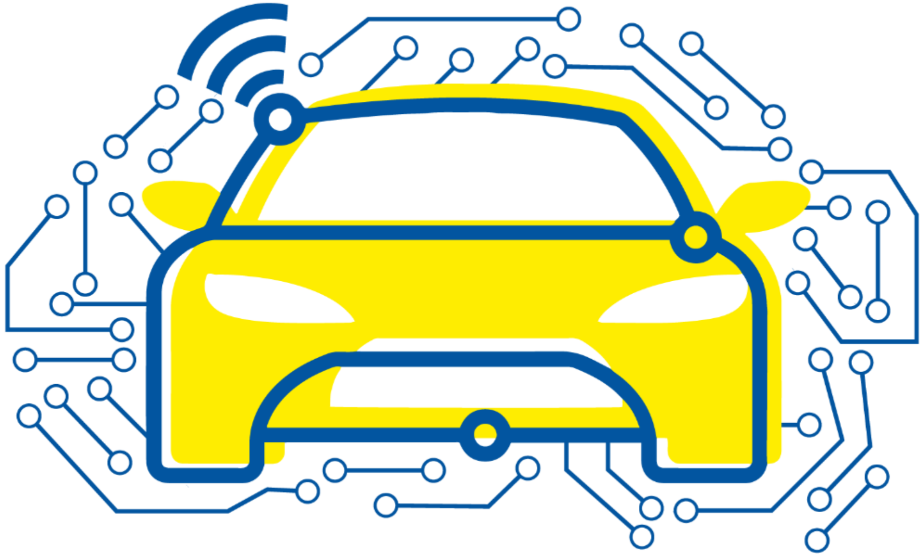
Automated and Connected Driving Challenges

Section 2 – Sensor Data Processing

Localization

Global Localization



Bastian Lampe

Institute for Automotive Engineering

Localization – Global Localization

Overview

Global Localization aims to estimate the vehicle pose in a global reference frame

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

- ... plan a route from the actual vehicle position to a desired target with respect to a given map.
- ... make use of additional information from digital maps for guidance and control.

<u>Common Approaches:</u>

- Global Navigation Satellite Systems (GNSS) (e.g. GPS, GLONASS, Galileo or BeiDou)
- Landmark Based Localization

<u>Strengths and Weaknesses of Global Localization Approaches:</u>

+ No accumulations of errors	- Inconsistent accuracy
+ High accuracies are possible	- Dependence on external elements

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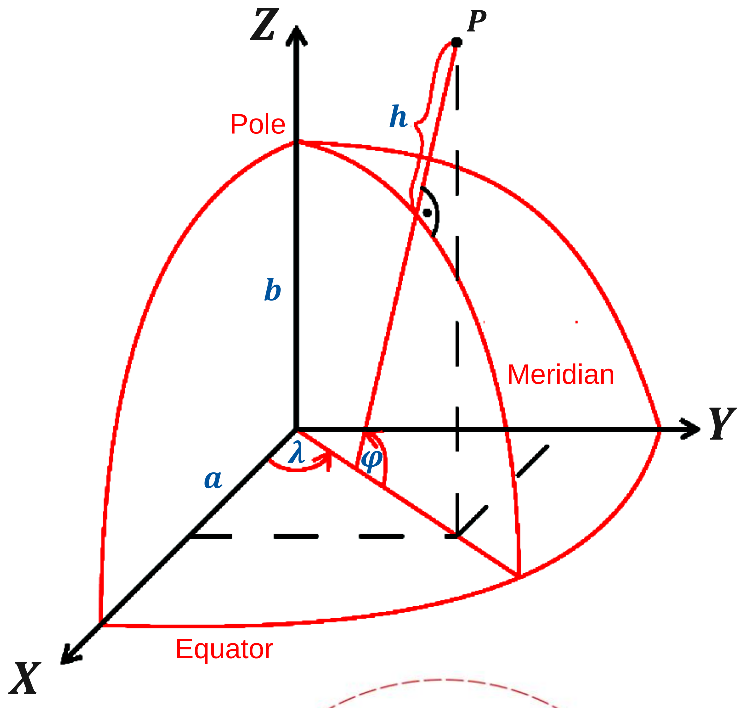
Localization – Global Localization

