Mobile robots & Locomotion

Structure

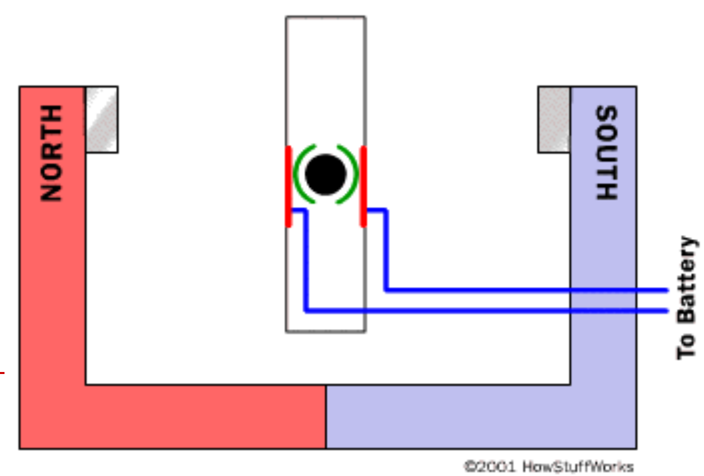
- Motors
- Types of locomotion
- Degrees of freedom
- Wheels
- Legs
- Other types of locomotion (swimming, skating, flying)

Motors

- **DC MOTORS**
- **AC MOTORS**
- **SERVOS**
- **STEPPERS**
- **Linear**
- **Piezo Motors**
- **Electroactive Polymers**

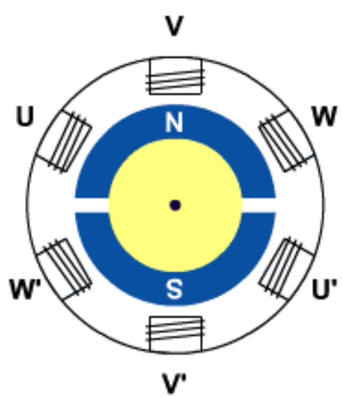
DC MOTORS

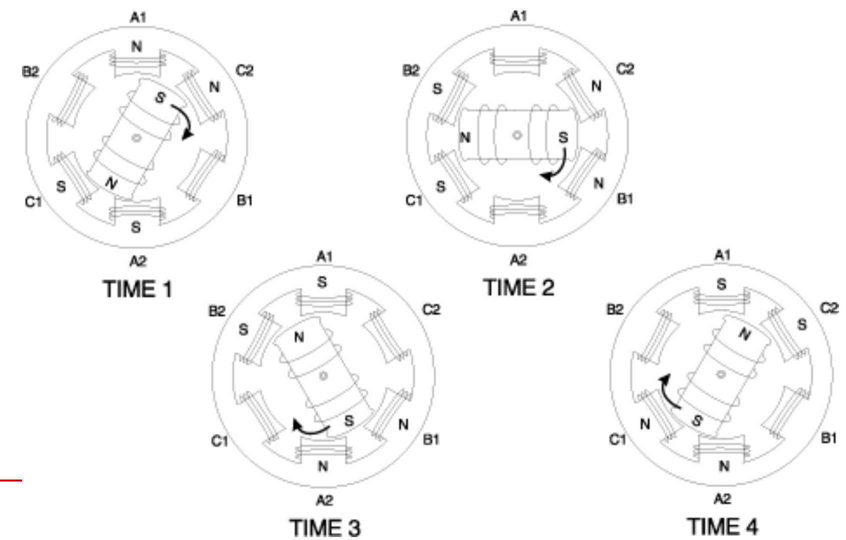
- Spin rapidly when an electric current is passed through them.
- Spin backwards if the current is made to flow in the other direction.
- Change speed by changing the voltage.

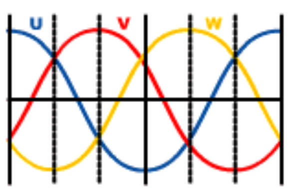


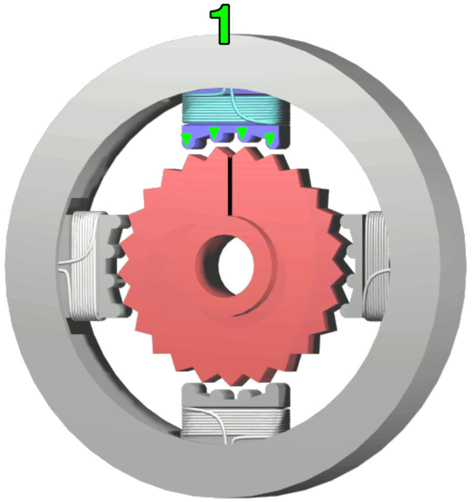
AC MOTORS

- Requires AC – depend on some generators / adapters wall socket.
- Limited applicability (arms)
- Invented by Nikola Tesla.









STEPPERS

- Do not spin freely like DC motors,
- Rotate in steps of a few degrees at a time, under the command of a controller.
- Easier to control, as the controller knows exactly how far they have rotated, without having to use a sensor.

SERVOS

- Modified DC motors
- Have an encoder.
- Most of them can rotate about 90 to 180 degrees.
- High precision positioning
- Connect the black wire to ground, the red to a 4.8-6V source, and the yellow/white wire to a signal generator (such as from microcontroller)
- Vary the pulse width and the servo will have a known position/velocity

- Can deliver more power to higher speeds than steppers.

