Lane-Level Positioning Using EGNOS and Enhanced Digital Maps in CVIS Project

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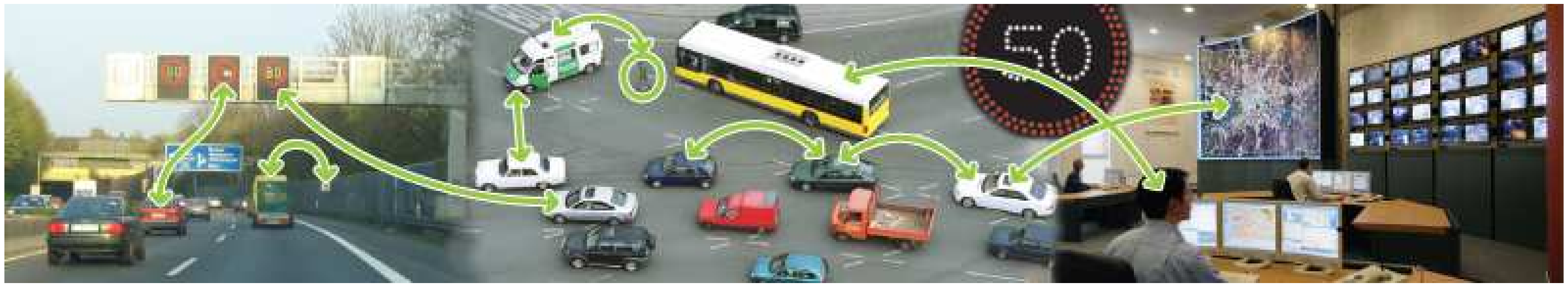
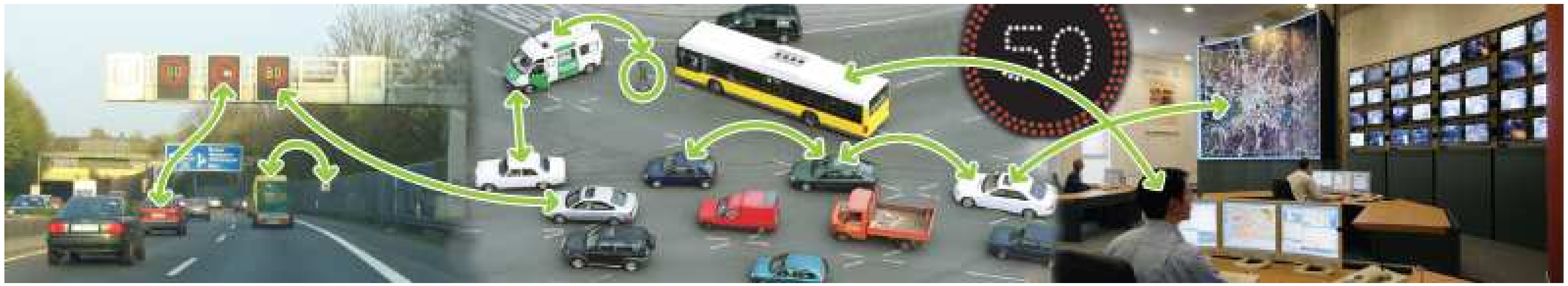


Outline

1. **CVIS project: brief overview**
   - One of the 3 IPs leading the European research on cooperative systems
2. **The importance of positioning in cooperative systems**
   - Position is needed everywhere
   - Positioning is a very challenging task
   - GNSS is absolutely central, but not enough
3. **Which positioning ?**
   - Absolute position is never used at the end of the chain, but map-matched position
   - A position without integrity indicator is very risky and even dangerous
4. **Emap-matching: lane-level positioning with enhanced maps**
   - A single process for positioning and accurate map-matching
   - A new way of modelling roads
   - A particle filter using map constraints
   - Providing integrity indicators
5. **Conclusion**

CVIS project: brief overview

One of the 3 IPs leading the European research on cooperative systems



CVIS: project objective

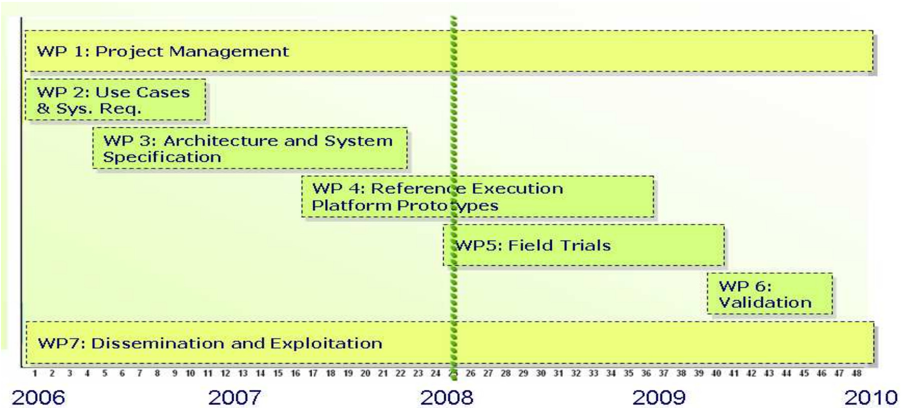
Increase efficiency and safety through V2V and V2I cooperation, enabled by:

- an open architecture and an universal platform prototype
- a wireless network amongst vehicles & infrastructure
- a framework for application management
- enhanced positioning and mapping solutions
- cooperative data management and sharing
- innovative cooperative applications

CVIS: project facts and figures

Coordinator:	ERTICO
Budget/EC funding:	M€41/22
Partners:	61 partners

VOLVO SIEMENS Vägverket Swedish Road Administration
CENTRO RICERCHE FIAT RENAULT RACC Automóvil Club Fundación BOSCH
ThalesAlenia Space NAVTEQ vodafone Department for Transport

