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UNIVERSITÄT
MAGDEBURG

INF

FAKULTÄT FÜR
INFORMATIK

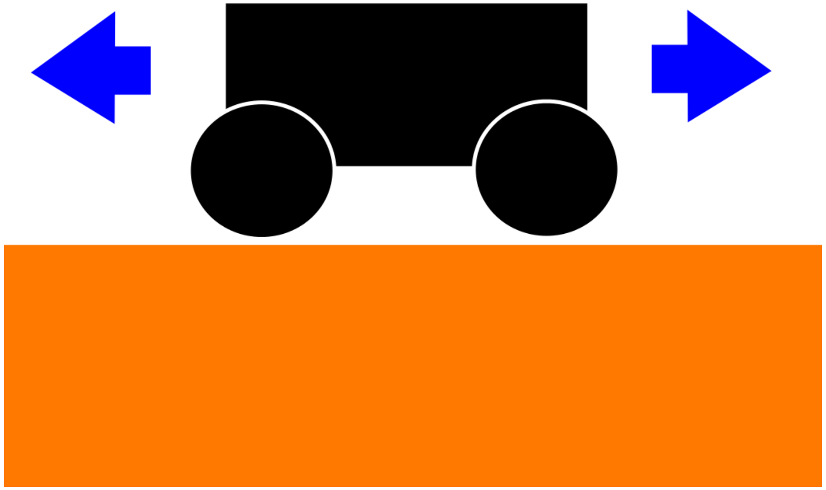
Robot Locomotion – An Introduction

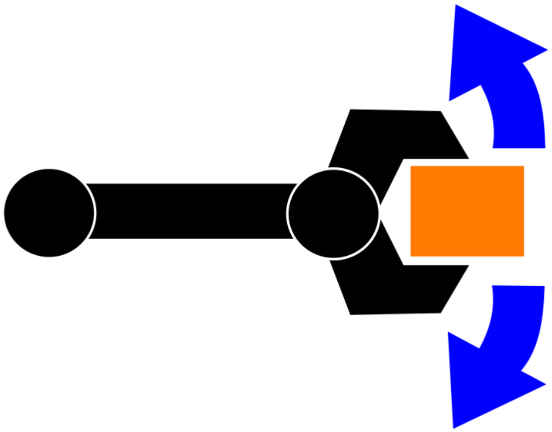
Softwaredevelopment for Industrial Robotics

Marcel Grotzke, Gabriel Kögler, Henri Hamann

Structure of presentation

Introduction to locomotion

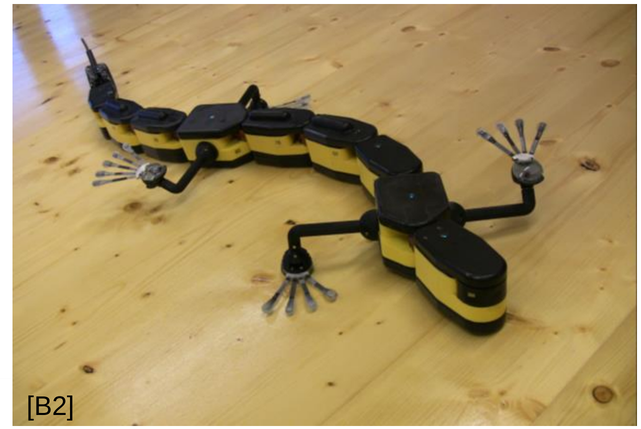




Locomotion
- Environment fixed
- Robot is moved

Manipulation
- Robot fixed
- Object is moved

Introduction to locomotion



Salamandra

Meshworm

Introduction to locomotion

[B5]

[B6]

Mini Whegs

[B7]

[B8]

WildCat

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Introduction to locomotion

[B10]

Asimo

?

[B11]

Pioneer

Why do we need mobile robots?

Do things which static robots can not do!

[B12]

[B13]

Where do we need them?