Global Reference Systems

- Earth is *nearly* spherical
- Earth is even better resembled by a **spheroid** *model*
- Different spheroid models are characterized by their choice of a and b
- In both models, a point P can be defined by $P = (\varphi, \lambda, h)^T$
  - φ: latitude (e.g. 50.786742°)
  - λ : longitude (e.g. 6.046399°)



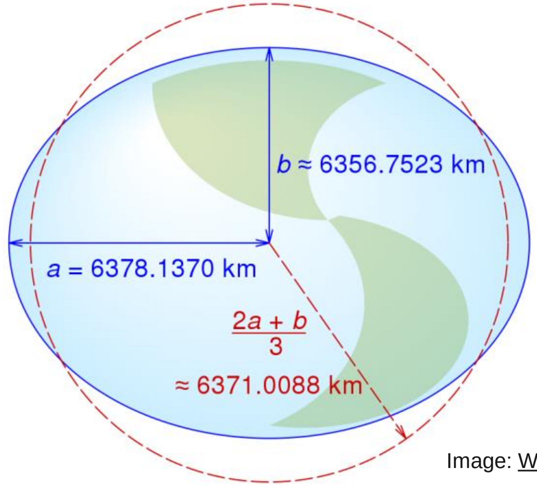


Image: Wikipedia

Source: Teunissen 2017

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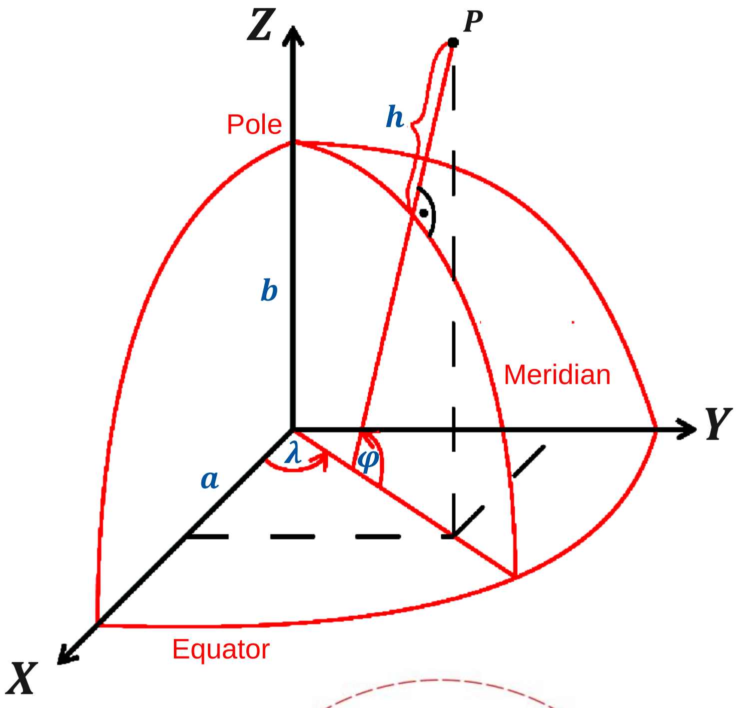
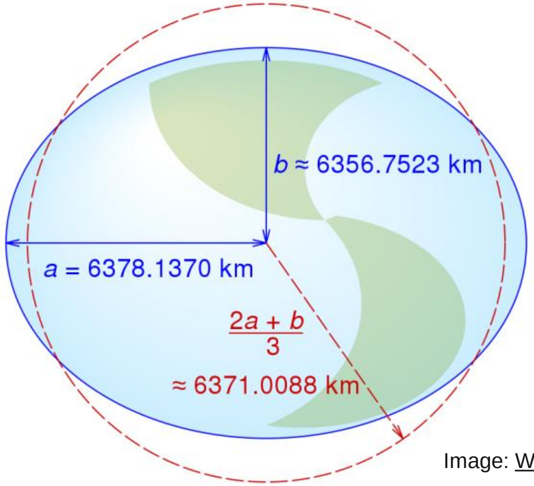
  - φ: latitude (e.g. 50.786742°)
  - λ : longitude (e.g. 6.046399°)
  - h: vertical position
- The World Geodetic System 1984 **(WGS84)** is typically used as the basis for GNSS-Applications
  - Its origin is located within the earth's center of mass





