Universidade Federal do Paraná

Especialização em Inteligência Artificial Aplicada

Mobile Robotics

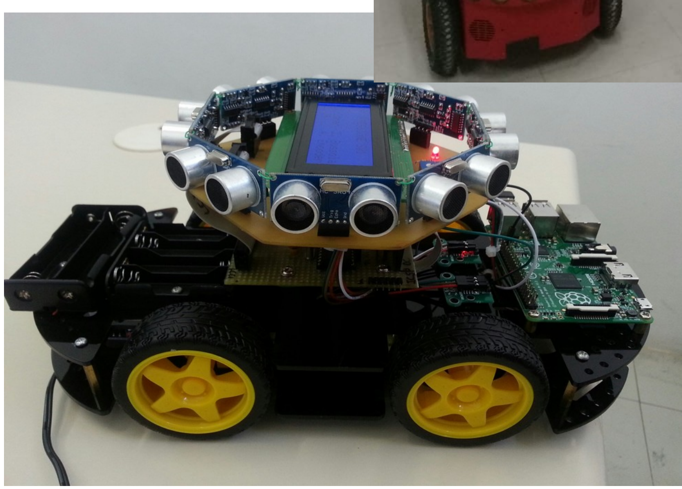
Introduction to locomotion

Prof. Eduardo Todt

2019

Mobile robots

Sucatao
(Victor Ruiz – VRI - UFPR)



Caco (Carlos Magrin – VRI - UFPR)

Pioneer em Chernobyl
http://www.frc.ri.cmu.edu/projects/pioneer/

Mobile robots

http://www.nimbro.net/@Home/robots.html

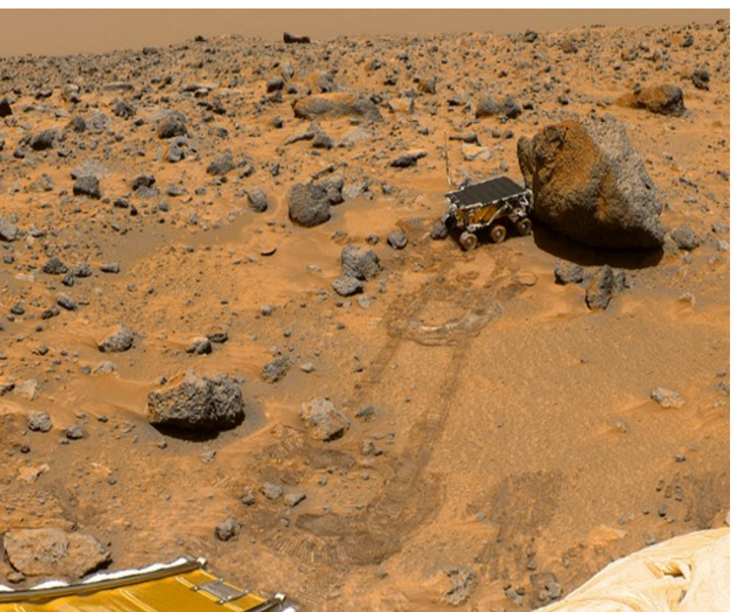
https://fetchrobotics.com

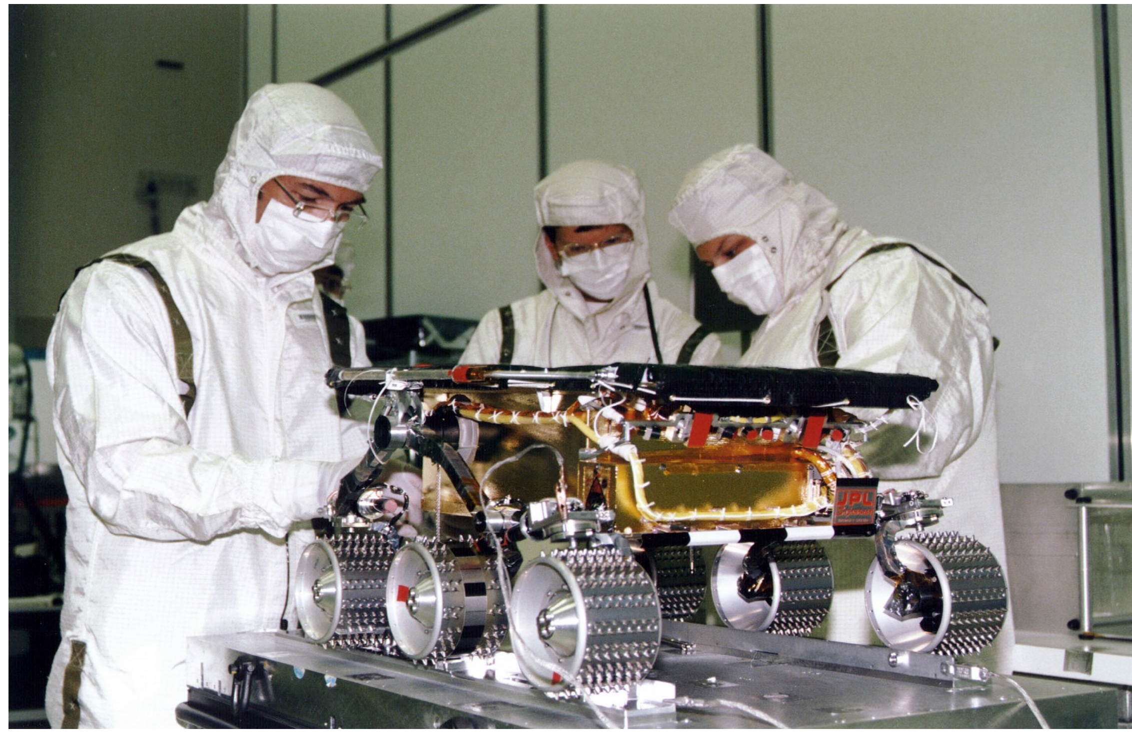
Mobile robots

WTC 2001, http://crasar.org

http://www.popsci.com/article/technology/
robots-may-replace-one-fourth-us-combat-soldiers-2030-says-general