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

[B14]

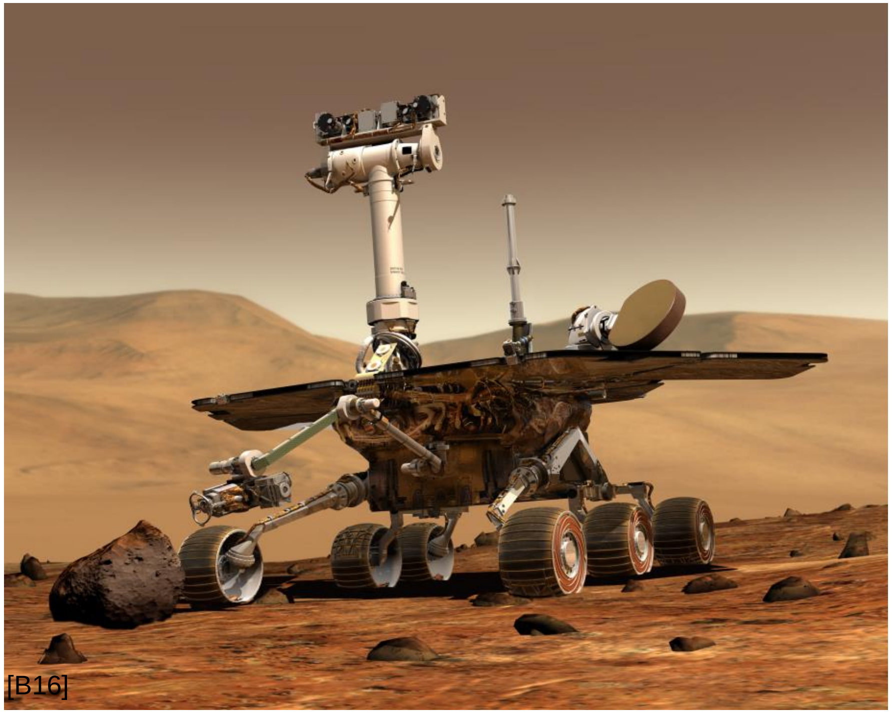
Where do we need them?

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


[B15]

Where do we need them?

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



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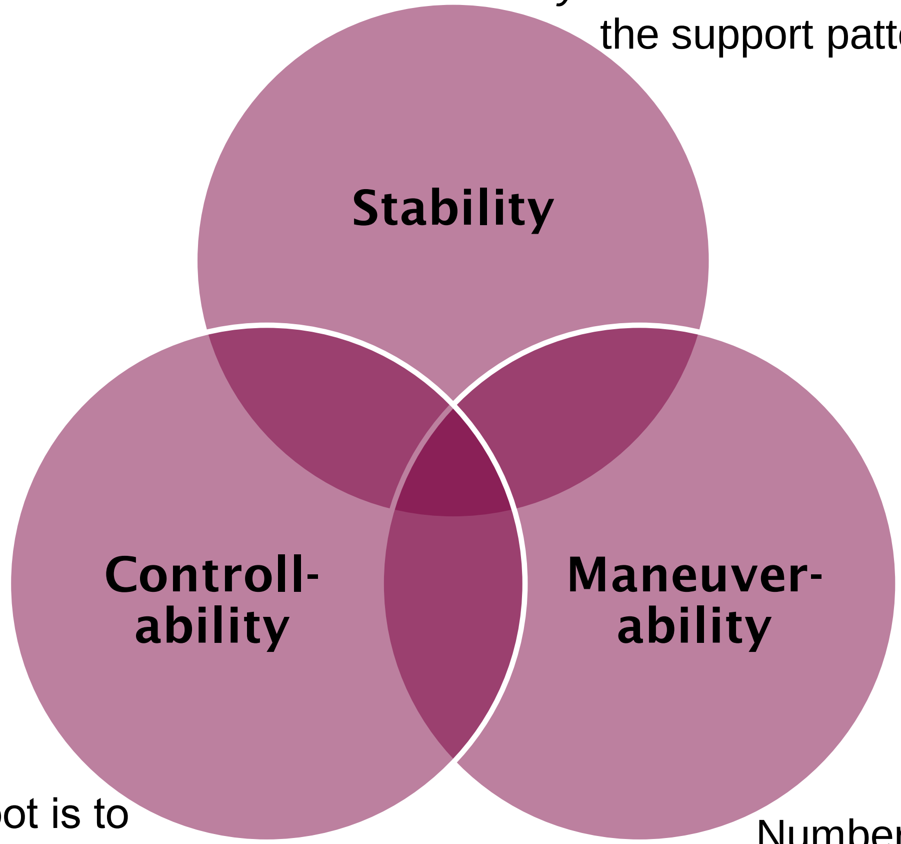
Core issues of locomotion (1)

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

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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

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

Important issues:

