Amélioration de la précision et l'intégrité GNSS par un modèle probabiliste de Tranchées Urbaines

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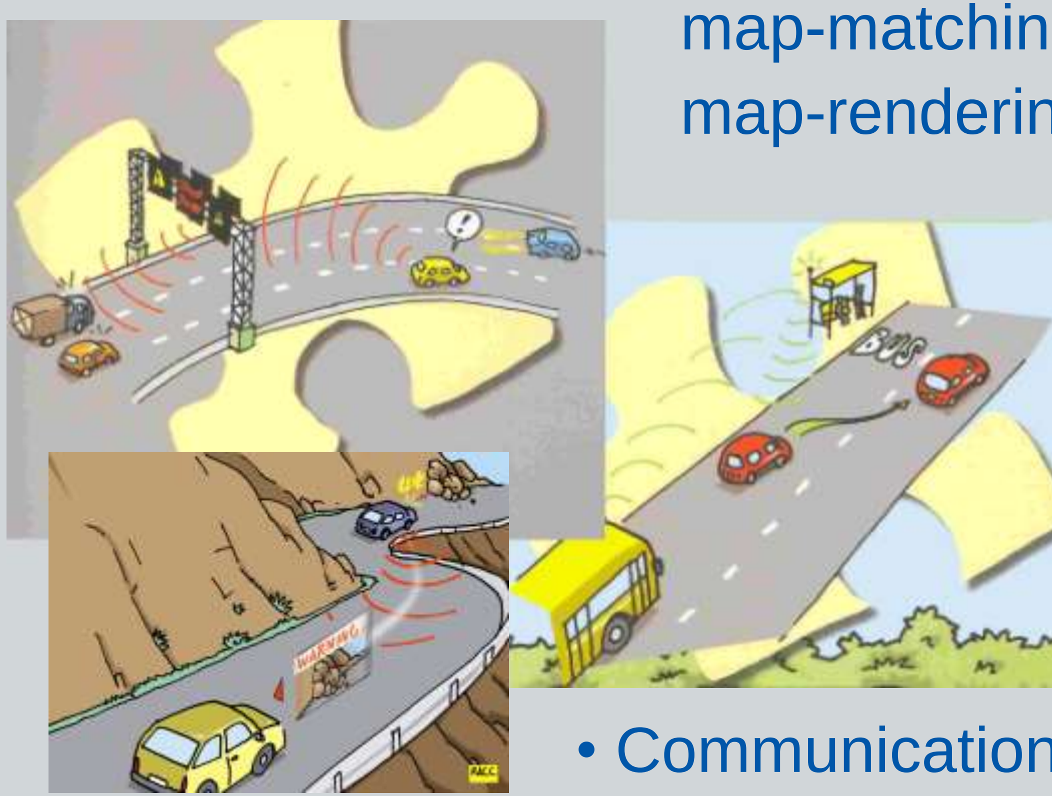
Outils d'aide à la décision

