Introduction to Floating base Robots

Motivation

- industrial fixed-base robots are fast and accurate in a limited, structured, known, static workspace

- to be useful in the outside world, robots must be able to move **freely** in large, **unstructured**, **uncertain**, **dynamic** environments

Mobile robots

Possible applications:

- Exploration / inspection
- Search & rescue
- Transportation
- Demining / nuclear decommissioning
- Monitoring / surveillance
- Agriculture

Examples

Underwater

Seagoo ROV
(inspection)

Space

A robotic arm on the International Space Station grabbed onto a cargo capsule from the SpaceX spacecraft. NASA, via Associated Press

NASA SpaceX
(space manipulation)

Air

Amazon Prime Air Quadrotor
(delivery)

Wheels

WooWee Rovio
(monitoring)

Tracks

Indumil
(demining)

Legs

Big Dog
(trasnportation)

Asimo
(research)

Floating base robot:

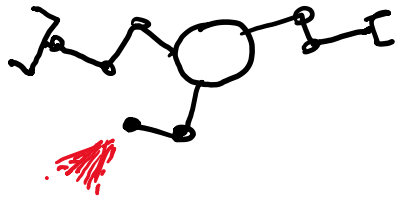
→ base is a moving body (in general underactuated)

FULLY ACTUATED → # actuators = # DOFs

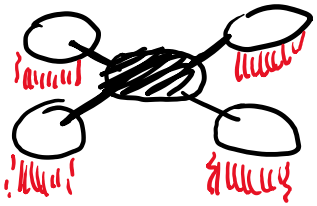
UNDERACTUATED → # actuators < # DOFs

→ The base can be controlled through the action of contact forces / Rockets!

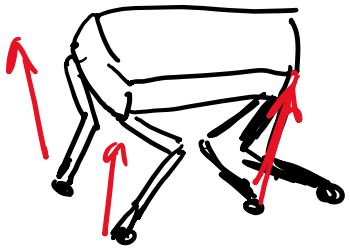
EXAMPLES:



space robots



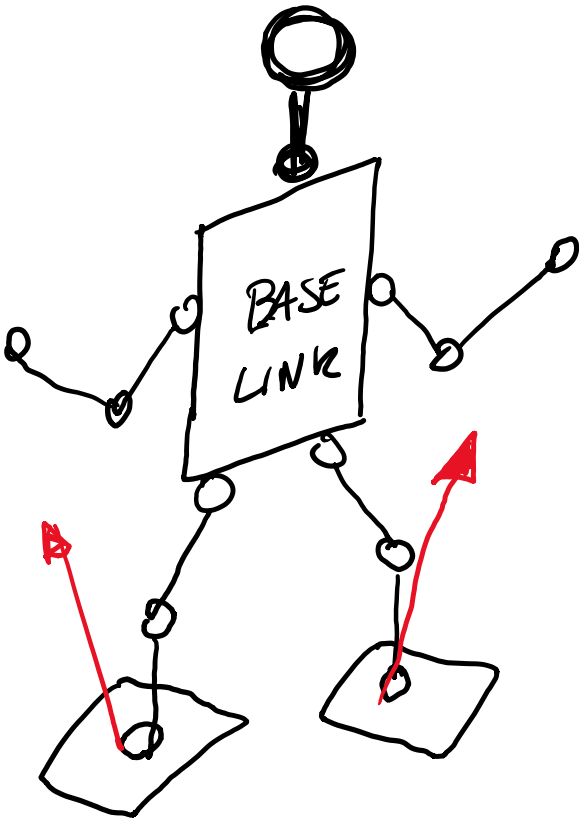
quadrotors



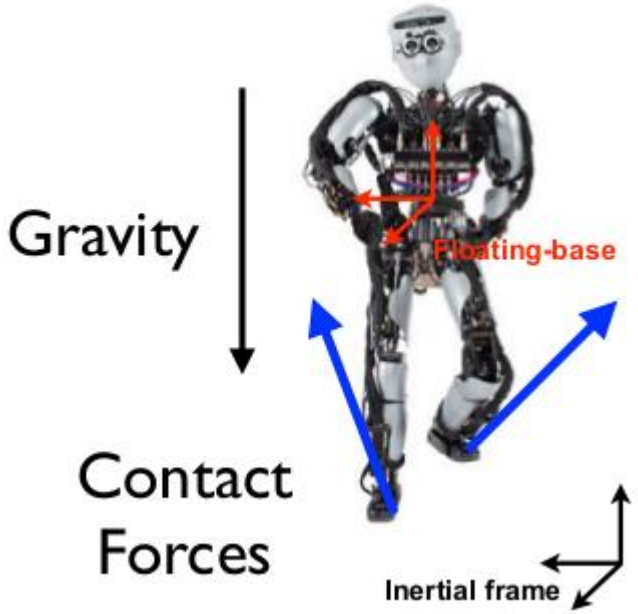
Legged Robots

Legged robots

Legged robot are peculiar tip of floating base robots with single chain kinematic structures (legs) that branch from the base (no kinematic loops)



