Experimental study of the precision of a multi-map AMCL-based localization system

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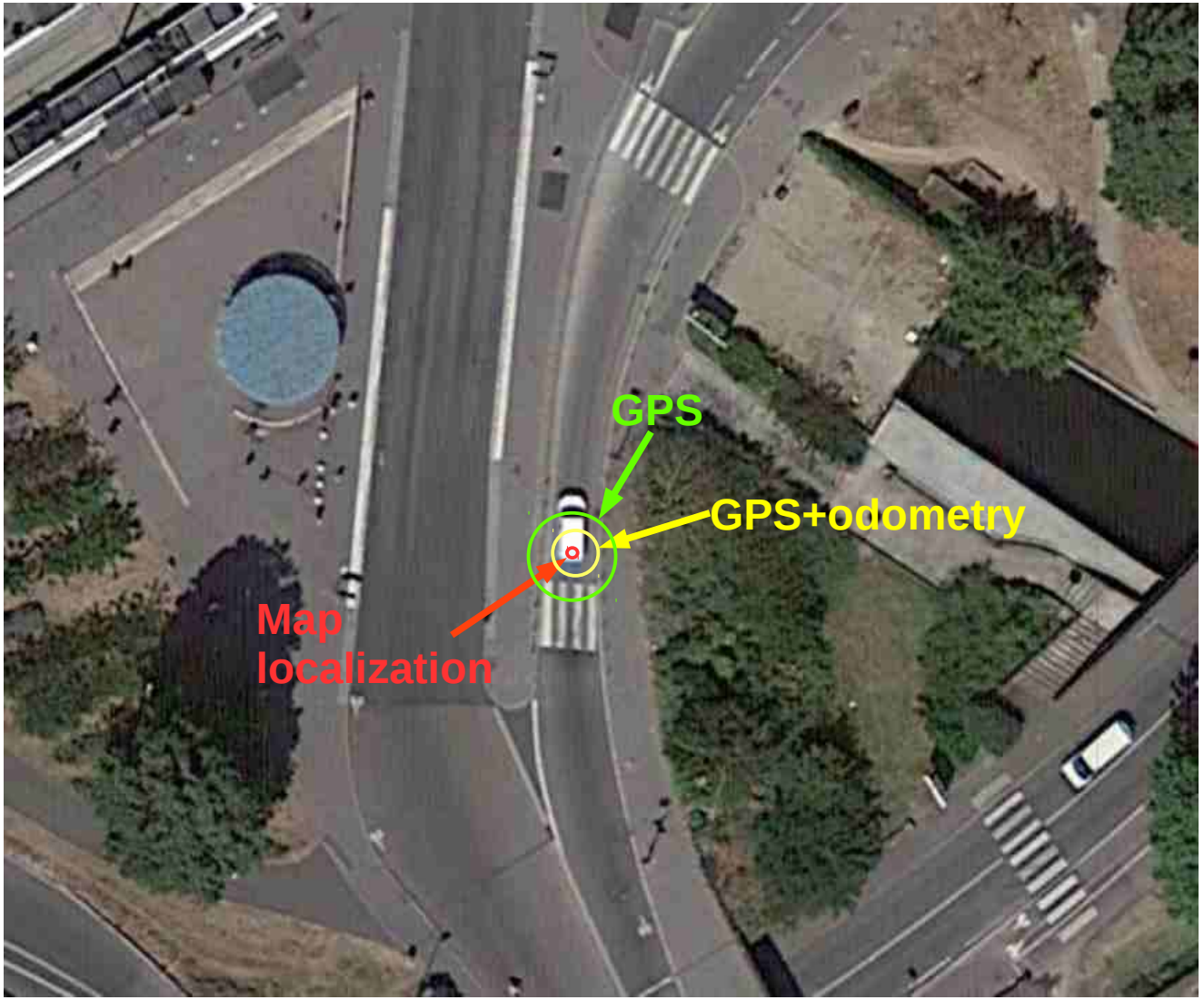
Motivation:

Self-localization with good precision for autonomous navigation in:

- Road ring-type environment
- Residential environment
- Urban environment

Why to use map localization?

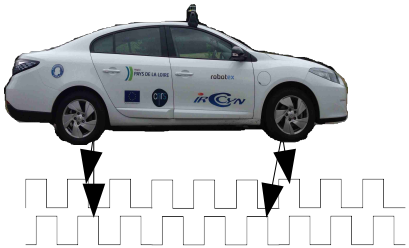


Positioning error GPS > GPS+odometry > map localization

Vehicle used: Renault Fluence ZE

- 100% Electrical
- Type: Compact sedan, 5 seats, 4 doors
- Battery power: 22kWh
- Autonomy 185 km
- Max speed 135 km/h
- Weight: 1605 Kg

Sensors used:



