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UNIVERSITÄT
MAGDEBURG

INF

FAKULTÄT FÜR
INFORMATIK


# Robot Locomotion – An Introduction

## Softwaredevelopment for Industrial Robotics

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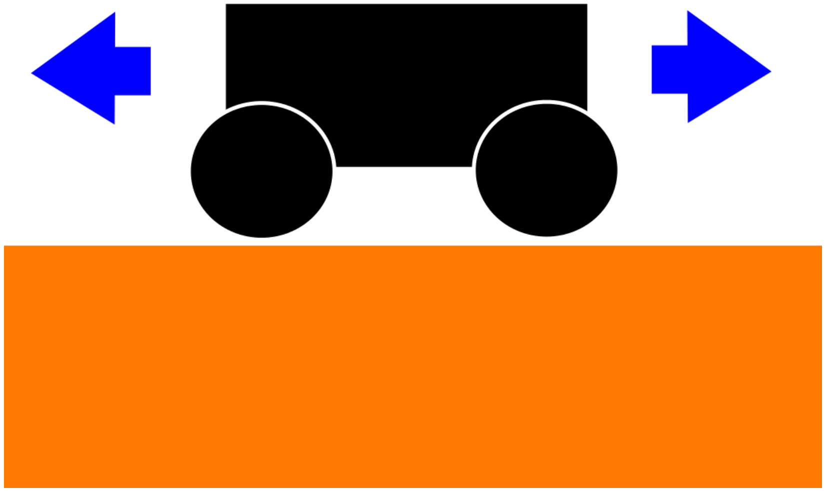
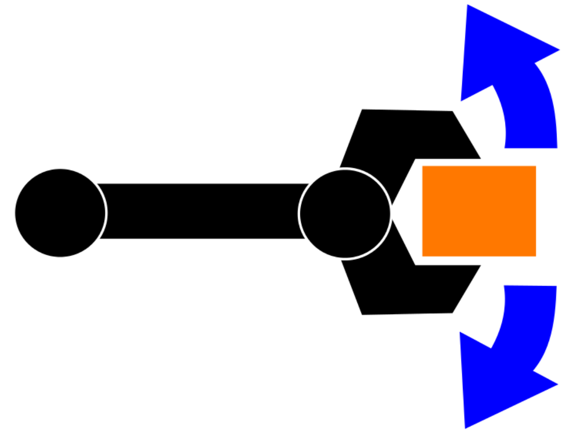
# Structure of presentation

# Introduction to locomotion





Locomotion
- Environment fixed
- Robot is moved

Manipulation
- Robot fixed
- Object is moved

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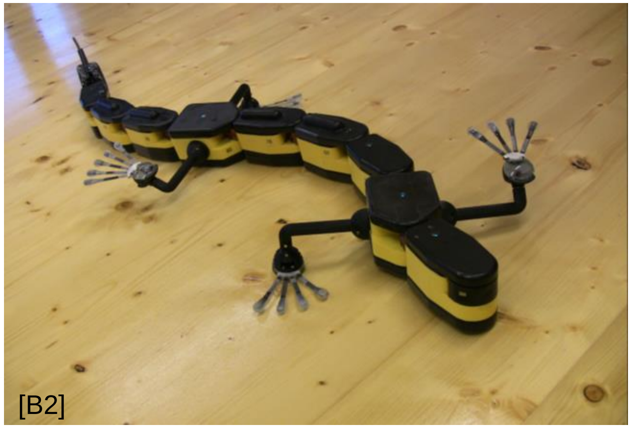
# Introduction to locomotion


Salamandra



Meshworm

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# Introduction to locomotion

[B5]

[B6]

Mini Whegs


[B7]

[B8]

WildCat

# Introduction to locomotion


[B9]


[B10]

Asimo

?


[B11]

Pioneer

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# Why do we need mobile robots?

Do things which static robots can not do!


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# Where do we need them?