Differently from fixed based robots Legged robots can fall…



Legged locomotion is about creating the right contact forces on the ground to keep balance and move in the desired direction

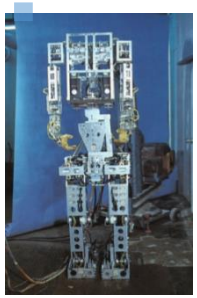
Brief history of legged robots

First computer-controller robot (Raiber, 70s – 80s)

P2
(Honda, 1996)

ZMP concept
(Vukobratovic, 1972)

1970 1980 1990 2000



First Humanoid Robot
(1973 - Waseda
University, Japan)

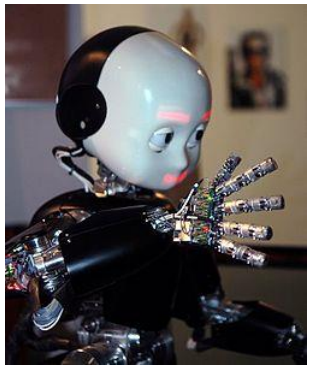
Purely passive dynamics
(McGeer, 1990)

The pre-robotic period
First walking machines were tele-operated by humans: GE Walking Truck (~1960s)

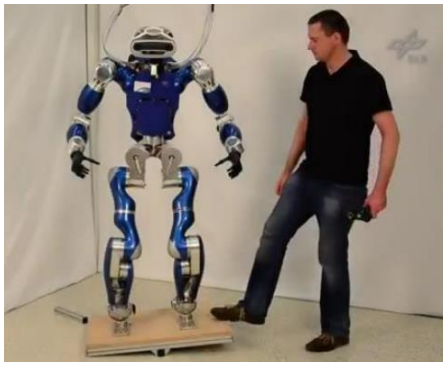
Brief history of legged robots

HRP-2
(Kawada, 2002)

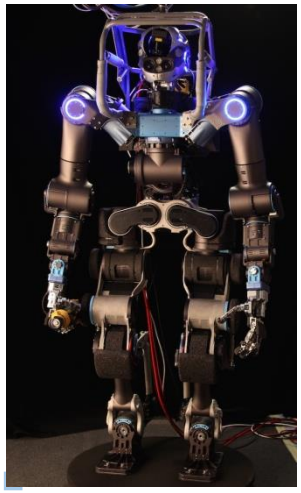
iCub
(IIT, 2009)



Toro
(DLR, 2013)



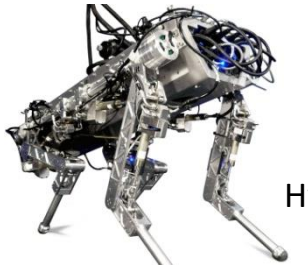
Walkman
(IIT, 2015)



2000 2010 2020

ASIMO,
Honda (2000)

BigDog, Boston Dynamics (2008)



HyQ, IIT (2010)

ANYmal, ETH
(2016)

Atlas, Boston Dynamics (2019)

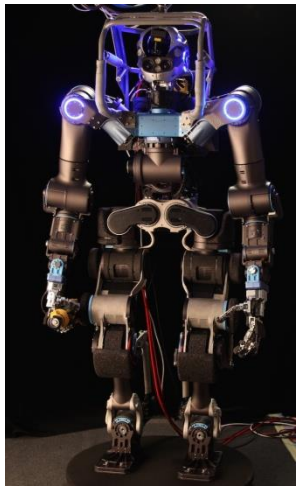
HyQReal, IIT (2019)

Humanoids VS Quadrupeds

Why Humanoids?

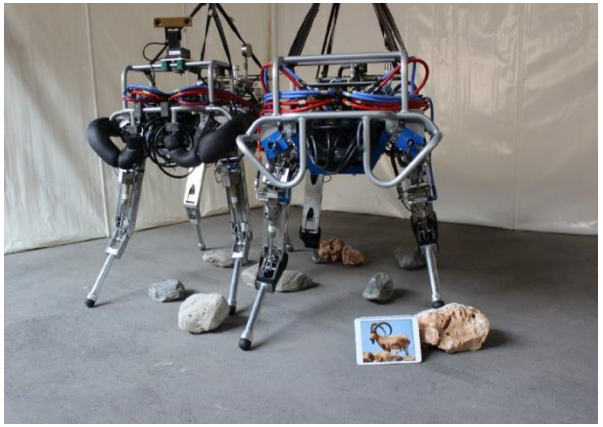
- adaptability: humanoids can work in environments suitable for humans and use machines designed for humans

- psychological and commercial reasons: humanoids have a major appeal because of human-like appearance: empathy



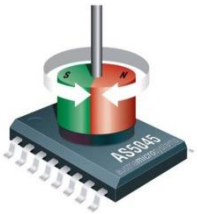
Why quadrupeds?