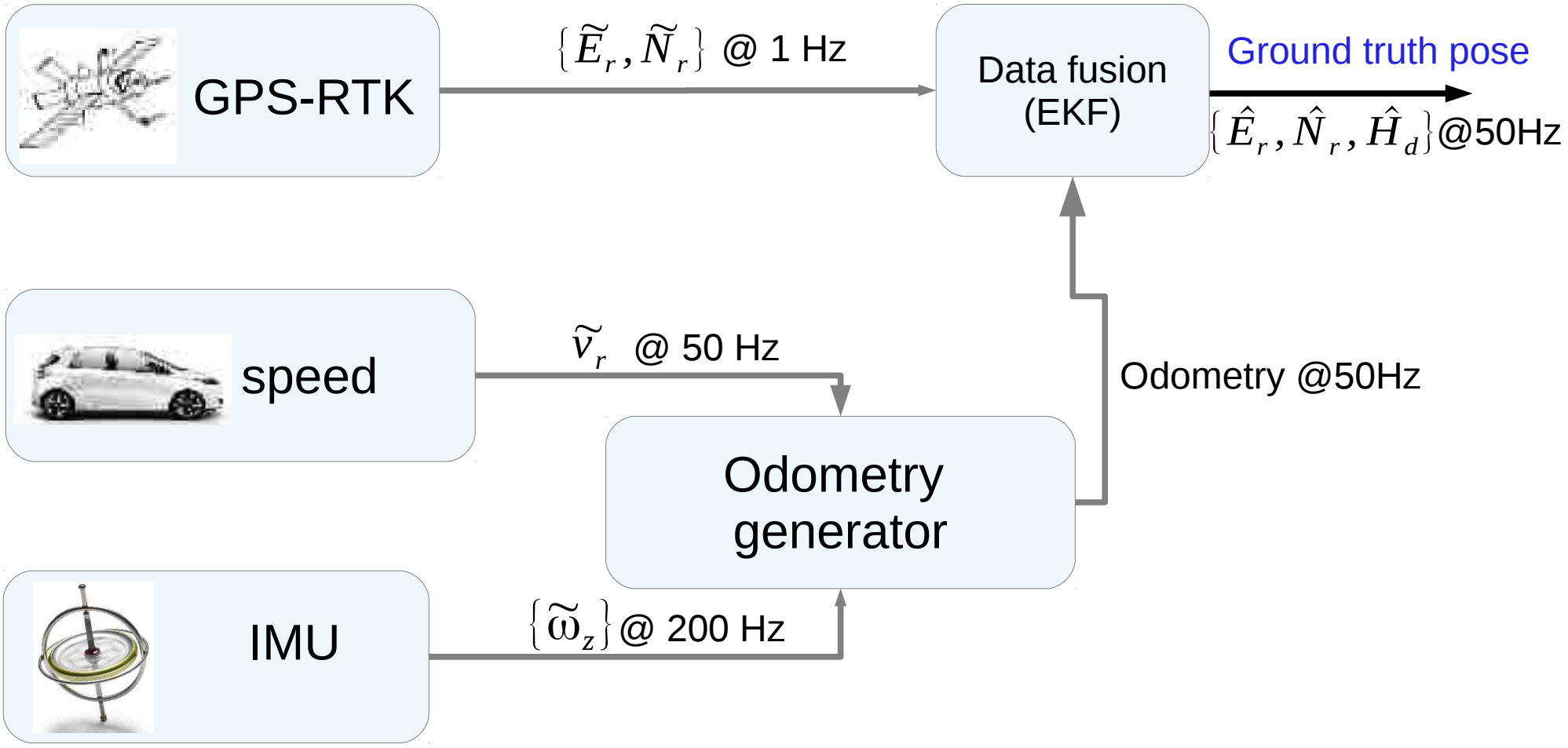
- **Wheel tachometers (CAN bus):** speed of the wheels @ 50 Hz

- **Inertial Measurement Unit Xsens MTI 100:** angular speeds XYZ @ 200 Hz.

