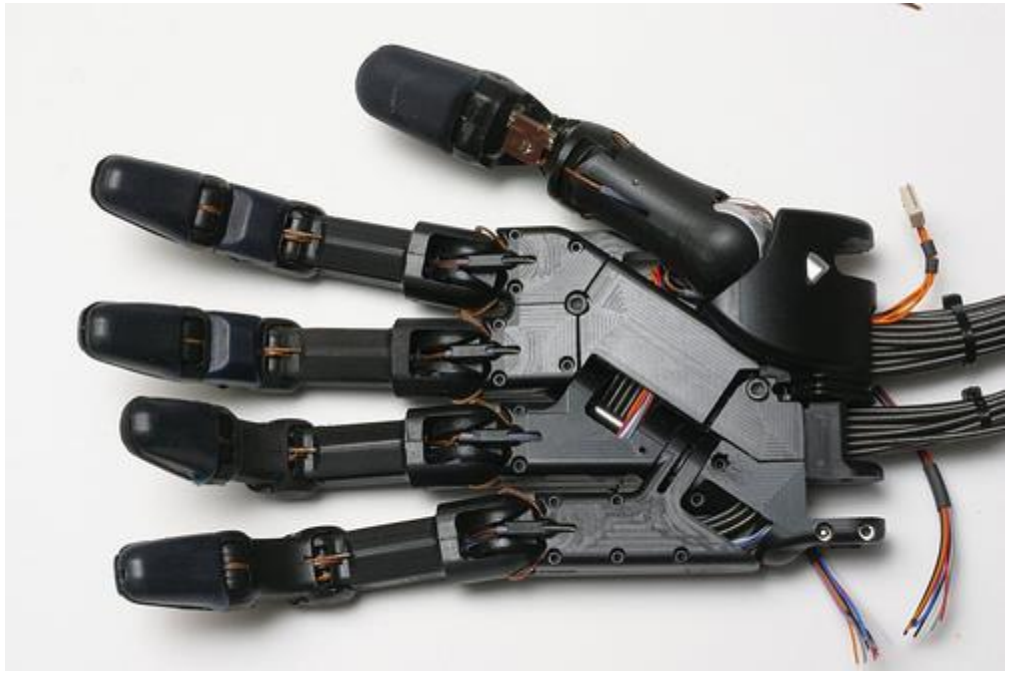


Figure 2-11: Kinematic representation of *Pneuman’s* arms.

Robotic Hand – not simple...



http://en.wikibooks.org/wiki/File:Shadowhand.jpg

Many actuators per robot

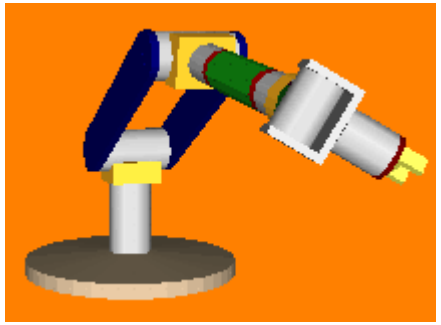
- Robot “Kaka”

Kinematics & Dynamics

Degrees of Freedom

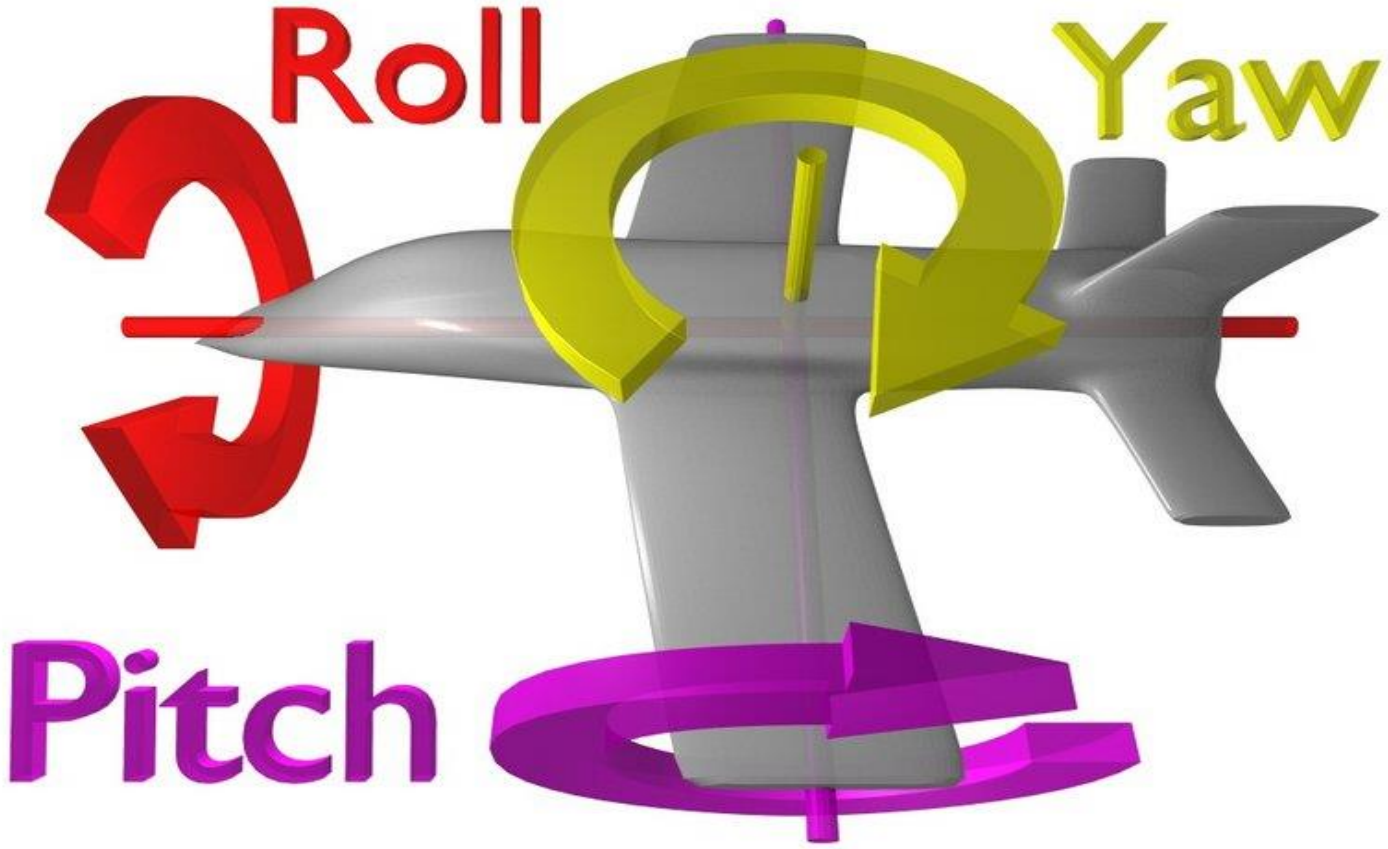
Mechanical engineering, aeronautical engineering, and robotics, the six DOFs of a rigid body have special names:
This is a typical robot arm which has 7 DOF (including surge at the end of the arm).

1. Moving up and down (heaving);
2. Moving left and right (swaying);
3. Moving forward and backward (surging);
4. Tilting up and down (pitching);
5. Turning left and right (yawing);
6. Tilting side to side (rolling).



Obs: Euler angles!!!

Degrees of Freedom (ii)



2D Robot dynamic model

- State Vector:

$$X_r^T = [x_r \; y_r \; \theta_r \; v_{rt} \; v_{rn} \; \omega_r]$$

- Dinamics:

$$\dot{x}_r = v_{rt} \cos\theta_r - v_{rn} \sin\theta_r$$

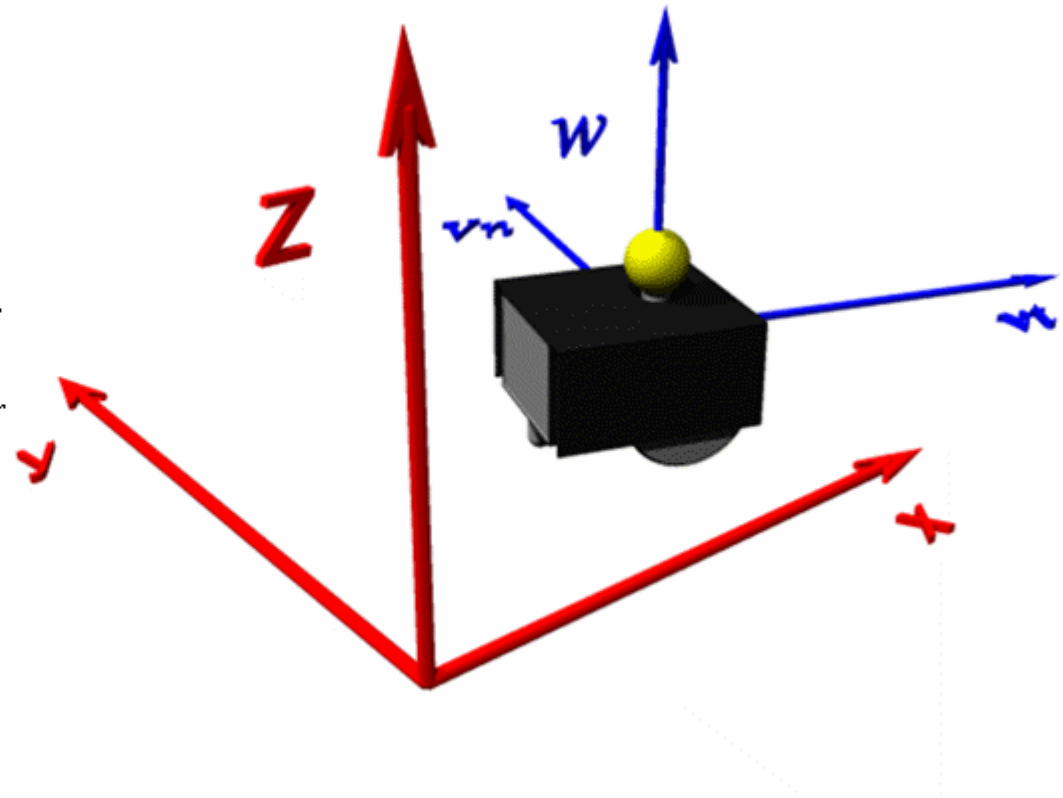
$$\dot{y}_r = v_{rt} \sin\theta_r + v_{rn} \cos\theta_r$$