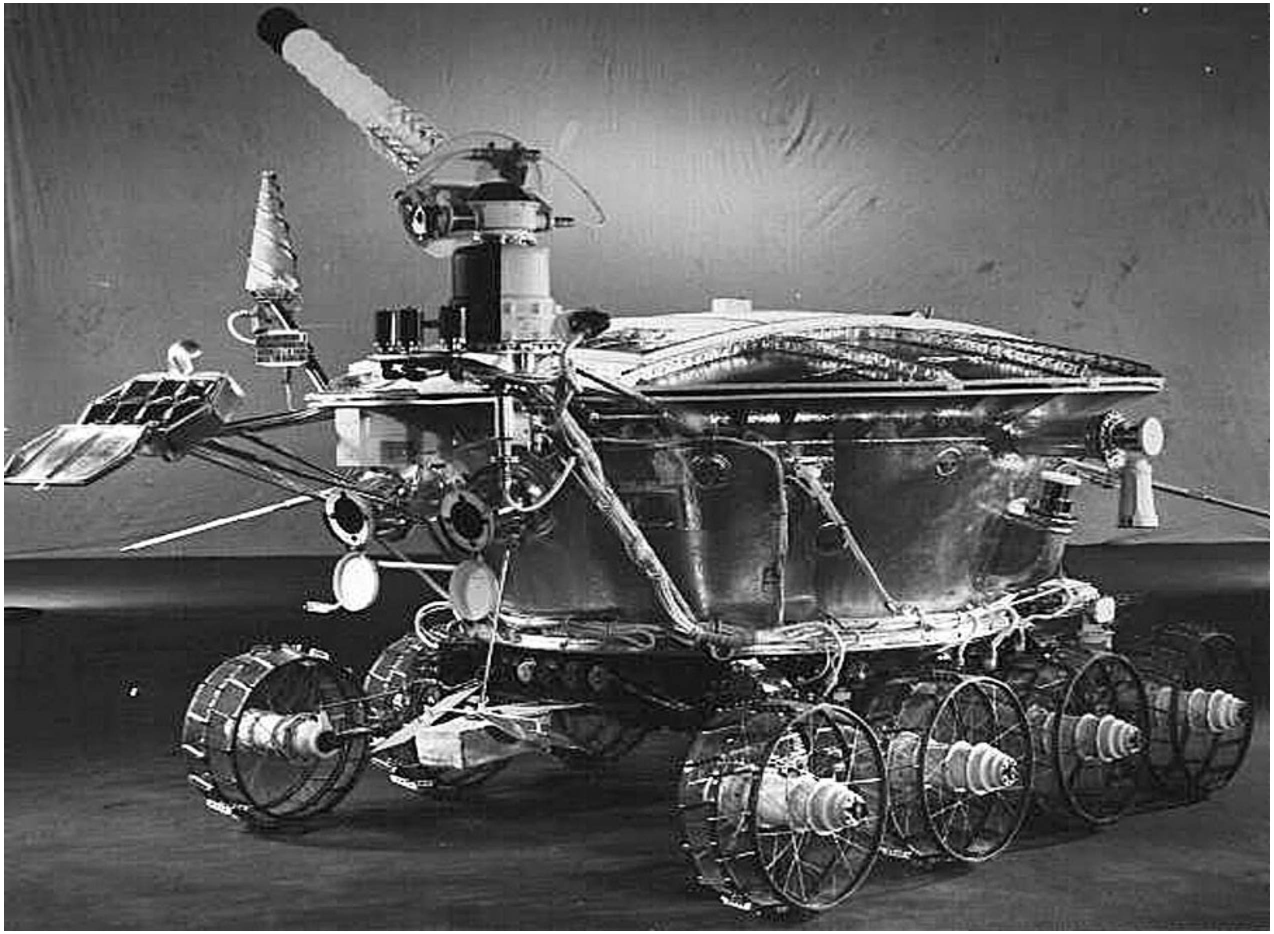
Mobile robots





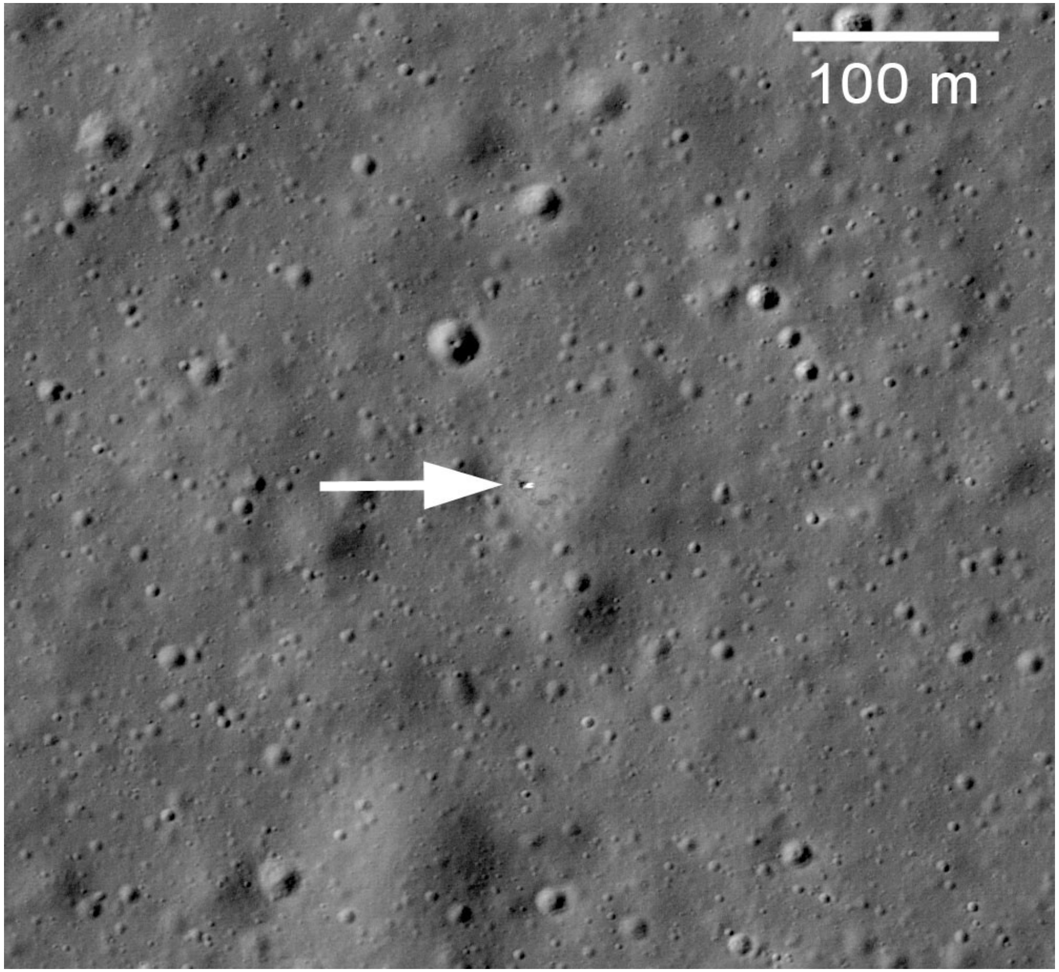
Pathfinder rover, NASA, 1996
www.nasa.gov