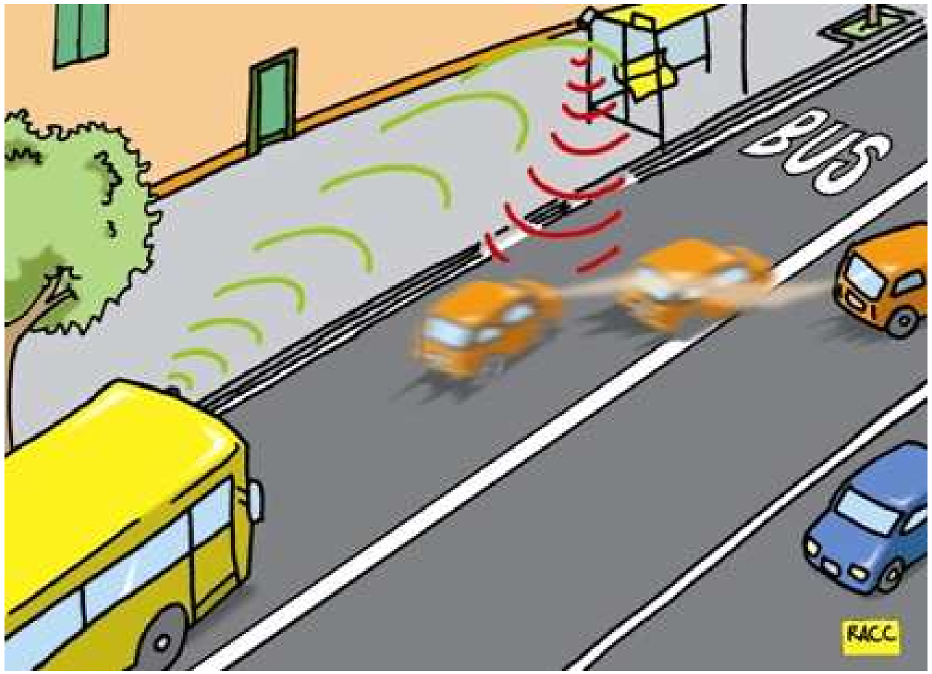


6 test sites

CVIS Applications

Urban area applications

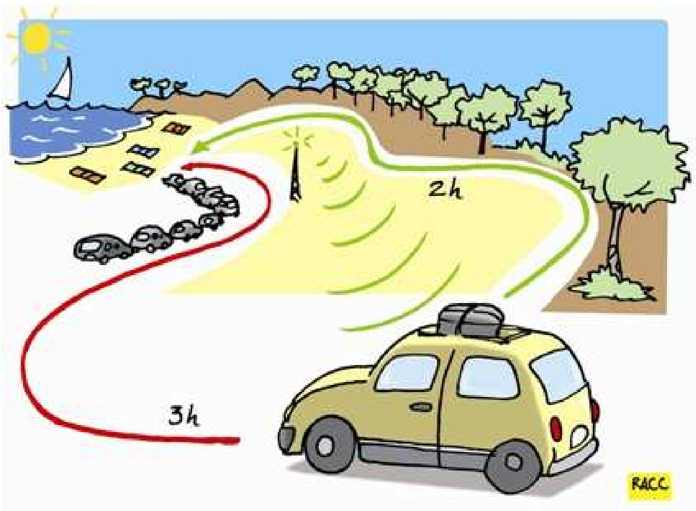
- Cooperative network management
- Cooperative area destination-based control
- Cooperative acceleration/deceleration
- Dynamic bus lanes

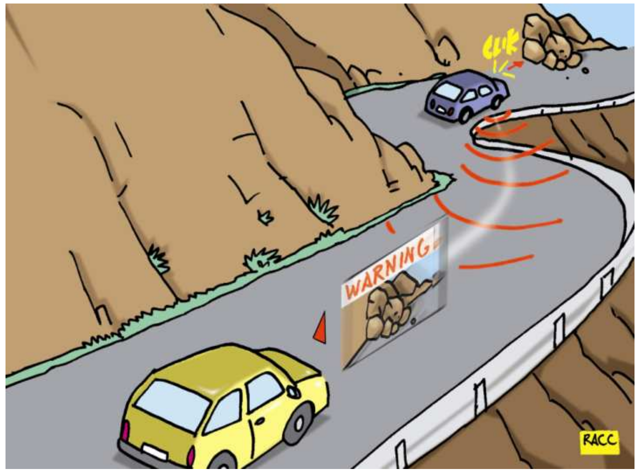


CVIS Applications

Interurban area applications

- Cooperative travellers' assistance
- Enhanced driver awareness

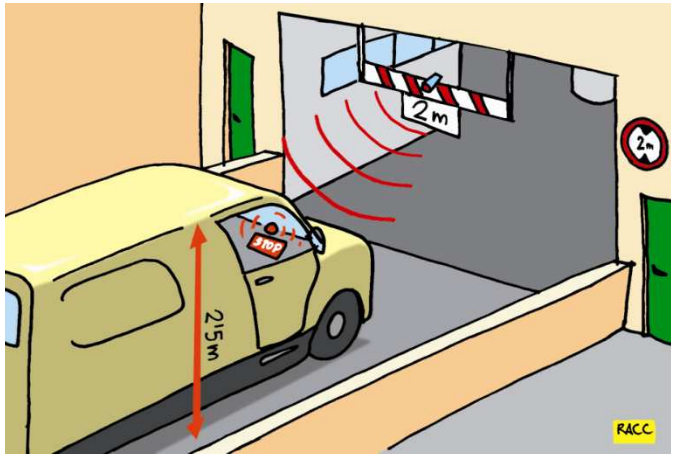




CVIS Applications

Freight & Fleet applications

- Access control
- Dangerous goods
- Delivery space / parking booking

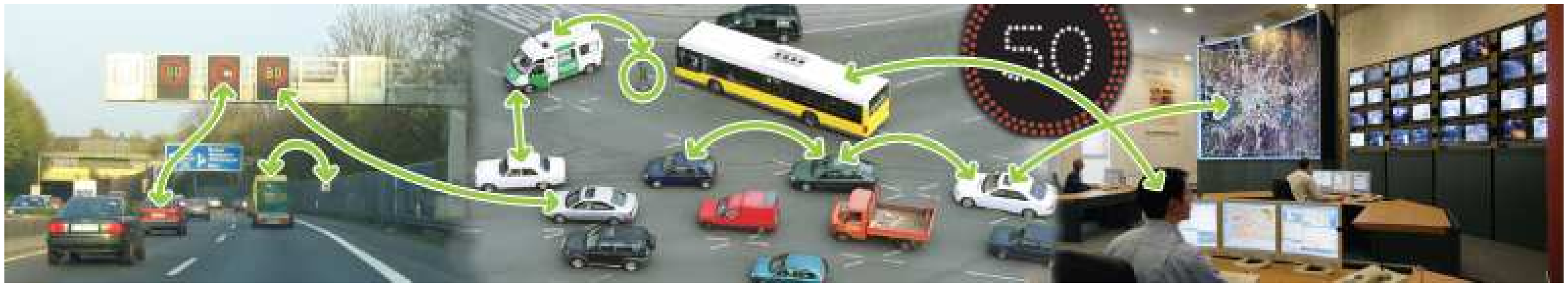


The importance of positioning in cooperative ITS systems

Position is needed everywhere

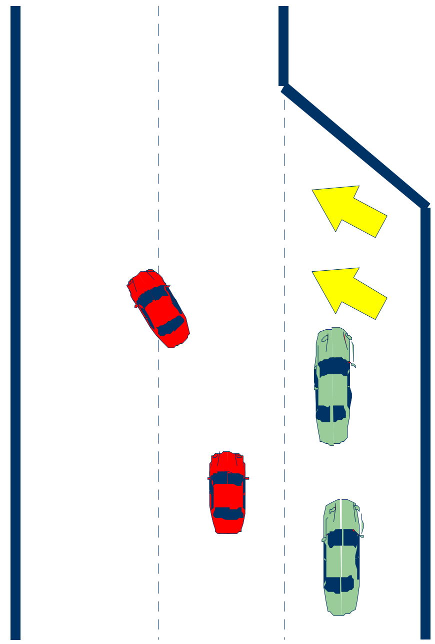
Positioning is a very challenging task

GNSS is absolutely central, but not enough



Position is needed everywhere

- All CVIS, SAFESPOT and COOPERS applications are based upon the knowledge of the vehicle(s) position, most of the time in real time
- The position is useless without the map information, the real interesting information is the estimation on the **vehicle position on the map**



