Unit 2: Mobility
Methods of Locomotion

Computer Science 4766/6912

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Methods of Locomotion

- In nature, we see many varieties of locomotion:
  - walking, jumping, running, sliding, skating, swimming, flying, rolling,...
- The wheel is not found in nature, but is highly efficient on flat ground

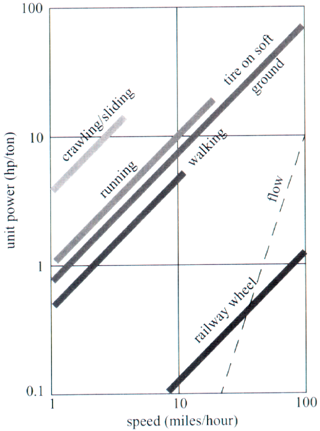
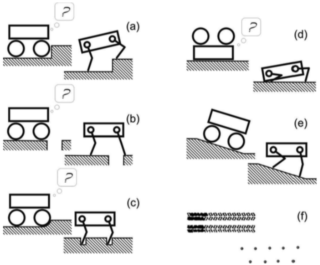


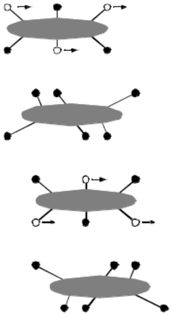
Figure 2.3
Specific power versus attainable speed of various locomotion mechanisms [33].

Legged Robots



- Advantages:
  - Ability to cross rough terrain (a, c) gaps (b), recover when fallen (d), keep level on uneven surfaces (e) and reduce environmental impact (e).
  - Legs can double as object manipulators
- Disadvantages:
  - Greater power needs, mechanical complexity, and control complexity
- Degrees of freedom:
  - ≥ 2 : one to lift, one to move leg forward

- Stability:
  - A robot with three or more legs exhibits *static stability* if its centre of mass is within the triangle formed by any three legs
    - A 6-legged robot can exhibit static walking by using the "tripod gait" (video)



  - Two-legged robots can exhibit only *dynamic stability* (i.e. forces must be applied to maintain balance)

Wheeled Robots

- Advantages:
  - Simpler, cheaper, faster, more efficient than legs
  - Stability constraint same as for legged robots (centre of mass within the triangle formed by 3 wheels) although the wheels usually stay on the ground
- Disadvantages:
  - Suspension system may be required
  - Restricted to flat terrain (overcome by hybrids such as the Mars rovers)

Wheel designs: Four main types

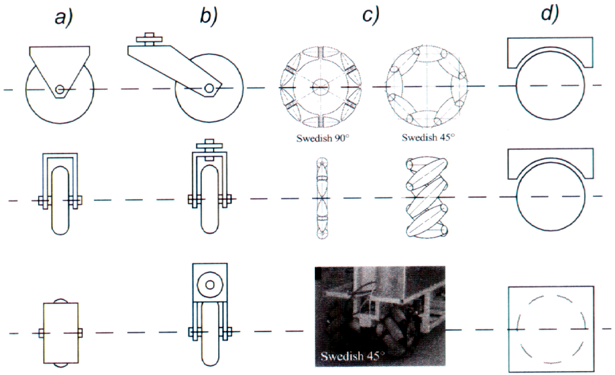


Figure 2.19
The four basic wheel types. (a) Standard wheel: two degrees of freedom; rotation around the (motorized) wheel axle and the contact point.(b) castor wheel: two degrees of freedom; rotation around an offset steering joint. (c) Swedish wheel: three degrees of freedom; rotation around the (motorized) wheel axle, around the rollers, and around the contact point. (d) Ball or spherical wheel: realization technically difficult.

- Castor wheels differ from standard wheels in that a Castor wheel rotates about an axis which is offset from the centre of the wheel
  - If a force perpendicular to the wheel is applied, the Castor wheel can move to accommodate this force; a standard wheel cannot
- Swedish and spherical wheels can also move to accommodate a force applied at any angle

Swedish Wheels

- The small rollers are passive, but provide the ability to role in an *additional* direction

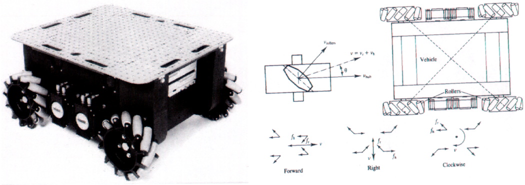
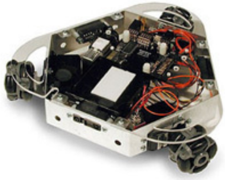


Figure 2.24
The Carnegie Mellon Uranus robot, an omnidirectional robot with four powered-swedish 45 wheels.

- The rollers above are at 45° to the wheel axis, those below are at 90°



`www.acroname.com/robotics/info/PPRK/overview.html`

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.

A variety of different wheel configurations follow...

Table 2.1
Wheel configurations for rolling vehicles

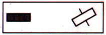
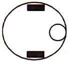
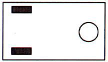
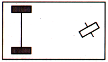
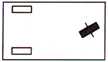
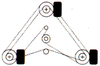
# of wheels	Arrangement	Description	Typical examples
2		One steering wheel in the front, one traction wheel in the rear	Bicycle, motorcycle
		Two-wheel differential drive with the center of mass (COM) below the axle	Cye personal robot
3		Two-wheel centered differential drive with a third point of contact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

Table 2.1
Wheel configurations for rolling vehicles

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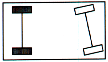
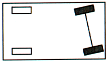
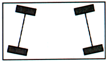
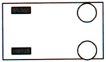
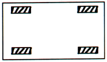
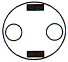
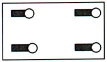
4		Two motorized wheels in the rear, 2 steered wheels in the front; steering has to be different for the 2 wheels to avoid slipping/skidding.	Car with rear-wheel drive
		Two motorized and steered wheels in the front, 2 free wheels in the rear; steering has to be different for the 2 wheels to avoid slipping/skidding.	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)
		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 Configurations

- Various criteria impact the utility of a particular configuration:
  - Stability:
    - A 2-wheel robot can exhibit static stability if the centre of mass is below the common axle
    - Otherwise, 3 wheels required
  - Manoeuvrability (addressed in "kinematics")
  - Controllability
    - e.g. Driving a robot with Swedish wheels in a straight line may be difficult; The passive rollers introduce extra slippage; This slippage is hard to compensate for because it is hard to measure