Linear motors

- http://www.youtube.com/watch?v=txZMLS7YD6Q

Piezo Motors

- Also known as ultrasonic motors.
- Tiny piezoceramic legs, vibrating many thousands of times per second, walk the motor round in a circle or a straight line.
- **Piezoelectricity** is the ability of some materials (notably crystals and certain ceramics) to generate an electric potential in response to applied mechanical stress.
- http://www.youtube.com/watch?v=BS3icZnO_vw

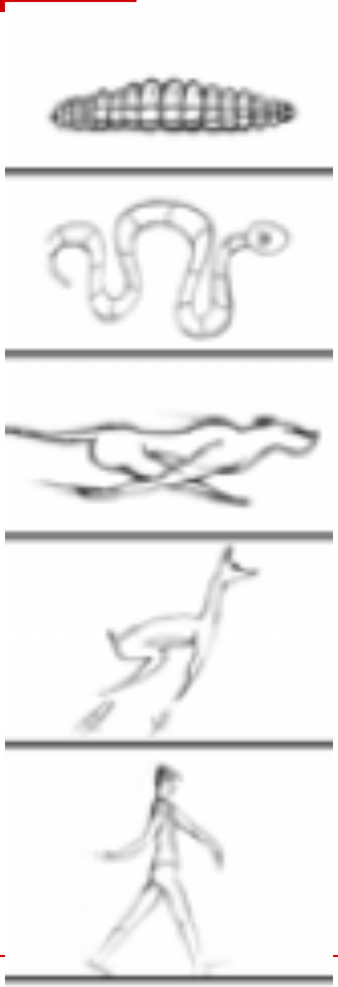
Electroactive Polymers

- These are a class of plastics which change shape in response to electrical stimulation.
- They can be designed so that they bend, stretch or contract,
- So far there are no EAPs suitable for commercial robots, as they tend to have low efficiency or are not robust.
  - All of the entrants in a recent competition to build EAP powered arm wrestling robots, were beaten by a 17 year old girl.

http://www.youtube.com/watch?v=hyycT2IMONk
http://www.youtube.com/watch?v=4g3JqUG_u30

Types of Locomotion in Nature

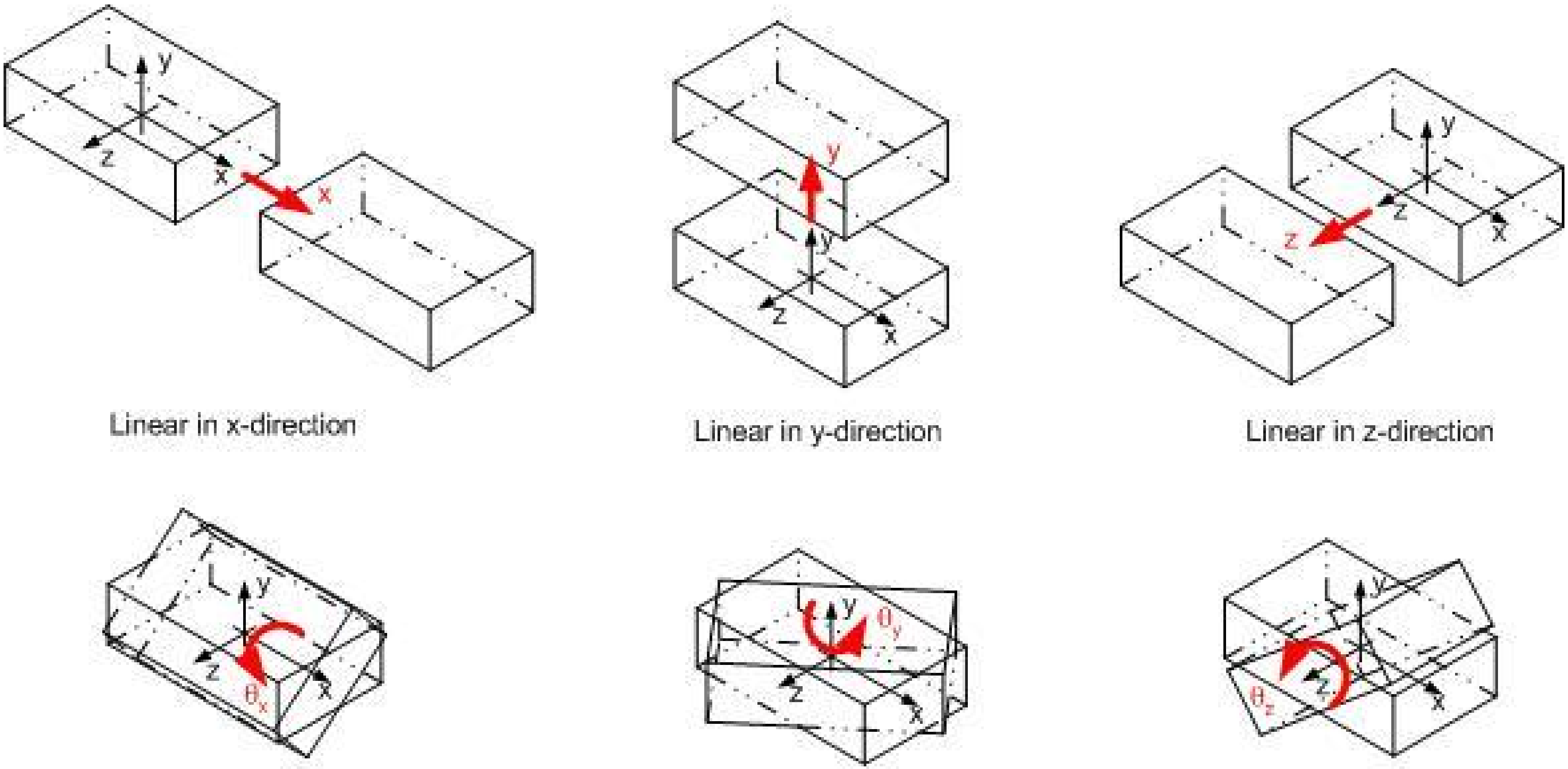
- Crawl
- Sliding
- Running
- Jumping
- Walking
- ? What is missing



Rolling in nature ???