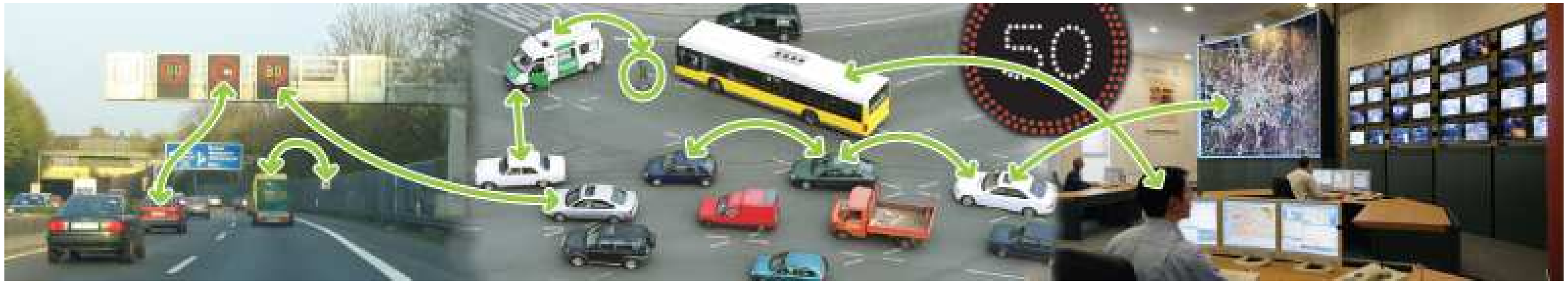
Positioning is a very challenging task, GPS is not enough…

- The apparently easy positioning performed by the standard navigation systems is misleading…
- In reality, the quality of service of standard GPS in constrained environments is generally quite poor, although the global performance is really impressive
- **Quality of service** =
  - Availability
  - Accuracy
  - Integrity

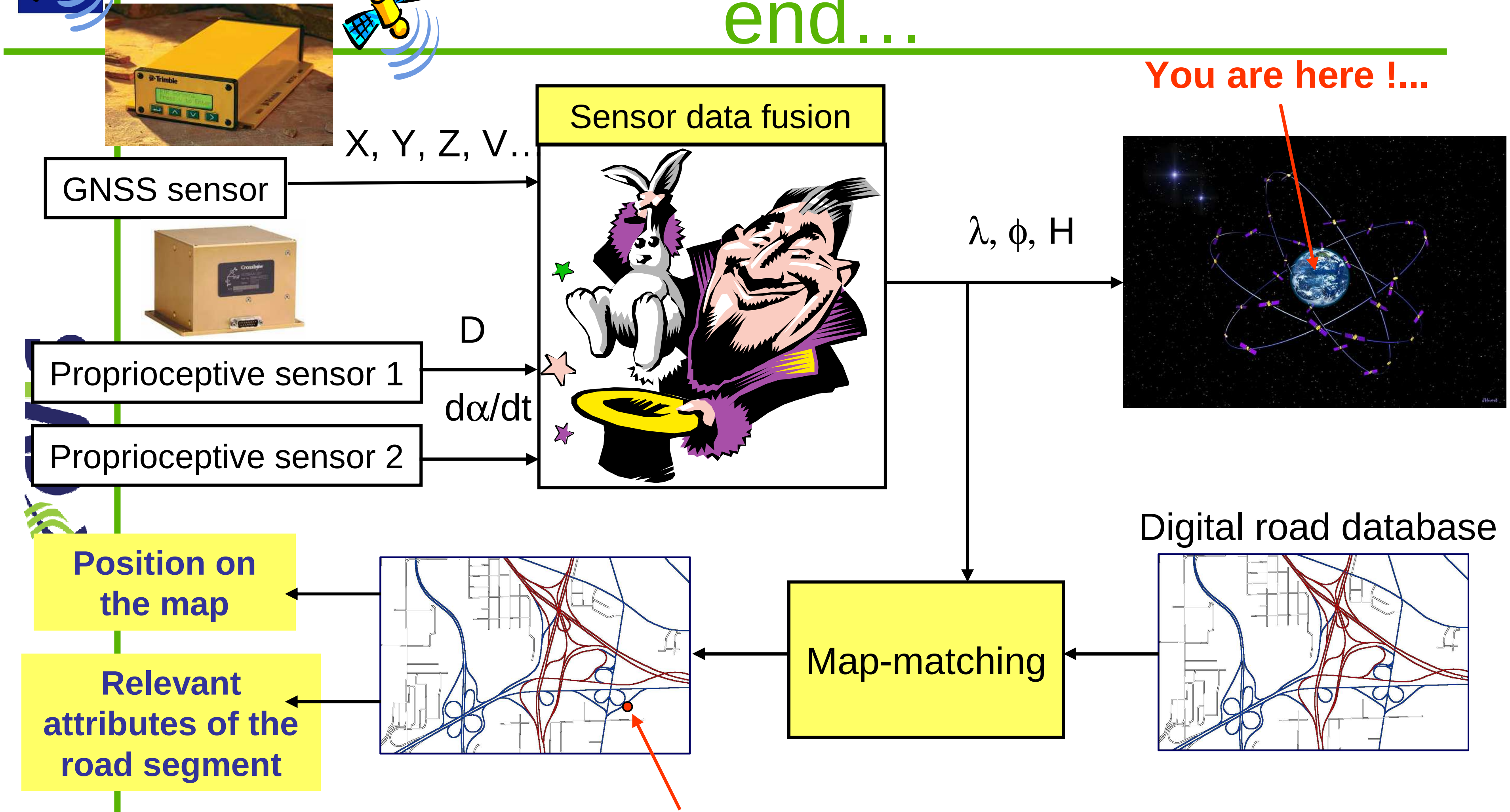
Which positioning ?