$$\dot{\theta}_r = \omega_r$$

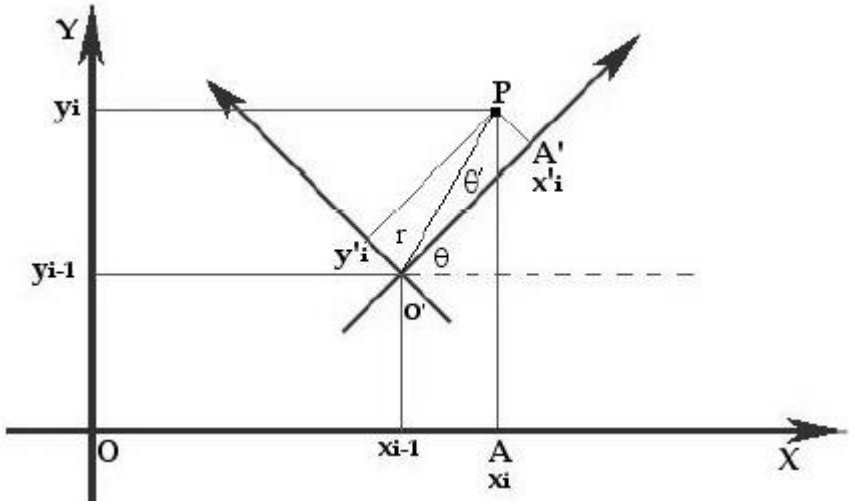
$$\dot{v}_{rt} = \alpha\left(v_{ref} - v_{rt}\right)$$

$$\dot{v}_{rn} = 0$$

$$\dot{\omega}_r = \gamma\left(\omega_{ref} - \omega_r\right)$$



2D movement



$$x_i = \overline{OA} = x_{i-1} + r*\cos(\theta+\theta') = x_{i-1} + r*\cos(\theta)*\cos(\theta) - r*\sin(\theta)*\sin(\theta) \quad (1)$$

$$y_i = \overline{AP} = y_{i-1} + r*\sin(\theta+\theta') = y_{i-1} + r*\sin(\theta)*\cos(\theta') + r*\cos(\theta)*\sin(\theta') \quad (2)$$

$$x_i' = \overline{O'A} = r*\cos(\theta') . \quad (3)$$

$$y_i' = \overline{A'P} = r*\sin(\theta') . \quad (4)$$

$$x_i = x_i'\cos(\theta) - y_i'\sin(\theta) + x_{i-1} . \quad (5)$$

$$y_i = x_i'\sin(\theta) + y_i'\cos(\theta) + y_{i-1} . \quad (6)$$

$$\theta_i = \theta_I' + \theta_{i-1} . \quad (7)$$

$$x_i = d_i*\cos(\theta_i) + x_{i-1} . \quad (8)$$

$$y_i = d_i*\sin(\theta_i) + y_{i-1} . \quad (9)$$

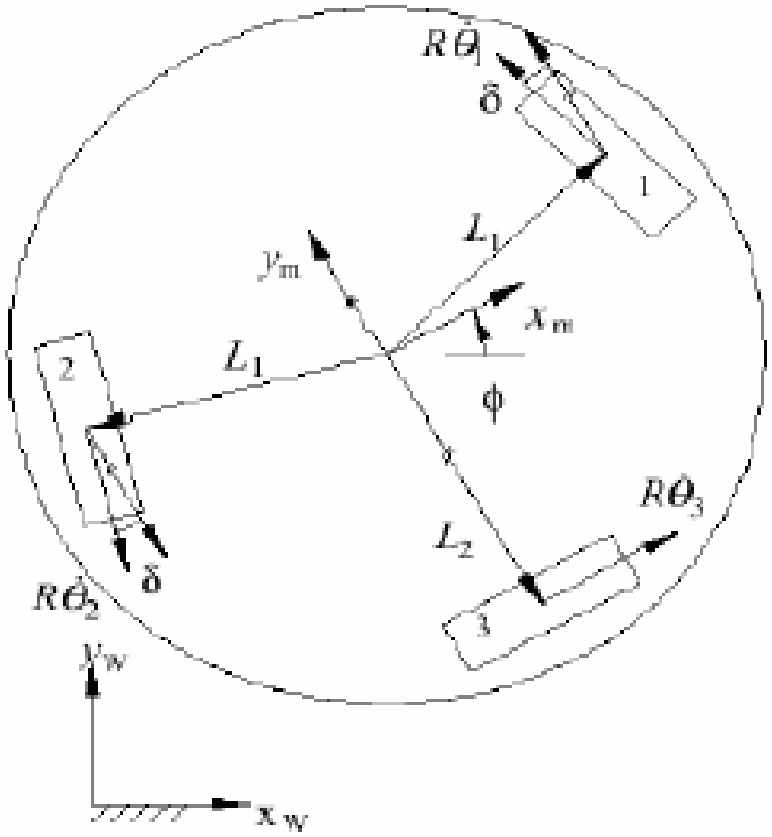
Simulation of Mobile Robots in Virtual Environments
Jesús Savage, Emmanuel Hernández, Gabriel Vázquez, Humberto Espinosa, Edna Márquez

Position: $x(t) = a_0 + a_1t + a_2t^2 + a_3t^3$.

Speed: $\frac{dx(t)}{dt} = a_1 + 2a_2t + 3a_3t^2$.

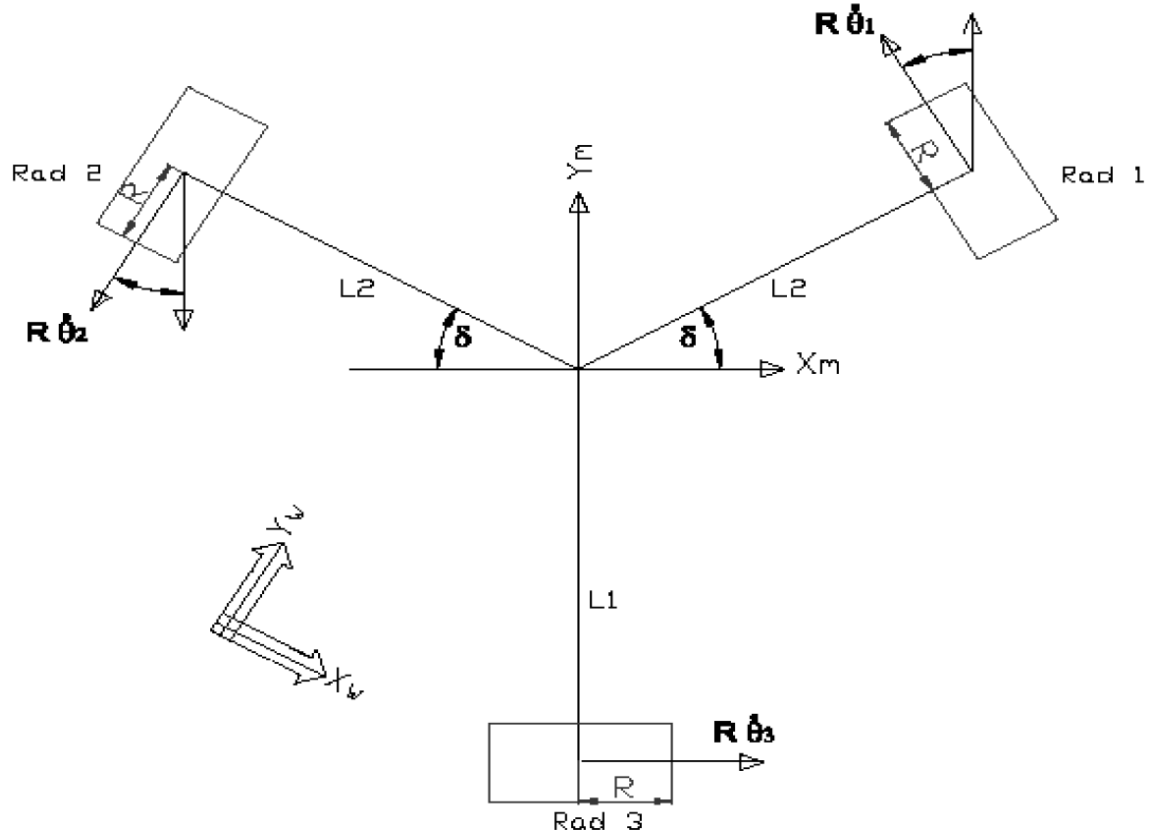
Acceleration: $\frac{dx(t)^2}{dt^2} = 2a_2 + 6a_3t$.