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Localization – Global Localization

The UTM Reference System

- Need for an additional reference system due to **inconvenience of WGS84 coordinates**
- The **Universal Transverse Mercator** (**UTM**) is a **Map Projection System** that can project spheroid coordinates onto a **2D plane**
- Divides earth's surface into **60 zones and 24 longitude bands**
  - Optimized projection for each zone of ~ 6° latitude

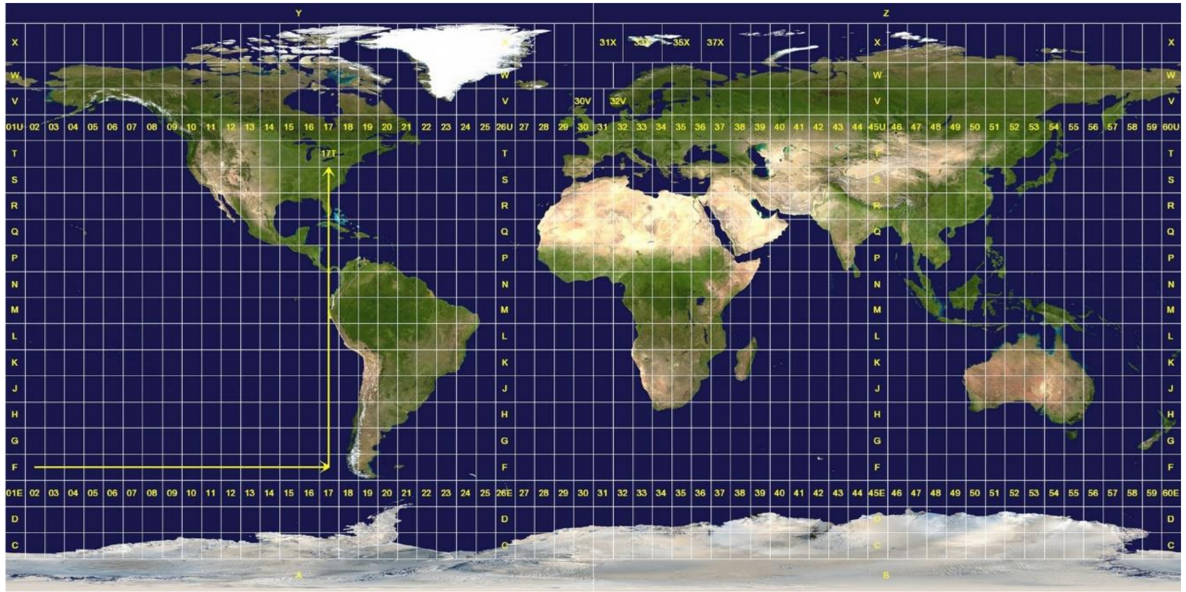

Image: wikipedia

Source: USGS2001

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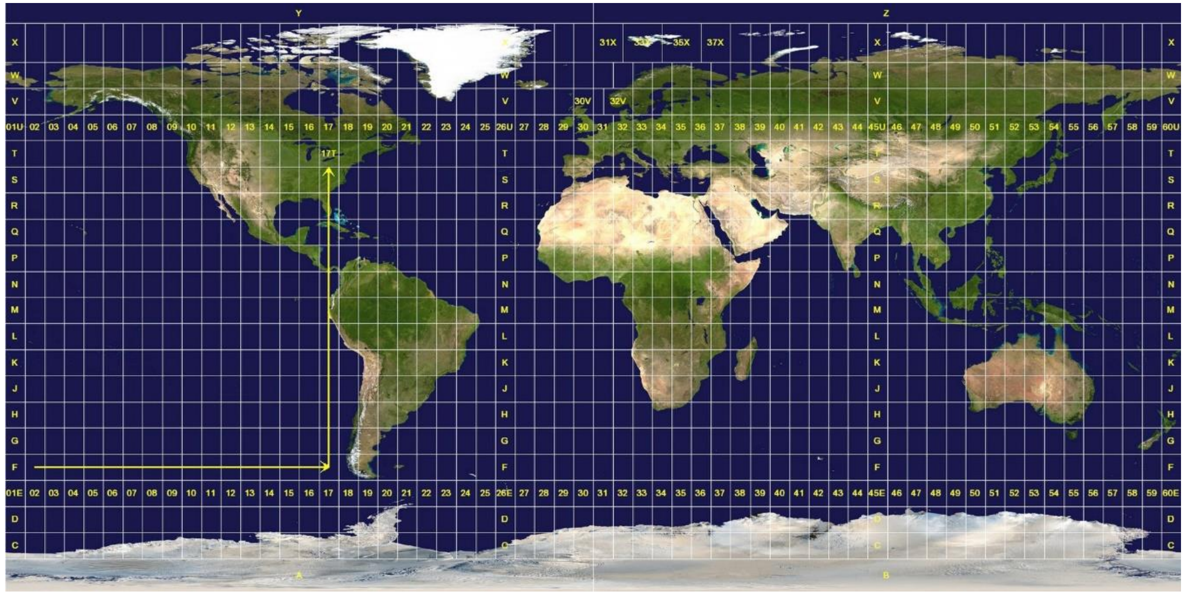