Absolute position is never used at the end of the chain, but **map-matched position**

A position without **integrity** indicator is very risky and even dangerous

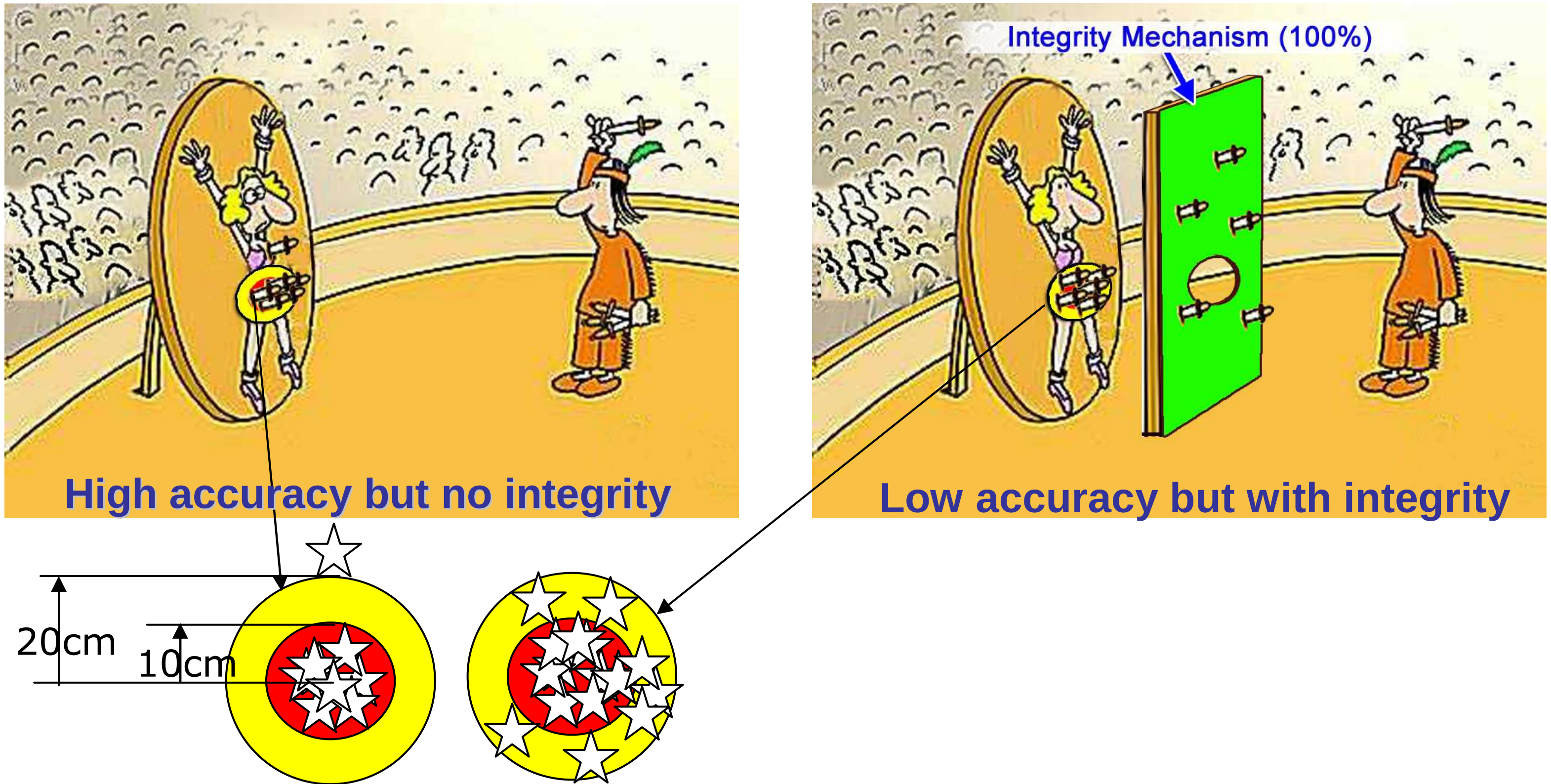


Absolute position is never used at the end…



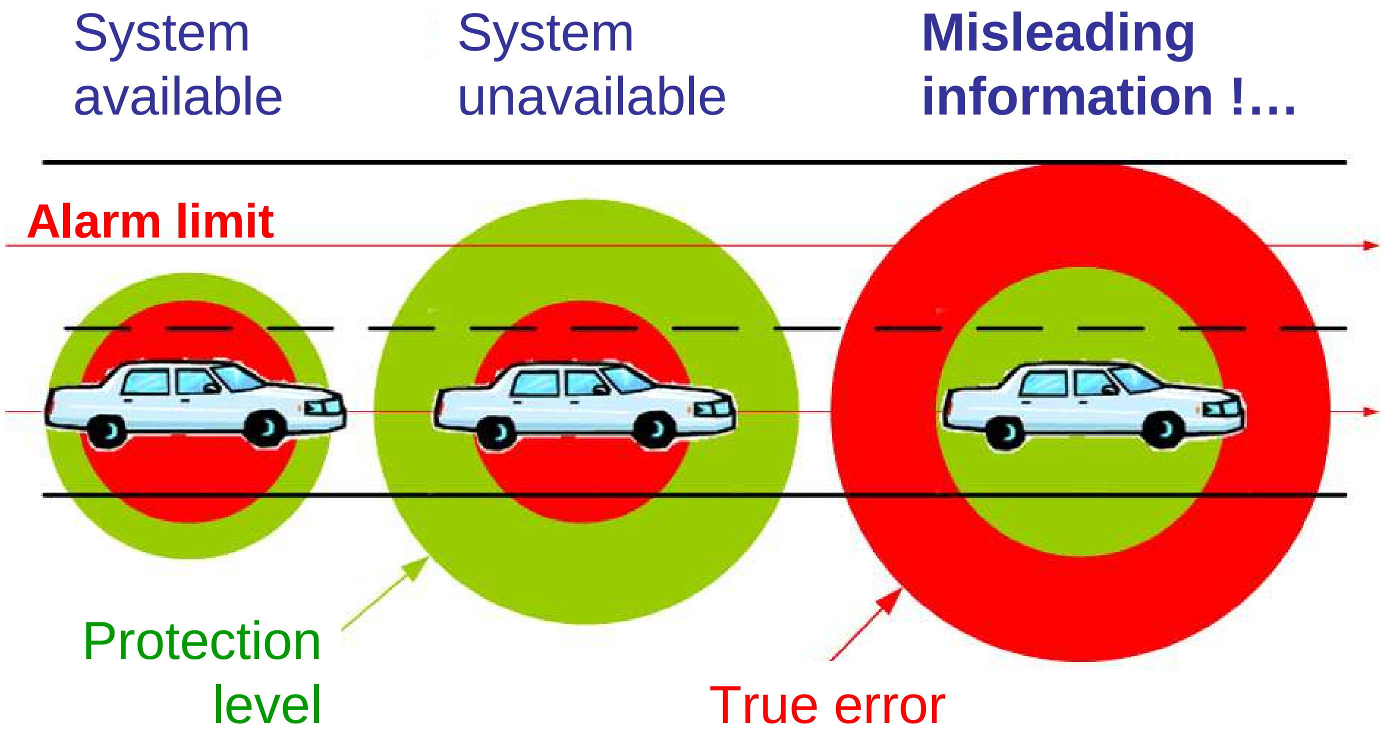
You are here, on this segment, at this abscissa !...