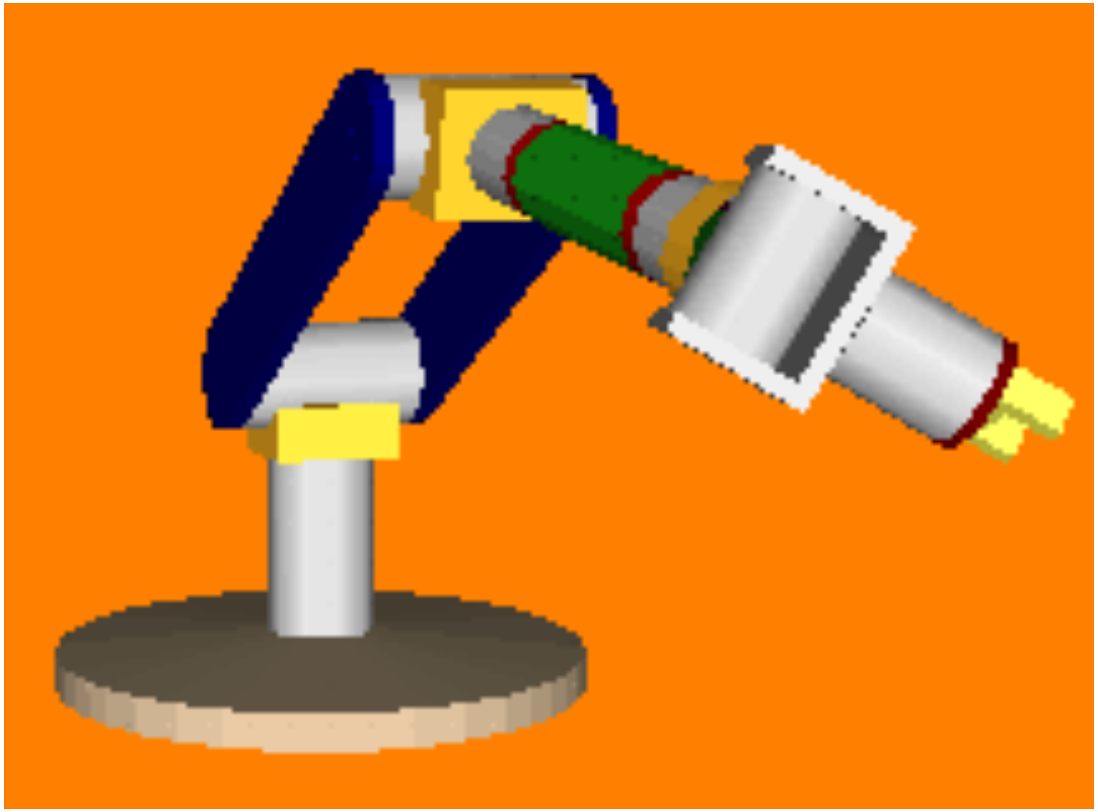
- Concepts found in nature
  - *difficult to imitate technically*
- Most technical systems use wheels
- Rolling is most efficient, but not found in nature
  - *Nature never invented the wheel !*

Degrees of freedom



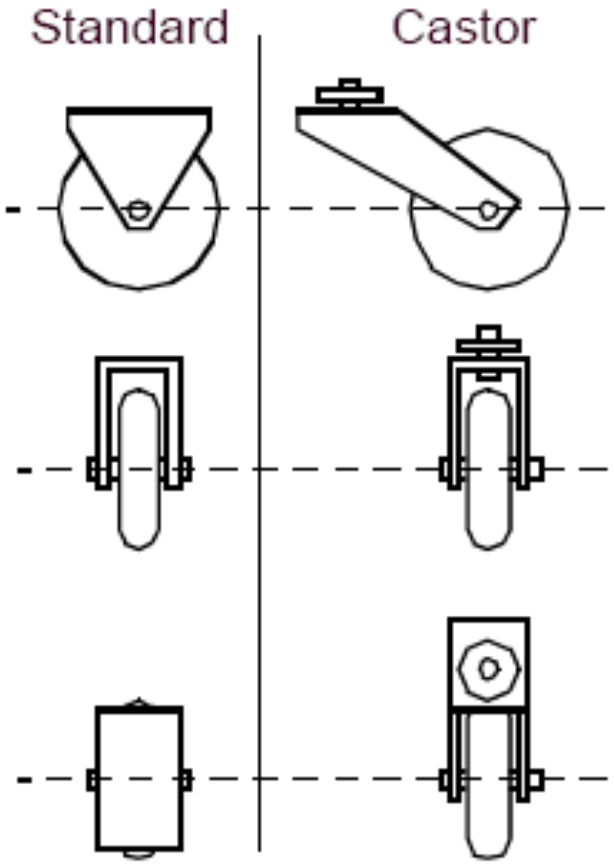
Linear in x-direction
Linear in y-direction
Linear in z-direction
Rotation around x-axis
Rotation around y-axis
Rotation around z-axis

Multiple degrees of freedom



Degrees of Freedom (1)

- **Standard wheel**: Two degrees of freedom; rotation around the (motorized) wheel axle and the contact point.
- **Castor wheel**: Three degrees of freedom; rotation around the wheel axle, the contact point and the castor axle.
  - aligning itself to the direction in which it is moving.