- **UTM Coordinates** are given in often more convenient format
  - UTM **Easting** (e.g. 291,816.82 m)
  - UTM **Northing** (e.g. 5,630,269.40 m)
  - UTM **Gridzone** (e.g. 32U)



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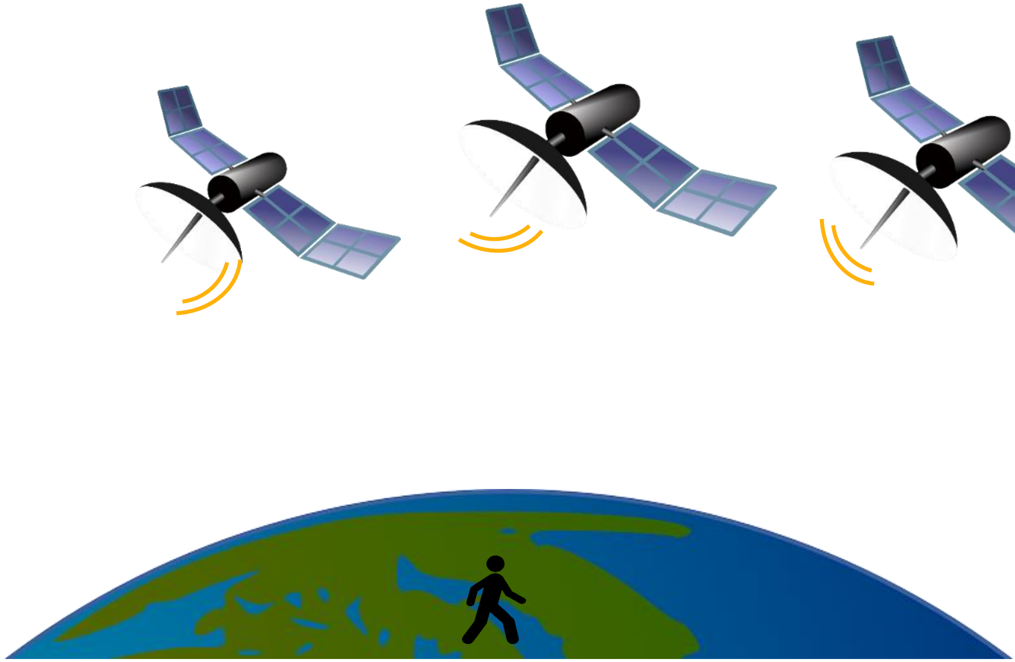
Localization – Global Localization

Global Navigation Satellite Systems (GNSS)

Key Principles:

- **Distance estimate** to a satellite based on **time of flight** and **constant speed of light**.
- **GNSS Signals** are sent over frequency band L1 (1575,42 MHz) and/or L2 (1227,60 MHz)
- **Multilateration** can be used to compute the position.