Integrity mechanism



8 cm	18 cm	**Acccuracy** (error RMS)
99 %	100 %	**Integrity** (probability to remain inside the yellow circle)

Interest of integrity for ADAS



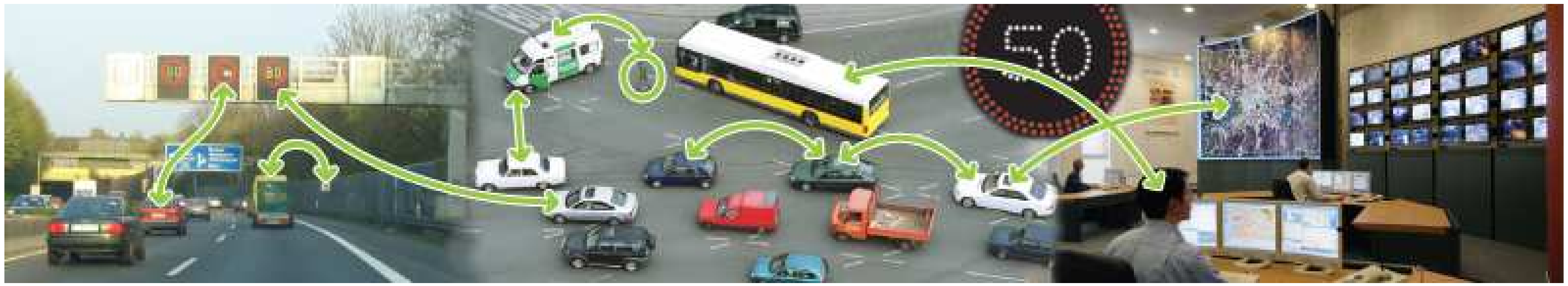
Emap-matching: lane-level positioning with enhanced maps

