Wheeled Locomotion | Introduction

Autonomous Mobile Robots

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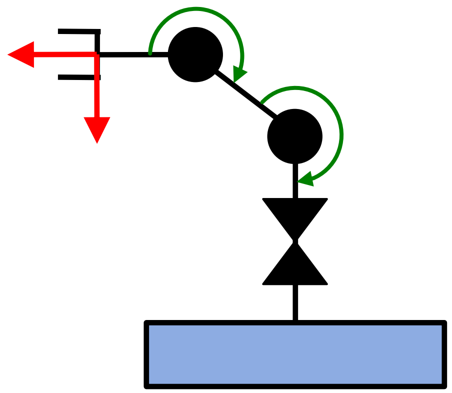
Motivation: Efficiency of Locomotion Types

- Wheeled locomotion
  - Highly efficient on hard surfaces
  - Generally restricted to man-made surfaces
  - The de facto standard in mobile robotics

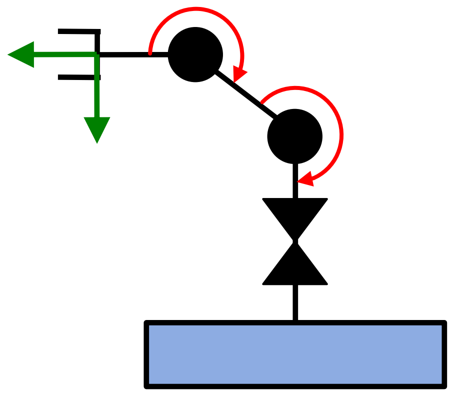
Review: Kinematics

- **Forward kinematics**
  - Given a set of actuator positions, determine the corresponding pose



Review: Kinematics

- Forward kinematics
  - Given a set of actuator positions, determine the corresponding pose
- **Inverse kinematics**
  - Given a desired pose, determine the corresponding actuator positions



Review: Kinematics

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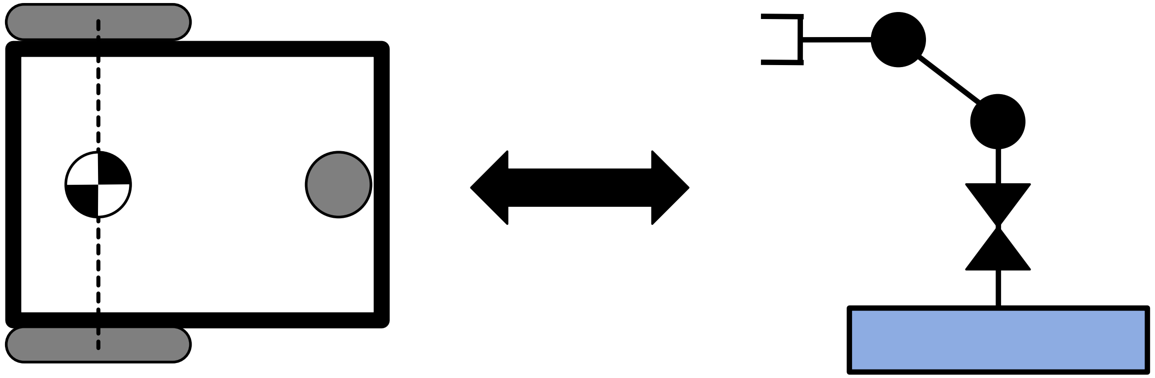
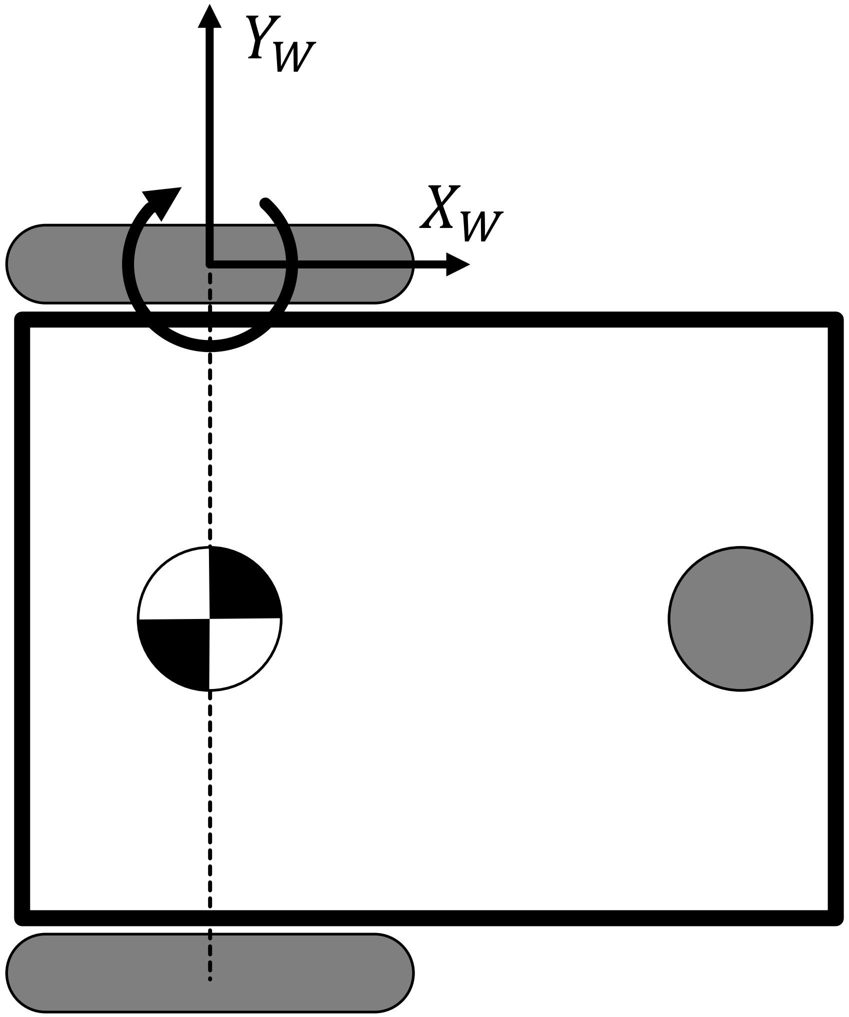