- Daily life → e.g. home, medical facilities, nursing, entertainment

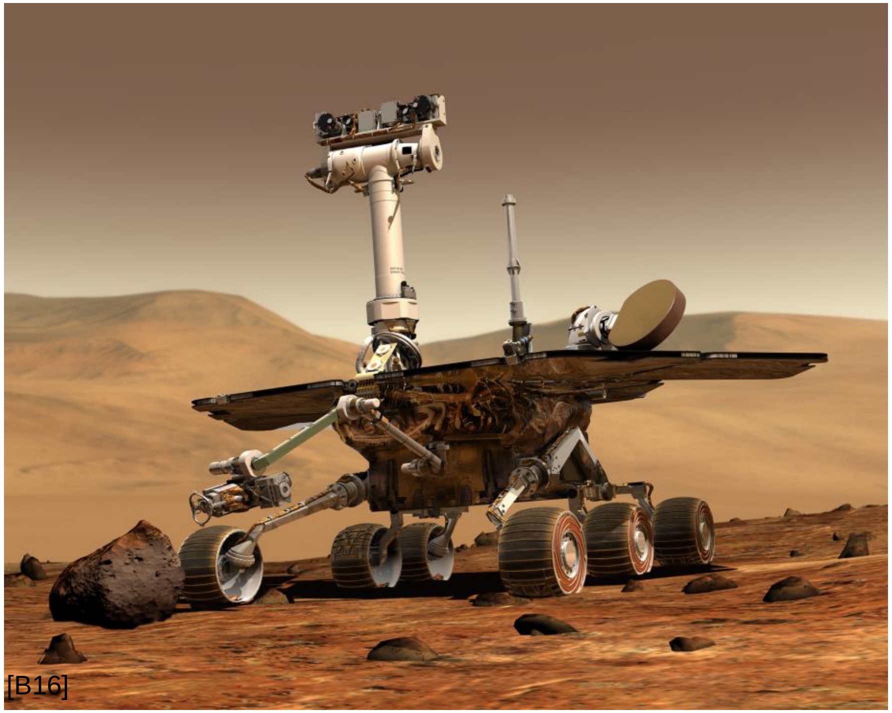

[B14]

# Where do we need them?

- Industry → e.g. carry heavy loads, logistics

# Where do we need them?

- Extreme environments → e.g. dangerous working places, disaster zones, war zones



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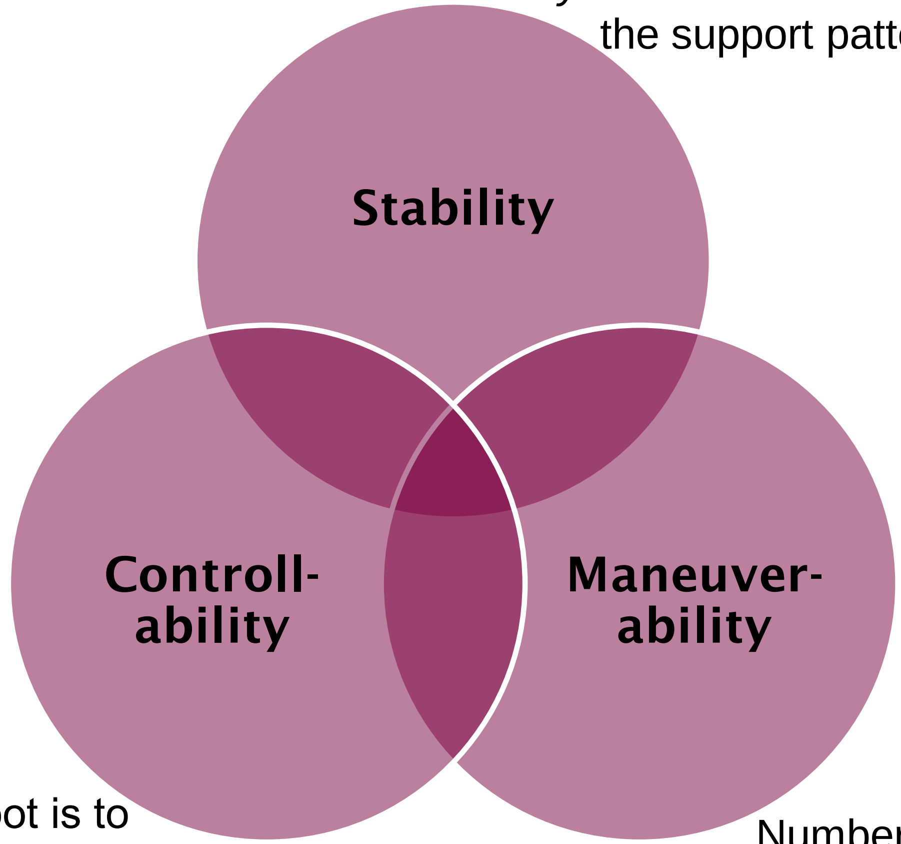
# Core issues of locomotion (1)