A single process for positioning and accurate map-matching

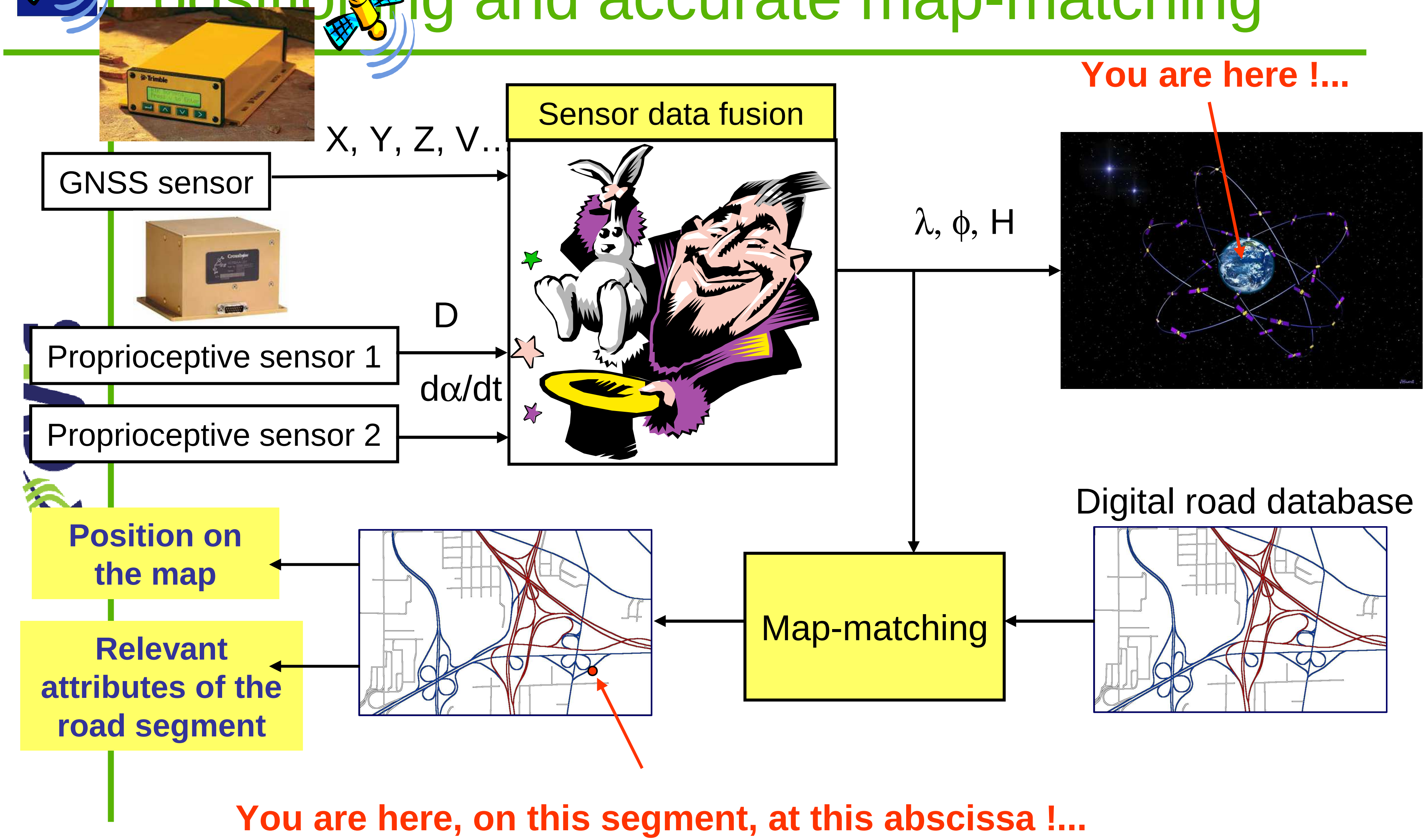
A new way of modelling roads

A particle filter using map constraints

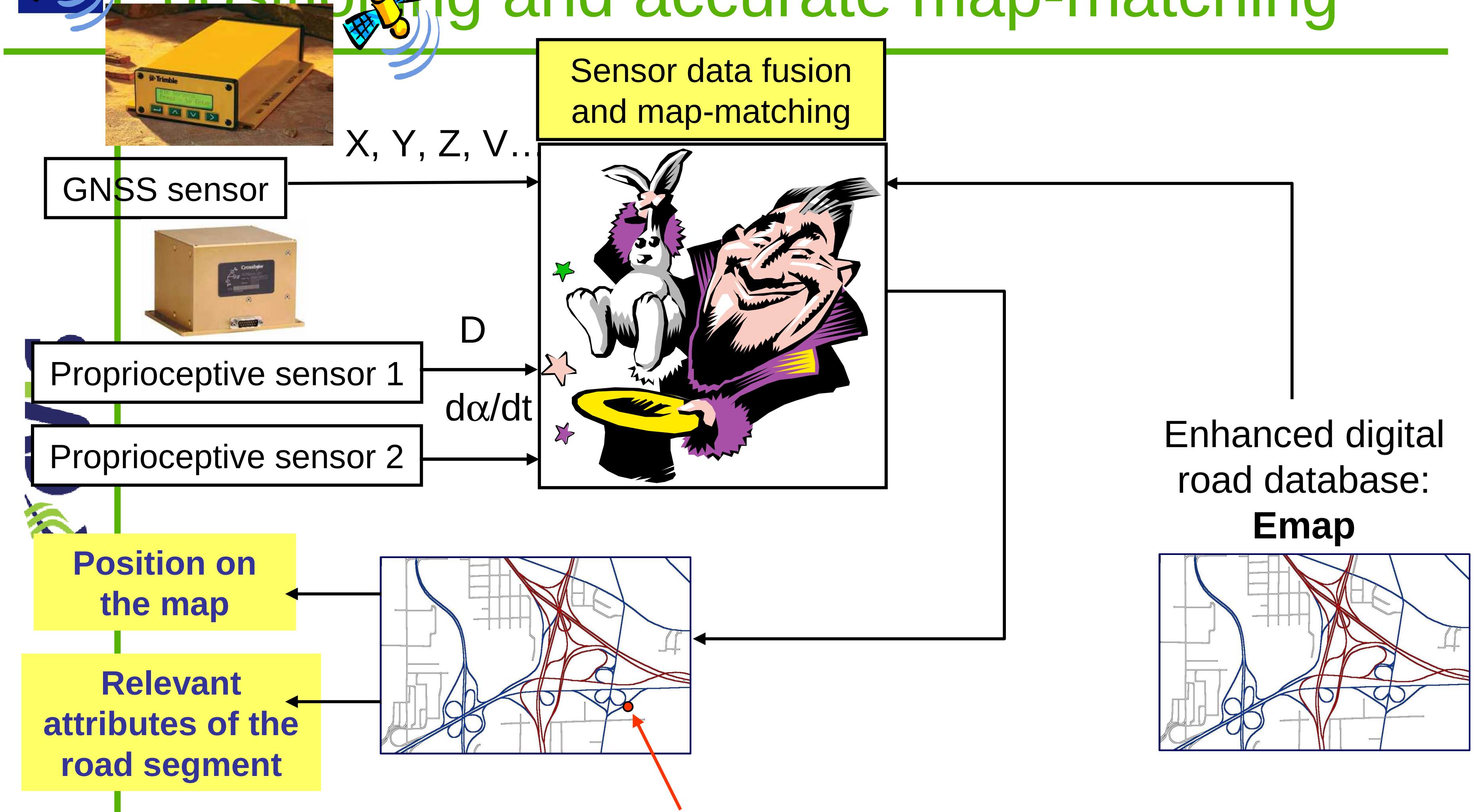
Providing integrity indicators



Emap-matching: a unique process for positioning and accurate map-matching



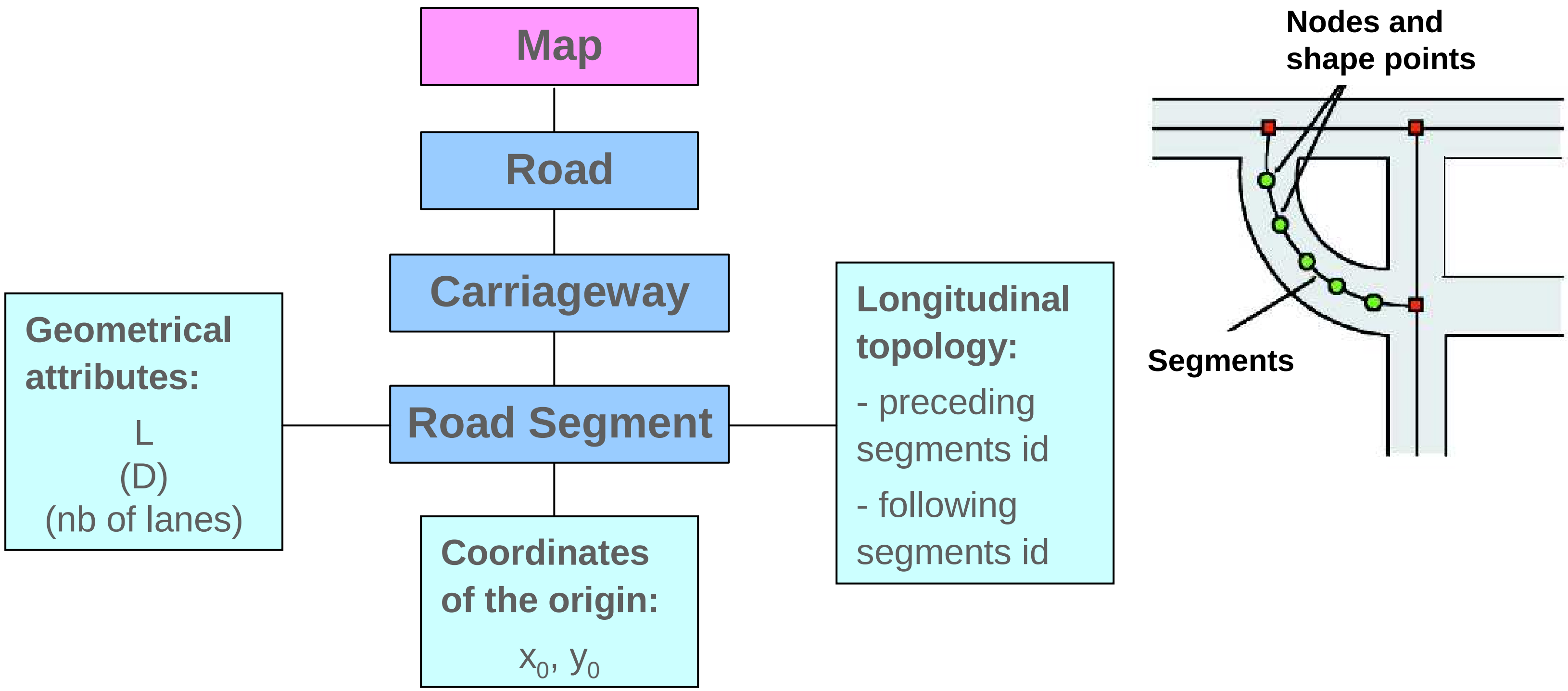
Emap-matching: a unique process for positioning and accurate map-matching



You are here, on this segment, at this abscissa, <u>on this lane</u> !...