Wheeled Kinematics

- Not all degrees of freedom of a wheel can be actuated or have encoders



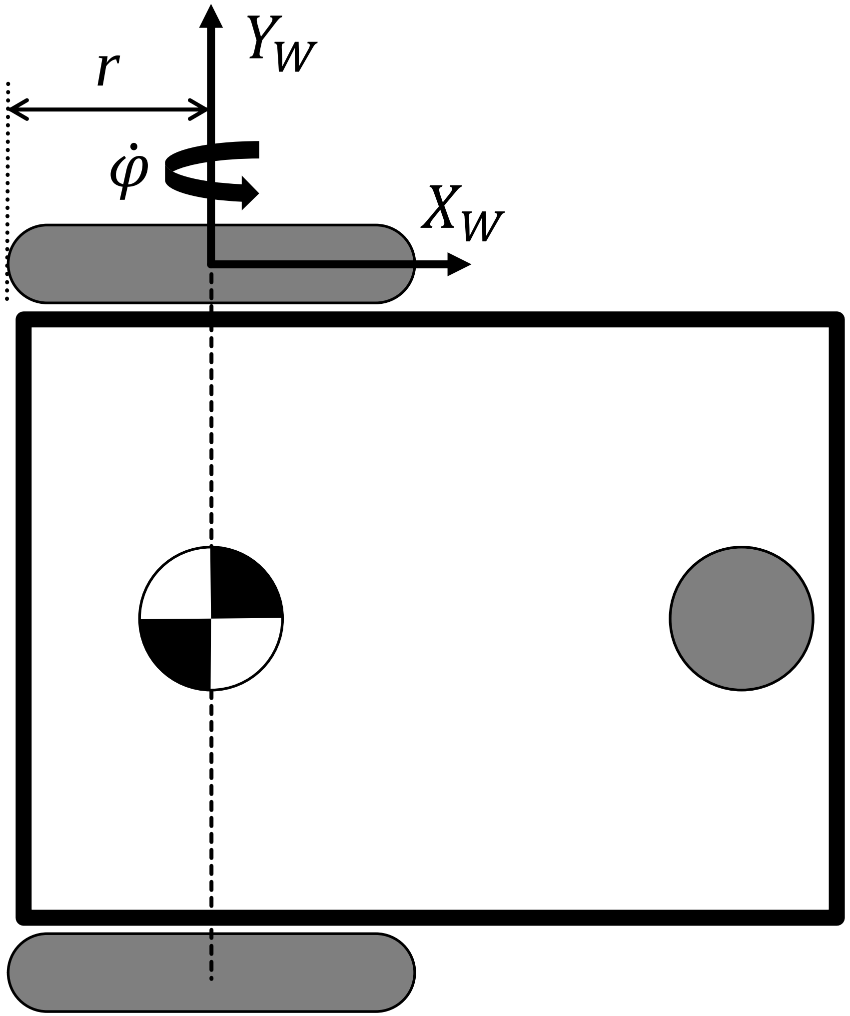
Wheeled Kinematics

- Not all degrees of freedom of a wheel can be actuated or have encoders
- Wheels can impose **differential constraints** that complicate the computation of kinematics

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} \dot{\varphi} r \\ 0 \end{bmatrix}$$

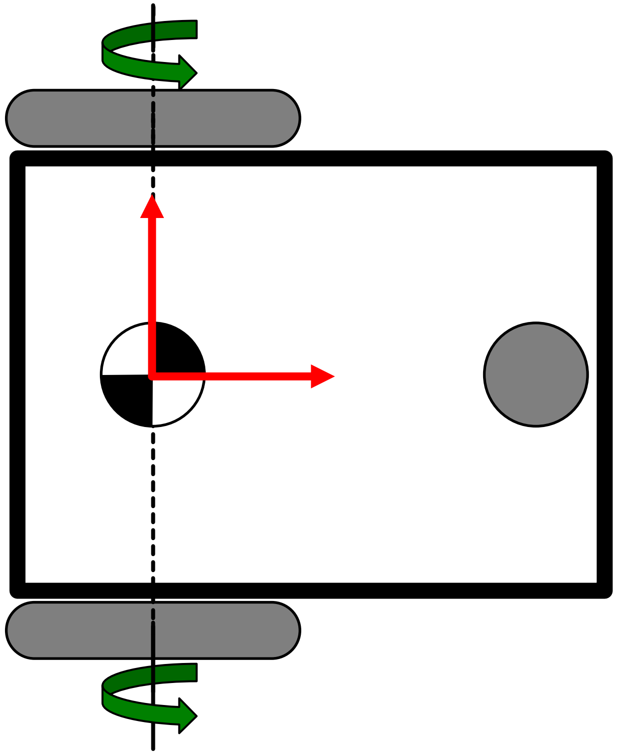
rolling constraint

no-sliding constraint



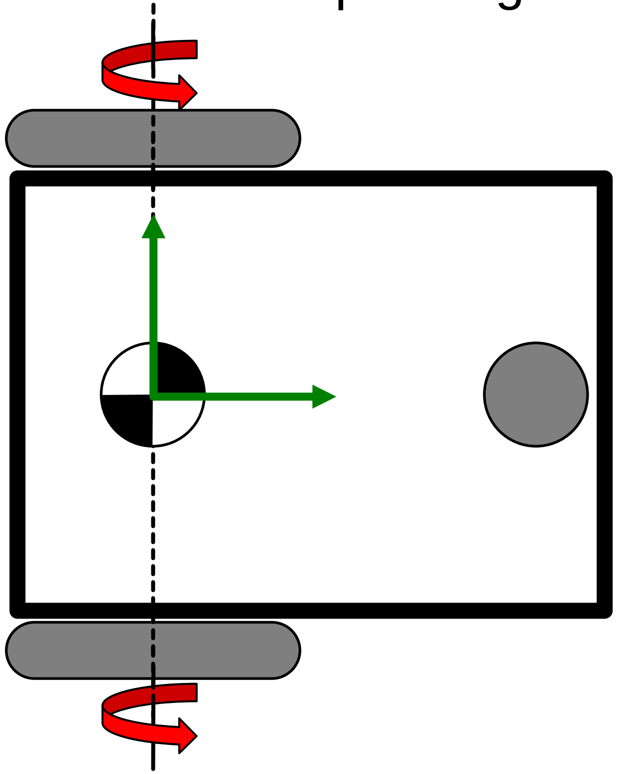
Differential Kinematics

- **Differential forward kinematics**
  - Given a set of actuator speeds, determine the corresponding velocity