## Major trade-off

*Statically-stable* → center of gravity lies inside the support pattern




how “easy” the robot is to control to achieve the desired motion

Number of manipulateable DOFs

# Core issues to locomotion (2)

- Stability
  - Number and geometry of contact points
  - Center of gravity
  - Static/dynamic stability
  - Inclination of terrain
- Characteristics of contact
  - Angle of contact
  - Friction
- Type of environment
  - Structure
  - Medium
- Velocity
- Energy efficiency
- Degrees of freedom

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# Legged Locomotion (1)

## … series of point contacts between the robot and the ground

⟶ Quality of ground between point contacts do not matter

Atlas, bipedal robot, Boston Dynamics, 2013 [Q3]

**Properties:**

- → Adaptability and maneuverability in rough terrain
- → Potential to manipulate objects in the environment
- → High power consumption and mechanical complexity

**Important issues:**

- → Maneuverability vs. energy, control and mass
- → Stability during walking

Mantis hexapod walking machine, micromagic systems, 2009 [B17]

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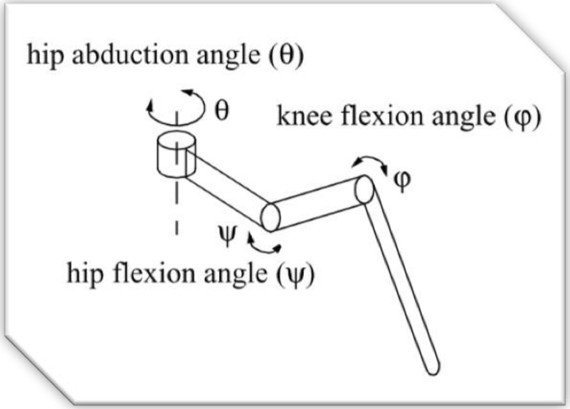
# Legged Locomotion (2)

## The leg

- Adding joints = adding degrees of freedom (DOF)
- Adding DOF =
  → increasing maneuverability
  → increasing power consumption and weight of the robot
  → controlling becomes more complex
- Minimum of 2 DOF required for moving leg forward:
  → a lift and a swing motion
- 3 DOF for each leg in most cases
  → travel in rougher terrain
  → do more complex manoeuvres




Example of a leg with 3 DOF [Q1]

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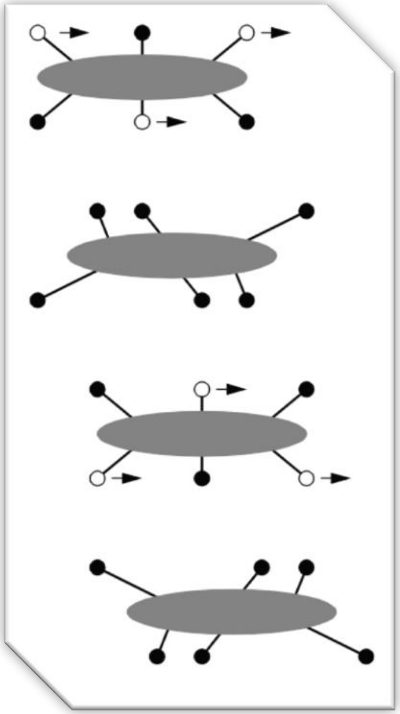
# Legged Locomotion (3)

## Stability during walking – static/dynamic stability

- During walking some legs are lifted
  –Thus loosing stability?
- The fewer legs the more complicated becomes locomotion
  → At least 3 legs are required for static stability
- Static walking requires at least 6 legs
  → more complex controlling,
  → higher weight,
  → higher power consumption
- Bipedal robots are just dynamically stable
  → continuous balance-correcting is needed



Static walking with 6 legs [Q1]

# Wheeled locomotion (1)

## Basic

- Most appropiate solution for many applications
- Most popular locomotion mechanism
- Simple mechanical implementation
- Easy balance
- Very high efficiency ratings
- Size of wheels can compensate environmental constrains


[B18]

# Wheeled locomotion (2)

## Stability

- 3 wheels always stable
- 2 wheels can be stable

## Environment

- Biggest limitation → best on planar surfaces
- Wheel size compensate environmental contrains

## Velocity

- Fastest movement

## Energy efficiency

- Wheels use simple mechanics → best e.e., but limited to planar surf.