Degrees of Freedom (2)

- c) **Swedish wheel**: Three degrees of freedom; rotation around the (motorized) wheel axle, around the rollers and around the contact point

Main types of locomotion

- Wheels
- Legs

Wheeled vs. legged robots

- Pros of wheeled robot:
  - Easy to construct
  - Easy to control
  - No use of power at stand still
- Cons:
  - Cannot move in complex terrains
  - Catastrophic failure due to motor damage (if few wheels)

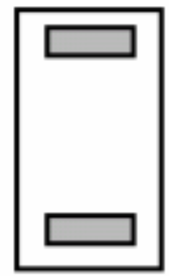
- Pros of legged robots:
  - Discrete contacts with the ground (good for passing obstacles)
  - Can tackle a large variety of terrains
  - Robustness against motor failure (because of redundancy)
- Cons:
  - Difficult to design and construct
  - Difficult to control (because of many DOFs)
  - Control required to keep balance

Characteristics of Wheeled Robots

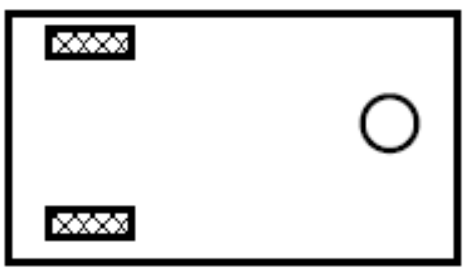
- Stability of a vehicle is guaranteed with 3 wheels
  - *center of gravity is within the triangle with is formed by the ground contact point of the wheels.*
- Stability is improved by 4 and more wheel
  - *however, this arrangements are hyperstatic and require a flexible suspension system.*
- Bigger wheels allow to overcome higher obstacles
  - *but they require higher torque*

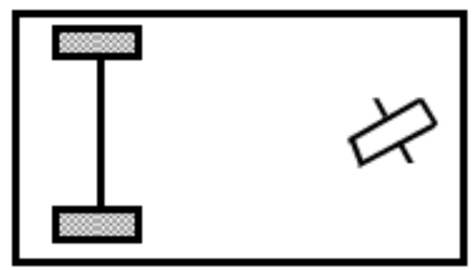
Different Arrangements of Wheels (1)

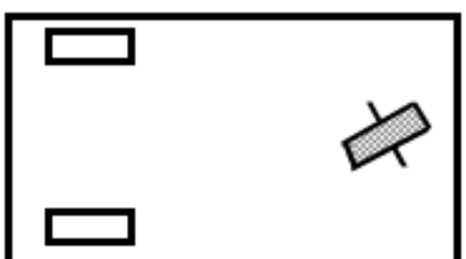
- Two wheels



- Three wheels

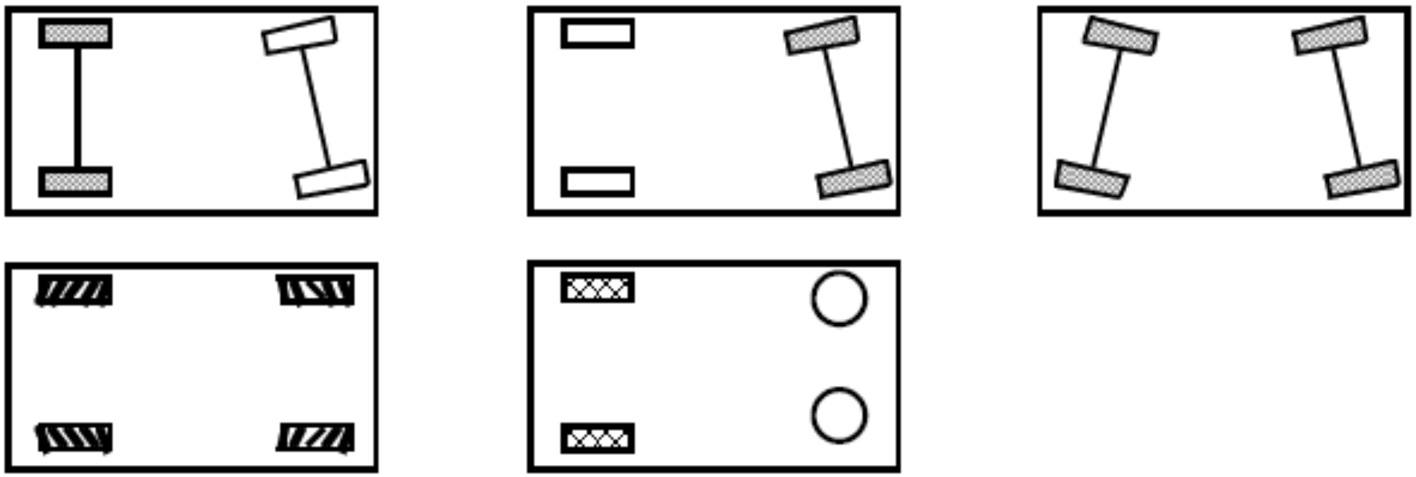




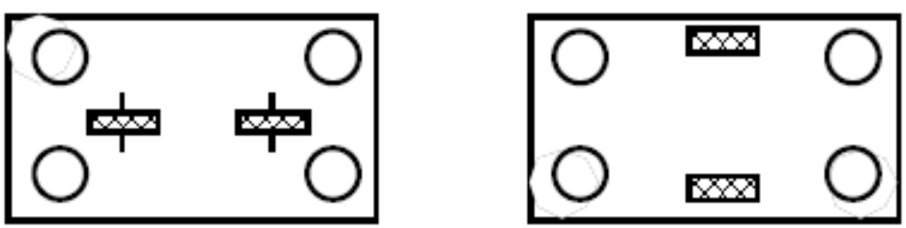


Different Arrangements of Wheels (2)

