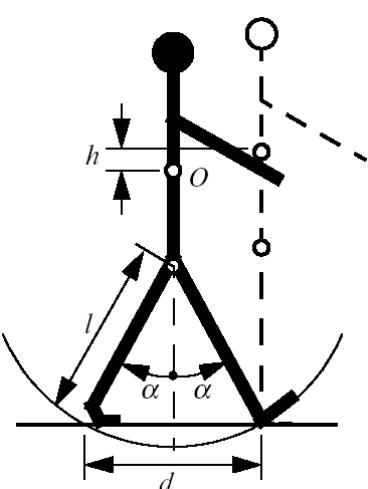


# Locomotion Concepts

- Concepts found in nature
  - difficult to imitate technically
- Most technical systems use wheels or caterpillars
- Rolling is most efficient, but not found in nature
  - Nature never invented the wheel !
- However, the movement of a walking biped is **close to rolling!**

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## Walking of a Biped



- Biped walking mechanism
  - not to fare from real rolling.
  - rolling of a polygon with side length equal to the length of the step.
  - the smaller the step gets, the more the polygon tends to a circle (wheel).
- However, fully rotating joint was not developed in nature.

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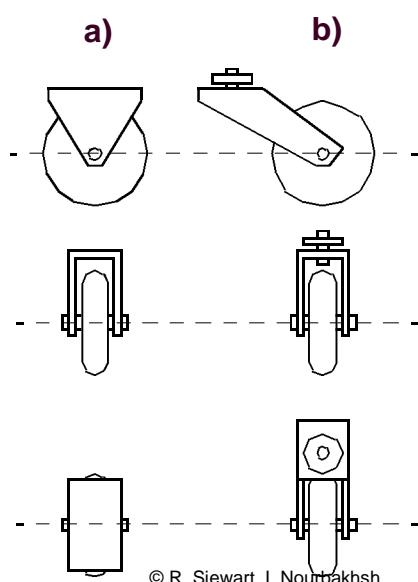
# Mobile Robots with Wheels

- Wheels are the most appropriate solution for most applications
- Three wheels are sufficient and to guarantee stability
- With more than three wheels a flexible suspension is required
- Selection of wheels depends on the application

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## The Four Basic Wheels Types

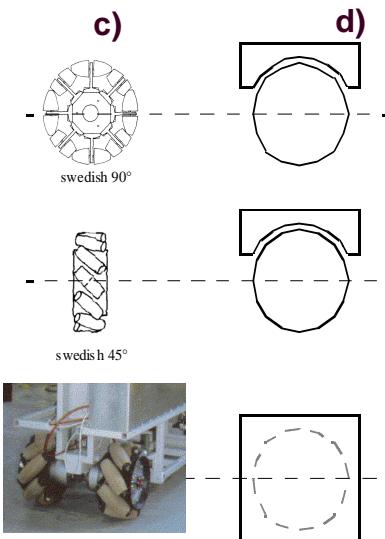
- a) Standard wheel: Two degrees of freedom; rotation around the (motorized) wheel axle and the contact point
- b) Castor wheel: Three degrees of freedom; rotation around the wheel axle, the contact point and the castor axle



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## The Four Basic Wheels Types

- c) Swedish wheel: Three degrees of freedom; rotation around the (motorized) wheel axle, around the rollers and around the contact point
- d) Ball or spherical wheel: Suspension technically not solved



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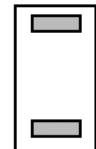
## Characteristics of Wheeled Robots and Vehicles

- Stability of a vehicle is guaranteed with 3 wheels
  - center of gravity is within the triangle formed by the ground contact point of the wheels.
- Stability is improved by 4 and more wheels
  - however, these arrangements are hyperstatic and require a flexible suspension system.
- Bigger wheels allow to overcome higher obstacles
  - but they require higher torque or reductions in the gear box.
- Most arrangements are non-holonomic (see chapter 3)
  - require high control effort
- Combining actuation and steering on one wheel makes the design complex and adds additional errors for odometry.