## Degrees of fredom

- Omnidrive → 3DOFs
- Need more, need special mechanisms

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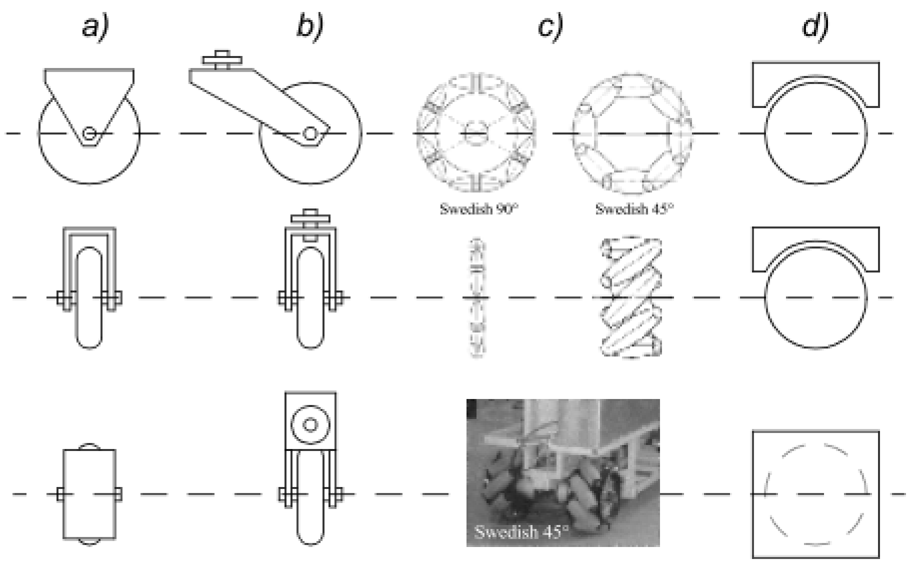
# Wheel types and DOF

a) Standard wheel
   2DOFs: Rotation around wheel axe (1) and contact point (2)
b) Castor wheel
   2 DOFs: Roation around wheel axe (1)
   and contact point (with offset)(2)
c) Swedish wheel
   3 DOFs: Rotation around wheel axe (1), contact point (2)
   and rollers (3) → omnidirectional
d) Ball / spherical wheel
   difficult technical realization → omnidirectional



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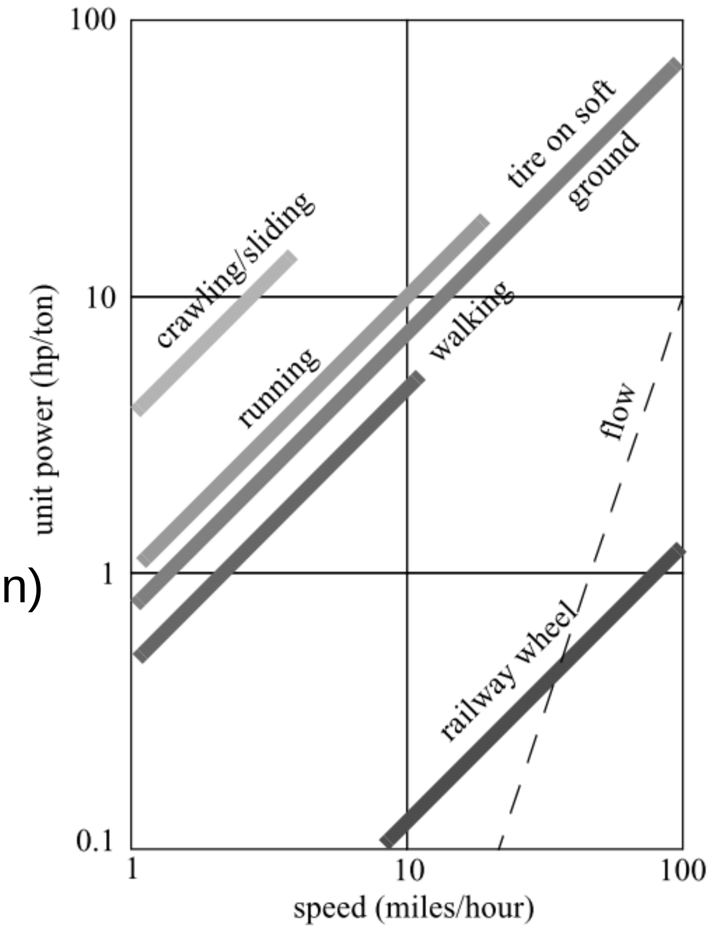
# Comparision walking ↔ rolling

| Core issue | Walking | Rolling |
|---|---|---|
| Stability | – | + |
| Environment | ++ | –– |
| Velocity | – | ++ |
| Energy efficiency | – | + |
| Degrees of freedom | + | – |