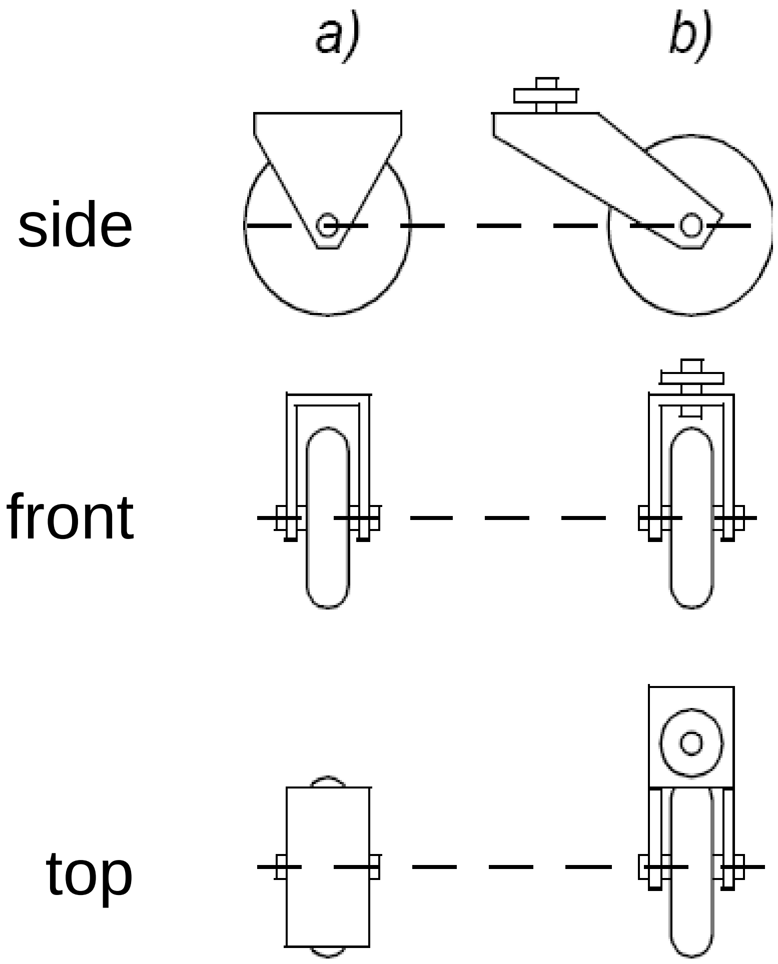


Differential Kinematics

- Differential forward kinematics
  - Given a set of actuator speeds, determine the corresponding velocity
- **Differential inverse kinematics**
  - Given a desired velocity, determine the corresponding actuator speeds