- Four wheels



- Six wheels



Types of drive

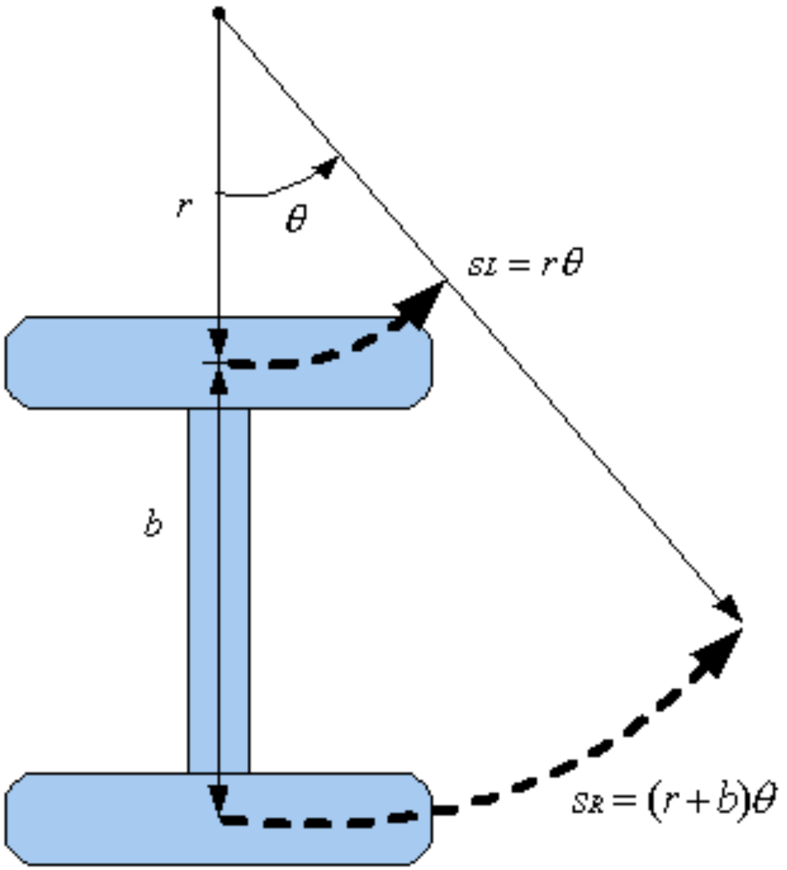
- Synchronized
- Differential
- Omni directional

Synchro Drive

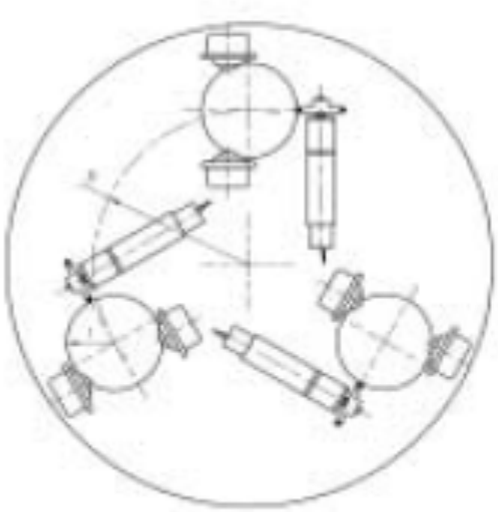
- All wheels are actuated synchronously by one motor
  - *defines the speed of the vehicle*
- All wheels steered synchronously by a second motor
  - *sets the heading of the vehicle*
- The orientation in space of the robot frame will always remain the same
  - *It is therefore not possible to control the orientation of the robot frame.*

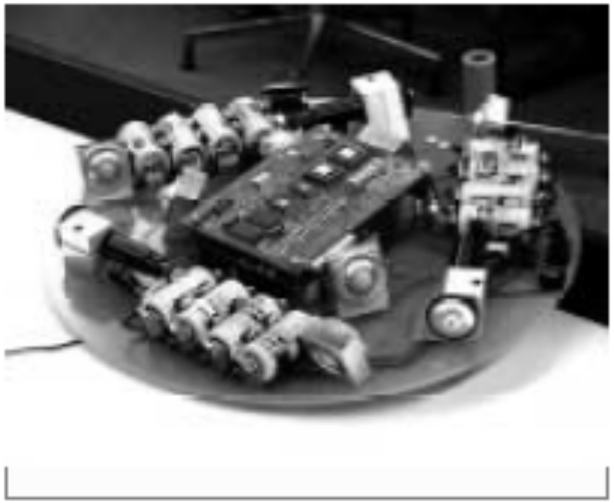
Differential Drive Robots

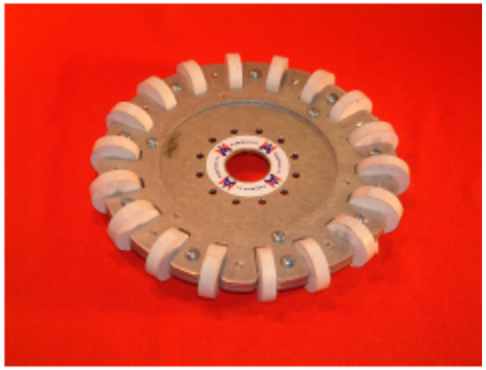
- A two-wheeled **drive** system with independent actuators for each wheel.