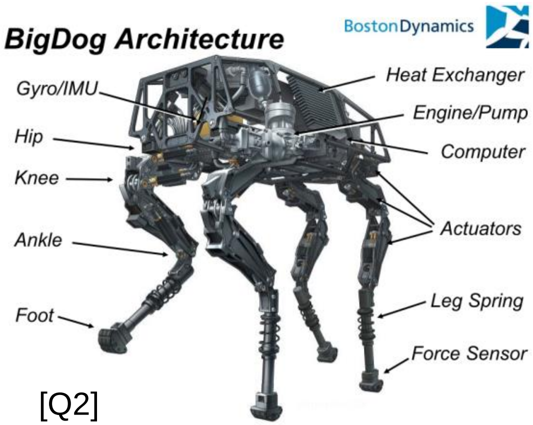

- At least 2 wheels can be stable (suspension)
- Legs don´t be limited to environement
- Wheels move faster (legs still on research)
- Energy efficiency depends on reference
- Legs can move upward (but complex)

# Outlook to locomotion: Walking Robots from Boston Dynamics

## BigDog

- Rough-terrain quadruped robot
- Runs at ~6.4km/h
- Climbs slopes up to 35 degrees
- Carries ~154kg
- Funded by DARPA

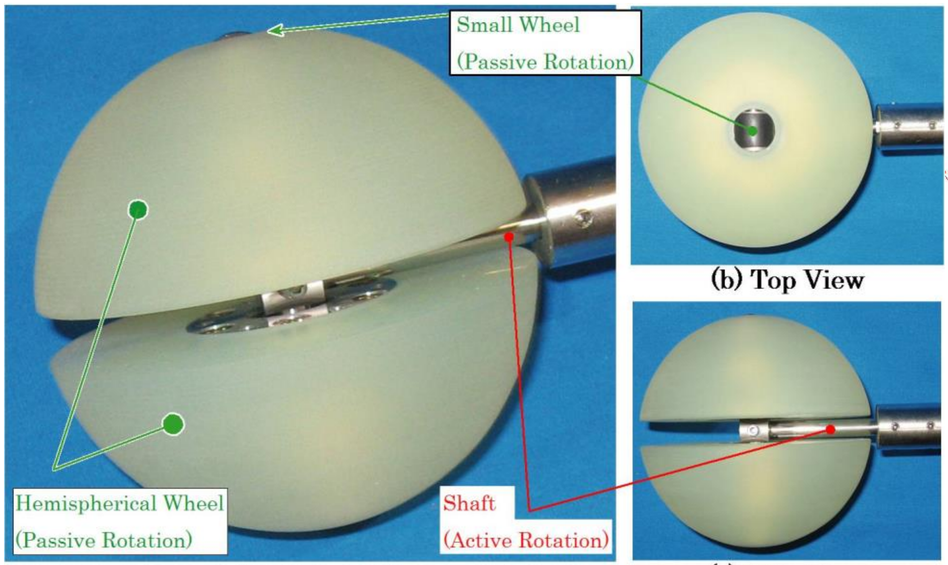
[removed video]