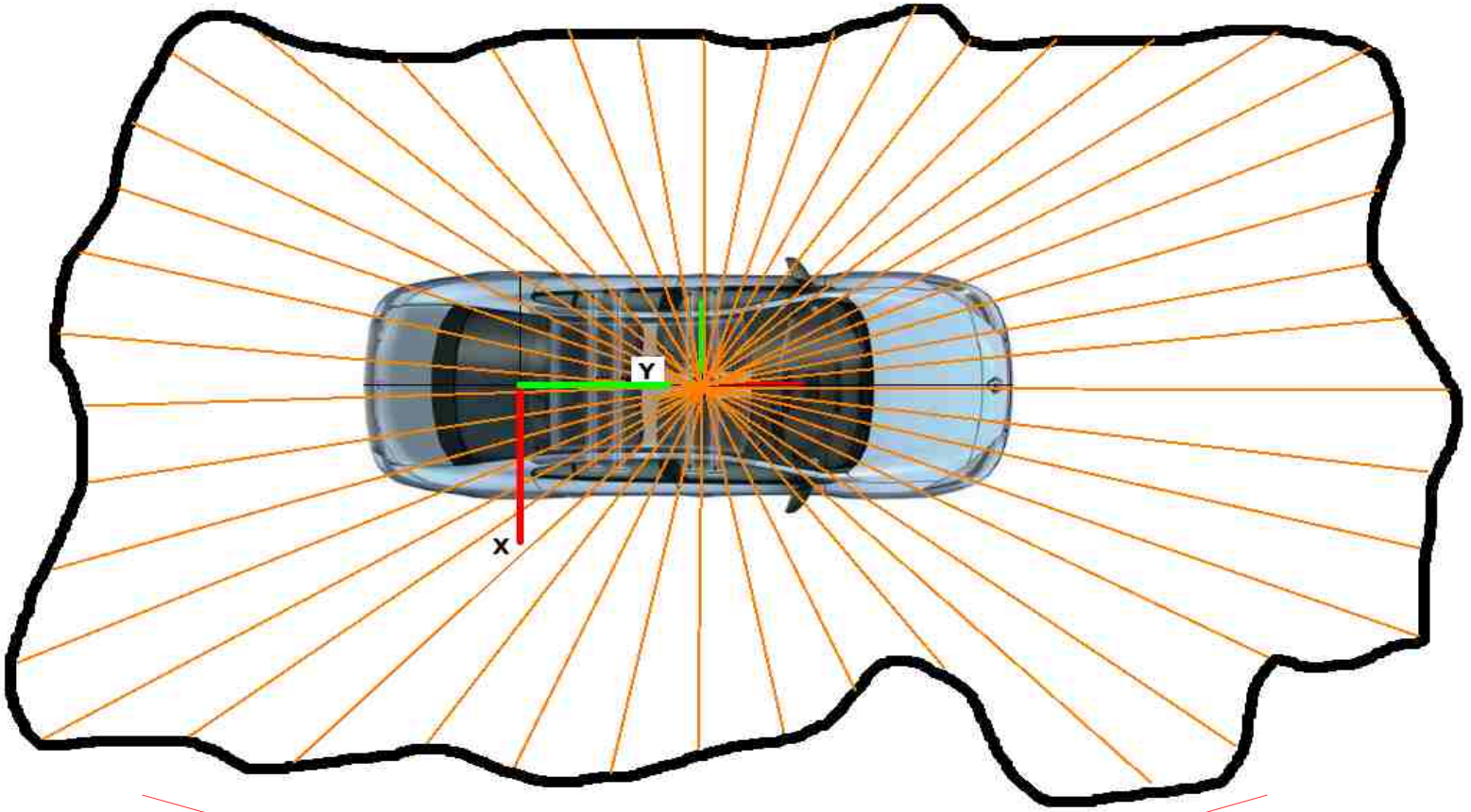
- **RTK-GPS receiver ProFlex 800:** positions with + 1 cm accuracy in RTK mode @ 1Hz

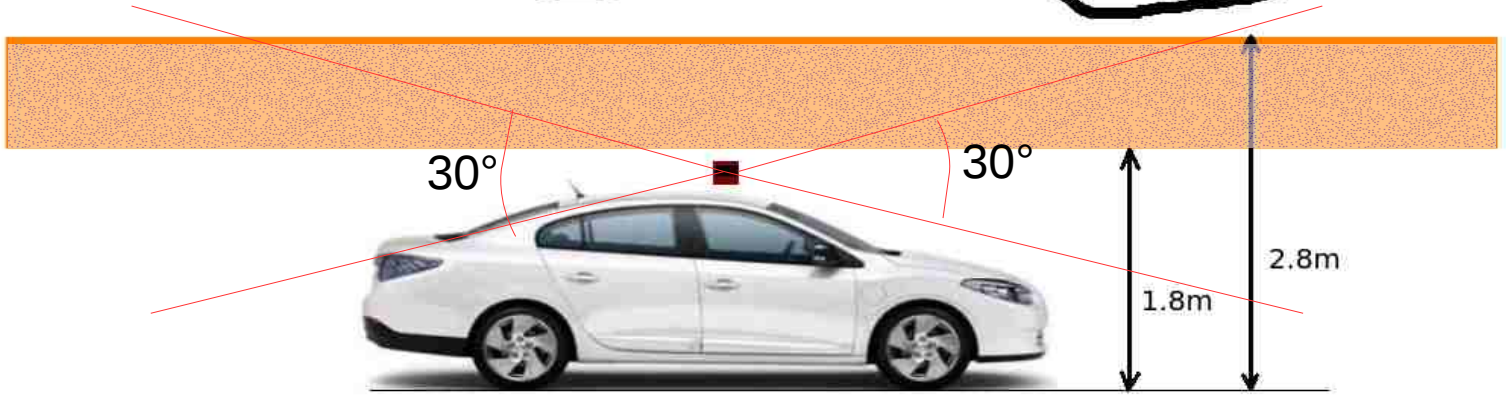
- **Puck Velodyne VLP 16 LiDAR:** range measurements
  - 16 planes [-15°,15°] vertical, 360 ◦ in horizontal
  - angular resolution of 0.25°
  - range accuracy of ±3 cm
  - maximum range of 100 m