Mobile robots



Lunokhod, 1970, www.nasa.gov

Mobile robots

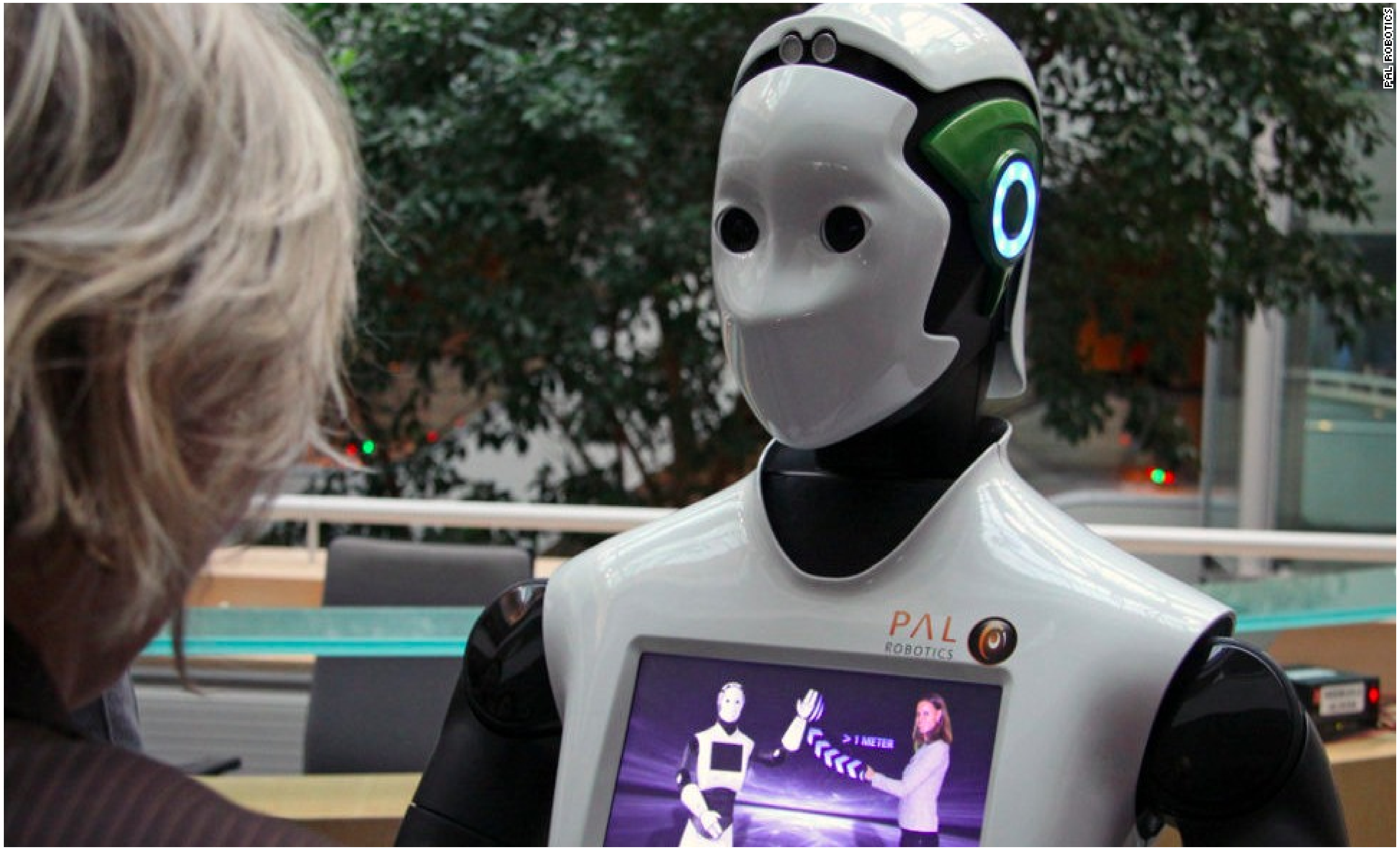


"Lunokhod1Spot" by LRO - http://www.nasa.gov/mission_pages/LRO/multimedia/lroimages/lroc-20100318.html
Licensed under Public Domain via Wikipedia - https://en.wikipedia.org/wiki/File:Lunokhod1Spot.jpg#/media/File

Antropomorphic robots

Lincoln animatronic
Feira Internacional de New York, 1964

Anthropomorphic robots



REEM Robot, PAL Robotics (Espanha)

Exoskeleton

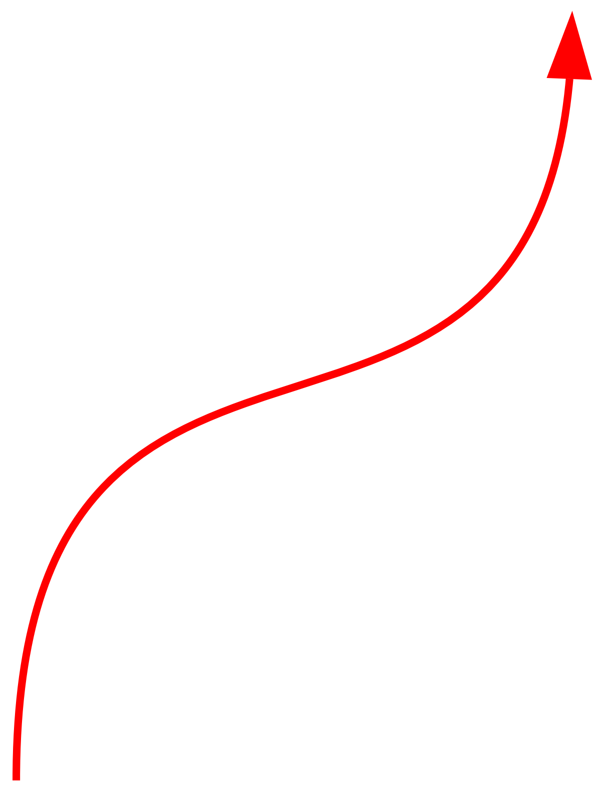
http://spectrum.ieee.org/img/NEW01OLEskoBionicsf2b-1324581899301.jpg