Omniwheels



$$\begin{Bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \end{Bmatrix} = \frac{1}{R} \begin{bmatrix} -\sin(\delta) & -\cos(\delta) & L_1 \\ -\sin(\delta) & \cos(\delta) & L_1 \\ 1 & 0 & L_2 \end{bmatrix} \begin{Bmatrix} \dot{x}_m \\ \dot{y}_m \\ \dot{\phi} \end{Bmatrix}$$

Omniwheels (ii)



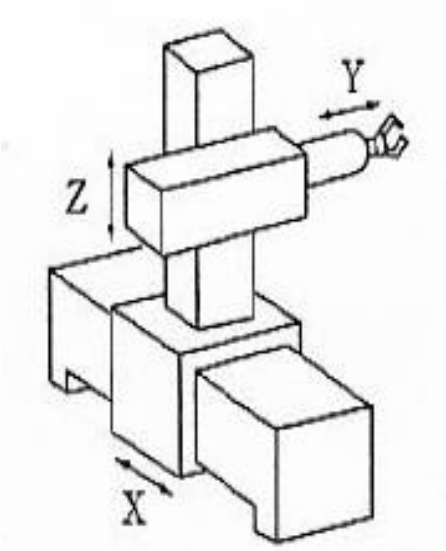
$$\begin{Bmatrix} \dot{\Theta}_1 \\ \dot{\Theta}_2 \\ \dot{\Theta}_3 \end{Bmatrix} = \frac{1}{R} \begin{bmatrix} -\sin(\delta+\Phi) & \cos(\delta+\Phi) & L_1 \\ -\sin(\delta-\Phi) & -\cos(\delta-\Phi) & L_1 \\ \cos(\Phi) & \sin(\Phi) & L_2 \end{bmatrix} \begin{Bmatrix} \dot{x_w} \\ \dot{y_w} \\ \dot{\Phi} \end{Bmatrix}$$

Conclusions

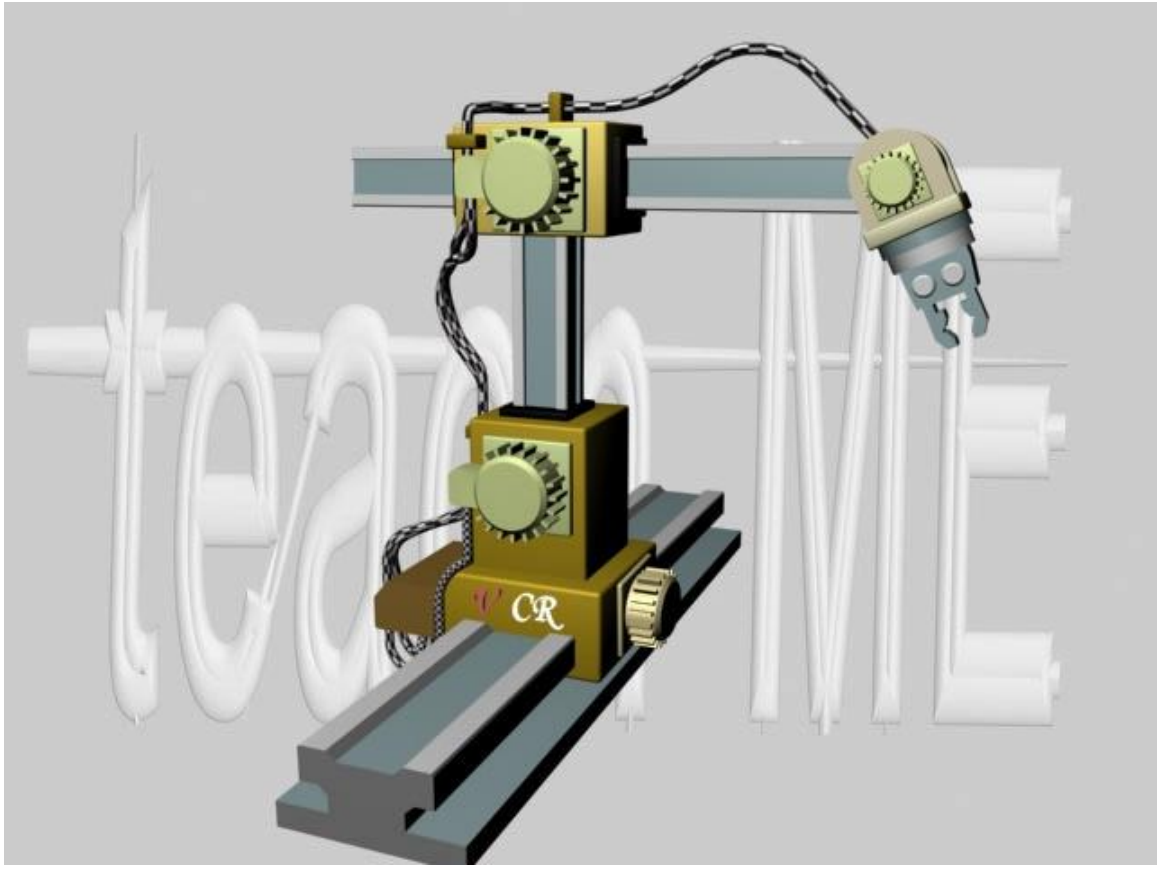
- Transducers change energy types
  - Sensors / sensibility
  - Actuators / efficiency
  - Actuator chains change movement / forces / efficiencies
- Many types of actuators
  - Most Important: DC motor / brushless
- Many locomotion types
  - Most Important: Differential drive and OmniWheels
- Kinematics and dynamics...

