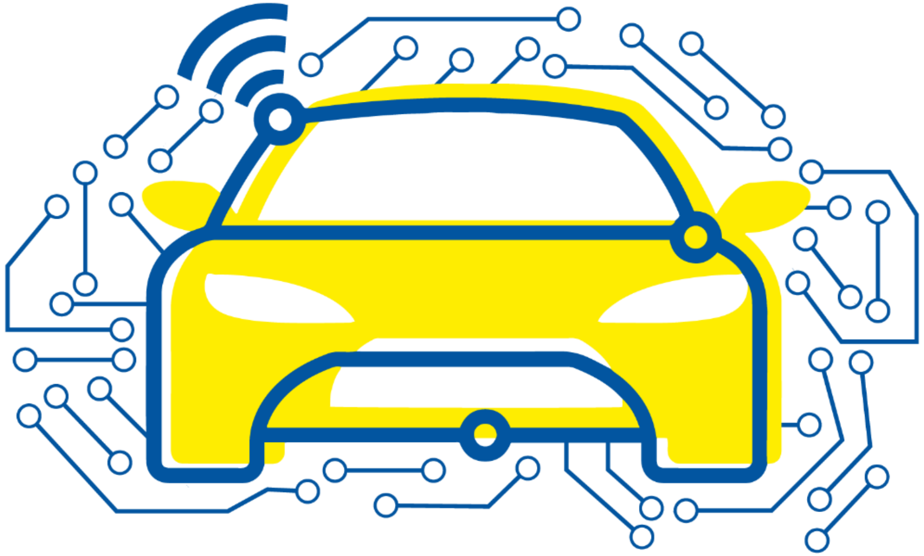
Automated and Connected Driving Challenges

Section 2 – Sensor Data Processing

Localization

Relative Localization



Bastian Lampe

Institute for Automotive Engineering

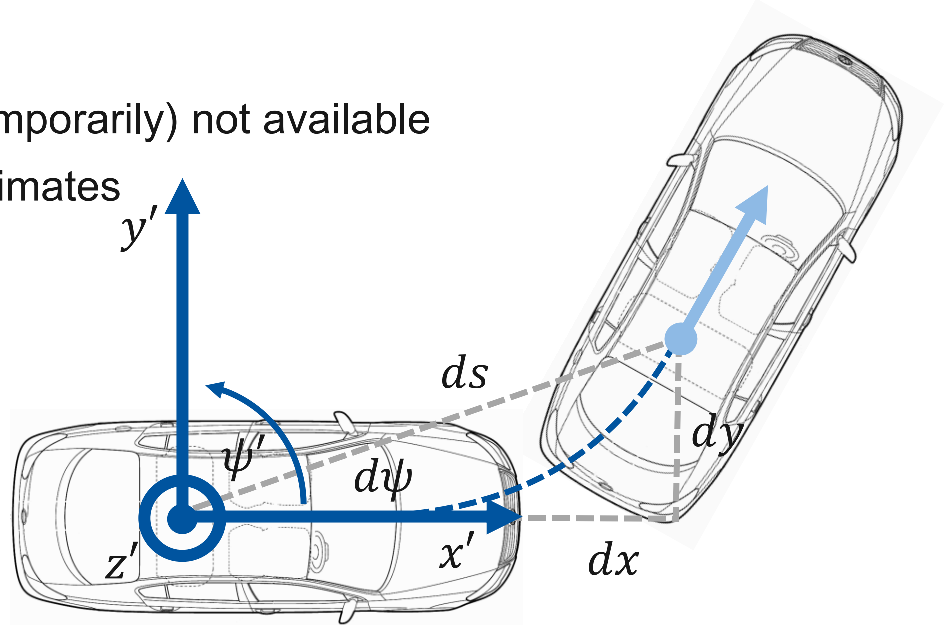
Localization – Relative Localization

Overview

Relative localization aims to estimate the vehicle pose relative to an initial or previous pose of the vehicle

It is crucial for automated and connected vehicles to ...