→ Maneuverability vs. energy, control and mass

→ Stability during walking

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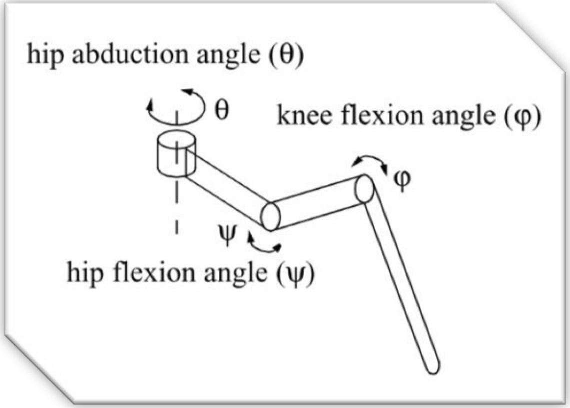
Legged Locomotion (2)

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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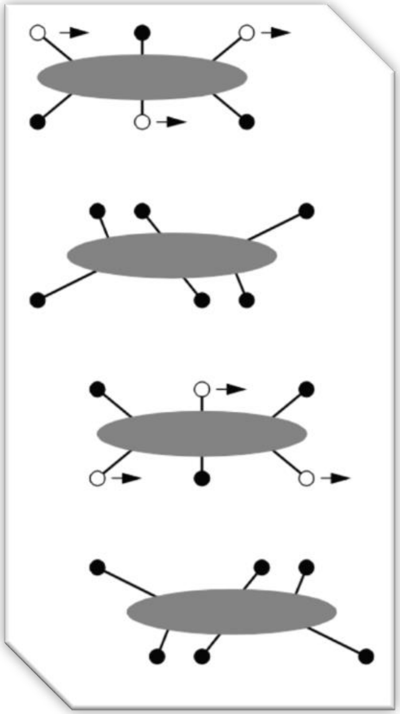
Legged Locomotion (3)

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]

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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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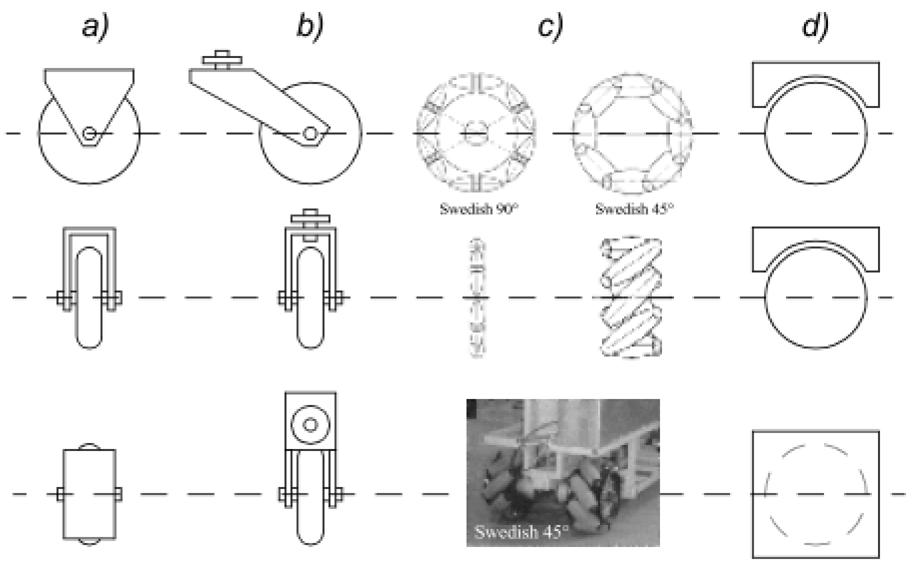
Wheel types and DOF