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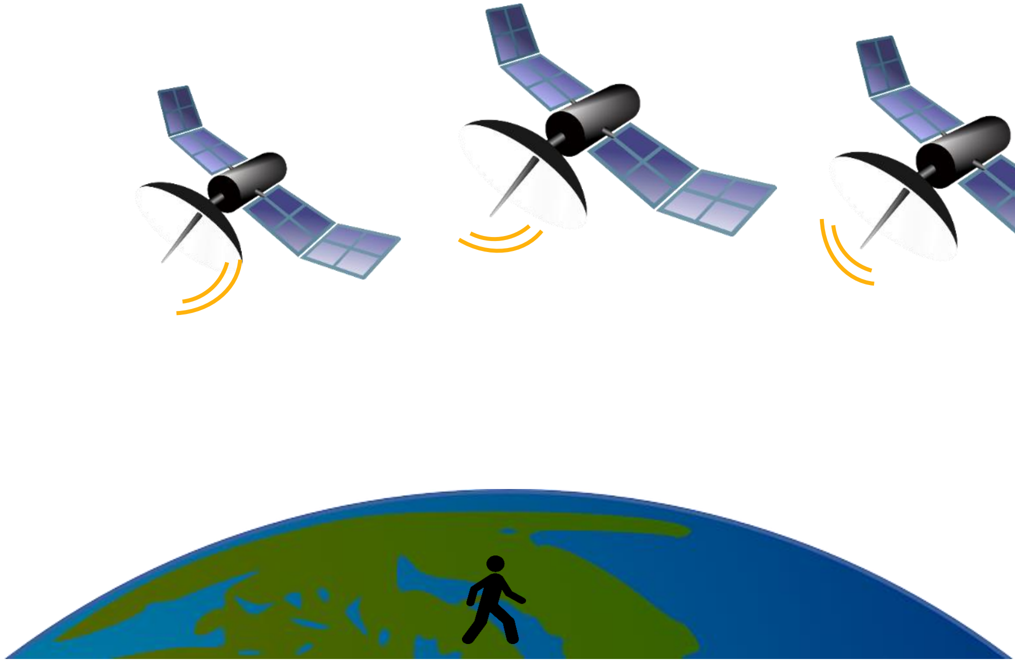
GNSS System	Country	Precision (public)
Global Positioning System (GPS)	United States of America	5-10 m
GLONASS	Russia	4,5 – 7,4 m
Galileo	Europe	4 m
BeiDou	China	10 m



Localization – Global Localization

GNSS – Methods to Enhance Accuracy

Dual frequency receivers

- If both L1 and L2 are used, ionospheric delay errors can be computed
  → *Accuracy: ~5 m*

GNSS-Augmentation

- **Basic Idea**
  - Estimate error by comparing calculated position with known position of base stations
  - Transmit error estimate from base stations to receiver
  - Subtract error from calculated position

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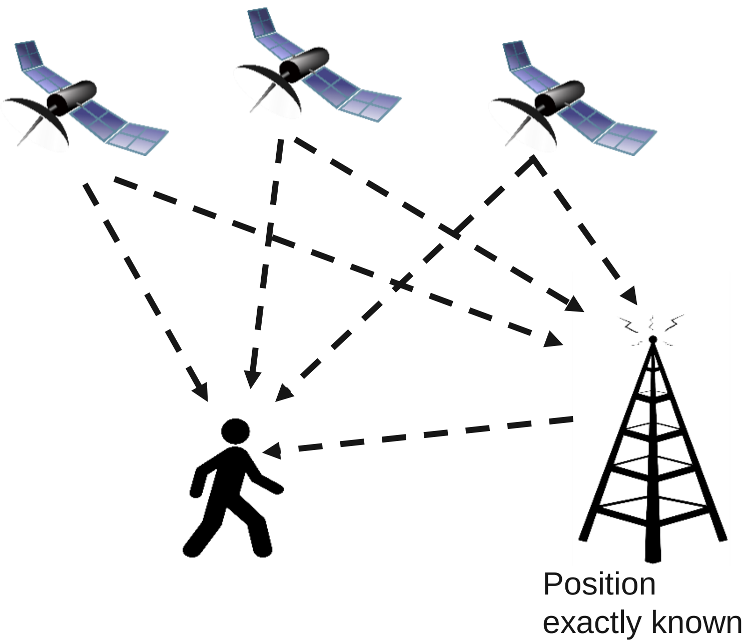
- **Types**
  - **Ground-based:** Send signals via radio signals to receivers close to the base stations
    - Examples: GBAS, LAAS
  - **Satellite-based:** Send signals via satellite to receivers
    - Examples: EGNOS, WAAS
  - **Internet-based**: Send signals via Internet to receivers
    - Examples: NTRIP