- … be able to localize themselves when global localization is (temporarily) not available
- … increase robustness and update rate of other localization estimates



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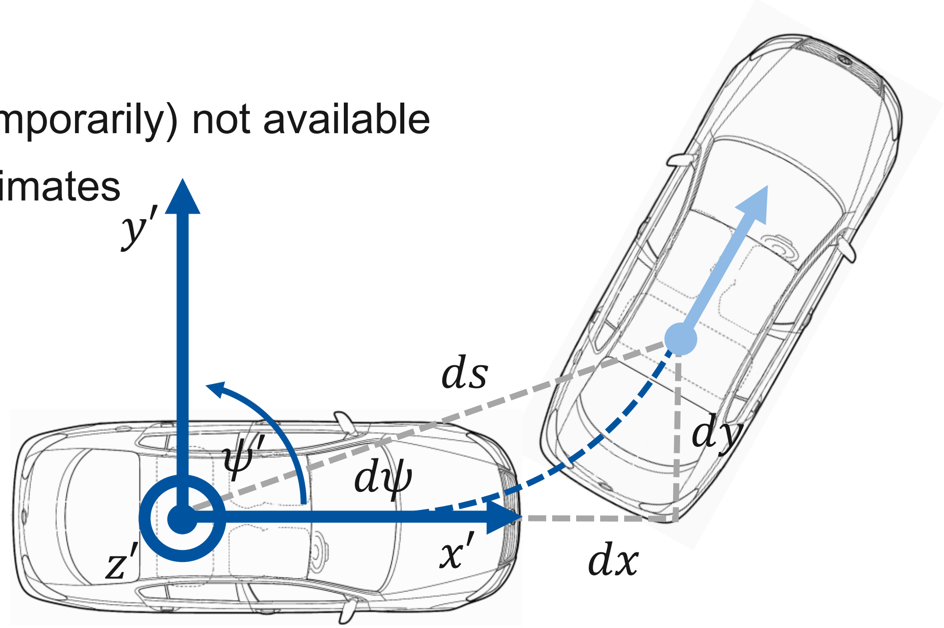

Common Approaches

- Dead Reckoning
  - Odometry, Inertial Navigation, Visual Odometry

Strengths and Weaknesses of Relative Localization Approaches

+ Robustness to challenging environments	- Error accumulation / drift
+ High precision for close-proximity maneuvering	- Lack of global context

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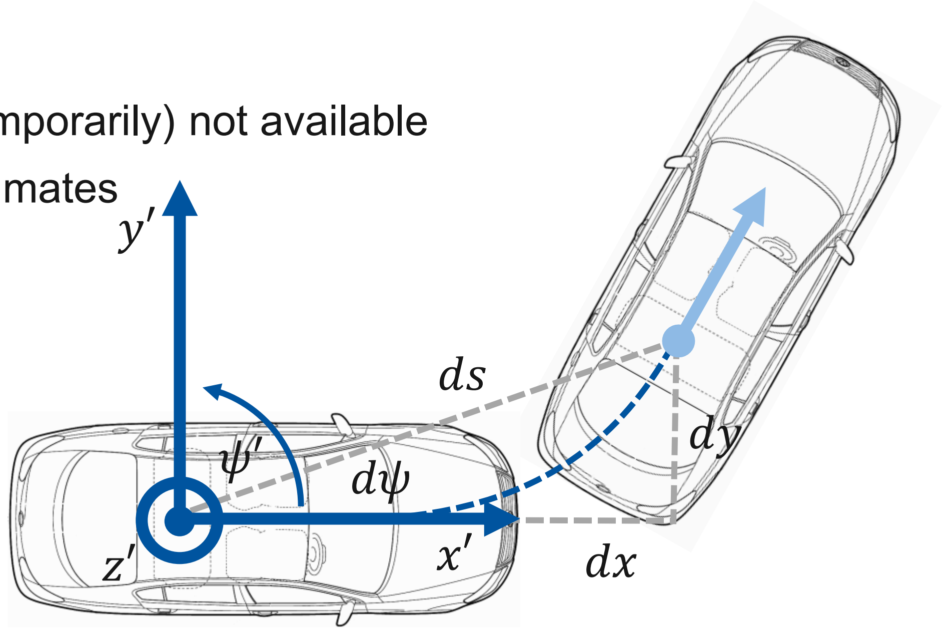