Mobile robot main tasks

Path planning

Navigation

Movement control



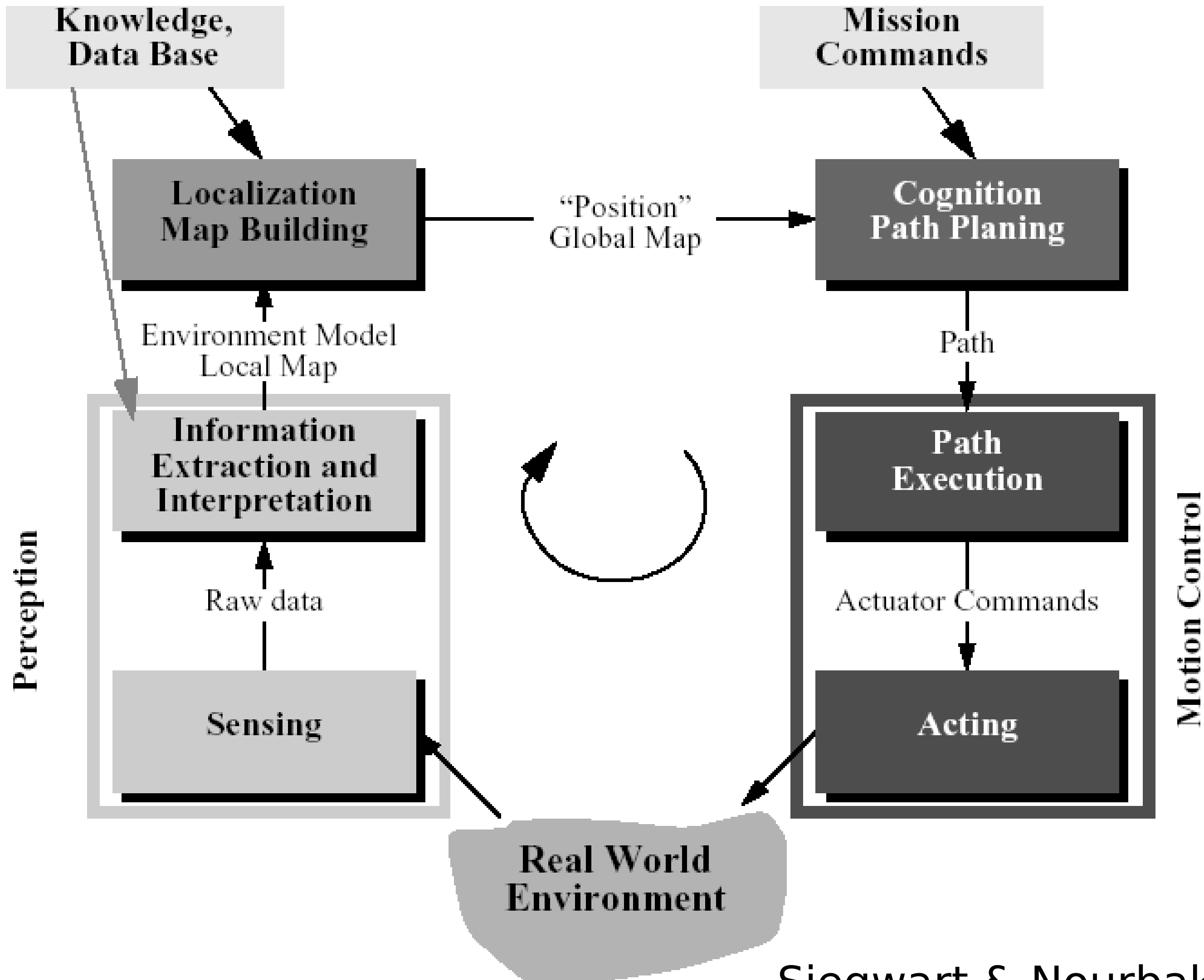
Autonomy vs Teleoperation

Communication delay

Complex movement coordination

Hostile environments

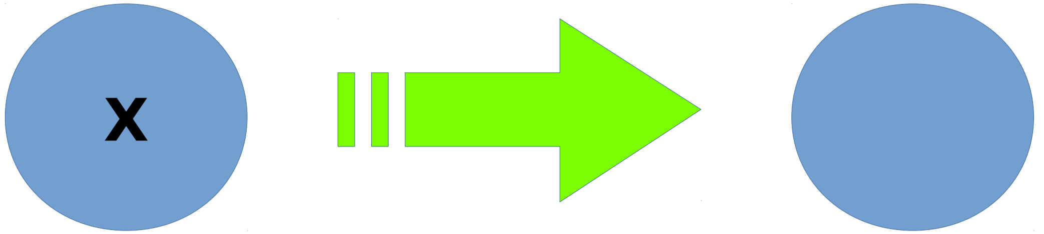
Reference model



Siegwart & Nourbakhsh 2004

Locomotion

Walk
Jump
Run
Slide
Swim
Fly
Roll (with wheels)



Locomotion

- Wheels
  - Simple
  - Efficient
  - Suitable for plane surfaces

- Legs
  - Biological approach
  - Many DoF (Degrees of Freedom)

Degrees of Freedom (DOF)

- Bulldozer
  - 1 DOF, hydraulic piston
- Human beings
  - More than 7 DoF, more than 15 muscles
- Legged robots
  - Usually 2, 3 or 4 DOF
    - up/down
    - forward/backward
    - Heel provides better terrain contact

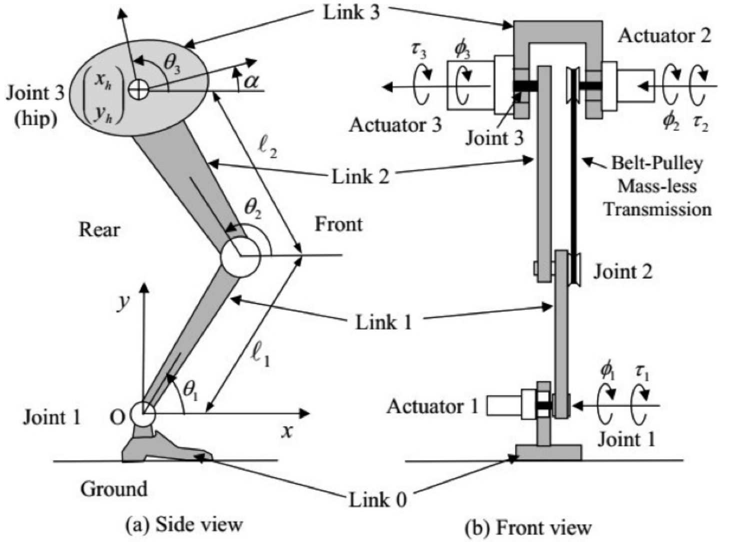


Figure 3 Leg robot

https://www.chegg.com/homework-help/questions-and-answers/problem-3-shown-planar-3-dof-robotic-leg-standing-ground-three-joint-angles-6-8-6-measured-q26942015

Keypoints

Stability
- Quantity and geometry of contact points
- Center of mass
- Static and dynamic stability
- Terrain geometry and inclination

https://airandspace.si.edu/multimedia-gallery/as11-40-5918hr-lunar-module-footpad

Contact
- Size and shape
- Angle of contact
- Friction

Environment
- Structure
- Material (water, air, soil, hard or soft floor, …)