("Industrial") Arms Manipulators

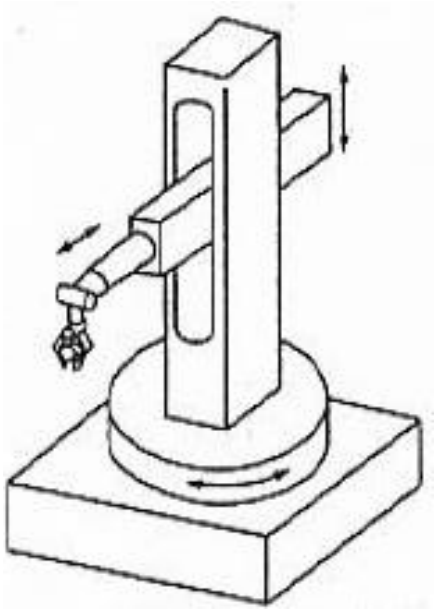
Industrial Manipulator

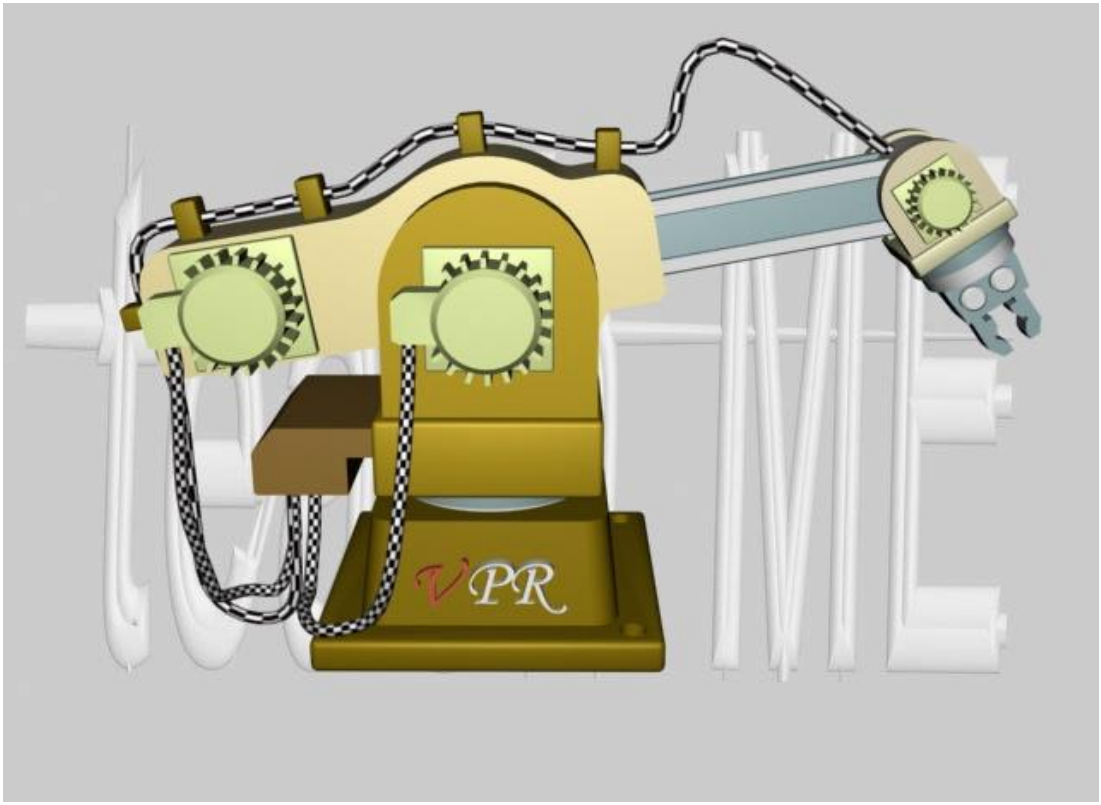


Cartesiano



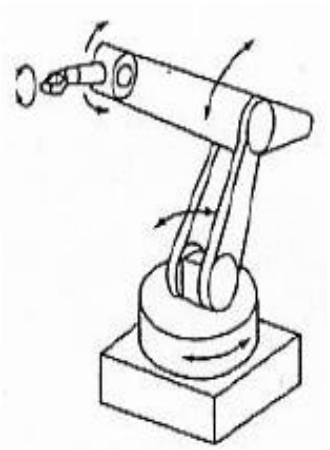
Industrial Manipulator



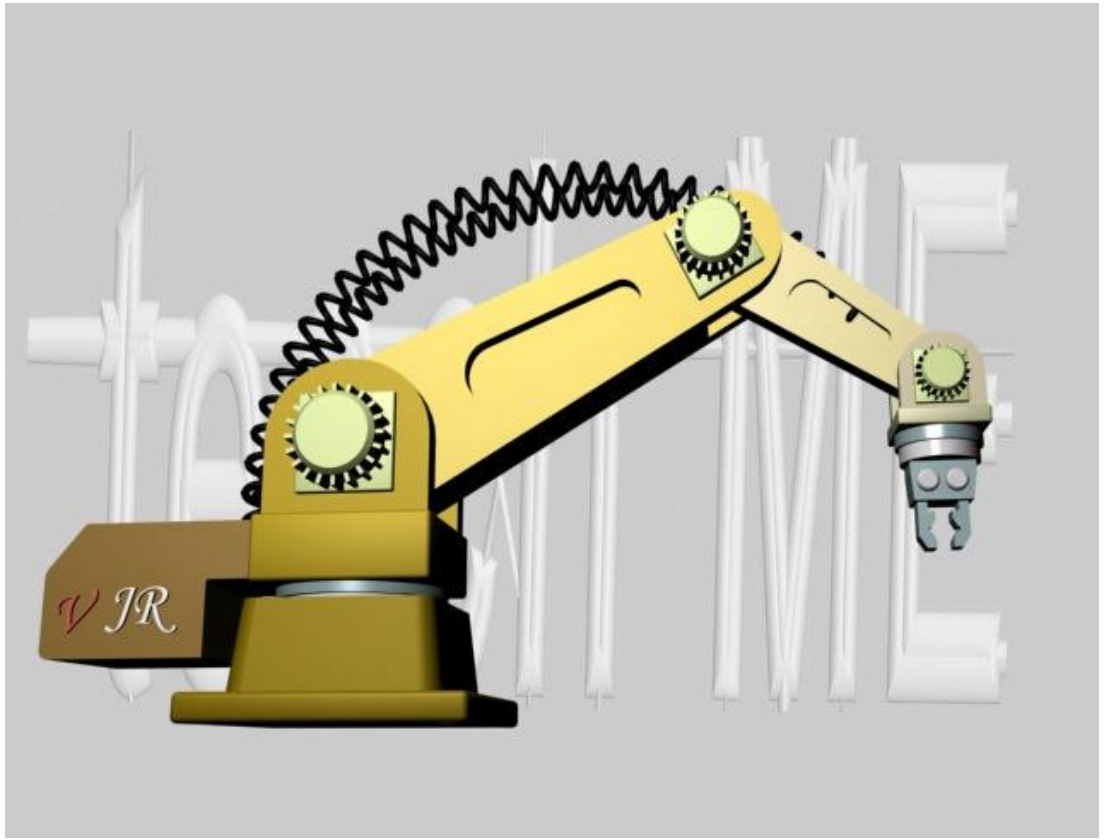


Cilíndrico
=
Polar

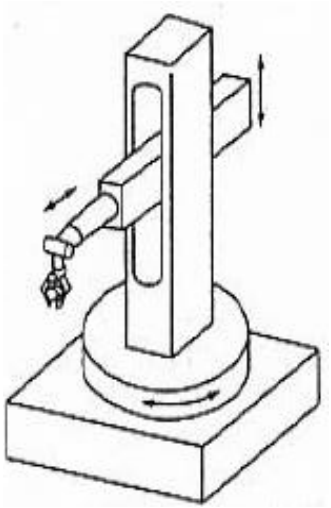
Industrial Manipulator



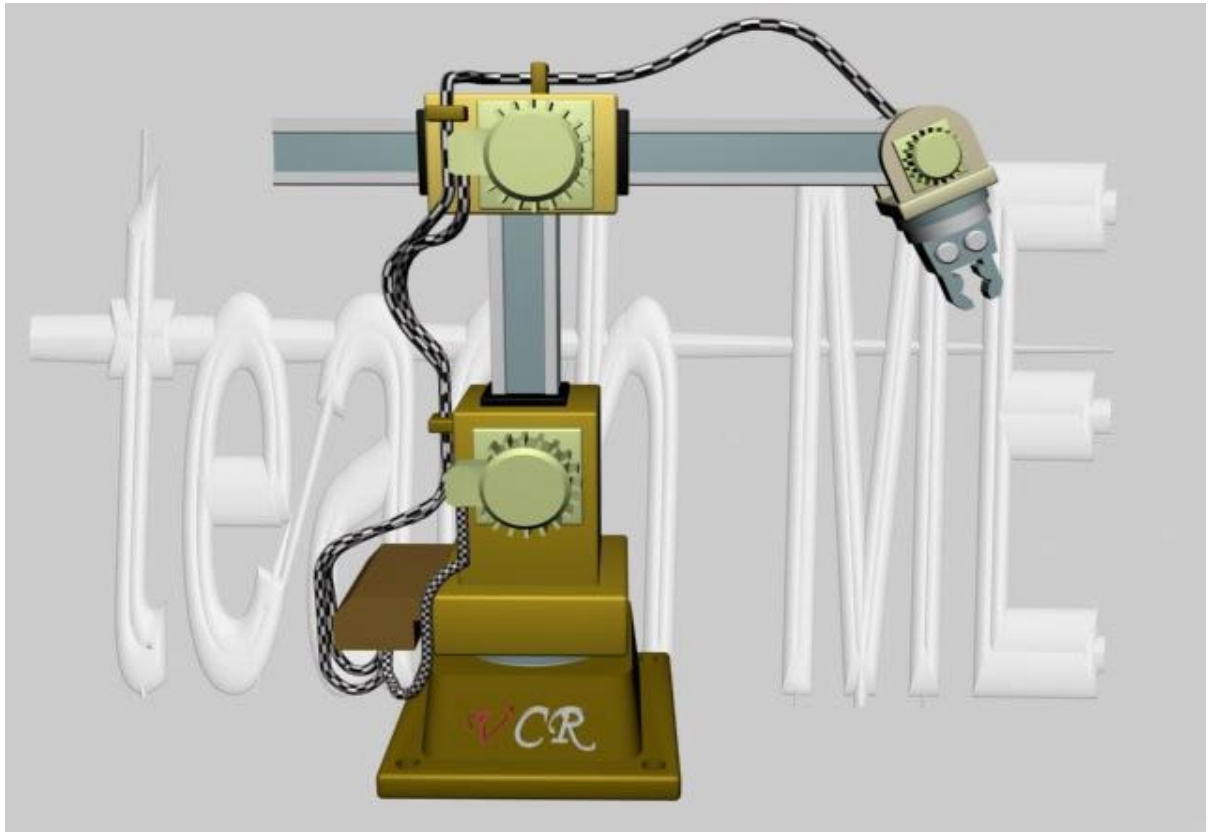
Articulado



Industrial Manipulator

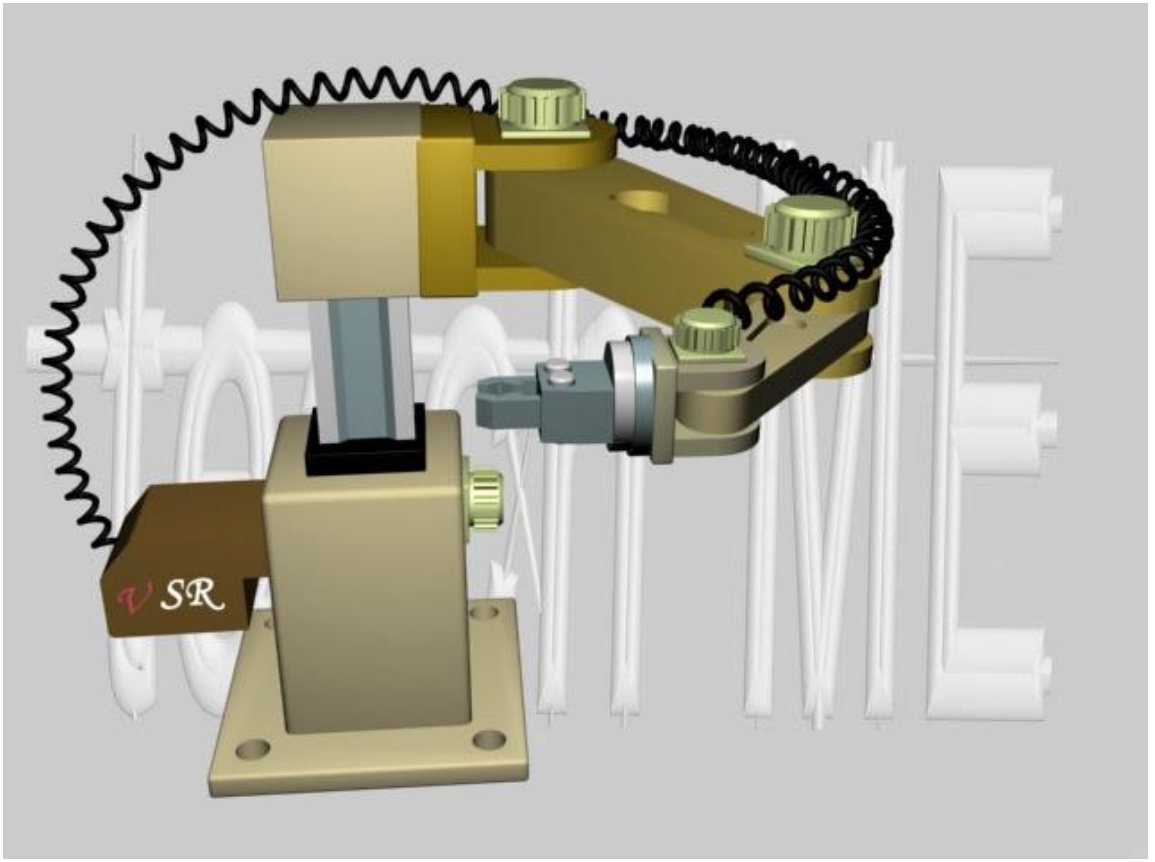


Cilíndrico



Industrial Manipulator

SCARA
Selection
Compliance
Assembly
Robot