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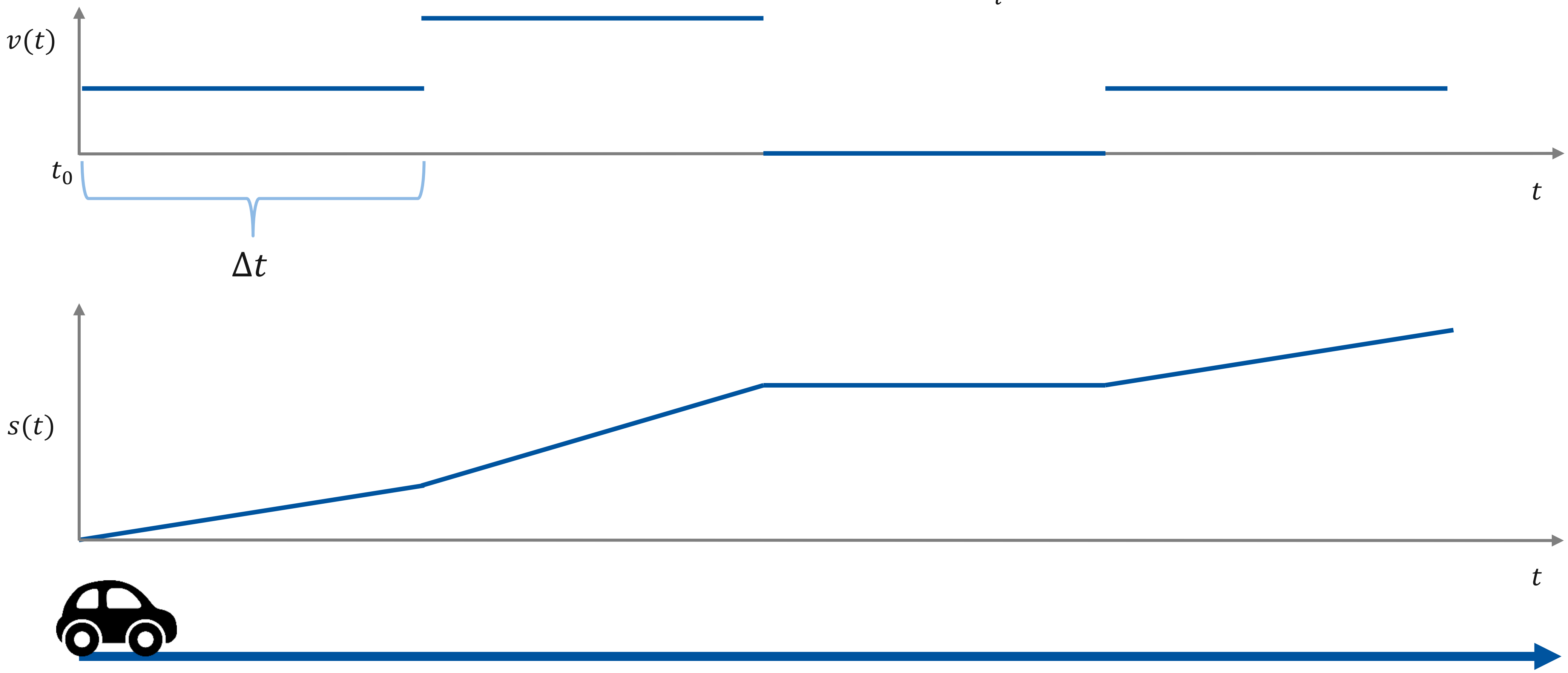
Localization – Relative Localization

Example: 1D Dead Reckoning from a standstill

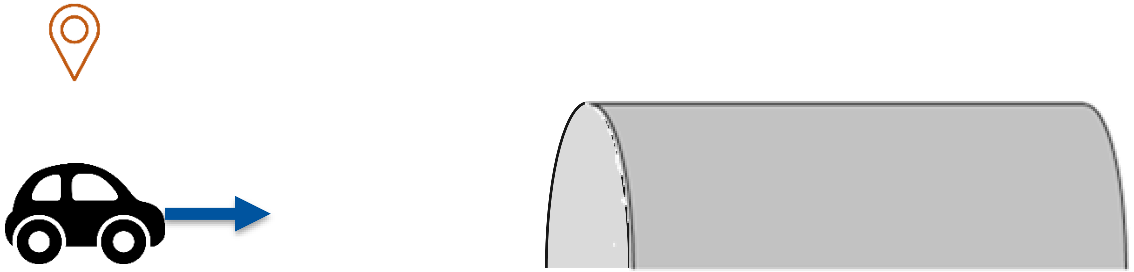
Simplified line integral: $\Delta s_{t_i \to t_{i+1}} = \iint_{t_i}^{t_{i+1}} a(t)dt = \left(v \cdot t + \frac{1}{2}at^2\right) \Big|_{t_i}^{t_{i+1}}$



Localization – Relative Localization

Odometry

- **Goal** Motion estimation based on motion sensors
- **Sensors** Wheel encoders, steering encoder, magnetometer
- **Velocity estimate** $v(t) = \omega(t) \cdot r_{tire}$ with $\omega(t)$: wheel speed in rad/s
- **Example use case** Dead Reckoning in tunnel