Usual GDF-based digital road map

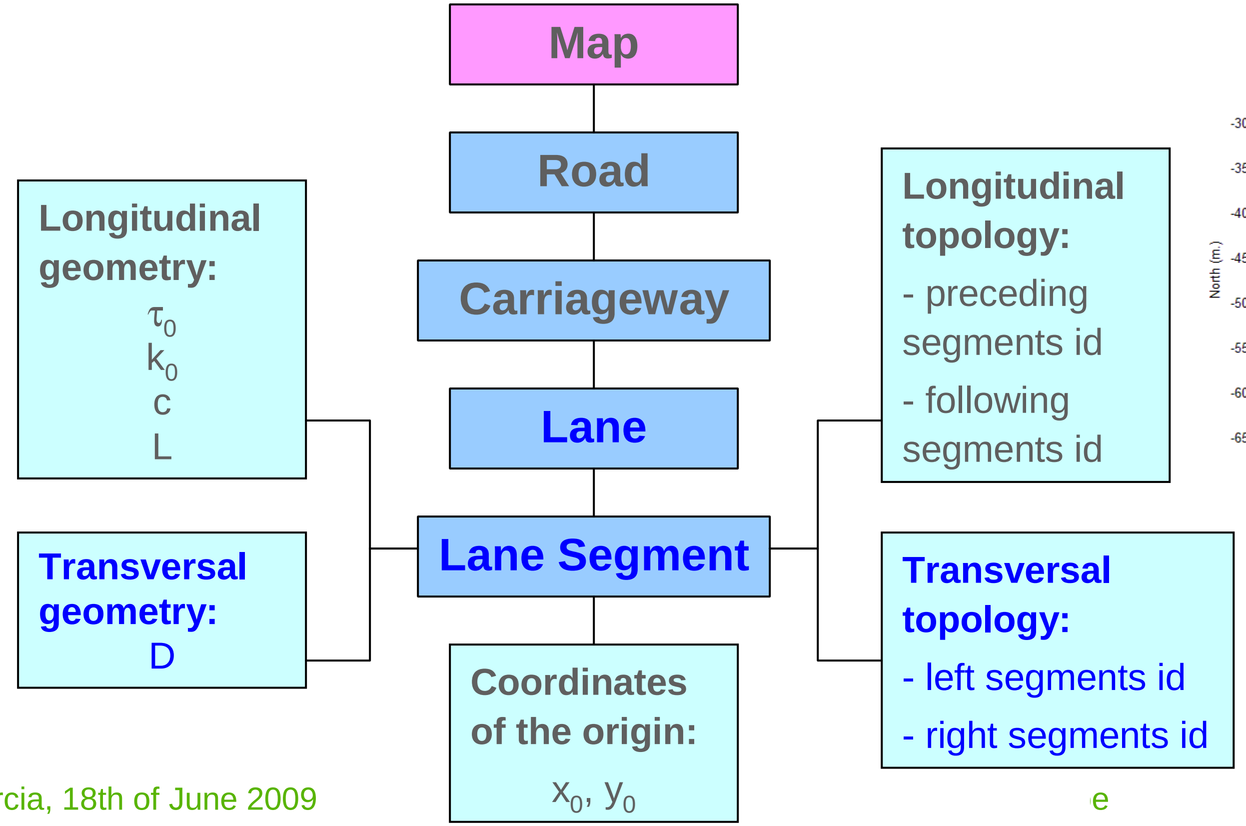
Usual digital road data model (GDF-based):
1 polyline / road (or separated carriageway)

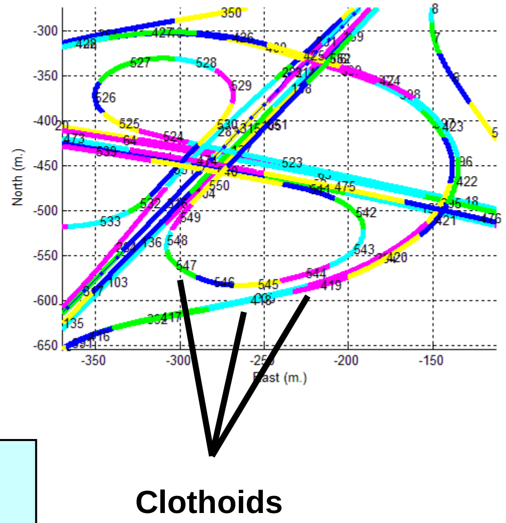


New Emap data model

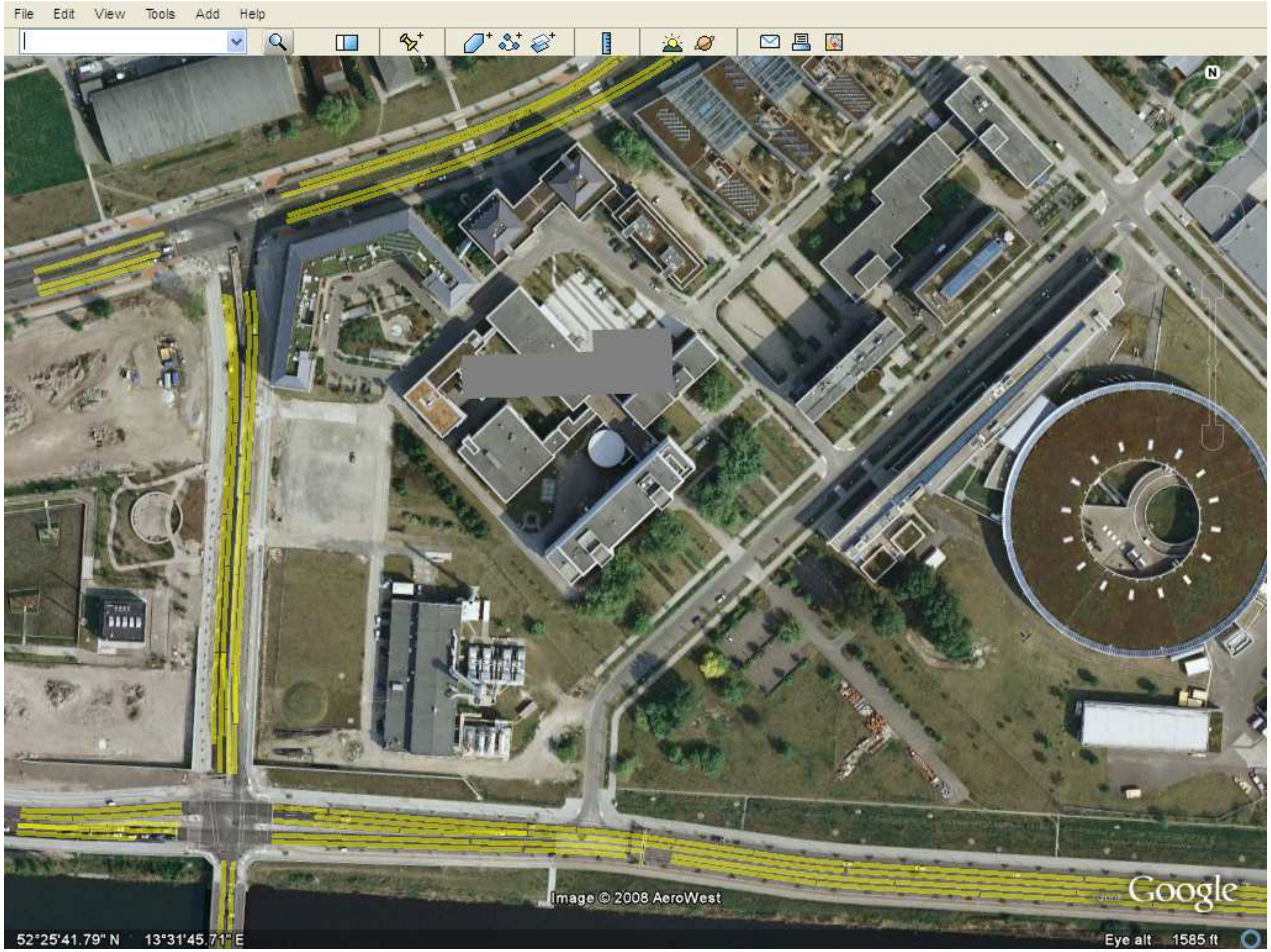
Exact geometry (clothoids, circles, lines):