Locomotion with legs

Several contact points robot – soil

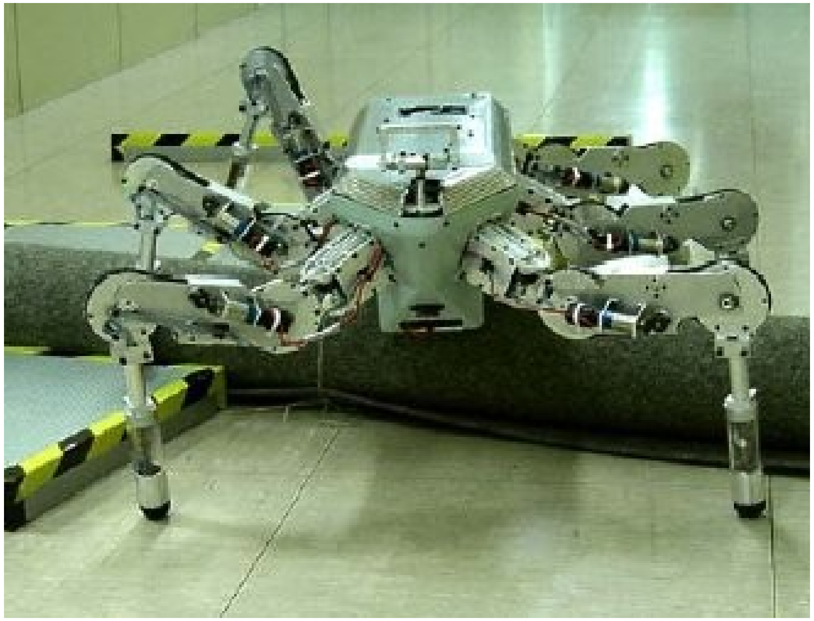
Adaptability and maneuverability

Good for irregular terrains

High energy requirements

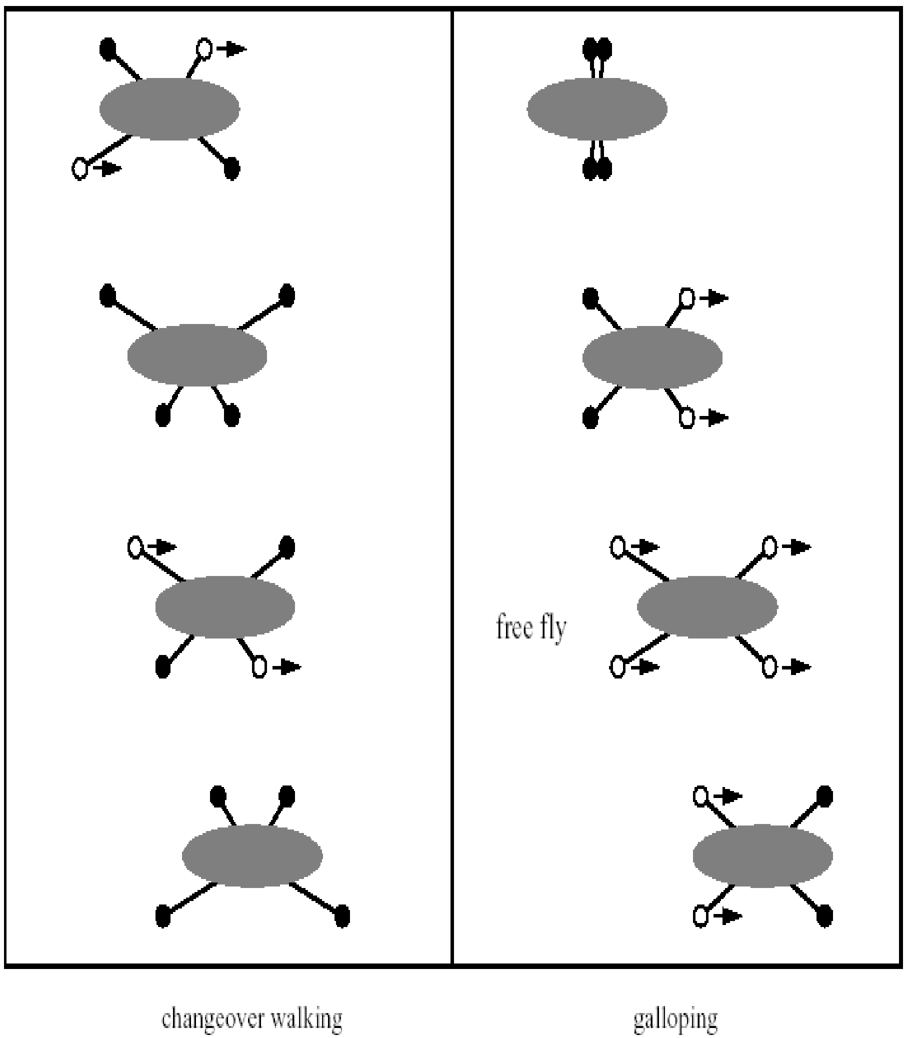
High complexity, many DoF

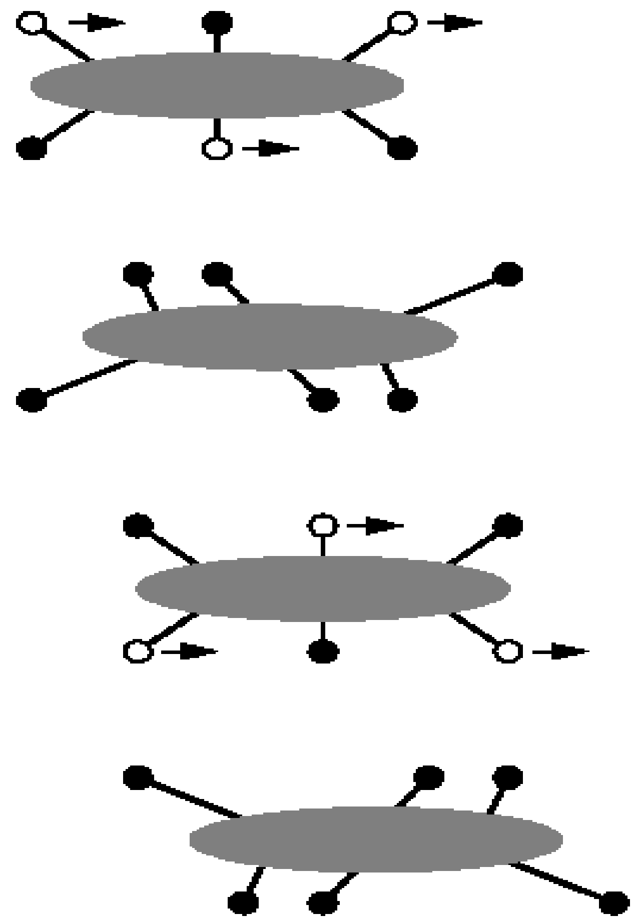
Biological inspiration



Lauron IV – Univ. Karlsruhe

Gait control





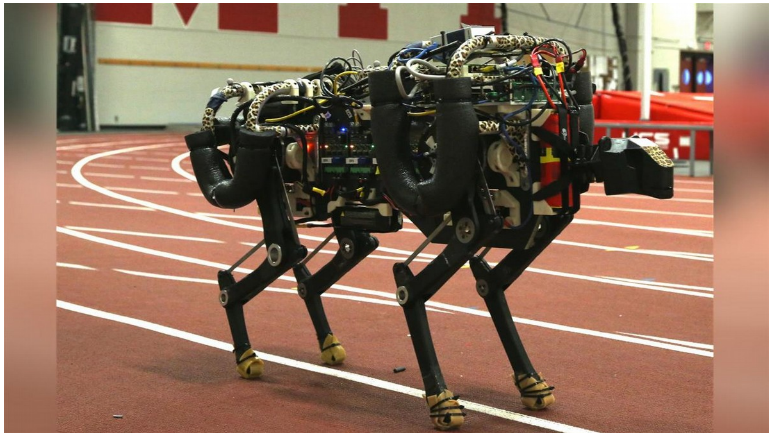
Siegwart & Nourbakhsh 2004

Gait control

With 2 or 4 legs there is no static movement

Walking learning is more complex