Ground truth generation: GPS-RTK + Odometry EKF

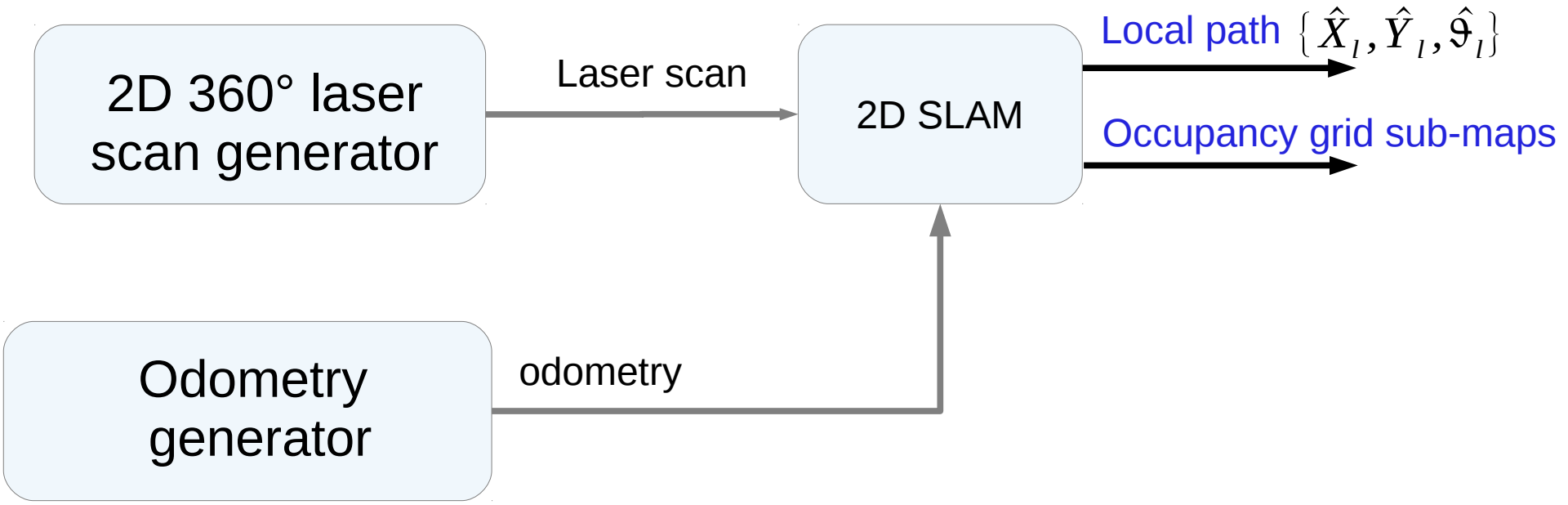


2D Laser scan generation. Velodyne 3D data

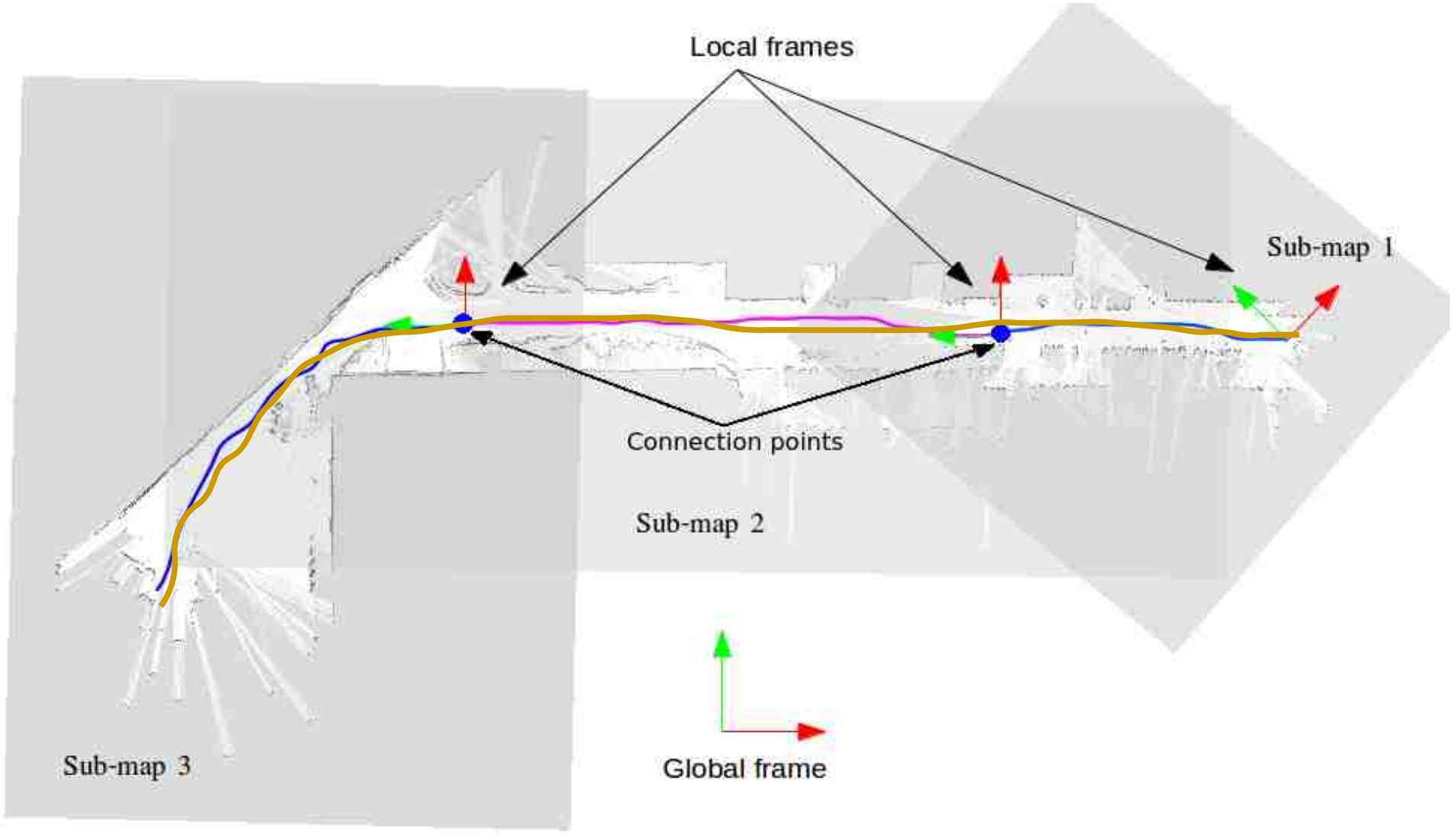