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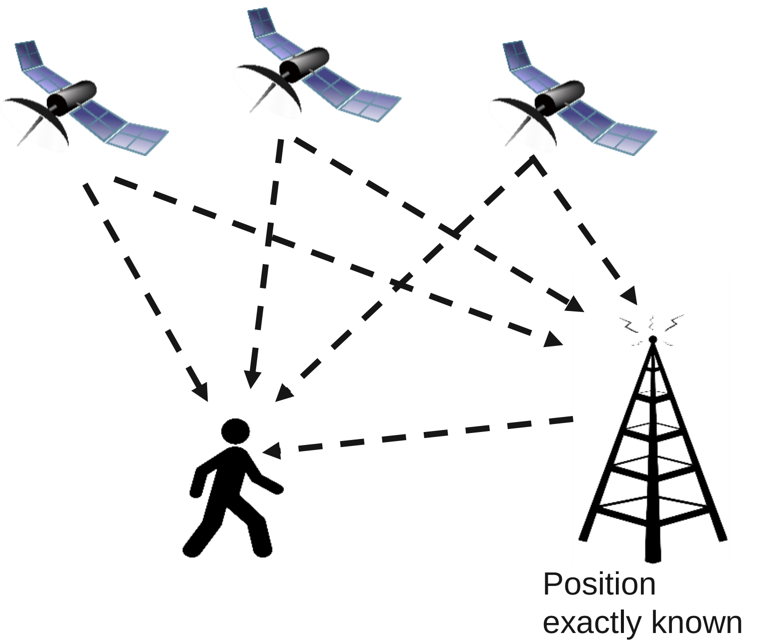


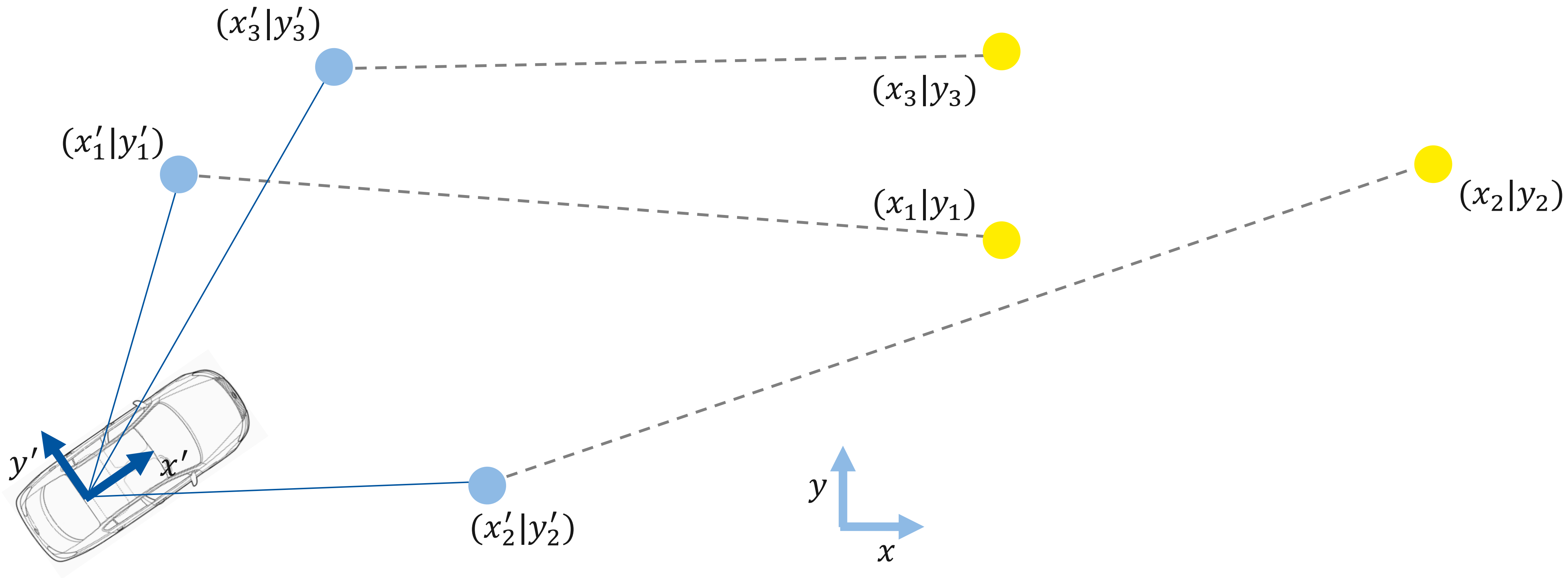
Real Time Kinematics (RTK)
- Based on real time communication between base stations and receiver
- Takes into account the phase of received signal