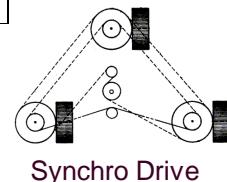
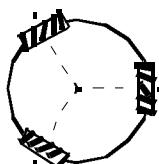
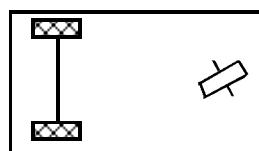
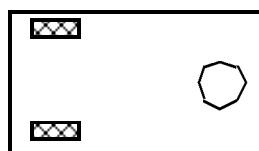
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## Different Arrangements of Wheels I

- Two wheels



- Three wheels

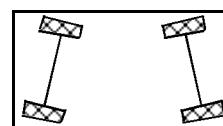
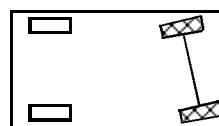
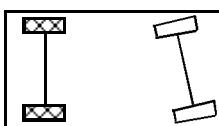


Omnidirectional Drive

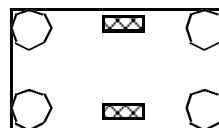
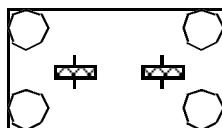
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## Different Arrangements of Wheels II

- Four wheels

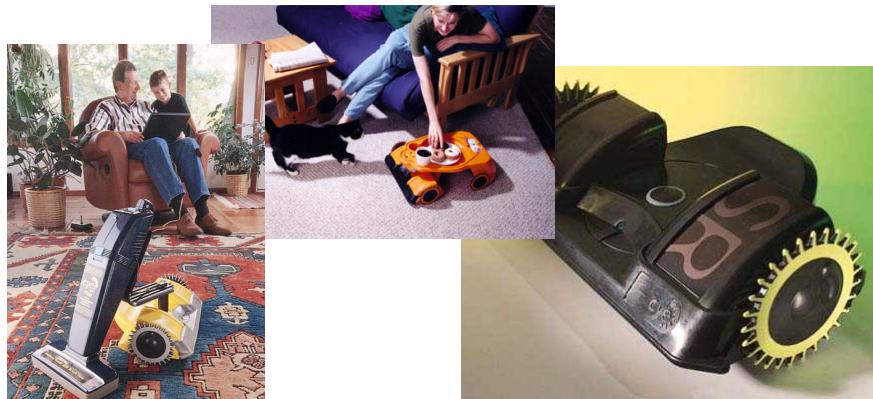


- Six wheels



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## Cye, a Two Wheel Differential Drive Robot

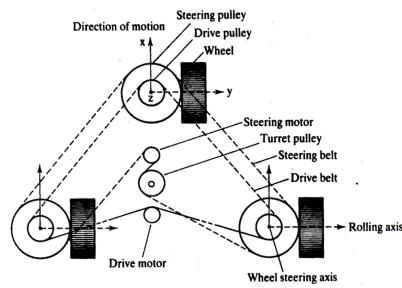


- Cye, a commercially available domestic robot that can vacuum and make deliveries in the home, is built by Probotics, Inc.

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## 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.



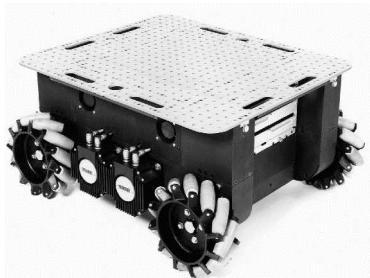
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## Tribolo, Omnidirectional Drive with 3 Spheric Wheels

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## Uranus, CMU: Omnidirectional Drive with 4 Wheels

- Movement in the plane has 3 DOF
  - thus only three wheels can be independently controlled
  - It might be better to arrange three swedish wheels in a triangle



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## Stepping / Walking with Wheels

- SpaceCat, and micro-rover for Mars, developed by Mecanex Sa and EPFL for the European Space Agency (ESA)



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## SHRIMP, a Mobile Robot with Excellent Climbing Abilities

- 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 sizing around 60 cm in length and 20 cm in height
  - highly stable in rough terrain
  - overcomes obstacles up to 2 times its wheel diameter



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