Introduction

- **Geolocalization:**
GNSS

- GIS:
map-matching
map-rendering



A **key technology** for connected vehicles, ITS, mobility…

- Communication:
V2I and V2V

Requirements

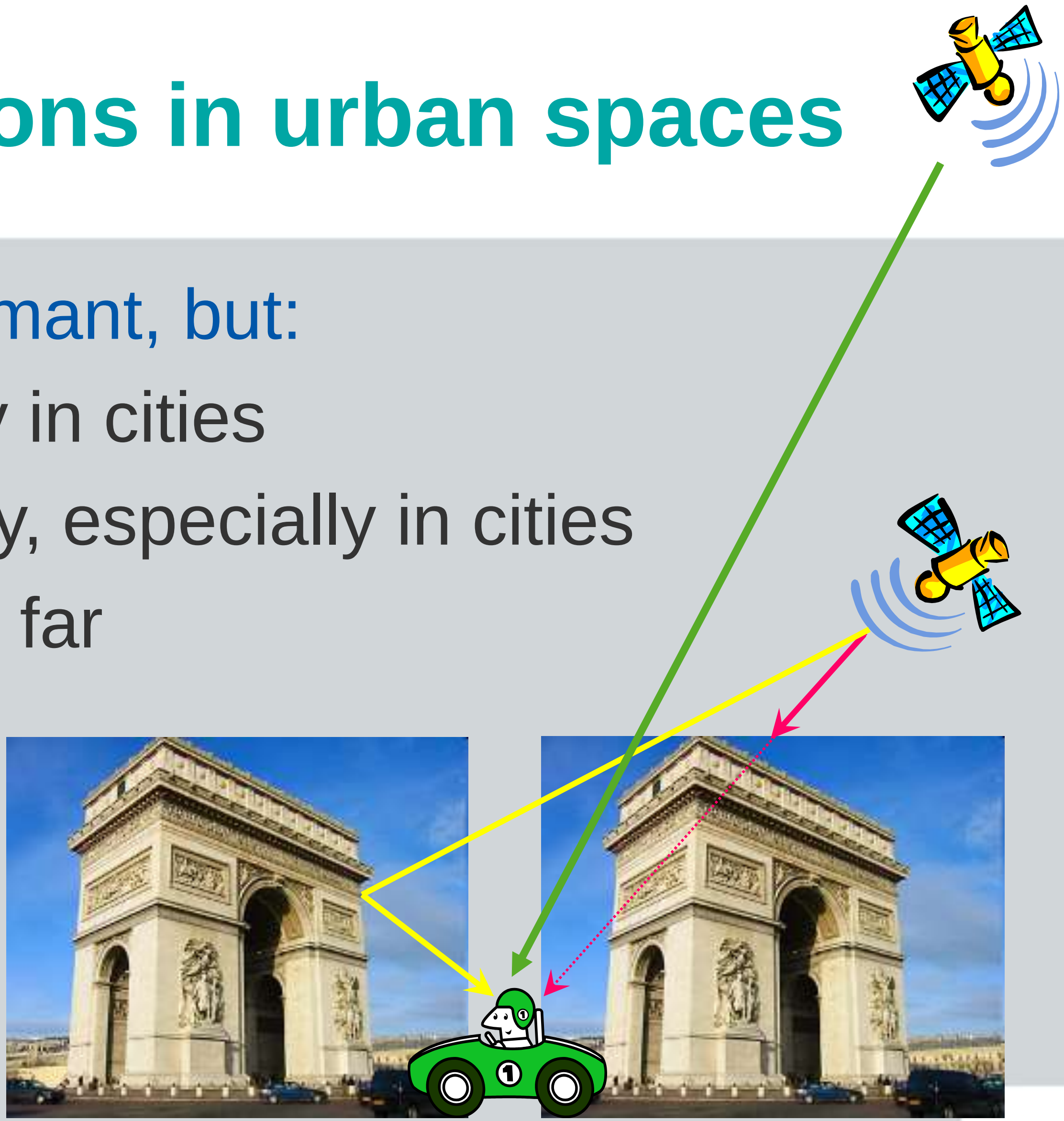
- Main requirements for driver assistance with regard to localization are:
  - availability (near 100%)
  - accuracy (at lane-level)
  - integrity (quantify the risk that the positioning error exceeds a protection level)

- Integrity is mandatory for safety-critical and liability-critical applications, such as:
  - anti-collision, active breaking system, lane-departure warning
  - pay-per-use, electronic toll collection

GNSS limitations in urban spaces

GNSS are performant, but:

- poor availability in cities
- limited accuracy, especially in cities
- **<u>no integrity</u>** so far