Walking vs galloping



m.wsj.ne

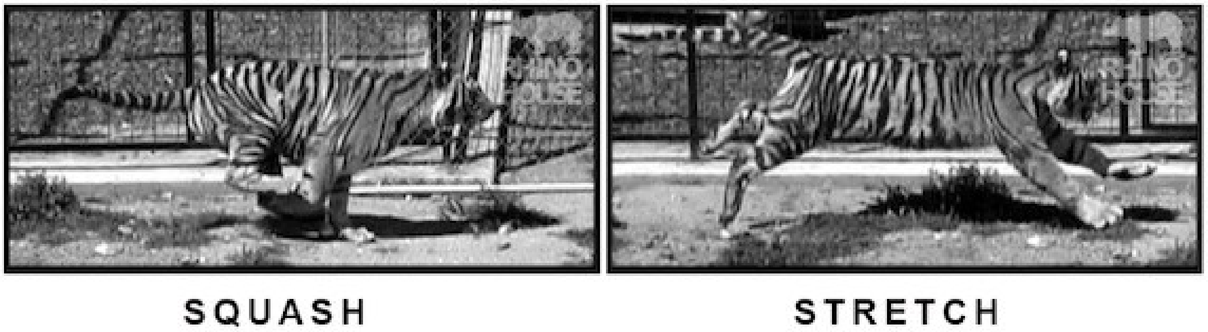
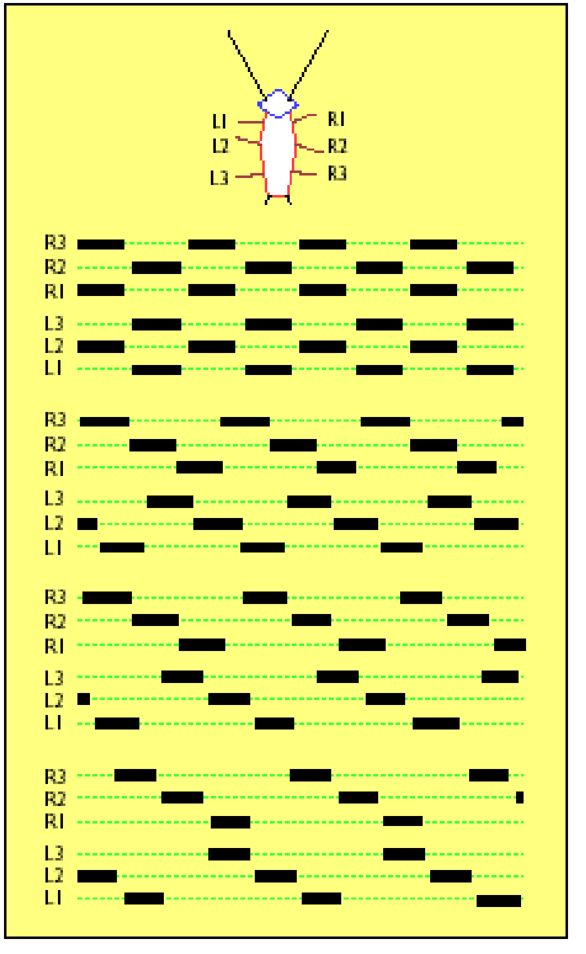


Image adapted from Tiger Locomotion Gallop 01, courtesy of www.rhinohouse.com

Gait control

Hexapods

- Usually each leg 3 DoF
- Several gait modes
- Biological inspiration
  - movements
  - adaptability



Clark-Haynes 2006

Wheeled locomotion

Most used in mobile robotics

Usually wheels in contact with soil
- Three wheels are enough for stability
- With more wheels suspension is needed