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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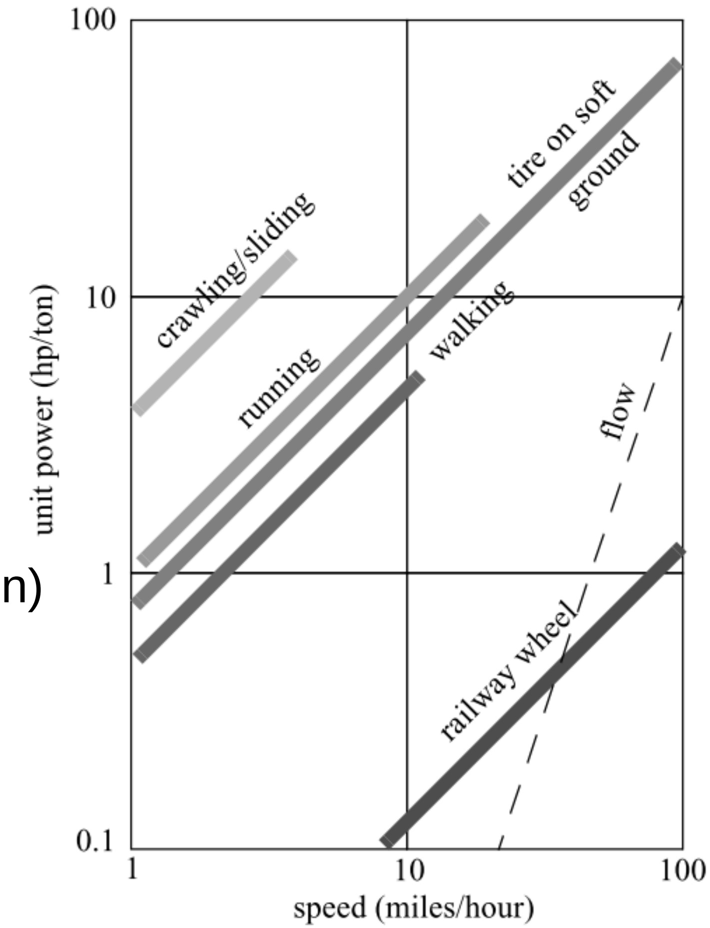
Comparision walking ↔ rolling

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)



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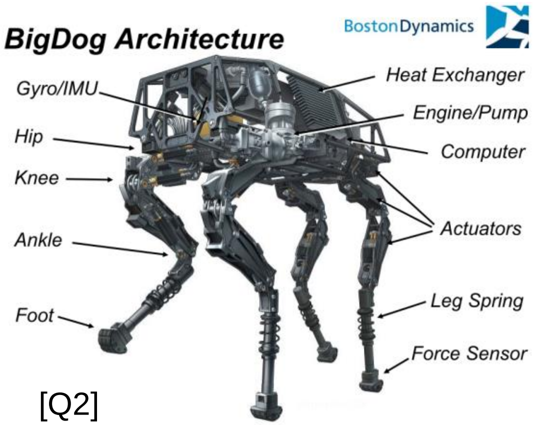
Outlook to locomotion: Walking Robots from Boston Dynamics

BigDog

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

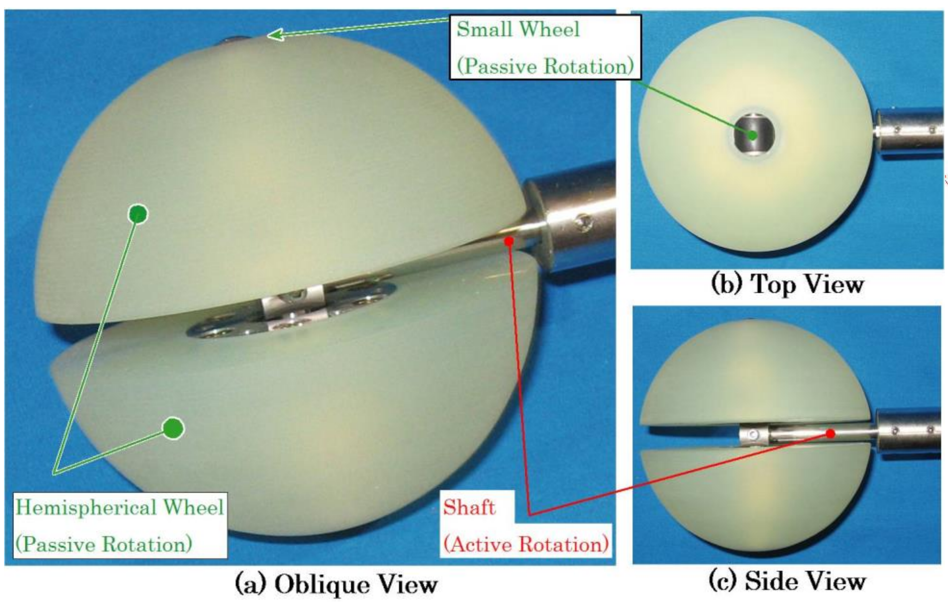
[removed video]