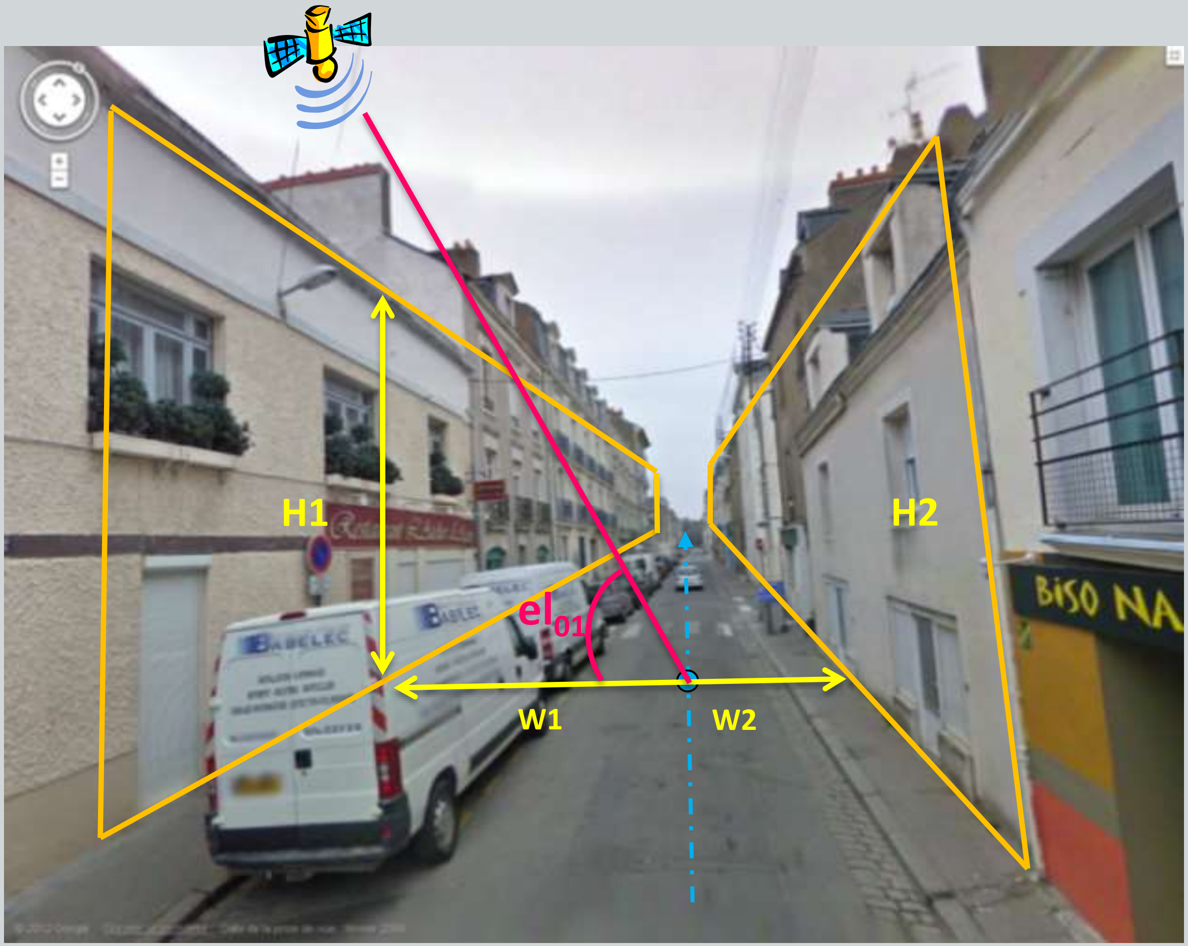


State of the art overview

- Improving GNSS antennas and receivers hardware
- Making data fusion in navigation software
  - SNR weighting
  - Coupling other sensors at range and Doppler measurement level
  - Using 2D road map constraint at the position level or 3D city model at the range level

- 3D-model-aided GNSS
  - Several groups : Univ. College London, Univ. of Tokyo, TU Chemnitz, Ifsttar GEOLOC
  - We specifically try to **comply with ITS** map standard

NLOS detection in Urban Trench



Streets are characteri-zed according to the set of parameters (Width, Height) at both sides of the road arc segment

The critical elevation angle is computed with respect to the azimut angle of the satellite with respect to the street direction