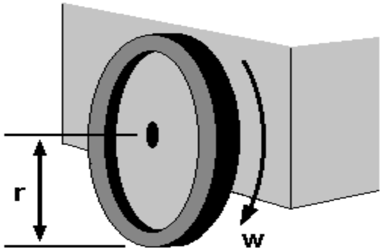
High energetic efficiency

Keypoints:
- Traction, estabilidade, maneuverability and control

Wheel types

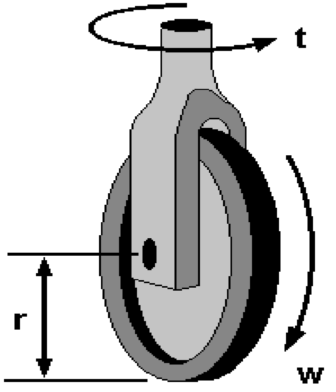
Fixed wheels

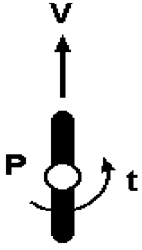
1 DOF



Steerable wheels

2 DOF

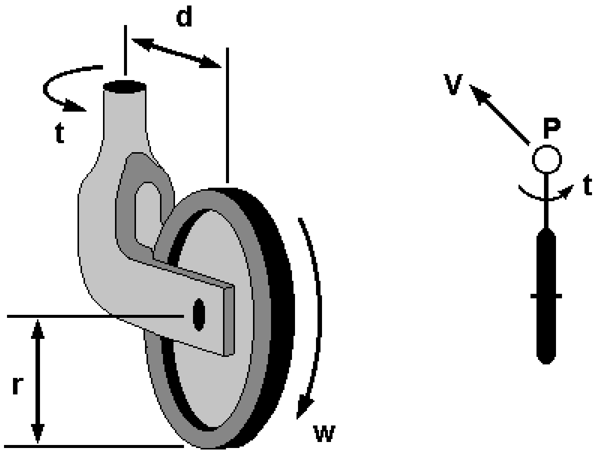




Wheel types

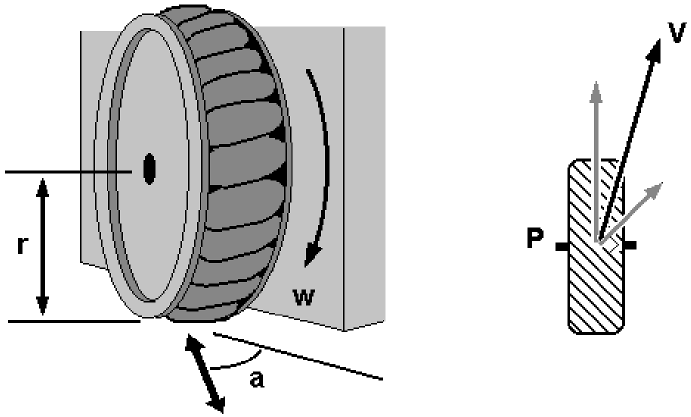
Castor wheels

- out of center orientable
- 3 DOF



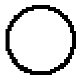
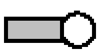
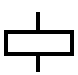
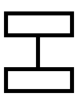
Swedish wheel

- Ominidirecional
- 3 DOF



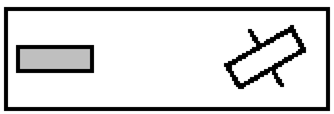
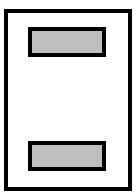
Siegwart & Nourbakhsh 2004

Wheel arrangement

Icons for the each wheel type are as follows:	
	unpowered omnidirectional wheel (spherical, castor, Swedish);
	motorized Swedish wheel (Stanford wheel);
	unpowered standard wheel;
	motorized standard wheel;
	motorized and steered castor wheel;
	steered standard wheel;
	connected wheels.

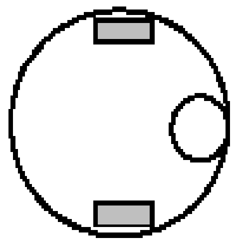
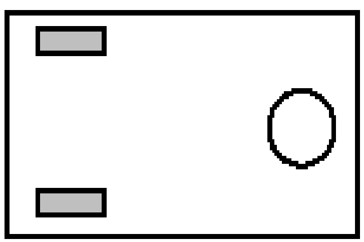
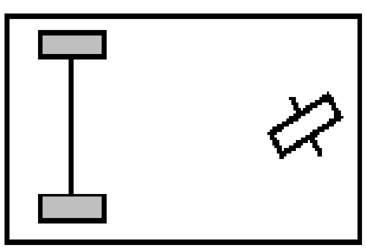
Siegwart & Nourbakhsh 2004

Wheel arrangement

# of wheels	Arrangement	Description	Typical examples
2		One steering wheel in the front, one traction wheel in the rear	Bicycle, motorcycle
		Two-wheel differential drive with the center of mass (COM) below the axle	Cye personal robot

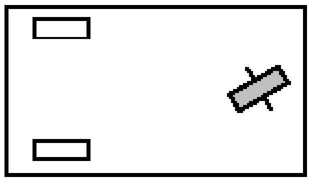
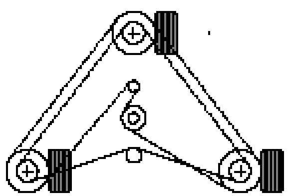
Siegwart & Nourbakhsh 2004

Wheel arrangement

3		Two-wheel centered differential drive with a third point of contact	Nomad Scout, smartRob EPFL
		Two independently driven wheels in the rear/front, 1 unpowered omnidirectional wheel in the front/rear	Many indoor robots, including the EPFL robots Pygmalion and Alice
		Two connected traction wheels (differential) in rear, 1 steered free wheel in front	Piaggio minitrucks

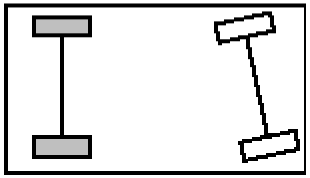
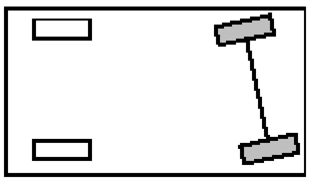
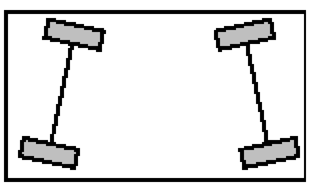
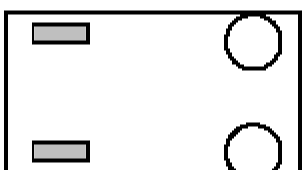
Siegwart & Nourbakhsh 2004

Wheel arrangement

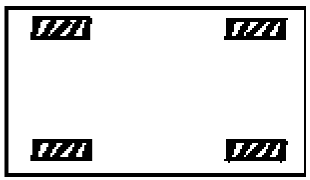
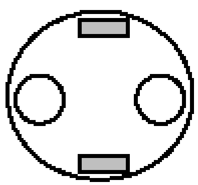
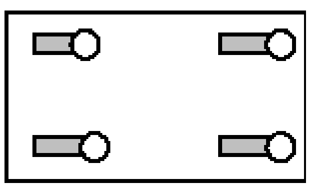
		Two free wheels in rear, 1 steered traction wheel in front	Neptune (Carnegie Mellon University), Hero-1
		Three motorized Swedish or spherical wheels arranged in a triangle; omnidirectional movement is possible	Stanford wheel Tribolo EPFL, Palm Pilot Robot Kit (CMU)
		Three synchronously motorized and steered wheels; the orientation is not controllable	“Synchro drive” Denning MRV-2, Georgia Institute of Technology, I-Robot B24, Nomad 200

Siegwart & Nourbakhsh 2004

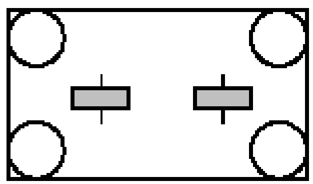
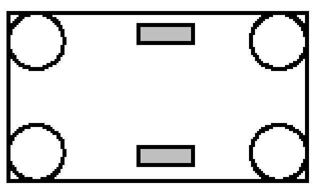
Wheel arrangement