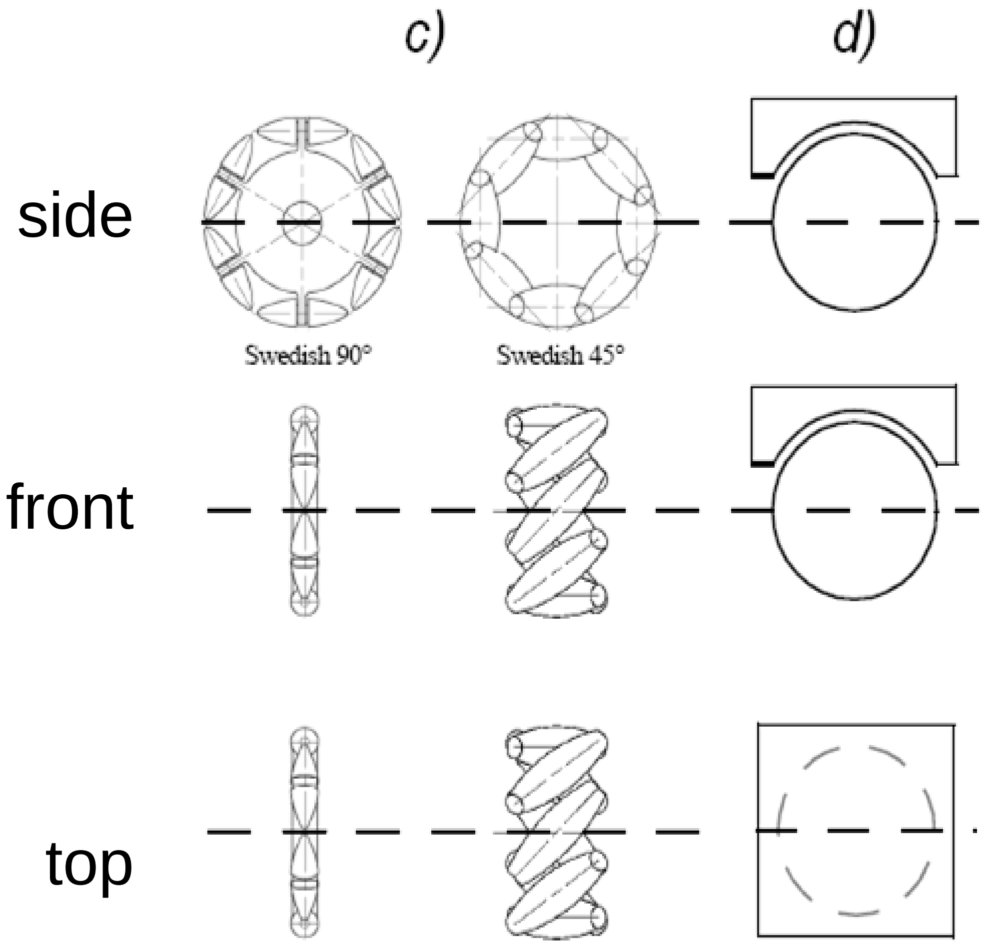
Basic Wheel Types



a) Standard wheel
- Two degrees of freedom
  - Rotation around the wheel axle
  - Free rotation around the contact point
- Can be steered or fixed

b) Castor wheel
- Three degrees of freedom
  - Rotation around the wheel axle
  - Free rotation around the contact point
  - Rotation around the castor axle

Basic Wheel Types



c) Swedish wheel
- Three degrees of freedom