- Higher stability due to the larger support polygon
- Smaller feet (point-like assumption)
- Different kind of gaits (walk, trot, pace…)



Sensor equipment

- **proprioceptive**: perception of the robot itself
  - Joint positions (encoders)
  - Joint torques (loadcell, torque sensors)
  - Base orientation, velocity, acceleration (IMU)

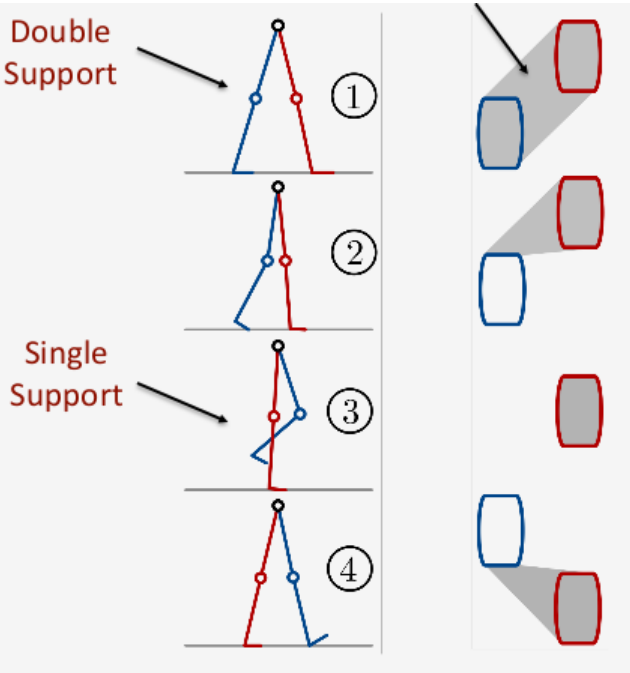


- **exteroceptive**: perception of the environment surrounding the robot (obstacles, robots, people, etc)
  - Infrared cameras
  - Stereo cameras
  - Laser cameras

Basic terminology: Support Polygon (SP)