4		Two motorized wheels in the rear, 2 steered wheels in the front; steering has to be different for the 2 wheels to avoid slipping/skidding.	Car with rear-wheel drive
		Two motorized and steered wheels in the front, 2 free wheels in the rear; steering has to be different for the 2 wheels to avoid slipping/skidding.	Car with front-wheel drive
		Four steered and motorized wheels	Four-wheel drive, four-wheel steering Hyperion (CMU)
		Two traction wheels (differential) in rear/front, 2 omnidirectional wheels in the front/rear	Charlie (DMT-EPFL)

Wheel arrangement

		Four omnidirectional wheels	Carnegie Mellon Uranus
		Two-wheel differential drive with 2 additional points of contact	EPFL Khepera, Hyperbot Chip
		Four motorized and steered castor wheels	Nomad XR4000

Wheel arrangement

# of wheels	Arrangement	Description	Typical examples
6		Two motorized and steered wheels aligned in center, 1 omnidirectional wheel at each corner	First
		Two traction wheels (differential) in center, 1 omnidirectional wheel at each corner	Terregator (Carnegie Mellon University)

Siegwart & Nourbakhsh 2004

Stability

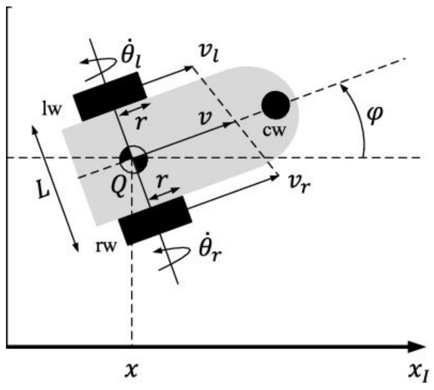


Figure by Raquel Dormido
Avaqilable at Research Gate

Center of mass location

Hiperstatic arrangements require flexible suspension

Bigger wheels traverse obstacles easier, but require greater tork

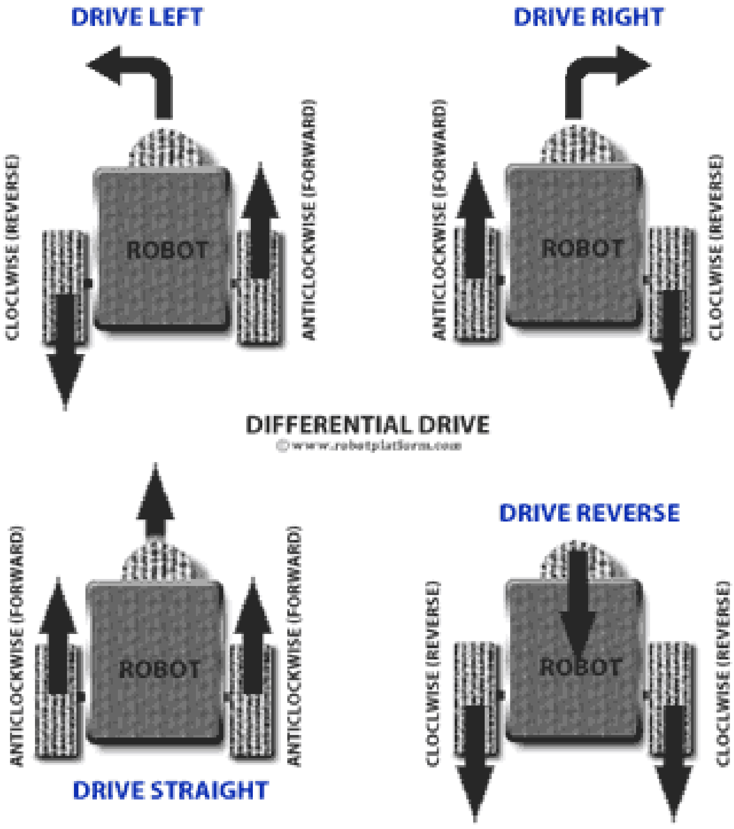
Traction and steering combined in the same wheel is more complex and results in bigger odometry errors

Minimum 2 wheels for static stability

Maneuverability

Two-wheel differential drive

Pioneer P3-DX



Maneuverability

Omnidirectional robots

http://www.cs.cmu.edu/~gwp/robots/Uranus.html

Maneuverability

Ackerman configuration

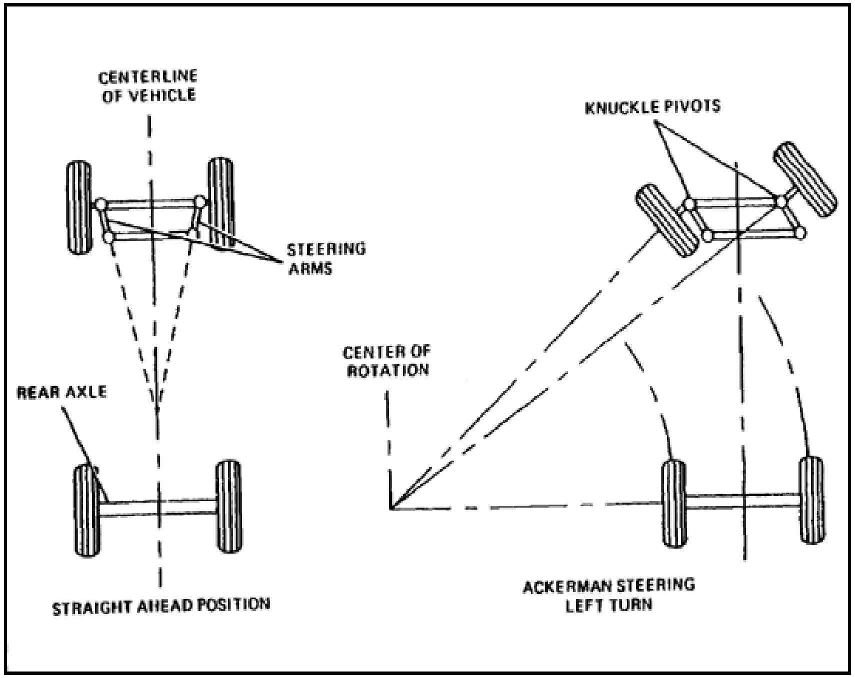
Georg Lankensperger, 1817 (München)

Turning radius usually greater than vehicle

Requires parking maneuvers

Poor maneuverability

High lateral stability



http://topmech.narod.ru

Controlability

Trade-off with maneuverability

With more DoF:

- Higher maneuverability
- More complex control
- Wheel coordination
- Wheel slipping

Recommended bibliography

Trade-off with maneuverability

With more DoF:

- Higher maneuverability
- More complex control
- Wheel coordination
- Wheel slipping