Sub-map building: 2D laser scan + odometry SLAM



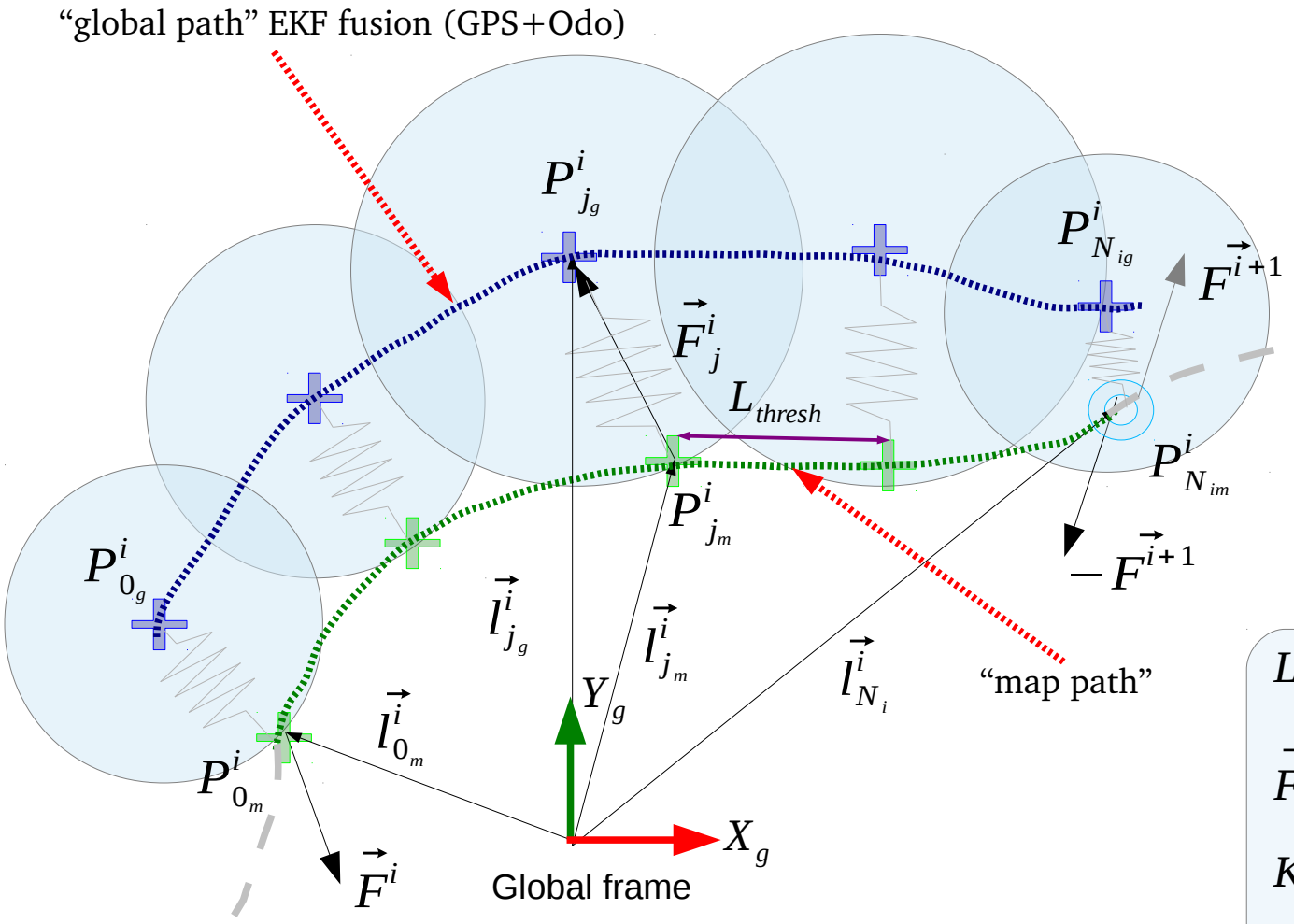
Map building. SLAM 2D + sub-map geo-positioning