  - Rotation around the wheel axle
  - Free rotation around the rollers
  - Free rotation around the contact point

d) Spherical wheel (ball)
- Three degrees of freedom

Basic Wheel Types

By Rotacaster (Rotacaster Wheel Pty Ltd) via Wikimedia Commons

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- Three degrees of freedom
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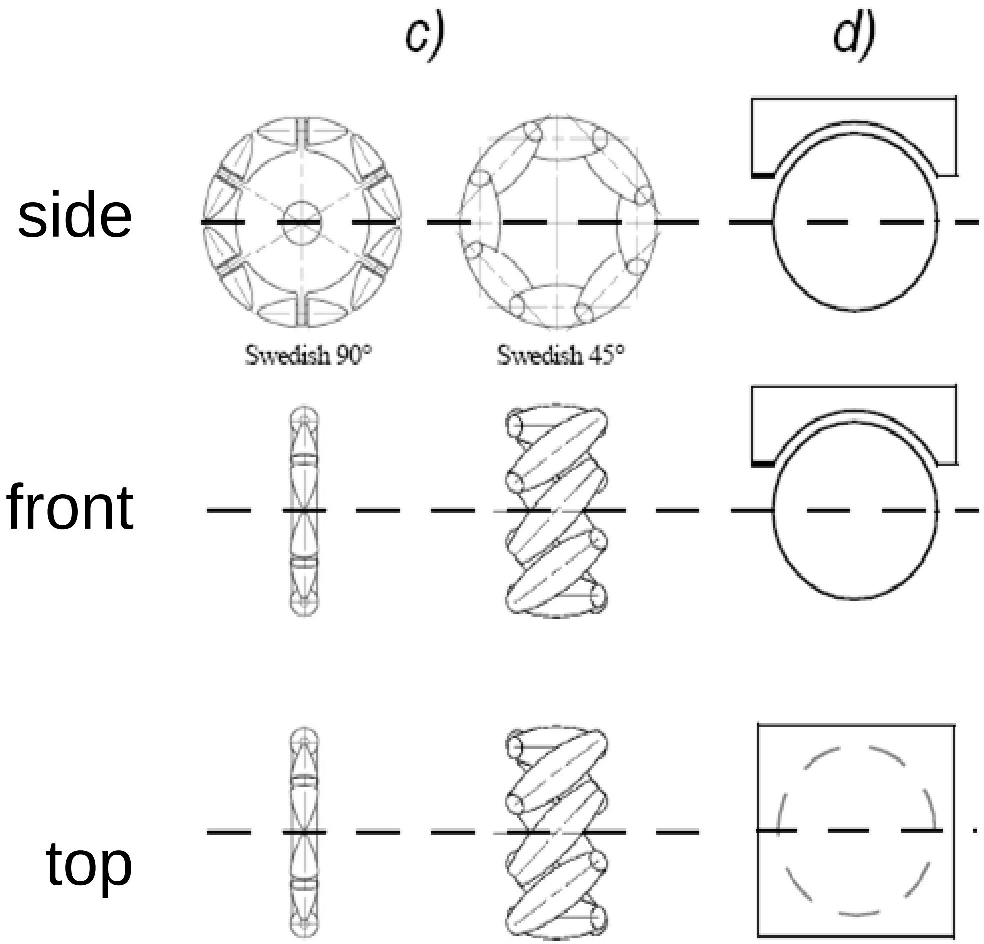
Basic Wheel Types