Omnidirectional Drive







Rolling Robots

- **Spherical robots**
- **Ballbot**
- **Two-wheeled balancing**

Spherical robot

- http://www.youtube.com/watch?v=OWkK-o4Vq-A

Ballbot

- **Carnegie Mellon University**
- balances on a ball instead of legs or wheels.
- self-contained, battery-operated, omnidirectional robot that balances dynamically on a single urethane-coated metal sphere.
- weighs 95 pounds, height and width of a person.
- Because of its long, thin shape and ability to maneuver in tight spaces, it has the potential to function better than current robots can in environments with people.
- http://www.youtube.com/watch?v=W7Svj3DcO_0&feature=related

Two-wheeled balancing:

- While the Segway is not commonly thought of as a robot, it can be thought of as a component of a robot. Several real robots do use a similar dynamic balancing algorithm, and NASA's Robonaut has been mounted on a Segway.
- http://www.youtube.com/watch?v=edmeLXXwTwU

Legs, Gait

The problems of legged locomotion control

- A robot **cannot** follow arbitrary motion commands !
  - Need to take advantage of the robot's dynamics
  - Need to coordinate multiple degrees of freedom
  - Need to keep balance
  - Need to modify the gait for different speeds and directions
  - Obstacle avoidance
  - Visually-guided feet placements
  - Adapting to perturbations

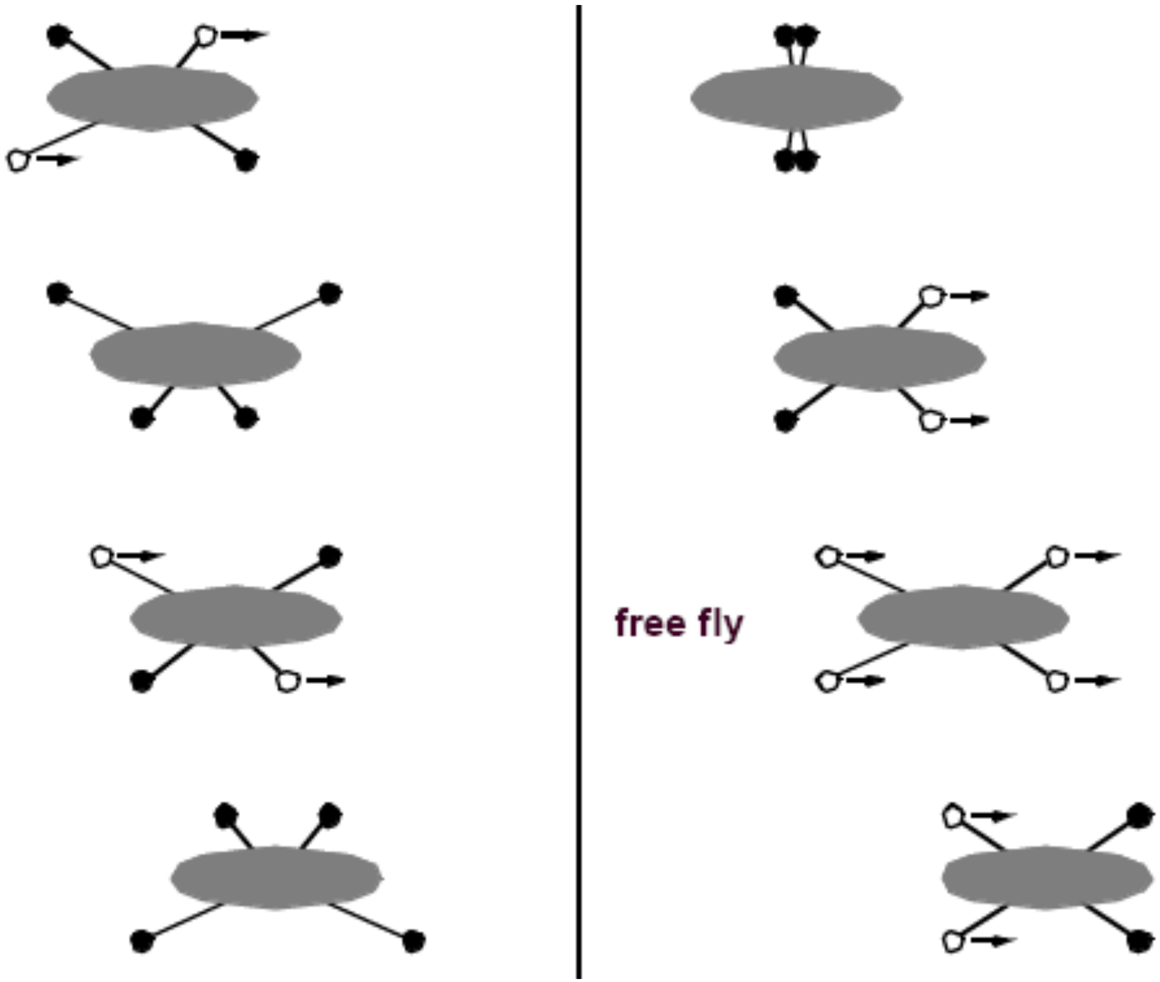
Static, Dynamic, Passive Walking

- Static = maintains a static equilibrium while walking.
- Dynamic = does not. The projected center of mass is allowed outside of the area inscribed by the feet, and the walker may essentially be falling during parts of the gait cycle.
- Passive walking = A natural steady gait maintained by gravitational forces. No actuators!
- http://www.youtube.com/watch?v=CK8IFEGmiKY