Optimization of the global position of the submaps

Superindex → sub-map → $i = 1 \cdots n$ **Sub-map index**

Subindex → path point → $j = 1 \cdots N_i$ **Path point index**

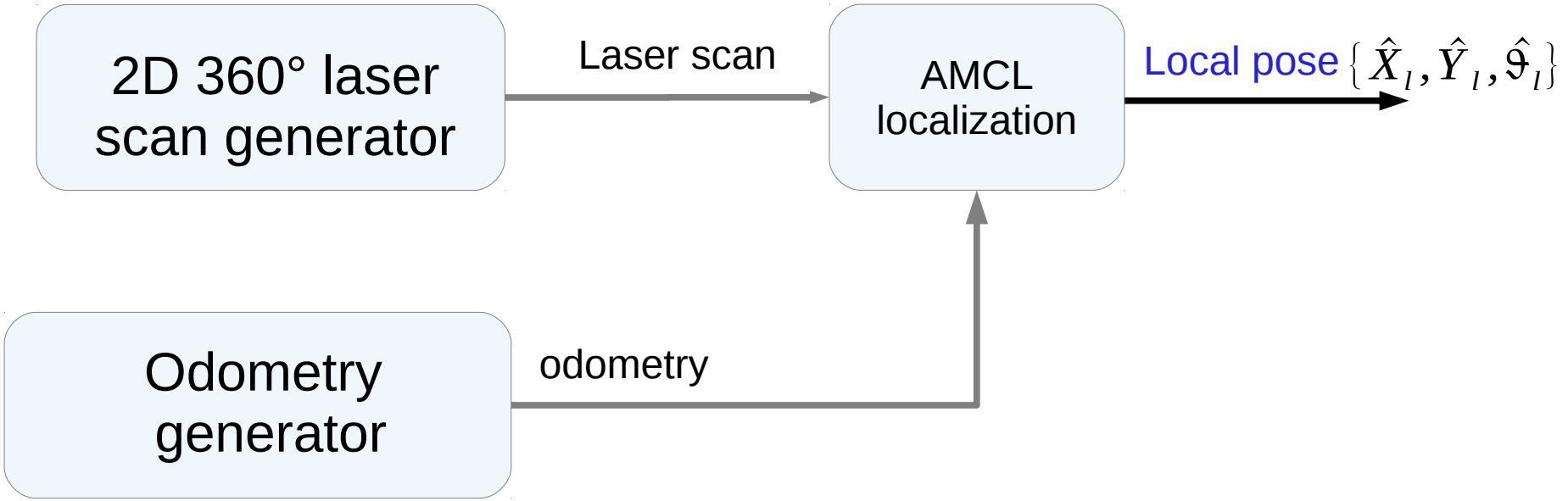


$$L_{j,\,j+1} \geqslant L_{threshold}$$

$$\vec{F}^i_j = K^i_j * \vec{l}^i_j$$

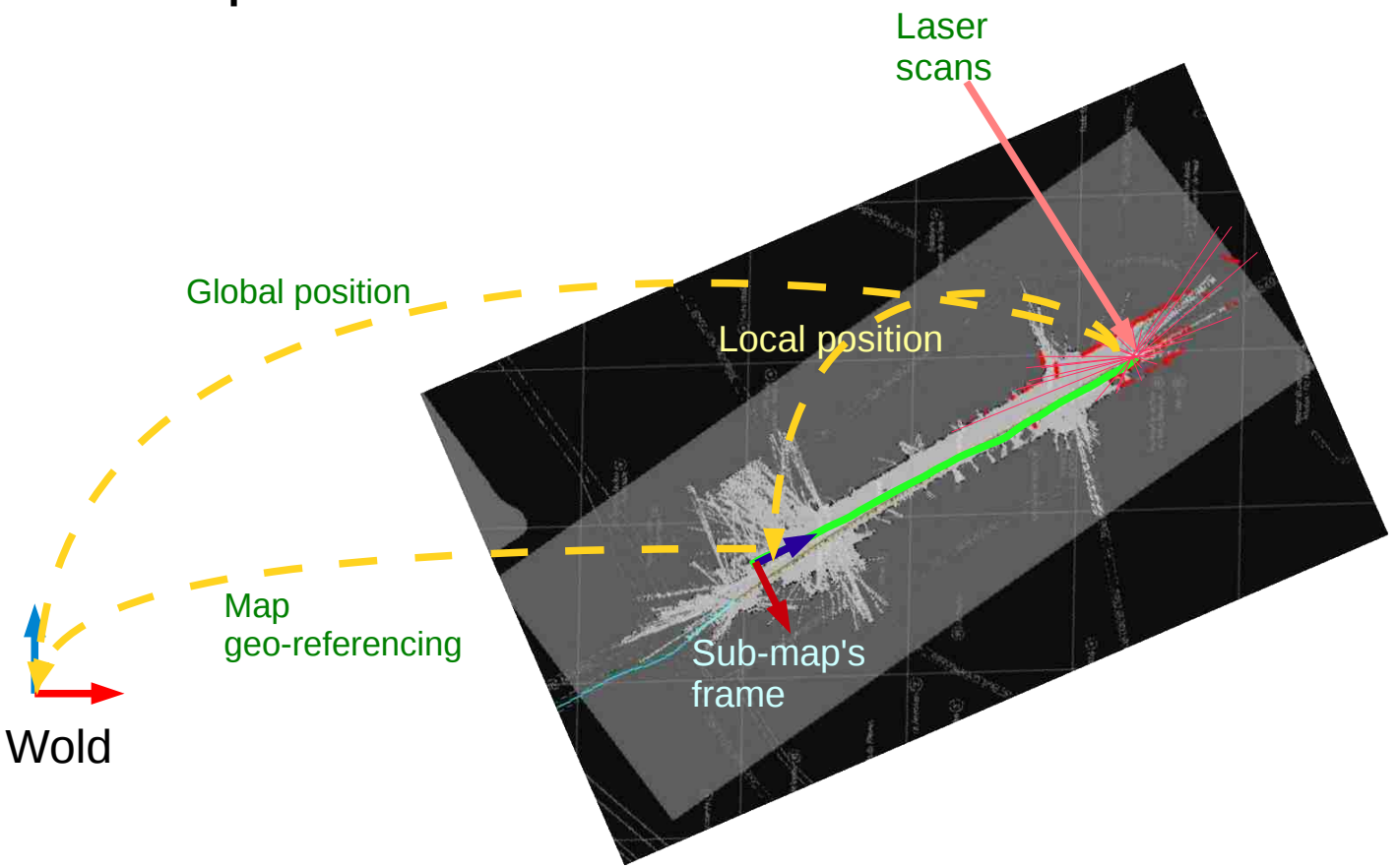
$$K^i_j = \frac{1}{cov^i_j}$$

AMCL sub-map localization: 2D laser scan + odometry



Localization algorithm:

- Local sub-map localization using AMCL (Adaptative Montecarlo Localization): particle filter-based that uses odometry + 360° planar laser scan
- Global localization composing map geo-localization with local sub-map localization



Experiment results