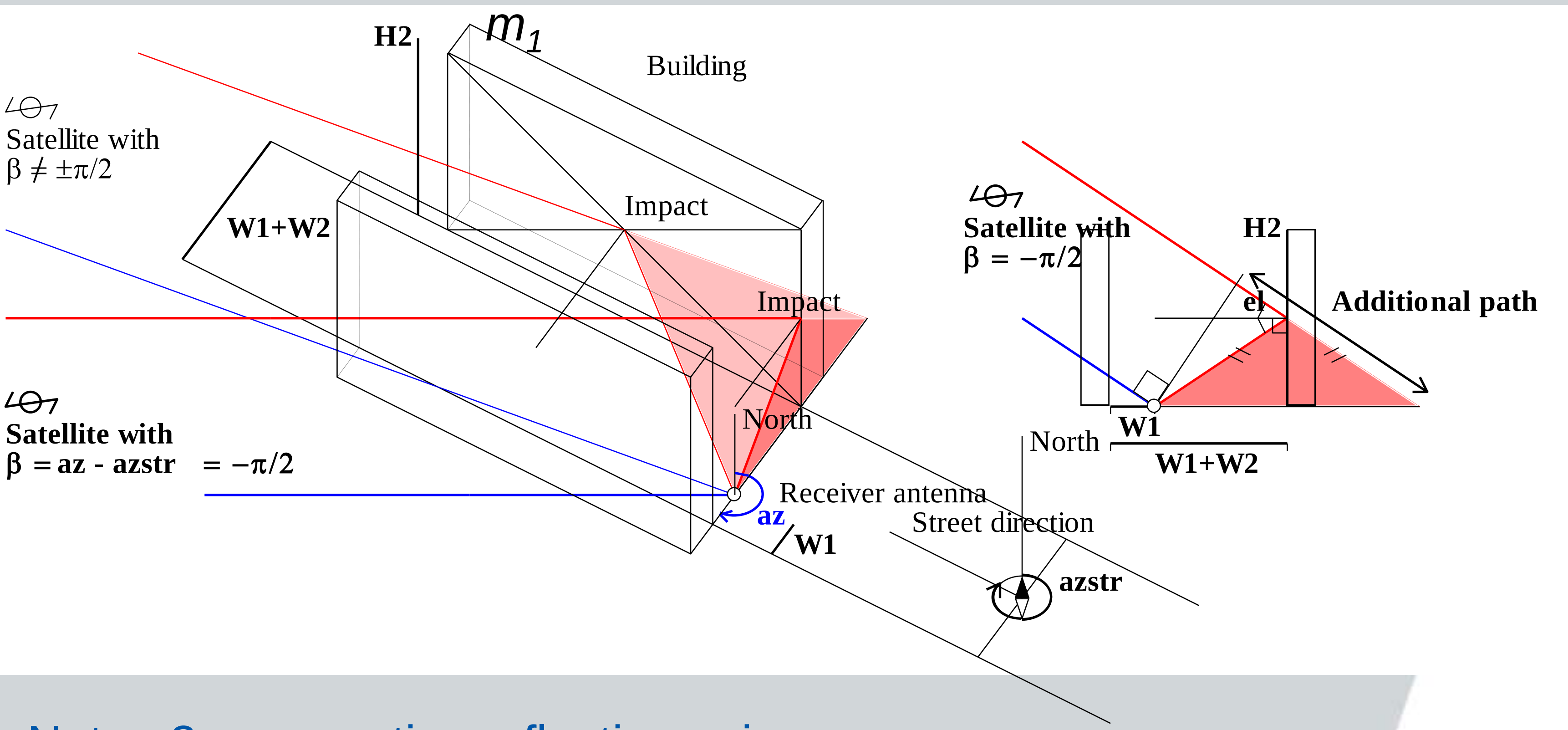
$$el_{01} = arctg\left|\frac{H1}{W1}\sin(\beta)\right|$$

Note : 2 consecutive reflections are also considered, below el_{12}

NLOS correction in Urban Trench

Additional distances performed by multipath signal are geometrically corrected, assuming specular reflexion