→ **Allows centimeter precision**

Localization – Global Localization

Landmark Based Localization

- Pose estimation based on a given map with various landmarks
  - Landmarks are fixed objects in the environment that can be detected by a vehicle's sensors
  - By matching detected landmarks with the same landmarks referenced in a map, a pose can be estimated



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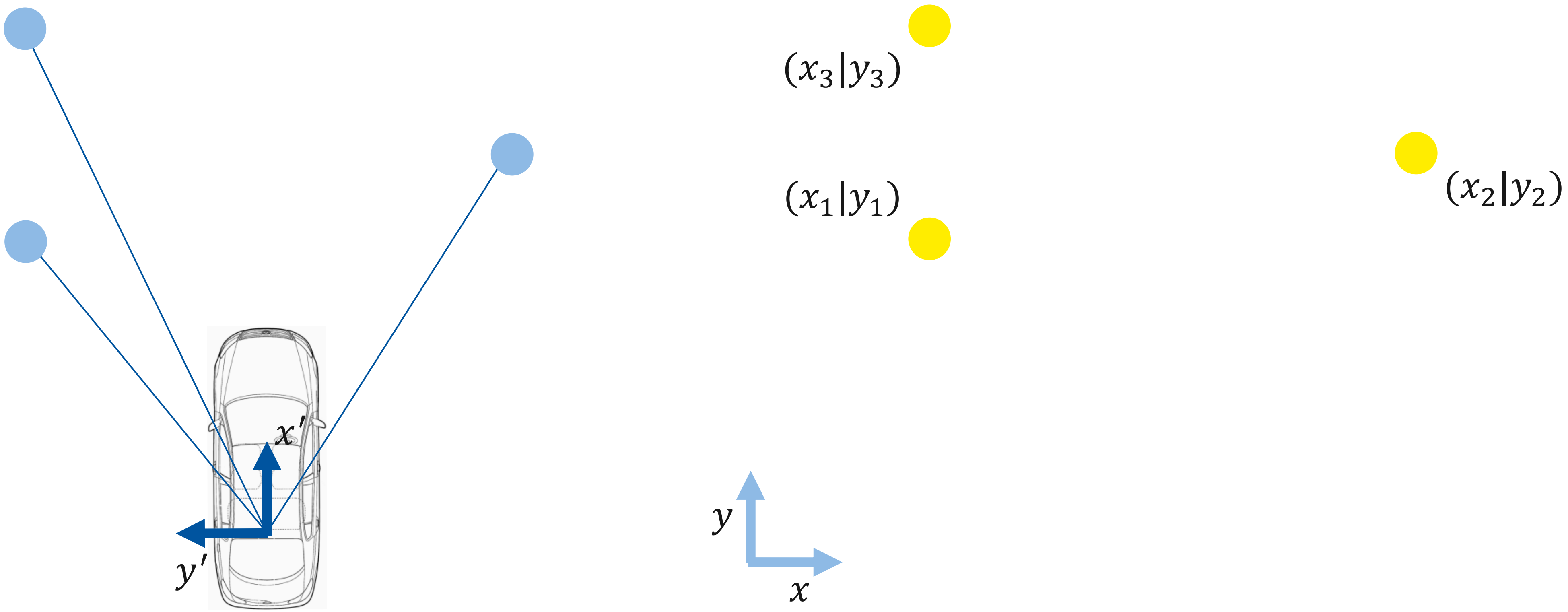
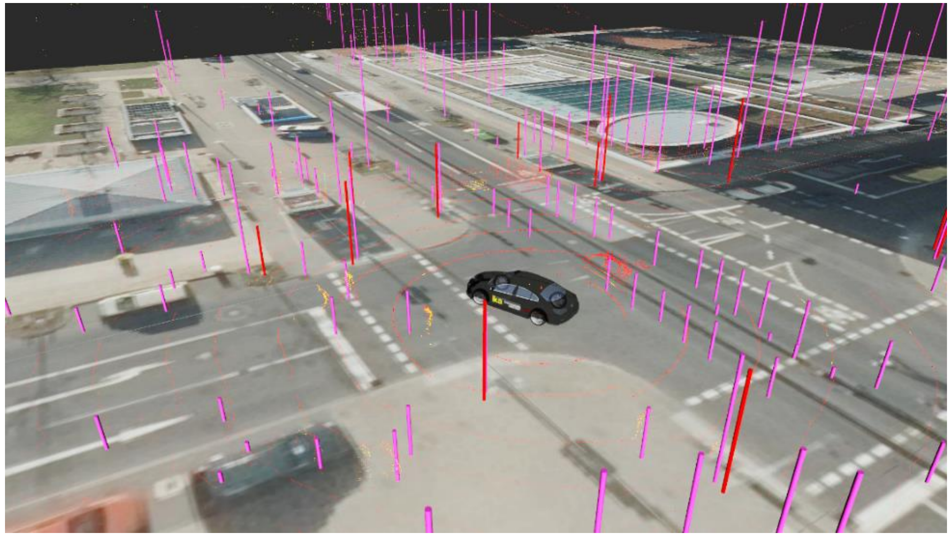