- Total distance covered about 100 Km
- Three types of environments:
  - **Road ring of Nantes:** mainly longitudinal features, up to 70 km/h, cars passing around.
  - **Residential zone of Nantes:** up to 30 km/h. Houses around, quiet
  - **Urban environment in Nantes:** up to 50 km/h, cars and people moving around, houses.

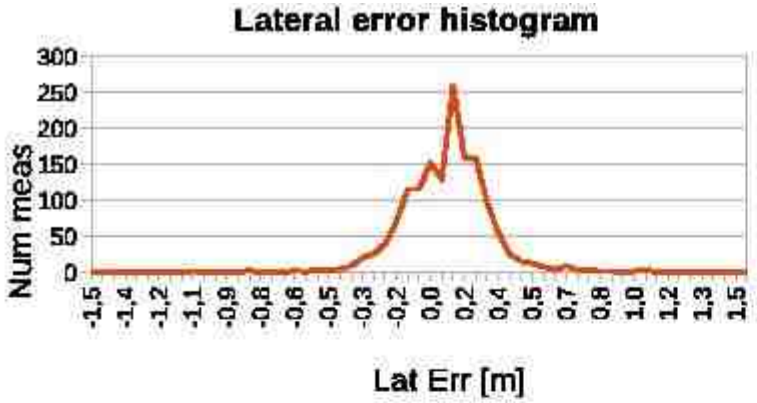
Road	Lat Error	Long Error
Average[m]	0,07	-0,02
Std. Dev[m]	0,22	0,22
Min[m]	-1,15	-0,62
Max[m]	1,35	0,96
Number of measurements		1533
Total distance [km]		26,2

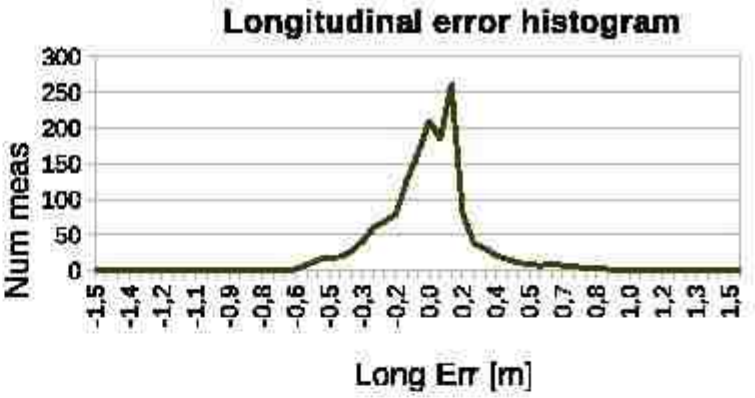
Residential	Lat Error	Long Error
Average[m]	0,03	0,01
Std. Dev[m]	0,13	0,17
Min[m]	-0,56	-0,66
Max[m]	0,56	1,25
Number of measurements		4487
Total distance [km]		37,7