$$= 2W2cos(el)sin(\beta)$$

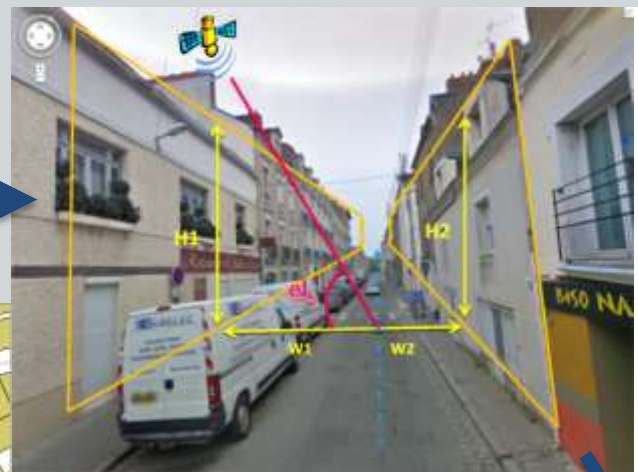


Note : 2 consecutive reflections give m_2

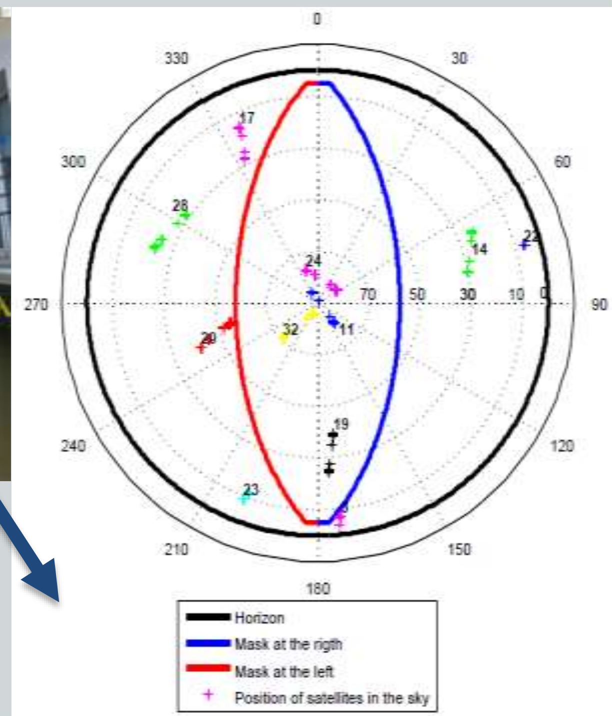
Creating Urban Trench using GIS

A usual GIS (geographical information system) like Quantum can be used to compute automatically, arc segment per arc segment, the (W,H) parameters of the Urban Trench model : in France, the National data base BD Topo ® contains the information required, at 1m accuracy

From **map data** to **Urban Trench** model…



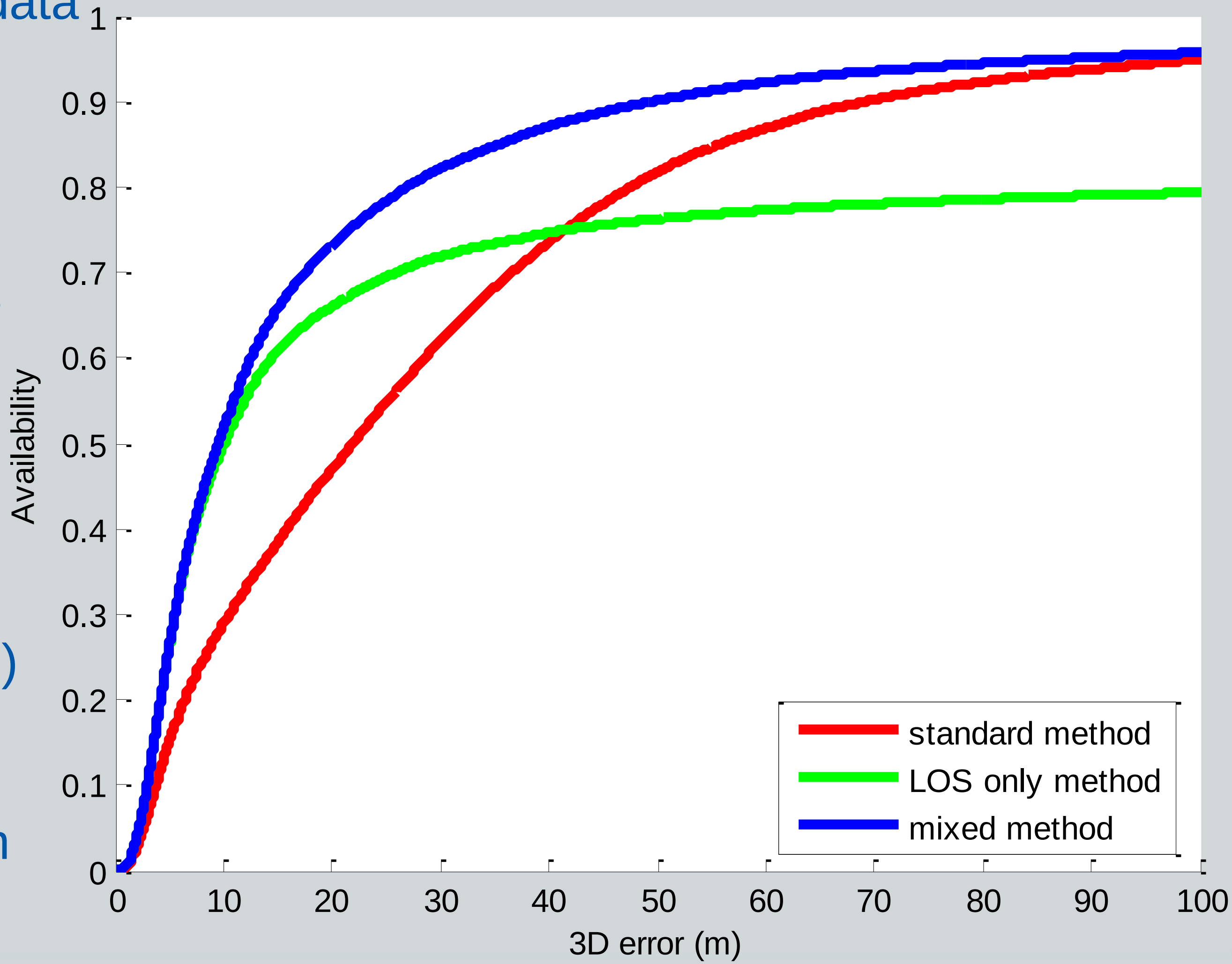
… and **critical elevations** and **add distances**



Experimental results (LS estim.)