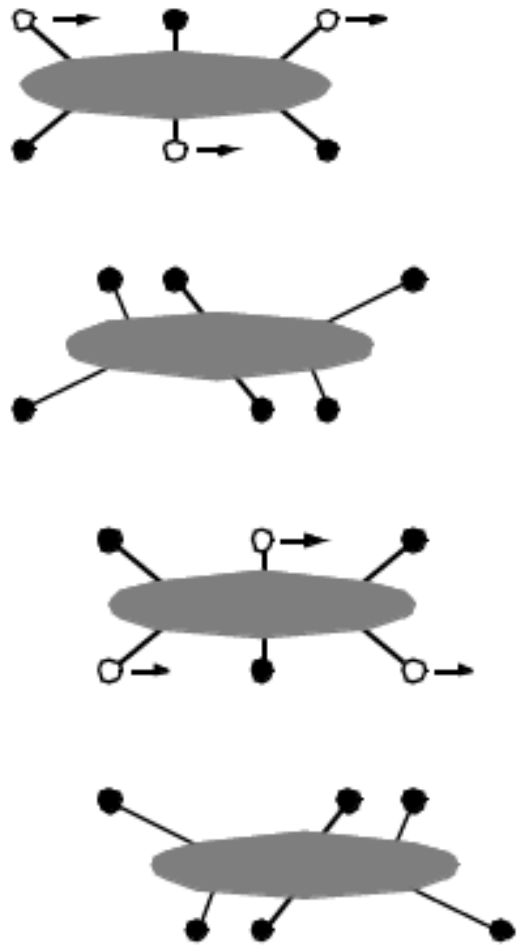
Number of Joints of Each Leg

- A minimum of two DOF is required to move a leg forward
  - *a* lift *and a* swing *motion.*
- Three DOF for each leg in most cases
- Fourth DOF for the ankle joint
  - *might improve walking*
  - *however, additional joint (DOF) increase the complexity of the design and especially of the locomotion control.*

Most Obvious Gaits with 4 legs



Most Obvious Gait with 6 legs



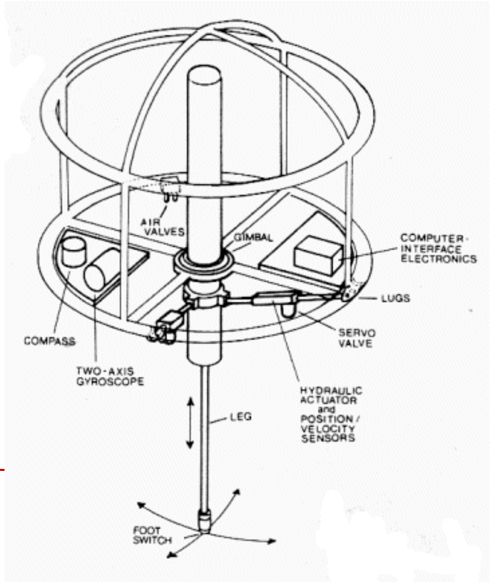
Types of locomotion in legged robots

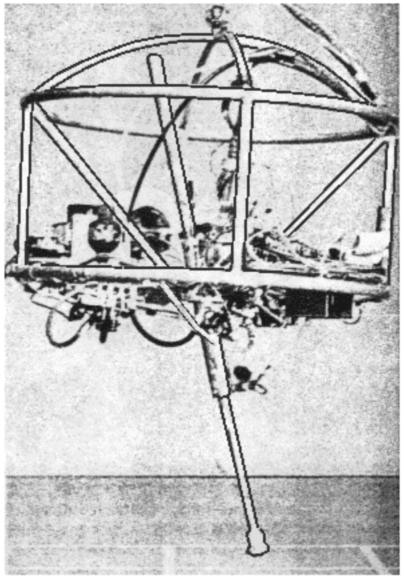
- Hopping
- Walking (humanoid, biped, 4 legs, etc)

Hopping

- Several robots, built in the 1980s by Marc Raibert at the MIT Leg Laboratory, successfully demonstrated very dynamic walking. Initially, a robot with only one leg, and a very small foot, could stay upright simply by hopping. The movement is the same as that of a person on a pogo stick. As the robot falls to one side, it would jump slightly in that direction, in order to catch itself.
- The algorithm was generalized to two and four legs.

- http://www.youtube.com/watch?v=moENDzu_rS0

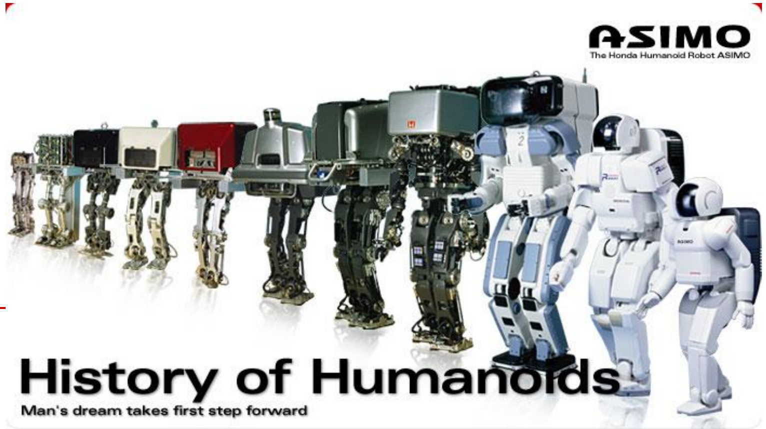




Humanoid Robots-bipedal robots

http://www.youtube.com/watch?v=Q3C5sc8b3xM

More about ASIMO



- **A**dvanced **S**tep in **I**nnovative **MO**bility – no connections with ASIMOV
- 54 kg, 130 cm, 2.7 km/h (walking), 6 km/h (running)

Walking Robots with Four Legs (Quadruped)