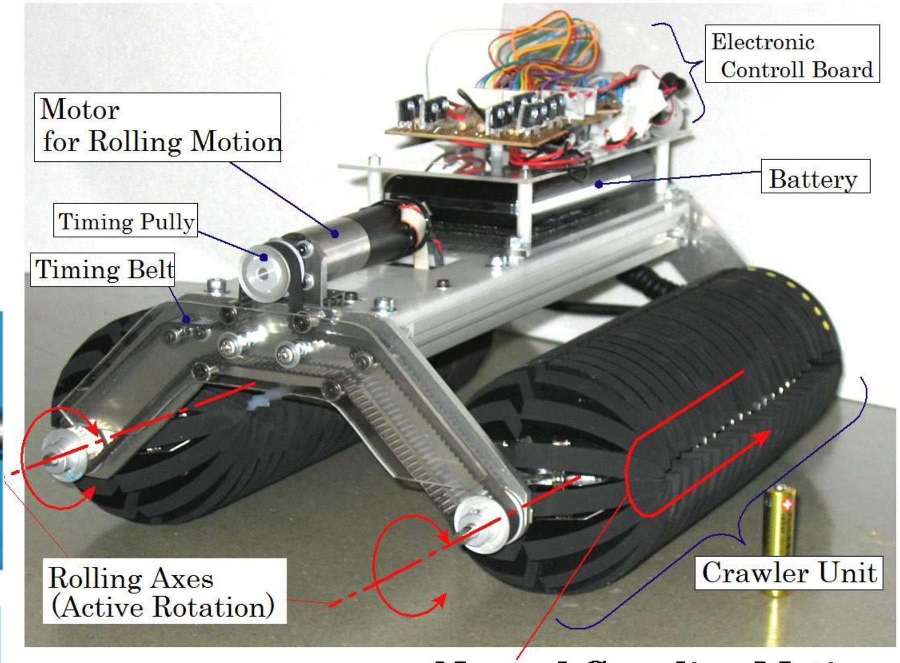

[Q2]

# Outlook to locomotion: Omni-Crawler

- From Osaka University (2009)
- Active Omnidirectional movement
- Crawler → big load capacities




(a) Oblique View (b) Top View (c) Side View




Normal Crawling Motion

[B19]

# Outlook to locomotion: VelociRoACH

- University of California, Berkeley (2013)
- Closed kinematic chain

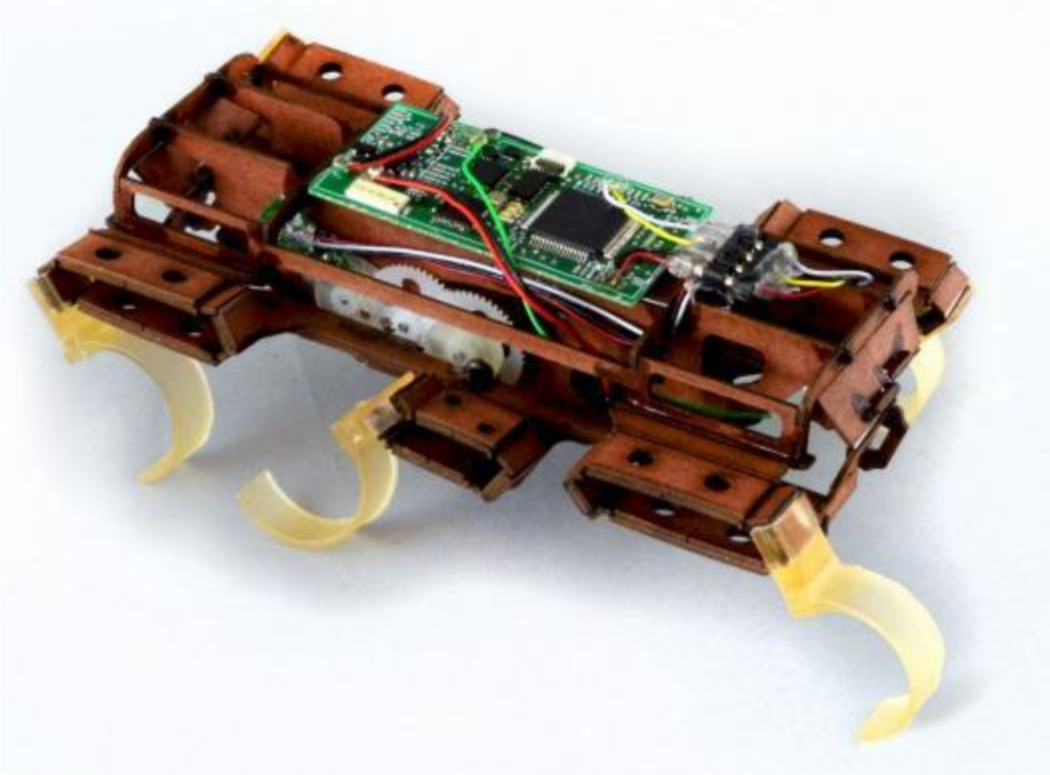
→ only one engine required!