Arm



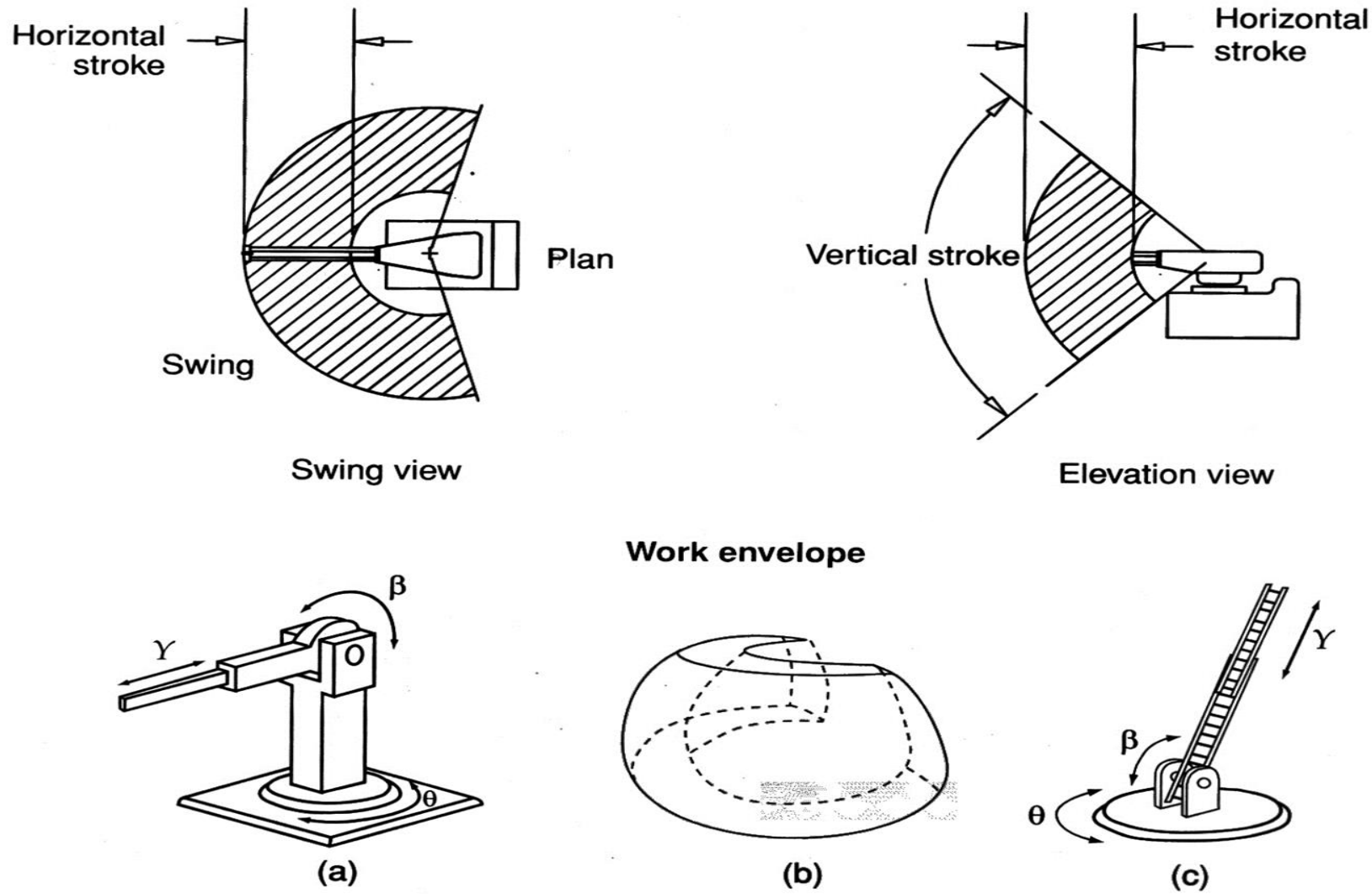


Figure 3.2.5 Spherical- or polar-coordinated robot: (a) A polar- or spherical-coordinated manipulator rotates about its base and shoulder and moves linearly in and out. (b) The work envelope of a polar-coordinated manipulator is the space between the two hemispheres. (c) A ladder on a hook-and-ladder truck has movements similar to those of a polar-coordinated manipulator.

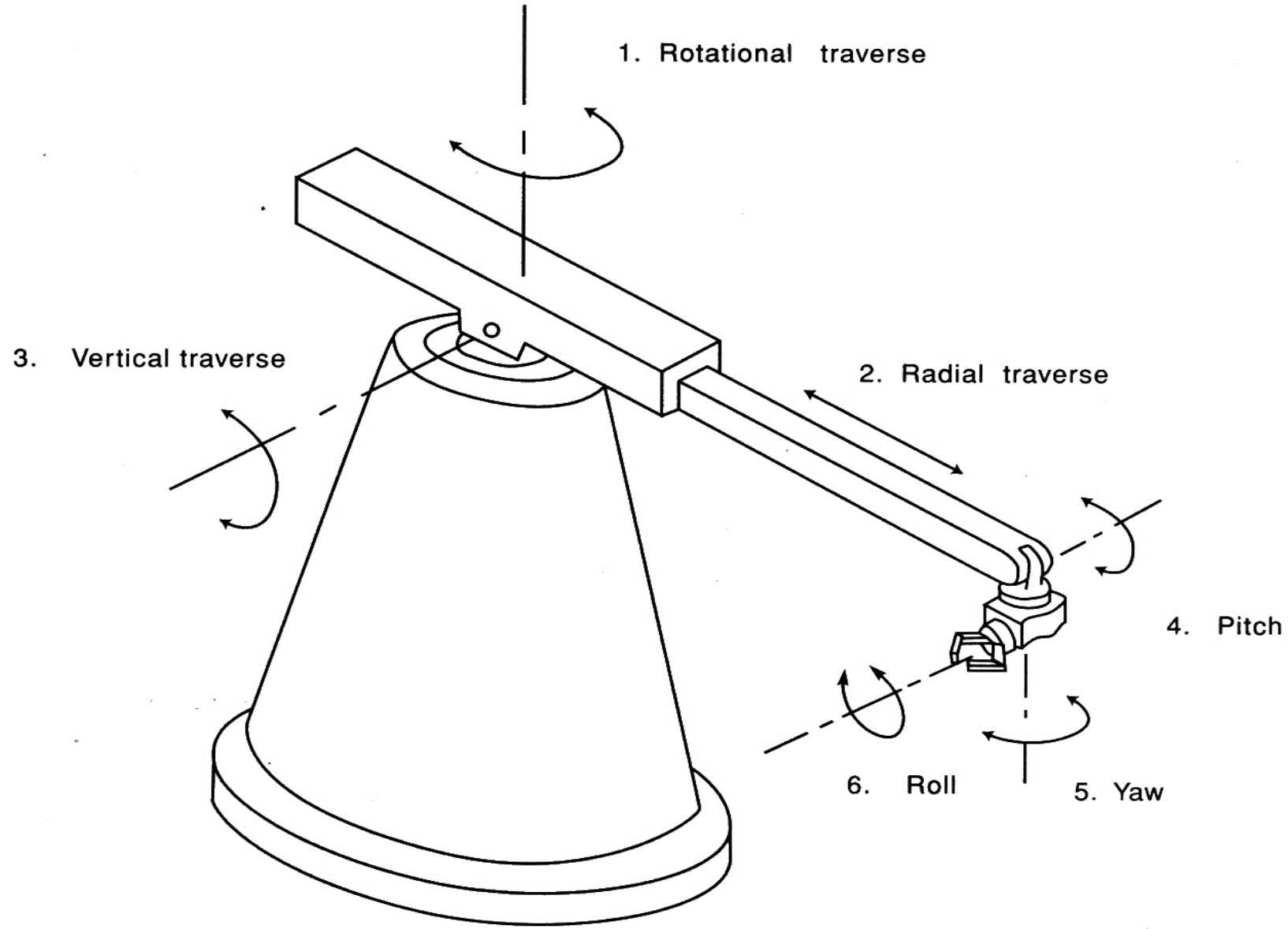
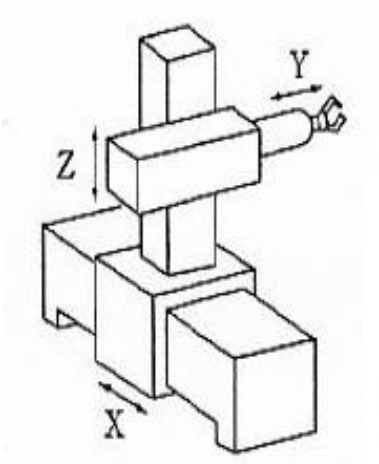
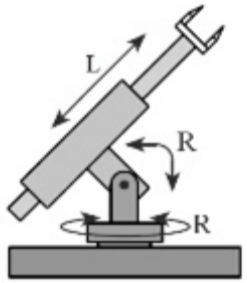


