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

GPS-RTK → \{\tilde{E}_r, \tilde{N}_r\} @ 1 Hz

Data fusion (EKF) → \{\hat{E}_r, \hat{N}_r, \hat{H}_d\} @ 50 Hz

Odometry generator

\tilde{v}_r @ 50 Hz

\{\tilde{\omega}_z\} @ 200 Hz

Ground truth pose

speed

IMU

Odometry @ 50 Hz
2D Laser scan generation. Velodyne 3D data
Sub-map building: 2D laser scan + odometry SLAM

2D 360° laser scan generator

Laser scan

2D SLAM

Local path \( \{ \hat{X}_1, \hat{Y}_1, \hat{\theta}_1 \} \)

Occupancy grid sub-maps

Odometry generator

odometry
Map building. SLAM 2D + sub-map geo-positioning
Optimization of the global position of the submaps

Superindex $\rightarrow$ sub-map $\rightarrow$ $i=1 \cdots n$  
Sub-index $\rightarrow$ path point $\rightarrow$ $j=1 \cdots N_i$  

Global frame

"Map path"

"Global path" EKF fusion (GPS+Odo)

$L_j, j+1 \geq L_{\text{threshold}}$

$\vec{F}_j = \vec{K}_j \cdot \vec{l}_j$

$K_j = \frac{1}{\text{cov}_j}$
AMCL sub-map localization: 2D laser scan + odometry

2D 360° laser scan generator → Laser scan → AMCL localization → Local pose $\{\hat{X}_1, \hat{Y}_1, \hat{\theta}_1\}$ → Odometry generator → odometry
Localization algorithm:

- Local sub-map localization using AMCL (Adaptive Monte Carlo 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 ring of Nantes:
- Average [m]: 0.07
- Std. Dev [m]: 0.22
- Min [m]: -1.15
- Max [m]: 1.35
- Number of measurements: 1533
- Total distance [km]: 26.2

### Residential zone of Nantes:
- Average [m]: 0.03
- Std. Dev [m]: 0.13
- Min [m]: -0.56
- Max [m]: 0.56
- Number of measurements: 4487
- Total distance [km]: 37.7

### Urban environment in Nantes:
- Average [m]: 0.01
- Std. Dev [m]: 0.17
- Min [m]: -1.06
- Max [m]: 0.90
- Number of measurements: 3825
- Total distance [km]: 33.9
Experiment results. Error histogram summary

Road ring

![Lateral error histogram](image)

![Longitudinal error histogram](image)

Residential zone

![Lateral error histogram](image)

![Longitudinal error histogram](image)

Urban zone

![Lateral error histogram](image)

![Longitudinal error histogram](image)
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

Contrás
- 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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