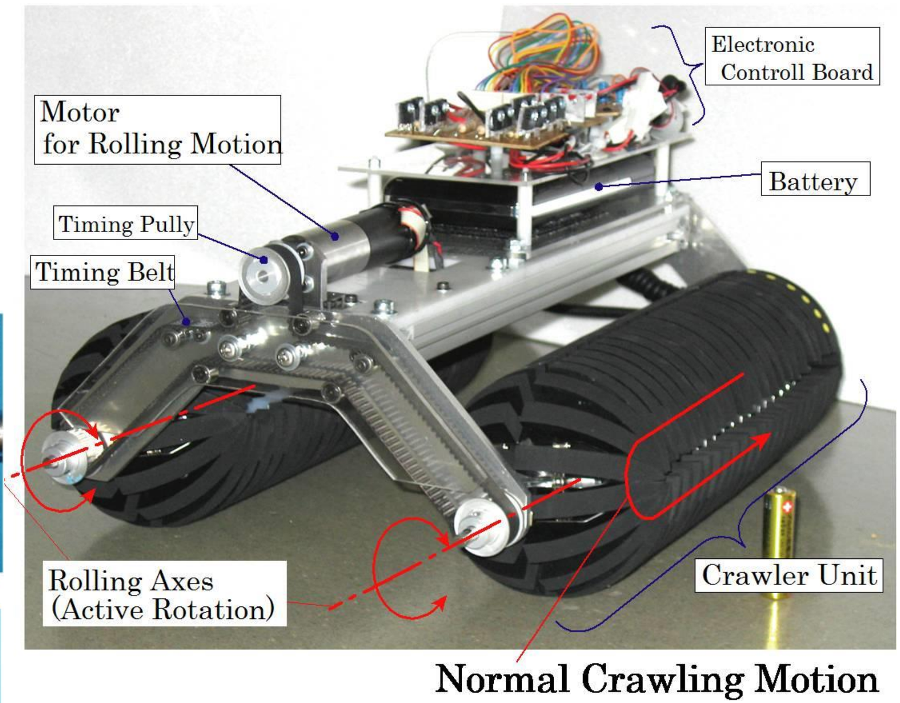


[Q2]

Outlook to locomotion: Omni-Crawler

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





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Outlook to locomotion: VelociRoACH

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

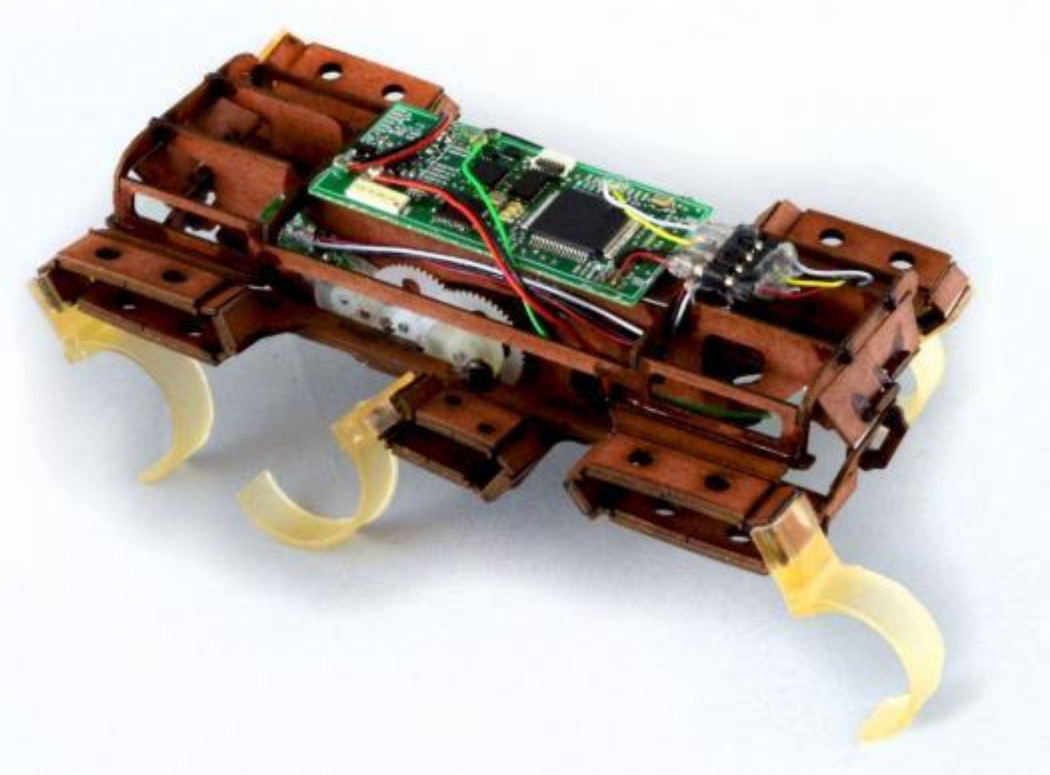
→ only one engine required!