Figure 3.3.2 Six major degrees of freedom of a robotic system

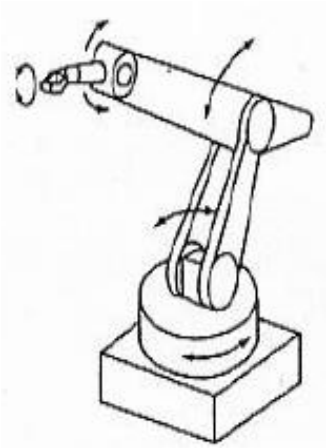
Industrial Manipulator



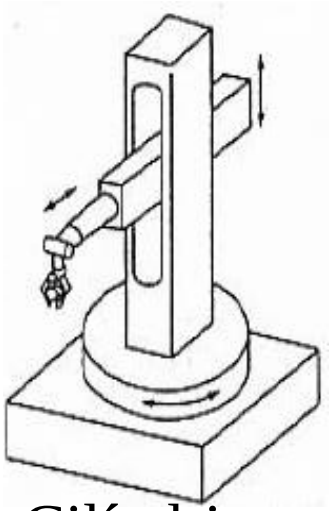
Cartesiano



Esférico



Articulado

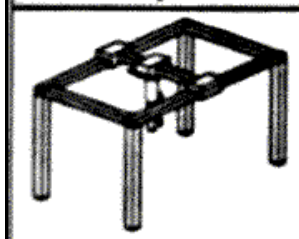
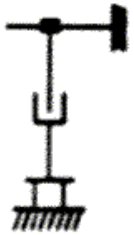
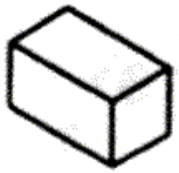
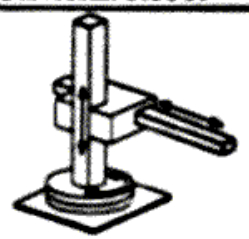


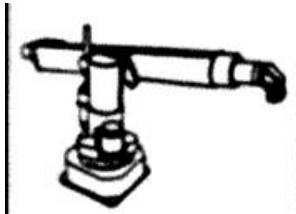
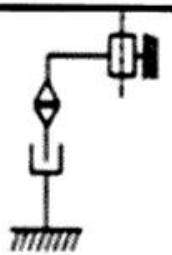
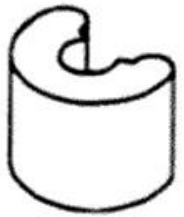
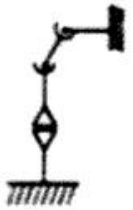
Cilíndrico

SCARA

Selection
Compliance
Assembly
Robot
Arm

Industrial Manipulator

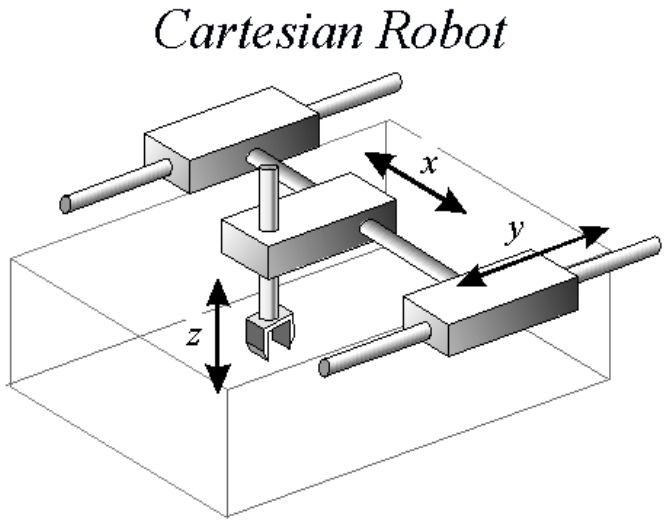
Principle	Kinematic Structure	Workspace
 Cartesian Robot		
 Cylindrical Robot		

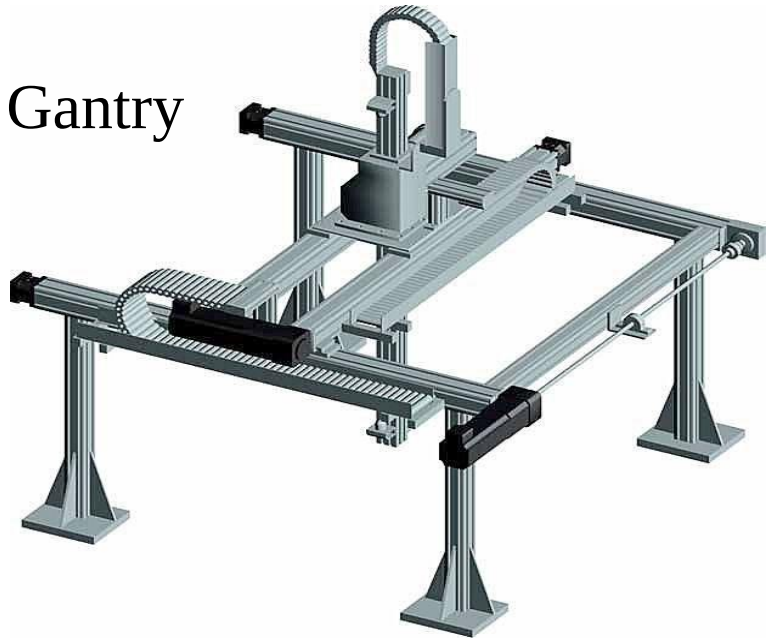
Principle	Kinematic Structure	Workspace
 Spherical Robot		
 SCARA Robot		
 Articulated Robot		

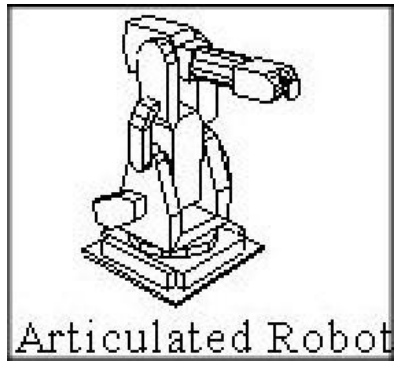
Types of robots - http://prime.jsc.nasa.gov/ROV/types.html

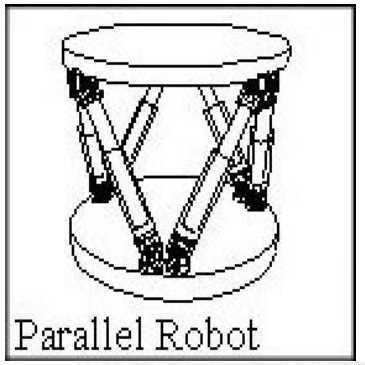
- Cartesian robot /Gantry robot: Used for pick and place work, application of sealant, assembly operations, handling machine tools and arc welding. It's a robot whose arm has three prismatic joints, whose axes are coincident with a Cartesian coordinator.
- Cylindrical robot: Used for assembly operations, handling at machine tools, spot welding, and handling at diecasting machines. It's a robot whose axes form a cylindrical coordinate system.
- Spherical/Polar robot: Used for handling at machine tools, spot welding, diecasting, fettling machines, gas welding and arc welding. It's a robot whose axes form a polar coordinate system.
- SCARA robot: Used for pick and place work, application of sealant, assembly operations and handling machine tools. It's a robot which has two parallel rotary joints to provide compliance in a plane.
- Articulated robot: Used for assembly operations, diecasting, fettling machines, gas welding, arc welding and spray painting. It's a robot whose arm has at least three rotary joints.
- Parallel robot: One use is a mobile platform handling cockpit flight simulators. It's a robot whose arms have concurrent prismatic or rotary joints.