- AIBO

http://www.youtube.com/watch?v=tJw8Xf3rNy8

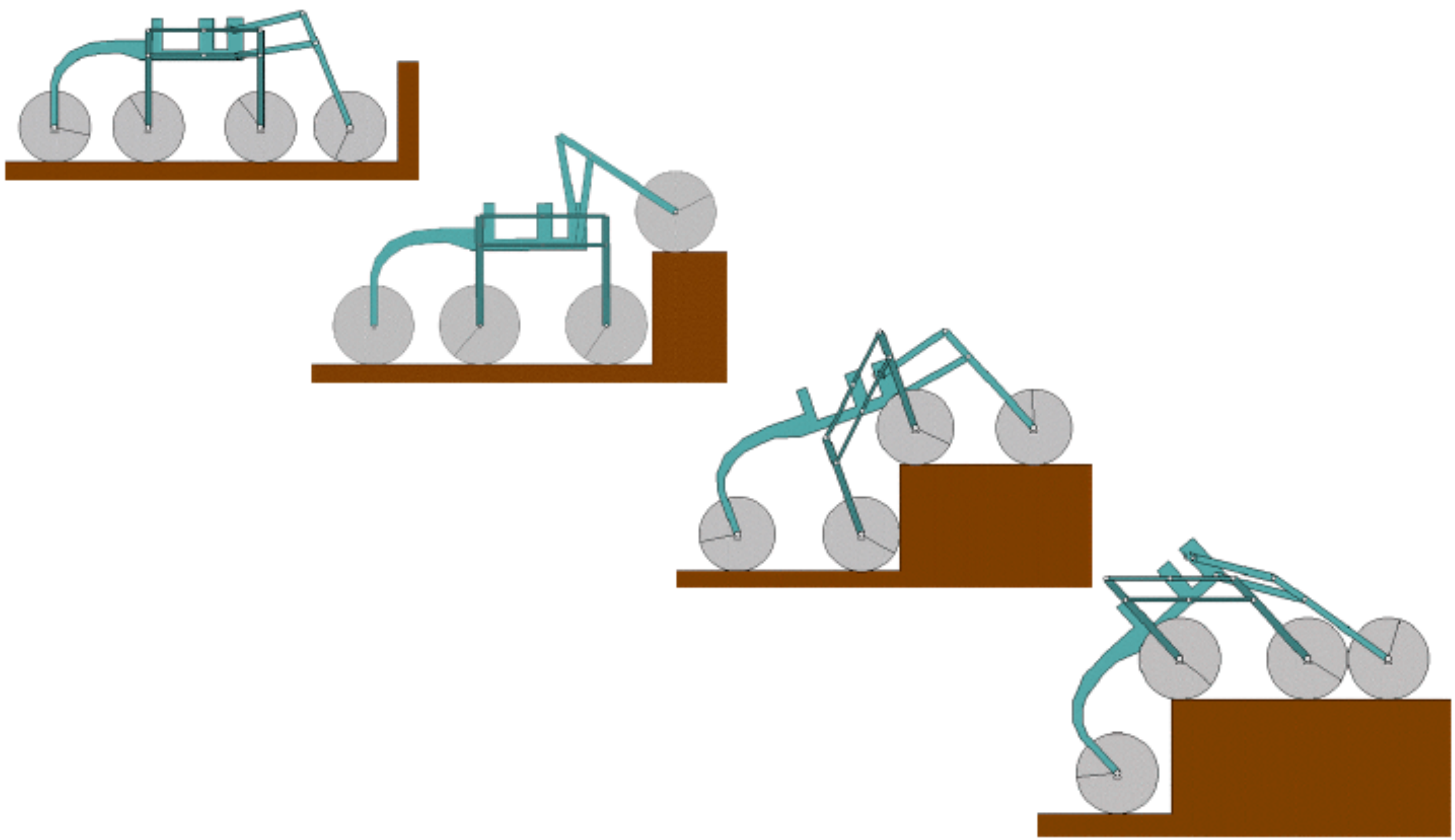
Walking Robots with 8 Legs

- http://www.youtube.com/watch?v=DJJv2ddCm-A

Wheels + legs = SHRIMP

- Objective
  - *Passive locomotion concept for rough terrain*
- Results: The Shrimp
  - *6 wheels*
    - *one fixed wheel in the rear*
    - *two boogies on each side*
    - *one front wheel with spring suspension*
  - *robot size is around 60 cm in length and 20 cm in height*
  - *highly stable in rough terrain*
  - *overcomes obstacles up to 2 times its wheel diameter*
- [*http://www.youtube.com/watch?v=n4ZB8Rg8La0*](http://www.youtube.com/watch?v=n4ZB8Rg8La0)

SHRIMP



Special locomotion

- **Flying**
- **Snake**
- **Skating**
- **Swimming**
- **Others…**

Flying

- A modern passenger airliner is essentially a flying robot, with two humans to attend it.
- The autopilot can control the plane for each stage of the journey, including takeoff, normal flight and even landing.
- Other flying robots are completely automated, and are known as **Unmanned Aerial Vehicles** (UAVs). They can be smaller and lighter without a human pilot, and fly into dangerous territory for military surveillance missions.

Snake

- Mimicking the way real snakes move, these robots can navigate very confined spaces, meaning they may one day be used to search for people trapped in collapsed buildings.

Skating

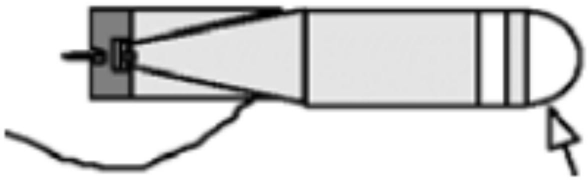
- Titan VIII - a multi-mode walking and skating device. It has four legs, with unpowered wheels, which can either step or roll.
- http://www.youtube.com/watch?v=4cAwzSZqO_w
- Another robot, Plen, can use a miniature skateboard or rollerskates, and skate across a desktop

Swimming

- It is calculated that some fish can achieve a propulsive efficiency greater than 90%.
- Furthermore, they can accelerate and manoeuver far better than any man-made boat or submarine, and produce less noise and water disturbance.
- Notable examples are the **Essex University Computer Science Robotic Fish**, and the **Robot Tuna** built by the Institute of Field Robotics.
- http://www.youtube.com/watch?v=GOSK4lVRTFw

Propeller-based versus swimming robots

- Pros of propeller-based robots:
  - Easy to construct
  - Easy to control
- Cons:
  - Limited agility
  - Bad speed/power ratio



- Pros of swimming robots:
  - Great agility (e.g. turning and acceleration)
  - Good speed/power ratio (good use of turbulences)
- Cons:
  - Difficult to design and construct
  - Difficult to control