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- Three degrees of freedom
  - Rotation around the wheel axle
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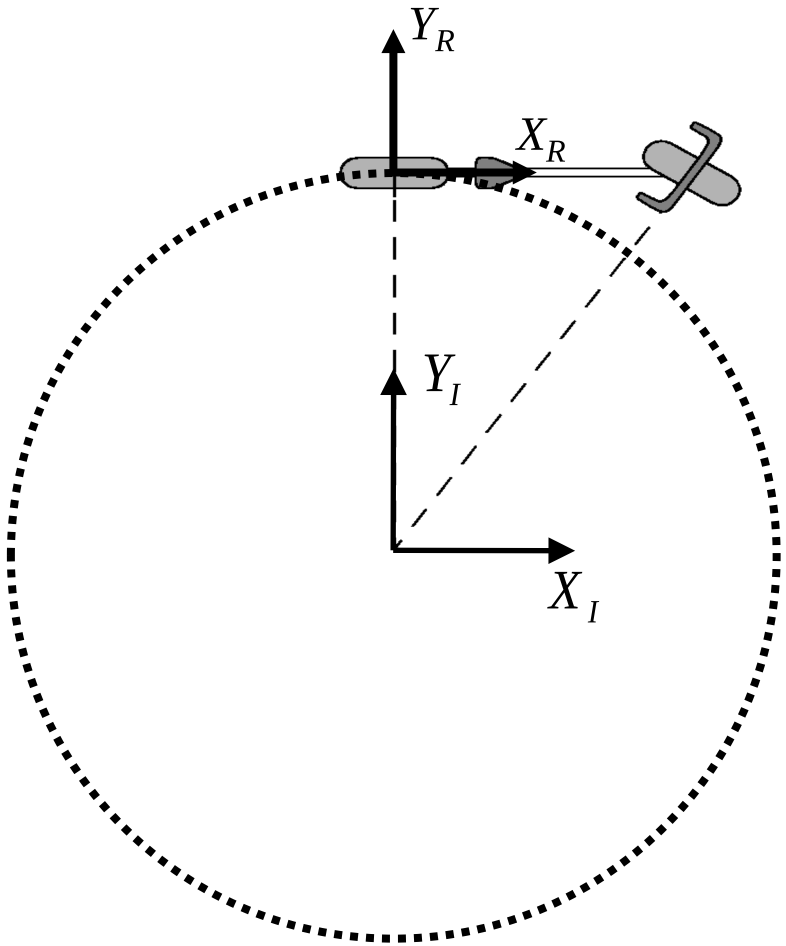
- Three degrees of freedom

Holonomic and Non-Holonomic Systems

- Holonomic systems
  - Differential constrains are **integrable**. They may be expressed as constraints on the robot's pose
  - The robot is able to move instantaneously in any direction in the space of its degrees of freedom

- Non-holonomic systems
  - Differential constraints are **not integrable**. There is no way to express them as constraints on the robot's pose
  - The robot is not able to move instantaneously in every direction in the space of its degrees of freedom

A Holonomic Mobile Robot



- A bicycle with fixed steering
  - Two non-steerable wheels
  - The workspace of the robot collapses to a single degree of freedom: a circle
  - The differential constraints can be expressed as constraints on position
  - In any configuration, it is possible to choose wheel velocities that move the robot any direction within its workspace