Localization – Global Localization

Landmark Based Localization

- ***Preexisting*** vs. ***localization-specific*** landmarks:
  - *Preexisting landmarks*
    - Objects that don’t primarily exist for the purpose of localization
    - Examples: road signs, traffic lights, lane markings, buildings, utility poles
  - *Localization-specific landmarks*
    - Objects that are placed in the environment for the purpose of localization → *Fiducial Marker*
    - Examples: RFID tags, QR codes, ArUco markers



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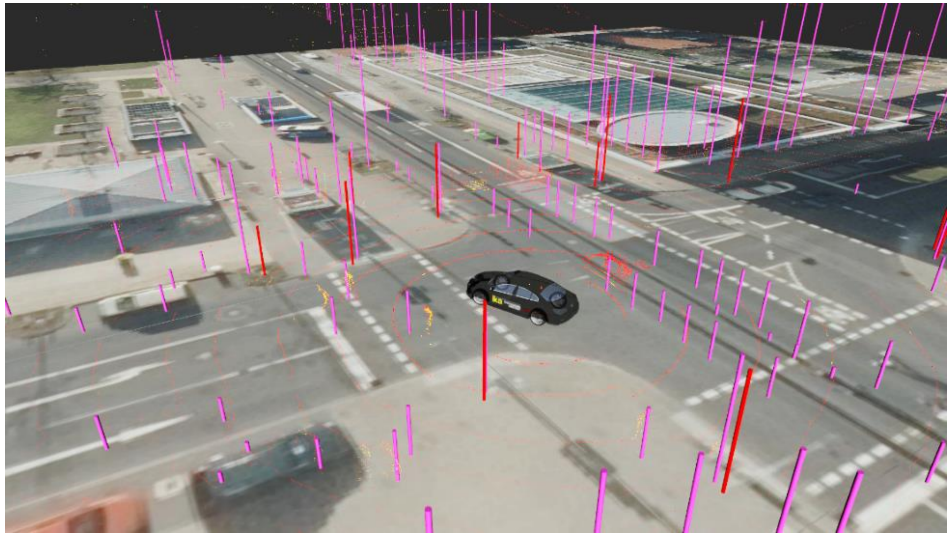

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