Urban	Lat Error	Long Error
Average[m]	0,01	-0,01
Std. Dev[m]	0,17	0,18
Min[m]	-1,06	-0,88
Max[m]	0,90	0,97
Number of measurements		3825
Total distance [km]		33,9

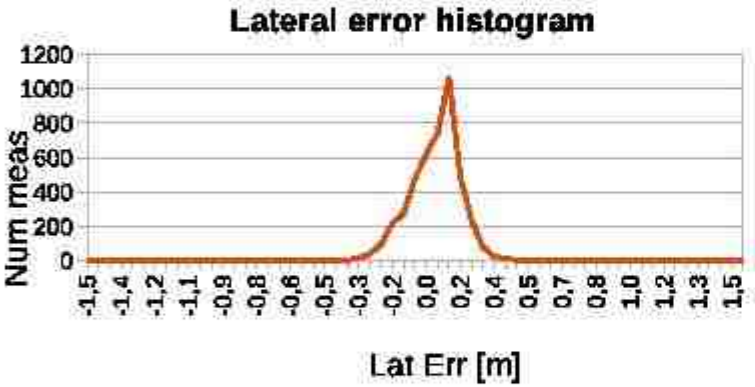
Experiment results. Error histogram summary

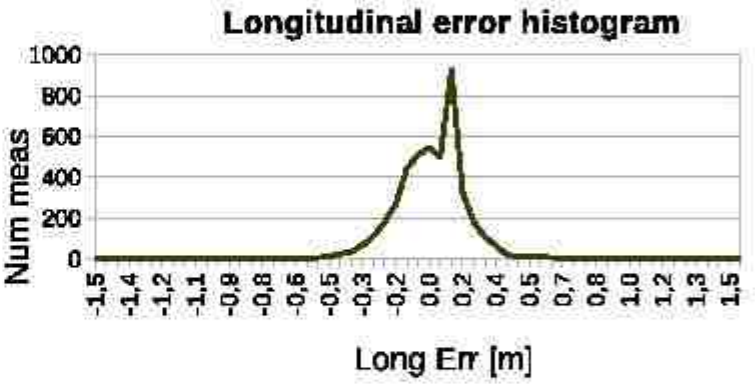
Road ring



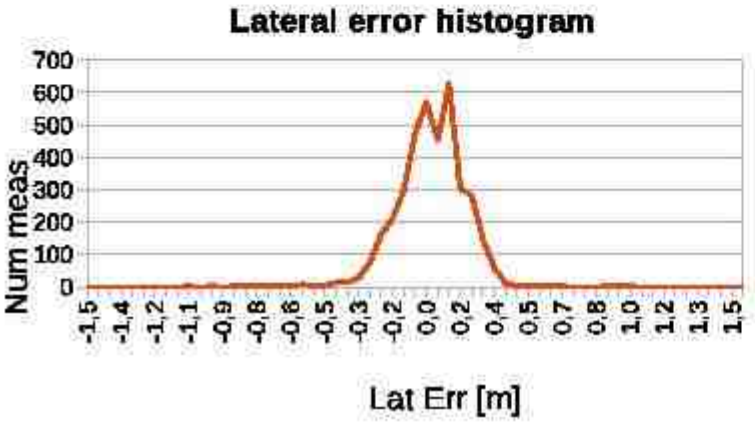


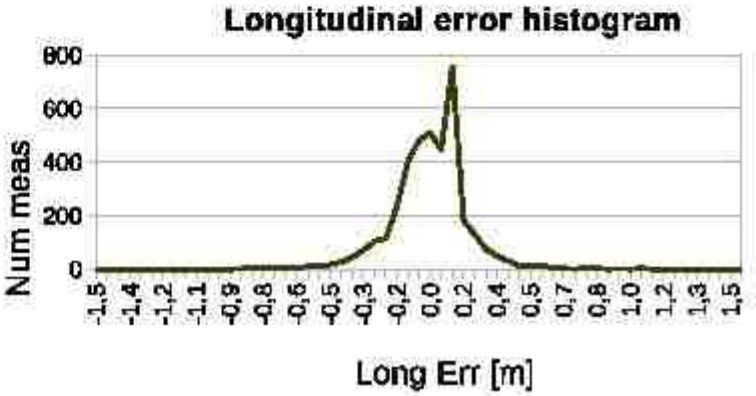
Residential zone





Urban zone





Conclusions

Pros

- Results of an intensive campaign of evaluation of a large scale mapping and localization experiments have been presented
- High robustness, precision and reliability of the algorithms

Contras

- Current accuracy may not yet be sufficient for autonomous navigation in the urban areas, but is getting closer to the requirements.

Work in progress

there is room for improvement of the performance with the same set of sensors:

- more precise data time stamping. Specially in the GPS measurements for generation of the ground truth and LiDAR
- Increasing the quality of the 2D sub-maps optimizing the algorithms to deal with higher resolution maps.

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