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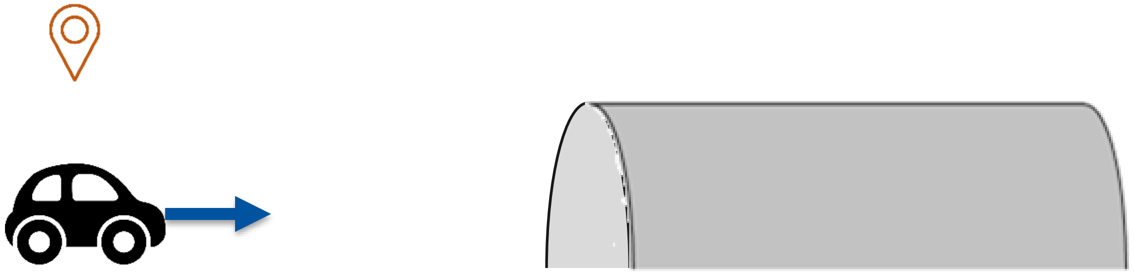
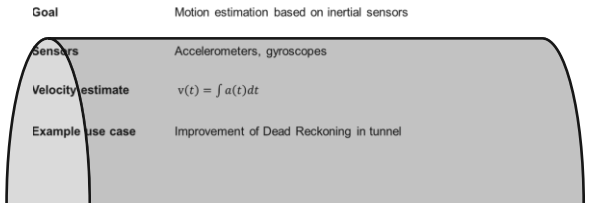


Localization – Relative Localization

Inertial Navigation

Goal	Motion estimation based on inertial sensors
Sensors	Accelerometers, gyroscopes
Velocity estimate	$\mathrm{v}(t) = \int a(t)dt$
Example use case	Improvement of Dead Reckoning in tunnel

Image: Bosch



Localization – Relative Localization

Visual Odometry with Cameras

- **Goal** Motion estimation based on a sequence of camera images
- **Sensors** Mono-, Stereo or Omnidirectional Camera

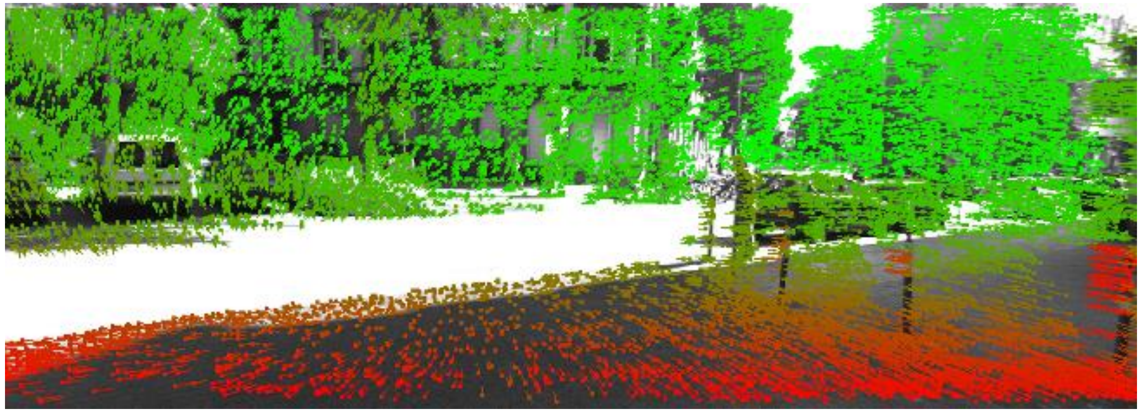


Image: Geiger2011

Source: Agel2016

Localization – Relative Localization

Visual Odometry with Cameras

- **Goal** Motion estimation based on a sequence of camera images
- **Sensors** Mono-, Stereo or Omnidirectional Camera
- **Common approaches**
  - **Feature-based approach:**
    Extraction of image features (i.e. corner, edge or curve) in sequential frames, tracking of associated features and estimation of the relative vehicle movement.
  - **Appearance-based approach:**
    Based on an observation of changes in the image appearance and intensity on a pixel level instead of extracting features.
  - **Hybrid approach:**
    Combination of the feature- and appearance-based approach. → In particular useful in environments with few features where a merely feature-based approach might fail.