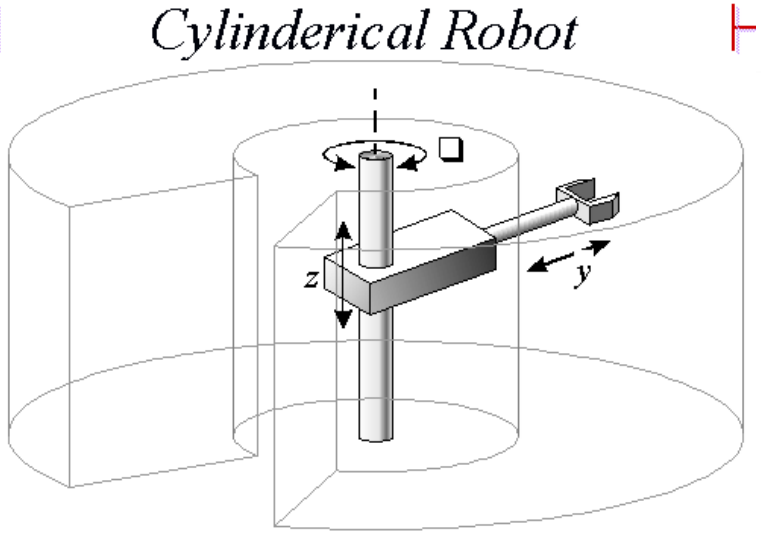
Types of robots - http://prime.jsc.nasa.gov/ROV/types.html

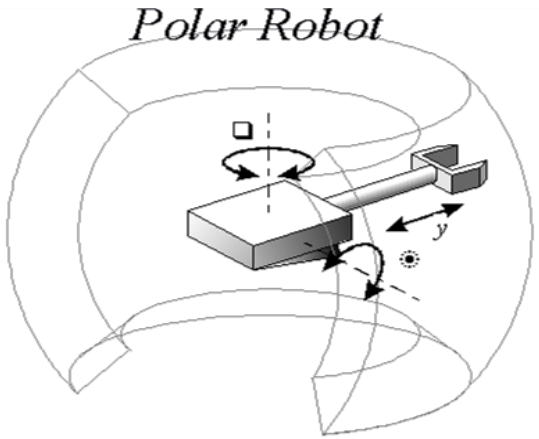


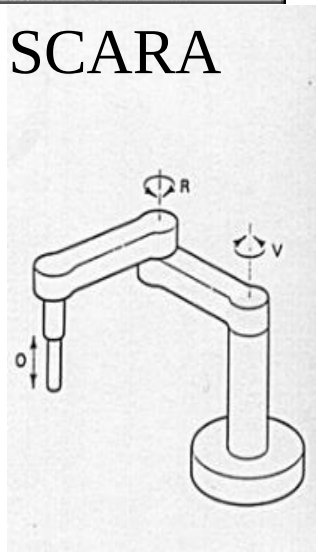




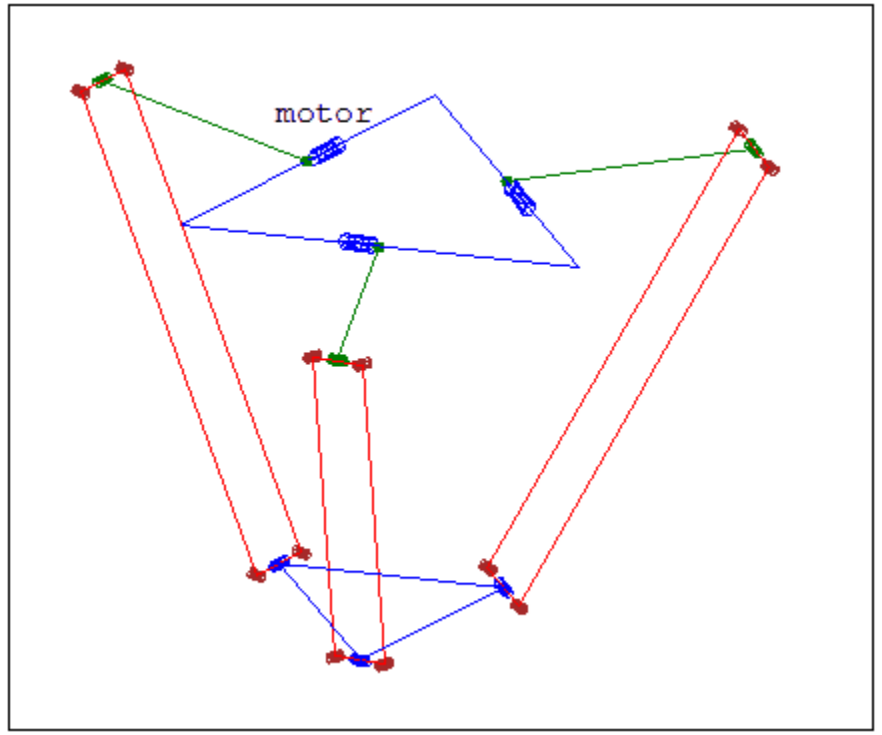








- https://www.youtube.com/watch?v=v9oeOYMRvuQ – Pancake
- https://www.youtube.com/watch?v=disekkn8YoQ - Macarons



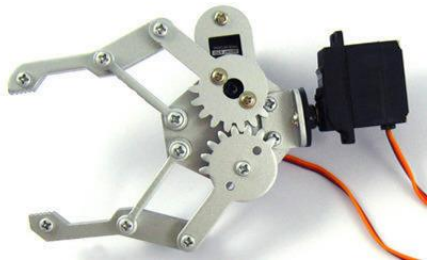
Parallel Robot
Quattro

SCARA Robot
eCobra

Articulated Robot
Viper

End Effectors / Grippers

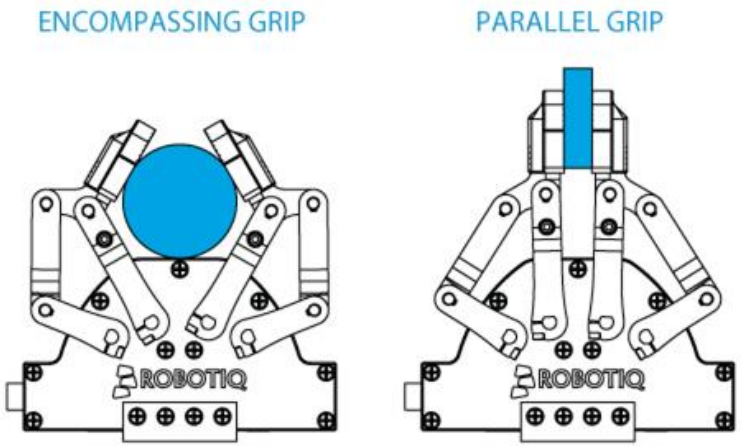
Example Manufacturer: http://robotiq.com/
Other Images: https://www.cs.rpi.edu/twiki/pub/RoboticsWeb/ReadingGroup/Manipulator_End_Effectors.pdf



Two, Three, N “Fingers”:



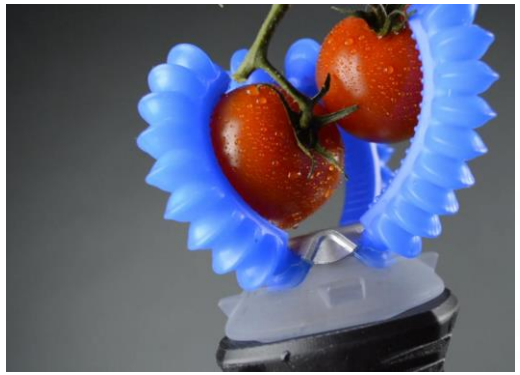
Force Torque Sensor:

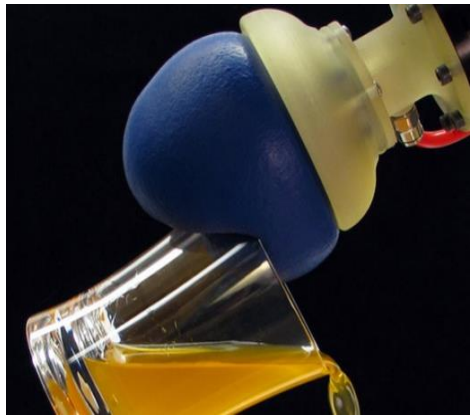


Parallel Gripping:

Grippers

- VersaBall - https://www.youtube.com/watch?v=_jDW0RI7gso
- " " - https://www.youtube.com/watch?v=ZKOI_lVDPpw
- FlexGripper - https://www.youtube.com/watch?v=m7l-87r4oOY
- Octopus Gripper - https://youtu.be/rKX3IKg5Qok
- Finn Gripper - https://www.youtube.com/watch?v=90cXfaFM4O8
- " " - https://www.youtube.com/watch?v=4MQmlvzE0i8
- " " - https://www.youtube.com/watch?v=Q1MBIaNuLa8 (egg crash...)





Differential Drive Robot

("Wheelchair" drive)

State Vector for a differential ground robot

Considere-se a figura 8.53 onde se mostra o robot em movimento.