10 h data
ublox 6T
5 Hz
Paris
Nantes
Toulouse

median
error (3D)
21.7 m
9.4 m
56% gain

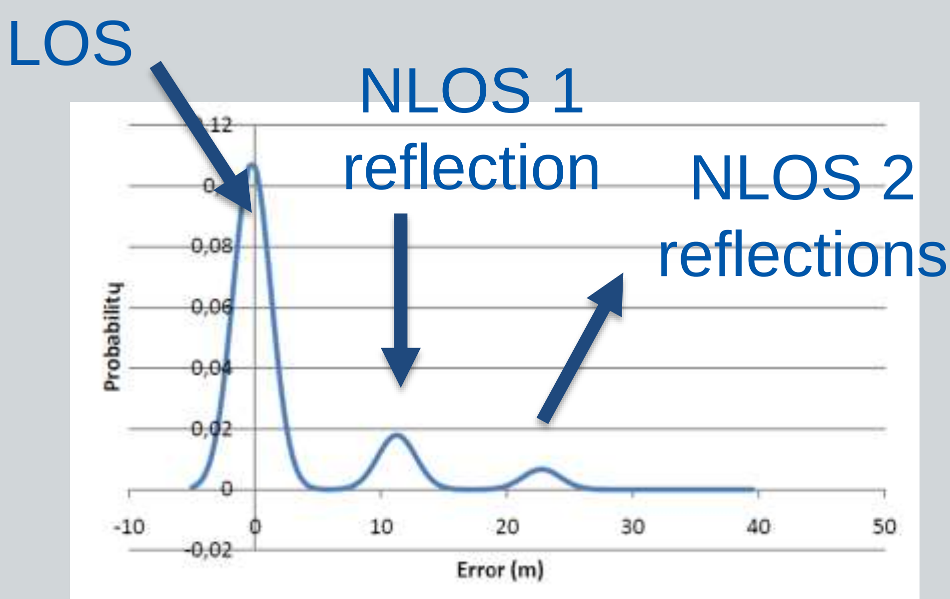


Probabilistic approach

Whereas the initial approach was totally deterministic, we will now introduce probabilistic modeling.

This idea is to take advantage of the 10 h dataset collected in Paris, Nantes and Toulouse, and seek to identify, in similar geometrical configuration, a multimodal Gaussian distribution law, applicable to the range error.