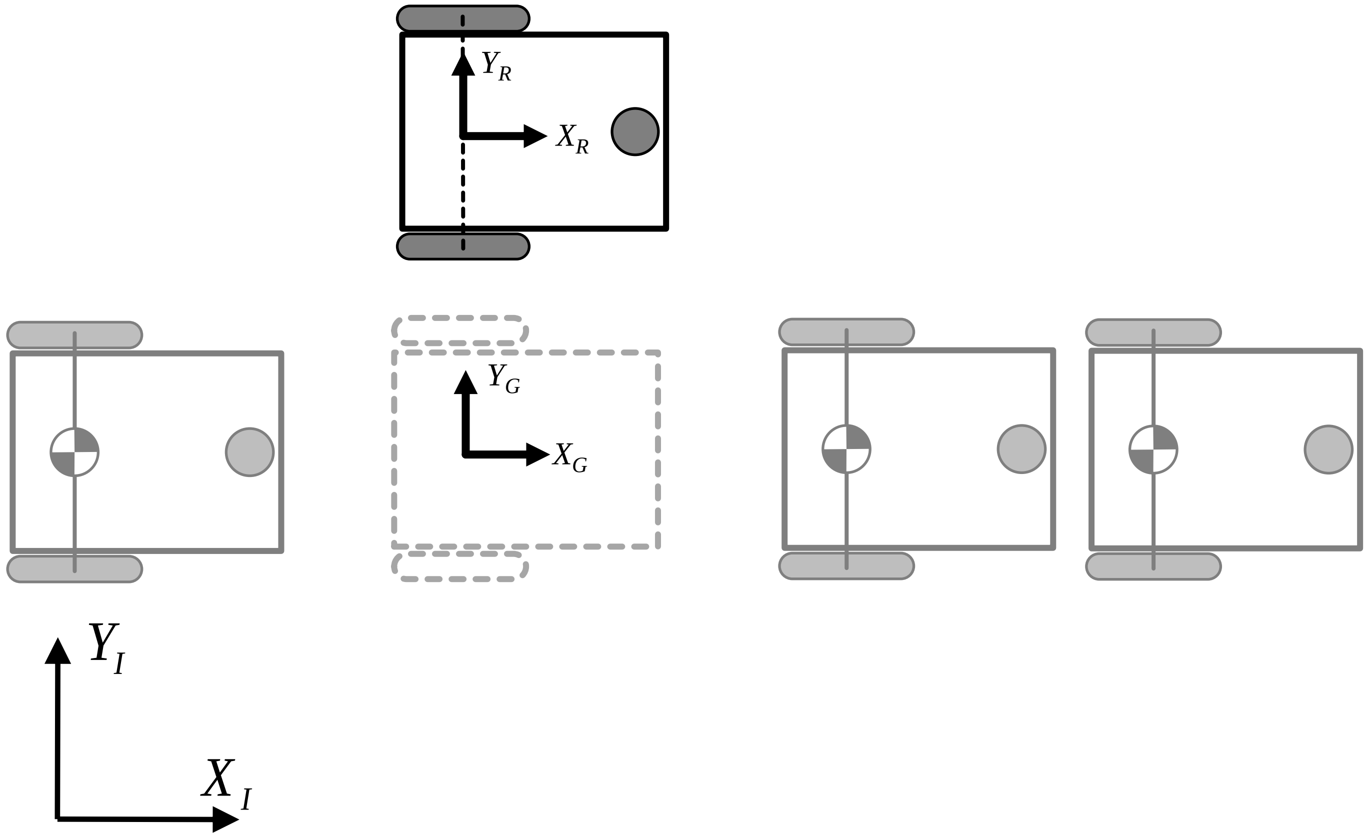
A Holonomic Wheeled Platform

Photographer: Frank C. Müller via Wikimedia Commons

- The office chair
  - Castor wheels impose no differential constraints
  - In any configuration, it is possible to choose wheel velocities that move the robot any with any velocity within the plane

A Non-Holonomic Mobile Robot

No sliding constraint: $\dot{y}_R = 0$



- A differential drive robot
  - Two non-steerable wheels aligned on a common axis
  - The workspace of the robot encompasses all poses in the plane
  - The no-sliding constraint, $\dot{y}_R = 0$, cannot be expressed as a constraint on position
  - Regardless of the configuration the robot is in, instantaneous motion in the $y_R$direction is not possible.

Preview: Deriving the wheel equation

- Next topic: Given a **specific wheel configuration**, what is the relationship between platform speed and wheel constraints