Speed: 10km/h

Weight: 30g

Length: 10cm

→ 27 body length / sec



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# Many thanks for your attention!

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[Q3] http://www.bostondynamics.com Stand: 25.10.2013

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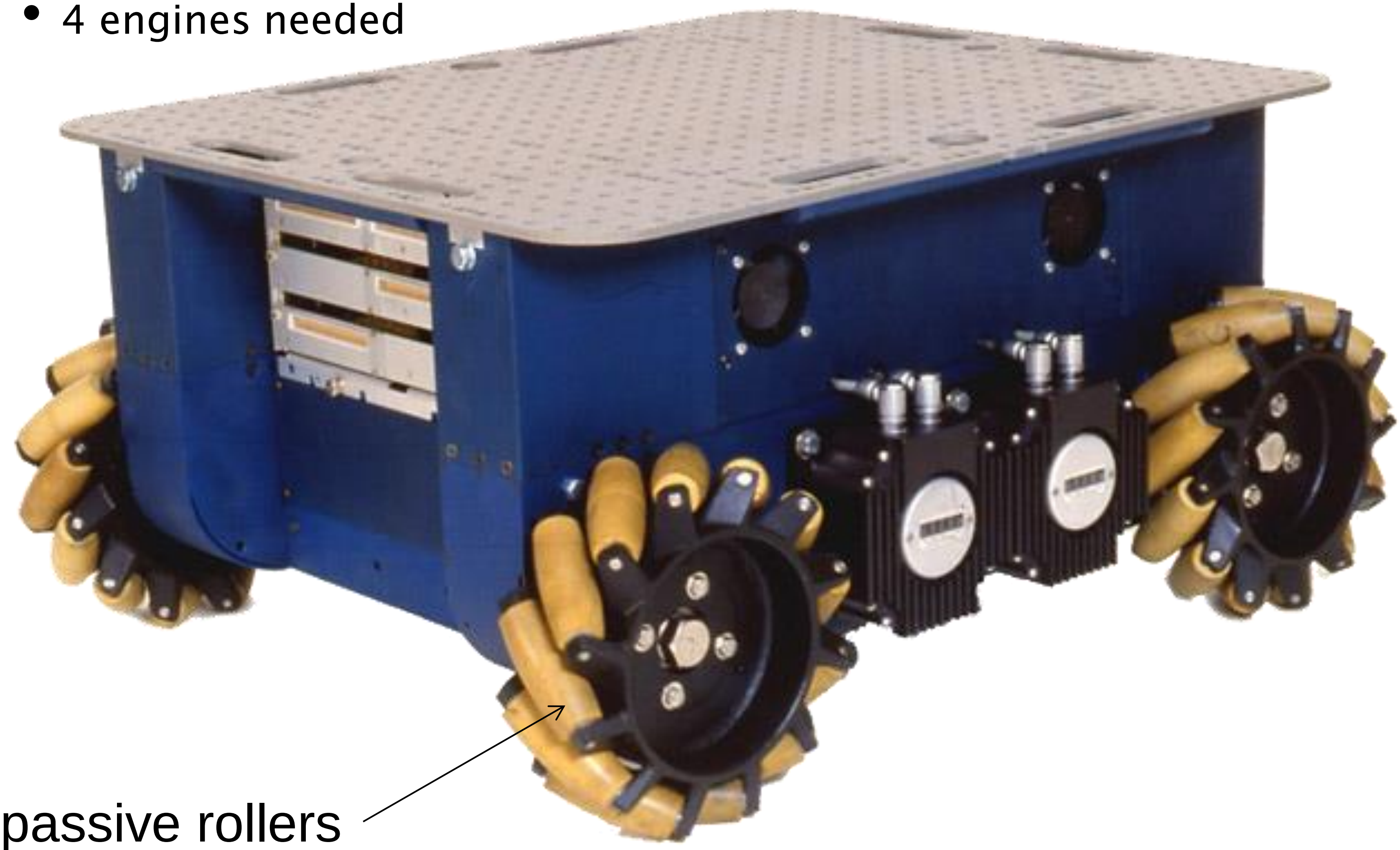
[B20] http://www-hh.mech.eng.osaka-u.ac.jp/robotics/Omni-Crawler_e.html Stand: 25.10.2013

# Appendix: swedish wheel

- Omnidirectional, but passiv
- 4 engines needed



passive rollers