Example of a **multimodal** Gaussian distribution

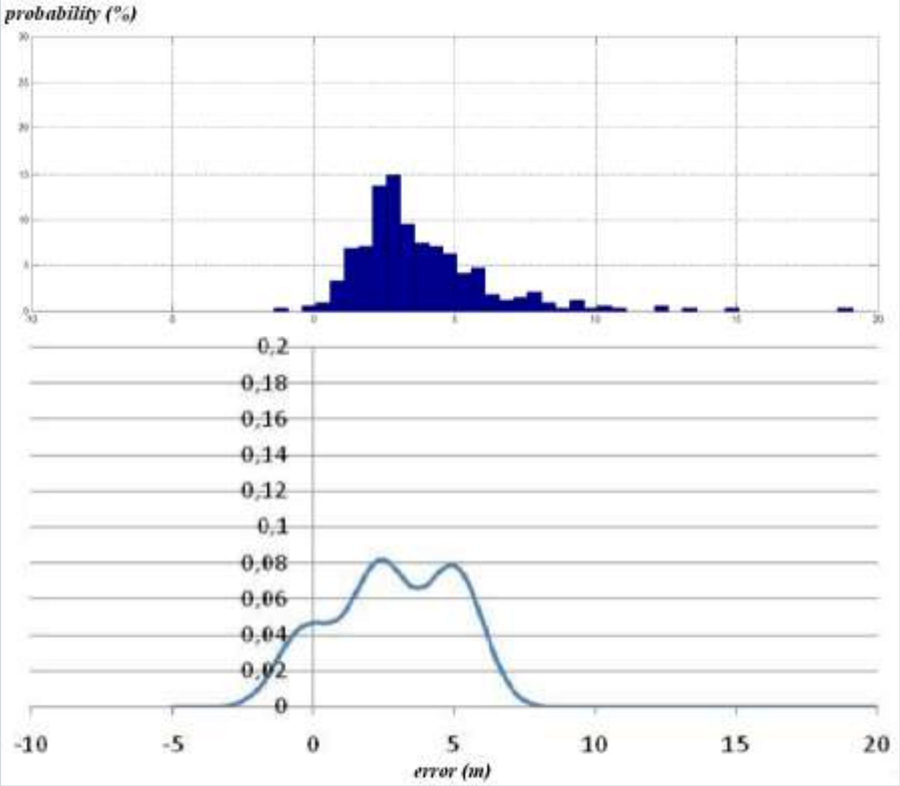


Probabilistic approach

Example on a subset of data, in Paris, for a given geometrical configuration (narrow street, high buildings).

Up :
Range errors
for satellites relatively low in elevation (strip 40 to 50°)

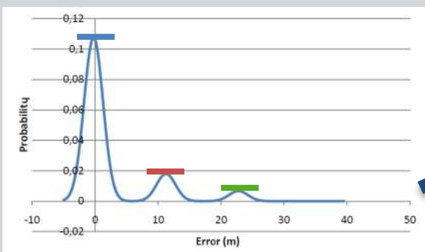
Bottom :
corresponding **multi-modal** modeling



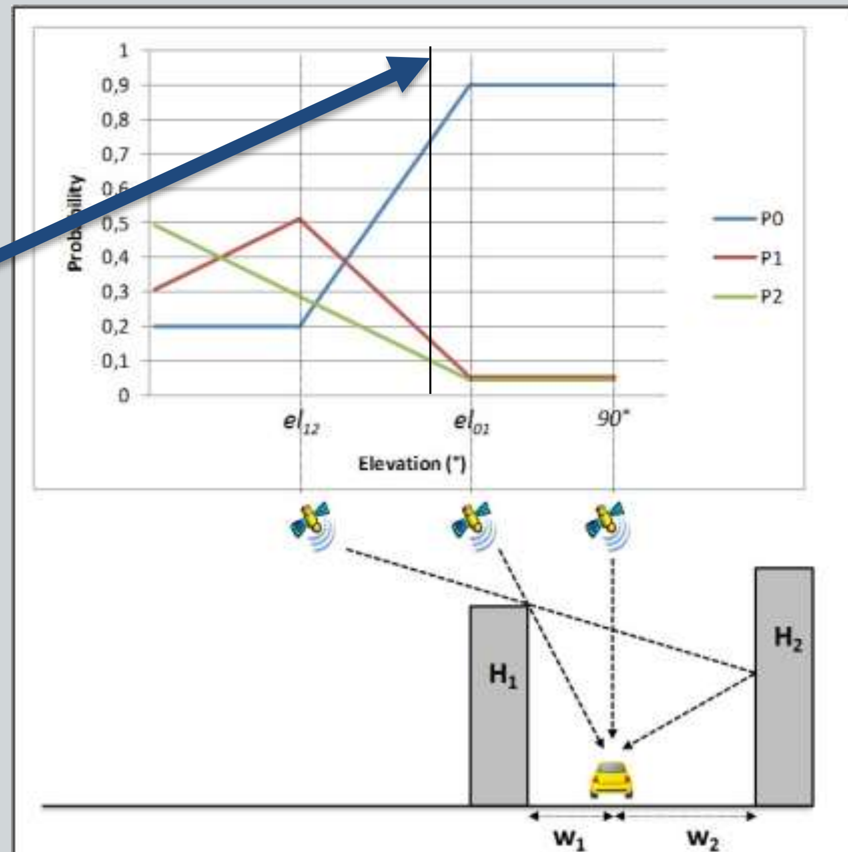
Probabilistic approach

After aggregation of many subsets of data, mainly in Paris, the following model is proposed, characterized by the 2 critical elevations el_{01} and el_{12}.

P0
P1
P2



P0+P1+P2 = 1



el_{01} and el_{12} : depend on H1, H2, W1, W2 and az-azstr

Probabilistic position estimation

The multimodal Gaussian law parameterized by (P0, P1, P2), and the corresponding additional distances, (0, m_1, m_2) are approximated by a discrete probability distribution.

Then a **combinatory** approach, instead of e.g. a particle filter, can be used.

With n satellites, this makes **3^n least squares estimations to compute and merge** proportionally to P0*P1*P2.