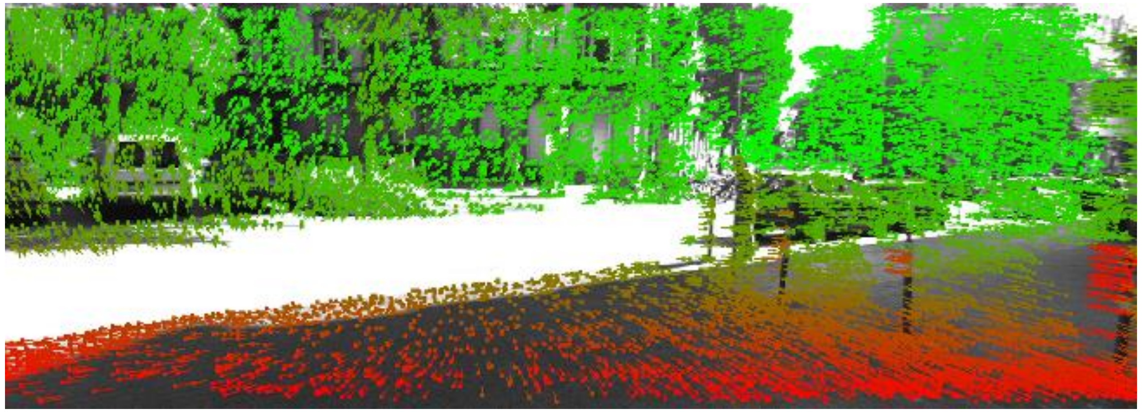


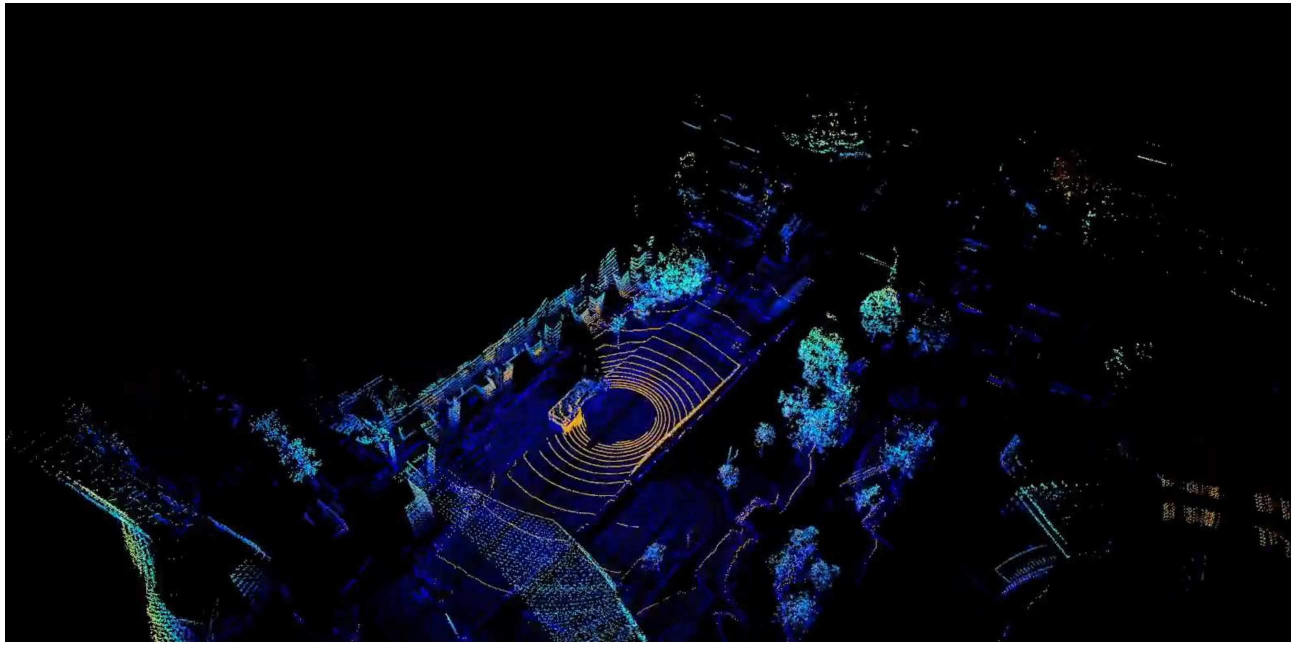
Image: Geiger2011

Source: Agel2016

Localization – Relative Localization

Visual Odometry with Lidar sensors

- **Goal** Motion estimation based on a sequence of lidar point clouds
- **Sensors** Lidar sensors or pseudo lidar (computed from depth estimates)
- **Common approaches**
  - **Scan Matching**
    Find a transformation between two point clouds that best aligns them, e.g., using the *Iterative Closest Point* (ICP) method.
  - **Feature Tracking**
    Find a transformation between features found in two different point clouds, e.g., detected landmarks.



Video: Vizzo2023