Speed: 10km/h

Weight: 30g

Length: 10cm

→ 27 body length / sec



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Many thanks for your attention!

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[B2] http://biorob.epfl.ch/files/content/users/179700/files/private/imports/importInto_ContentContainerList_469885_20110110155706.JPG

[B3] http://1.bp.blogspot.com/-R4EnpcDKpIE/Tvn3Qth8RvI/AAAAAAAACTQ/cXWhSaPwGQc/s1600/Raupe%2BSchwalbenschwanz.jpg

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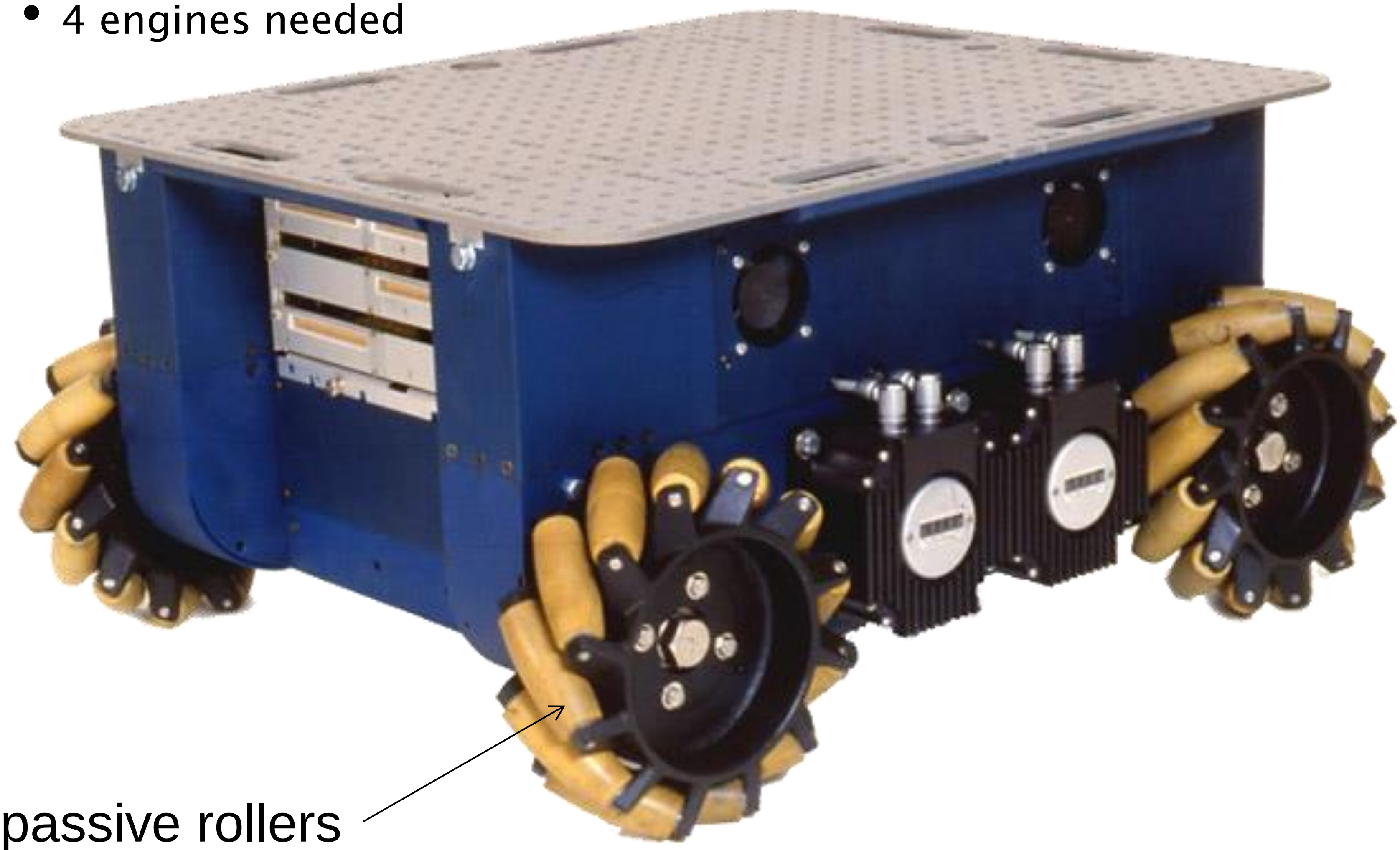
Appendix: swedish wheel

- Omnidirectional, but passiv
- 4 engines needed



passive rollers