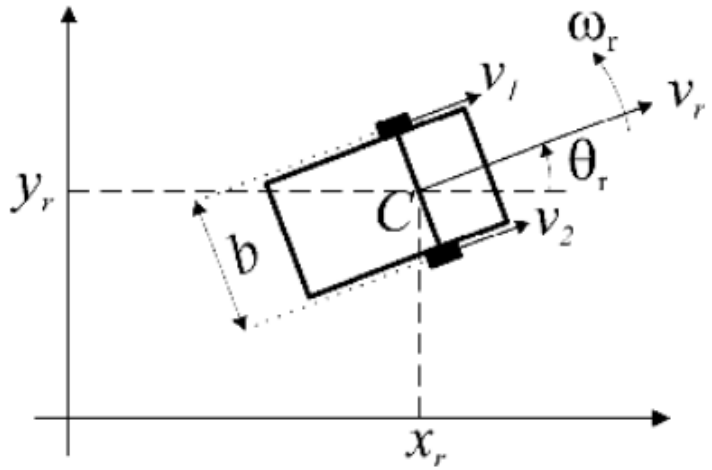


Figura 8.53 Ilustração do robot em movimento

$$v_t = v_r$$

$$\begin{cases} v_t = \dfrac{(v_1 + v_2)}{2} \\ \omega_r = \dfrac{(v_1 - v_2)}{b} \end{cases}$$

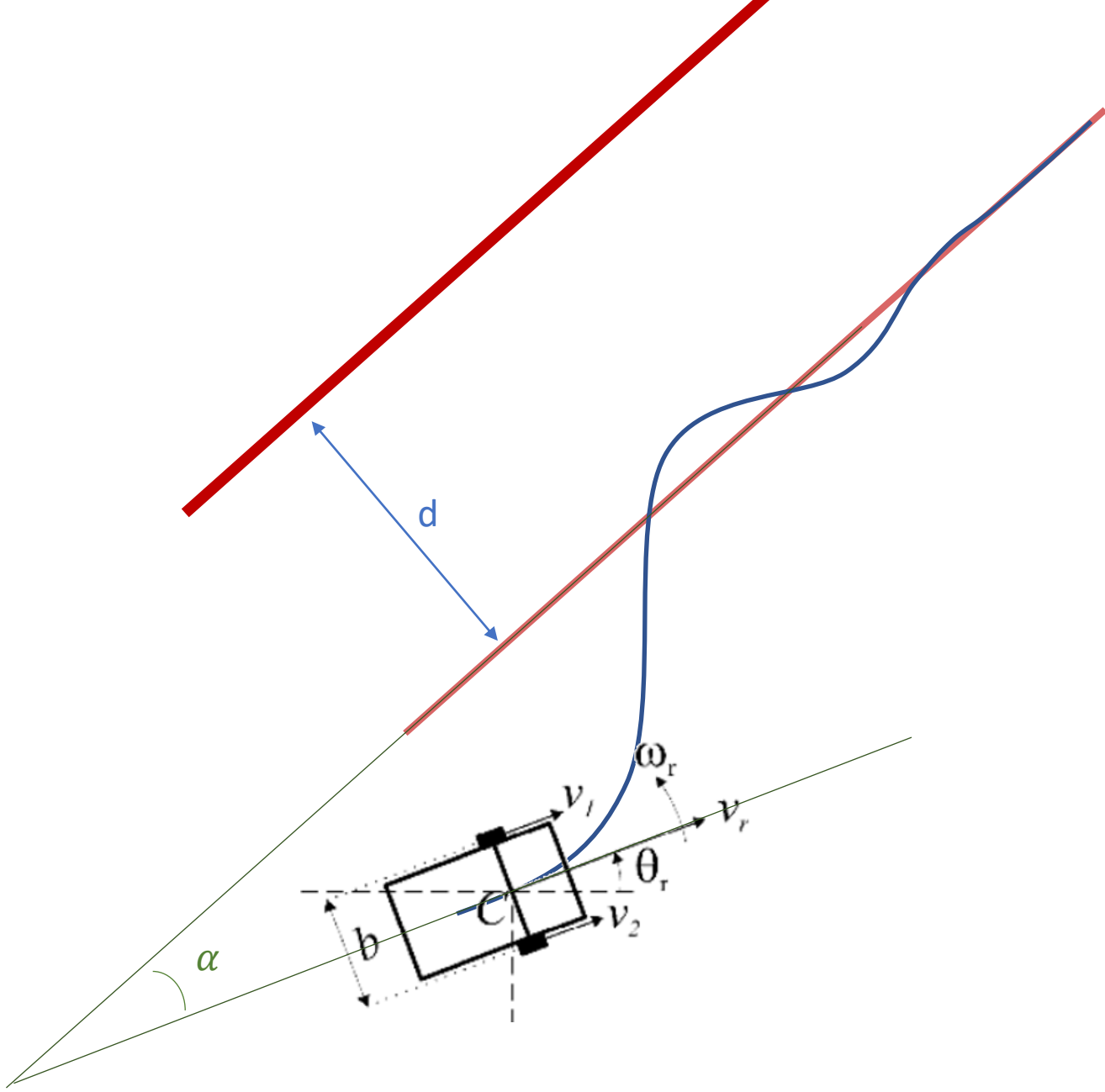
O vector de estado escolhido para o sistema é:

$$X(t) = [x_r(t) \quad y_r(t) \quad \theta_r(t) \quad v_r(t) \quad \omega_r(t)]^T$$

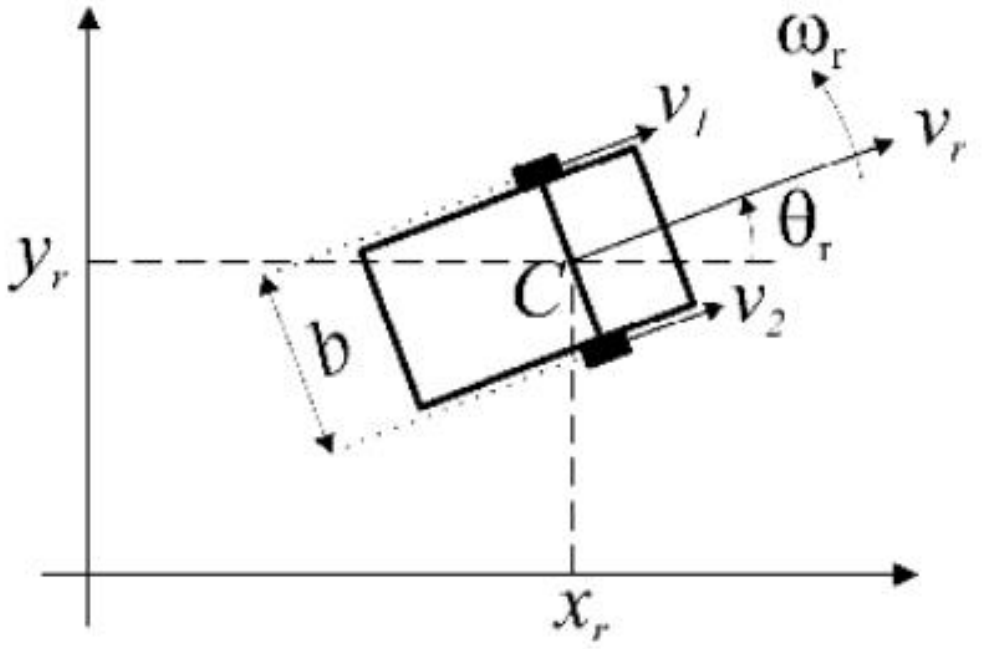
$$\begin{cases} x_r(t+1) = x_r(t) + v_r(t) \cdot \cos\theta_r(t) \cdot \Delta t \\ y_r(t+1) = y_r(t) + v_r(t) \cdot \sin\theta_r(t) \cdot \Delta t \\ \theta_r(t+1) = \theta_r(t) + \omega_r(t) \cdot \Delta t \end{cases}$$

Wall following control

- Always use floating point and SI units
- Many solutions…
- Example of a simple control:
  - Have robot rotate proportionally to the difference of angle (robot and Wall to follow)
  - $\omega_r(t) = k \cdot \alpha(t-1)$
    (try k and –k)



$$\left\{\begin{matrix} v = \frac{v_1+v_2}{2} \\ \omega = \frac{v_1-v_2}{b} \end{matrix}\right\}$$



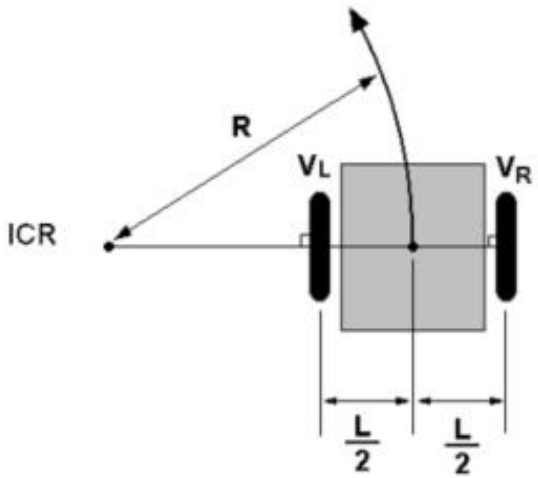
$$\left\{\begin{matrix} \\ v_2 = v_1 - \omega b \end{matrix}\right\}$$

$$\left\{\begin{matrix} 2v = v_1 + v_1 - \omega b \\ \\ \end{matrix}\right\}$$

$$\left\{\begin{matrix} v_1 = v + \omega b/2 \\ \\ \end{matrix}\right\}$$

$$\left\{\begin{matrix} v_1 = v + \omega b/2 \\ v_2 = v - \omega b/2 \end{matrix}\right\}$$

V, ω,v_L,v_R,



$$(V_R - V_L)/\ L\ =\ V_R\ /(R+\frac{L}{2})$$

$$R=\frac{L}{2}\frac{V_R+V_L}{V_R-V_L}$$

R : Radius of rotation

- Straight motion

  R = Infinity → $V_R = V_L$

- Rotational motion

  R = 0 → $V_R = -V_L$

Thank You

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