The **covariance of the 3D cloud of positions** gives the **3D Urban Trench Protection Level** (3D UTPL).

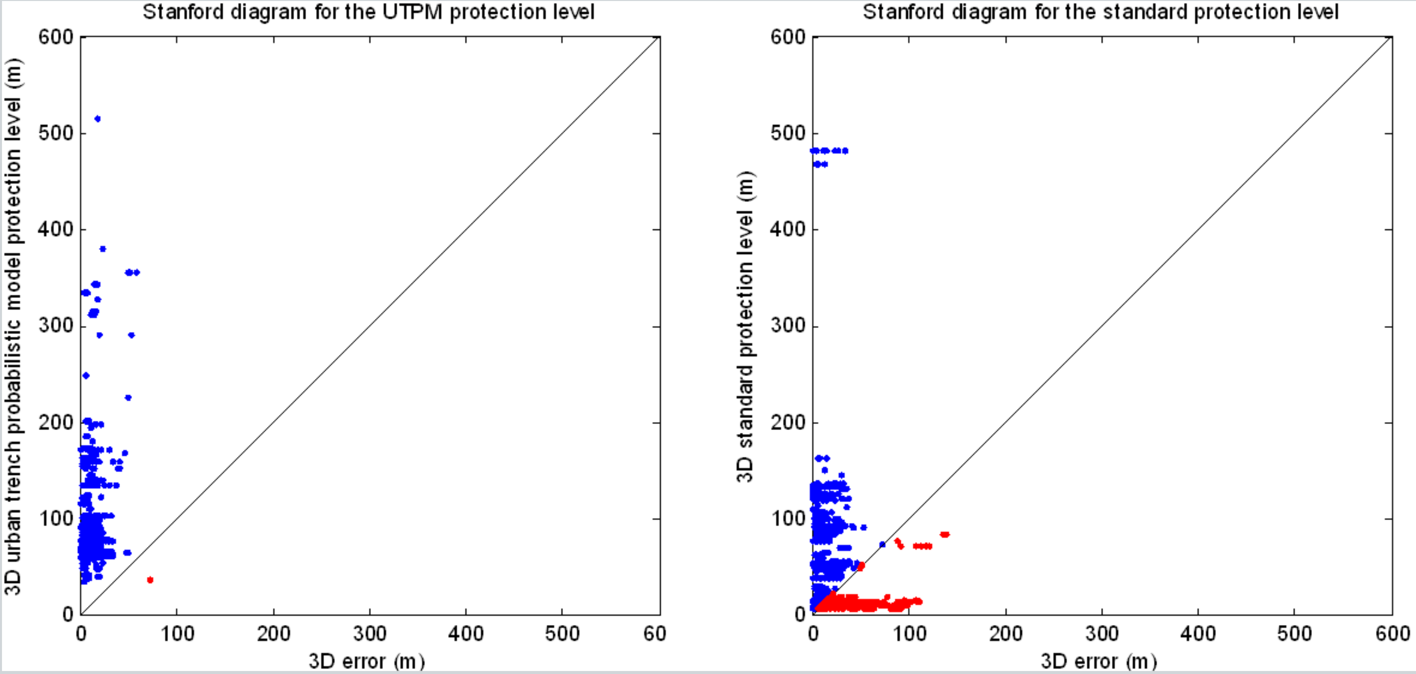
First results

- First results have been obtained with the same previous 10 h data set in Paris-Nantes-Toulouse:
  - using the Urban Trench Probabilistic Model parameters made as described previously
  - comparing the probabilistic solution to the ground truth
  - quantifying the risk that the positioning error exceeds the 3D Urban Trench Protection Level

- The improvement of the positioning error is the same as it used to be with the deterministic approach, with better integrity. Over 161724 epochs when applicable, it gave:
  - 994 Misleading Information (0.6% vs 50% in stdLS)
  - 126 m 3D UTPL median (versus 20 m in stdLS)

First results: example in Nantes

- Integrity is improved, compared to the standard Least Squares using all satellites and no multipath correction



  - 1 Misleading Information (versus 883 in stdLS)
  - 88 m 3D UTPL median (versus 37 m in stdLS)

Conclusions

- Main outcome
  – a model that is compatible with automotive embedded system requirements in terms of storage and process
  – an improvement of the positioning accuracy
  – as well as an adapted integrity mechanism for the urban environment, with a probabilistic approach of local reflection on buildings

- First results have been obtained, but…
  – need additional test campaigns or simulations to compute a relevant risk of integrity associated to the Urban Trench Protection Level