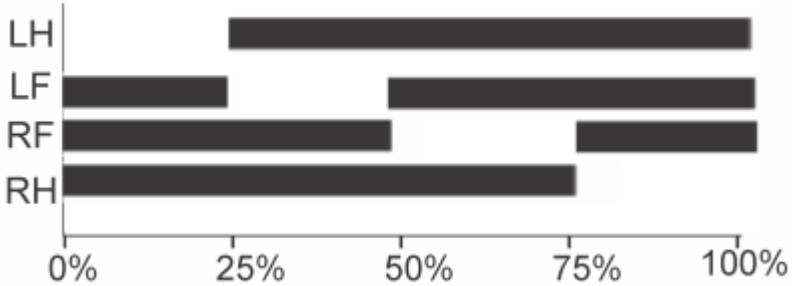
Convex hull of the contact points

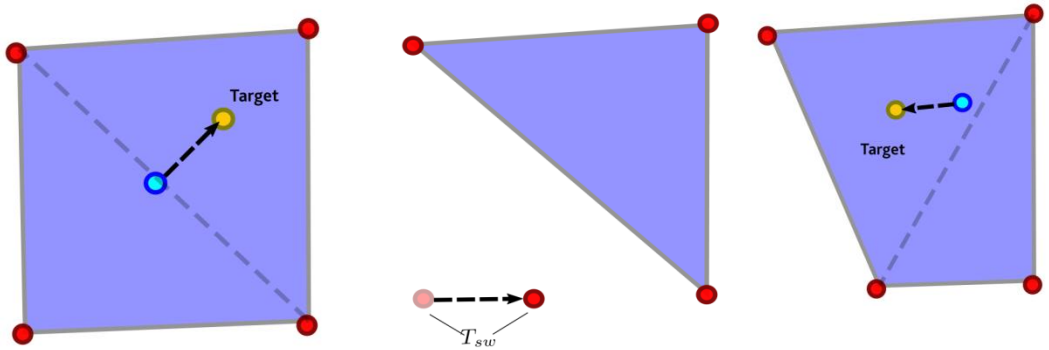
Humanoids



Quadrupeds

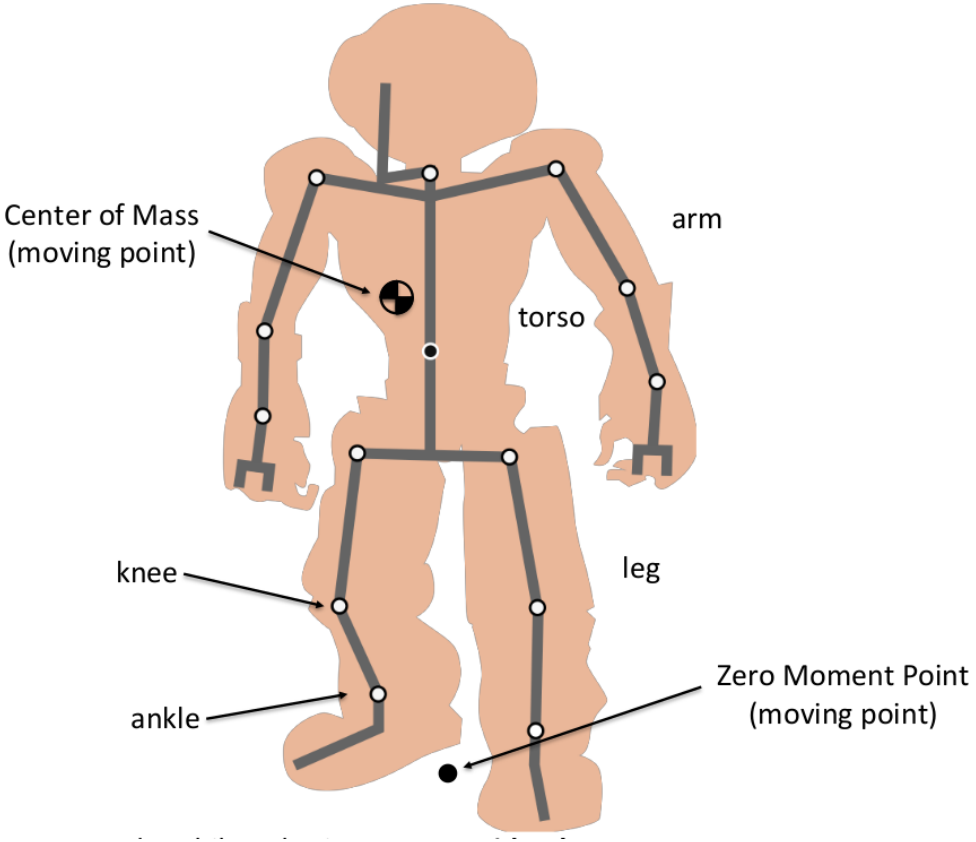
Gait scheduler: crawl example

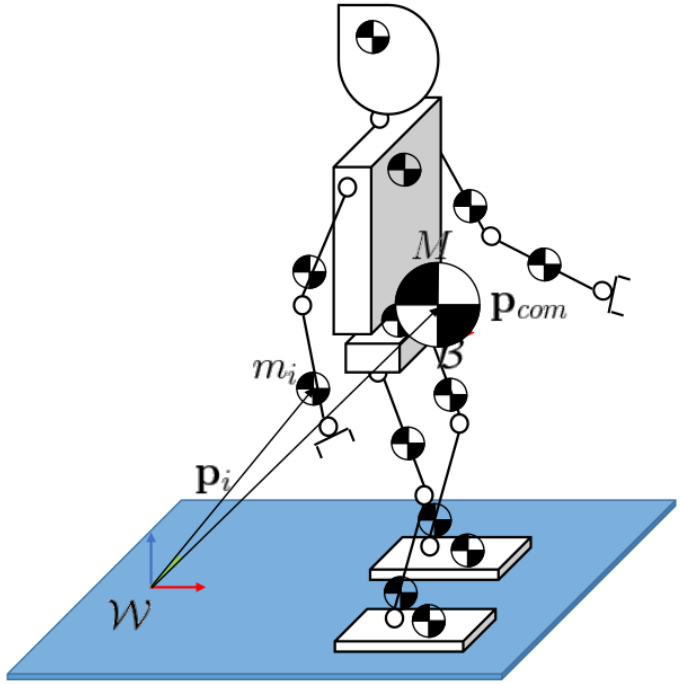




4-leg stance | 3-leg stance | 4-leg stance

Basic terminology: Center of Mass (CoM)





$$x_{COM} = \frac{\sum_{i=0}^{n} x_i m_i}{\sum_{i=0}^{n} m_i \rightarrow M_{TOT}}$$

x_i = Position of The COM of Link i in The frame of interest