1 series of geometrical elements per lane

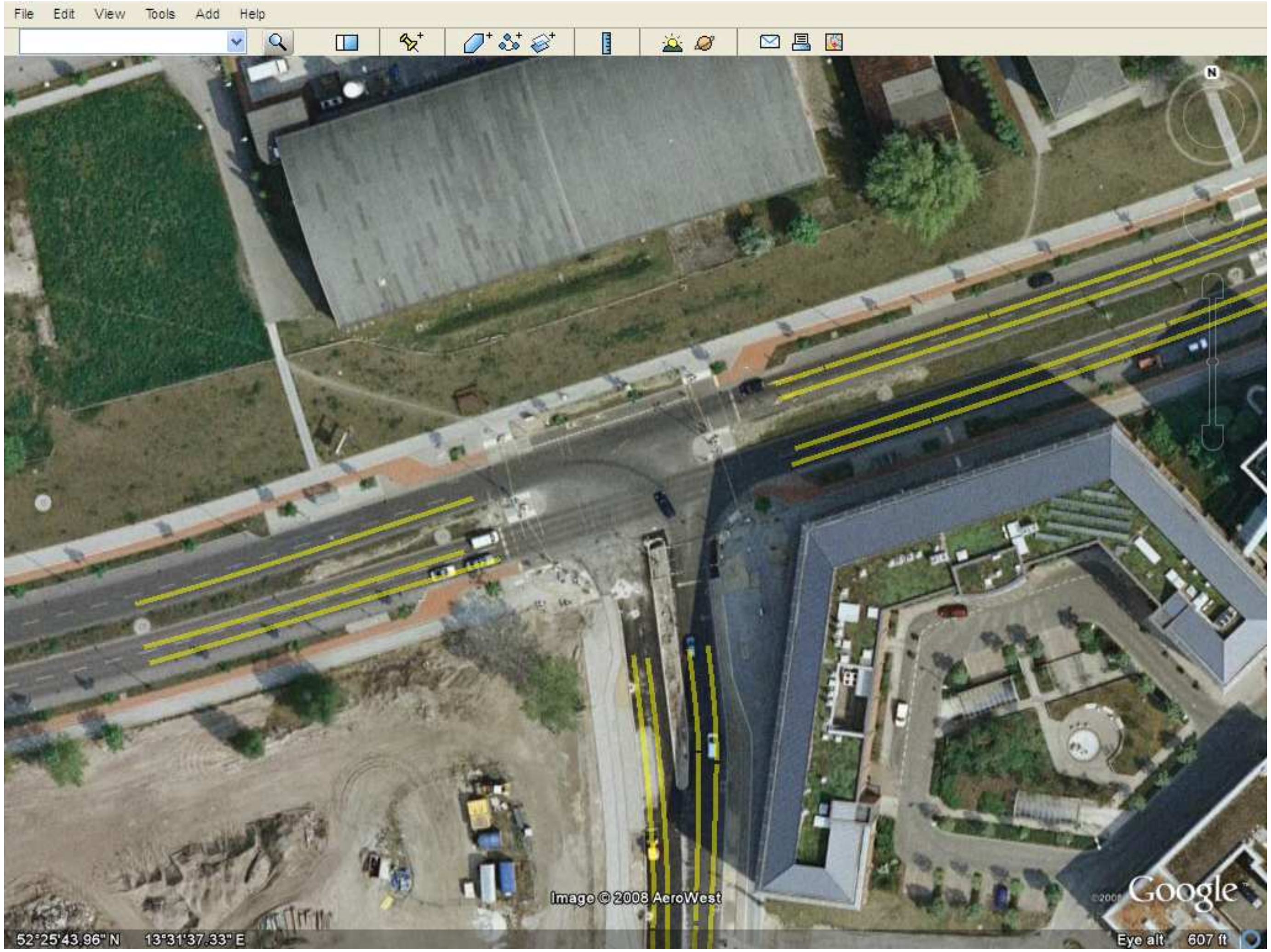




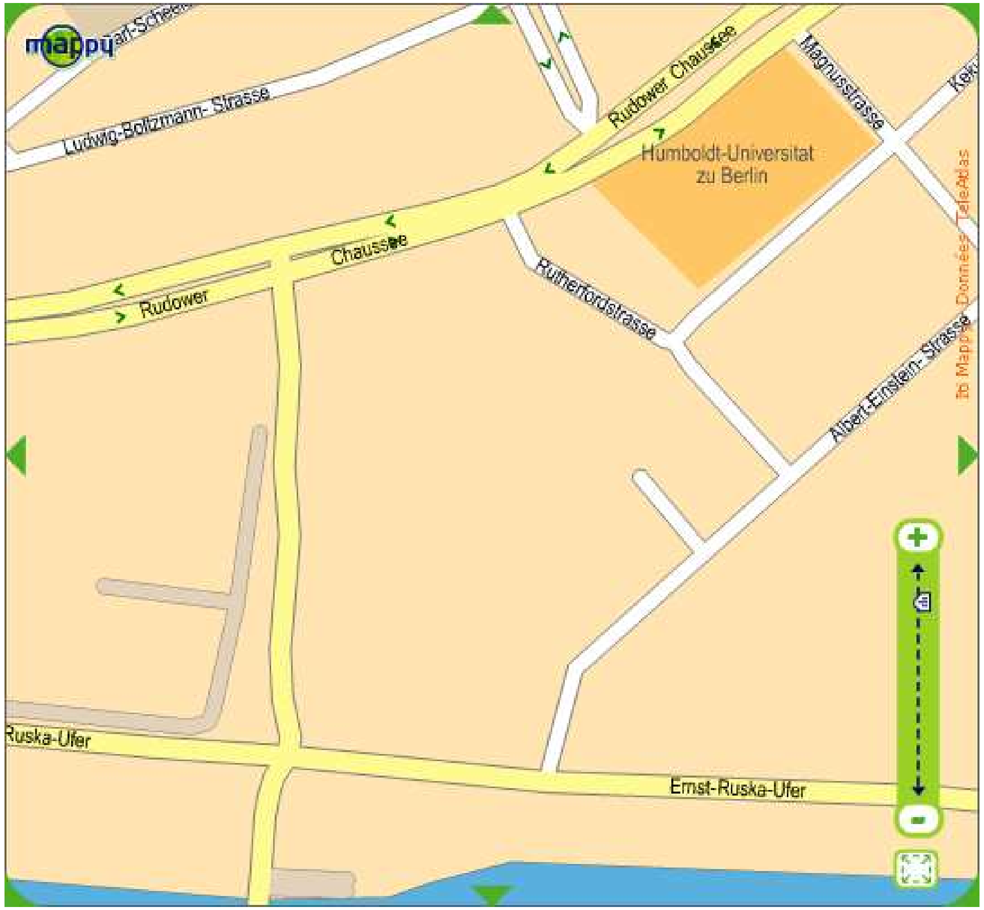
Emap overview - Berlin test site



Emap zoom (Berlin test site)

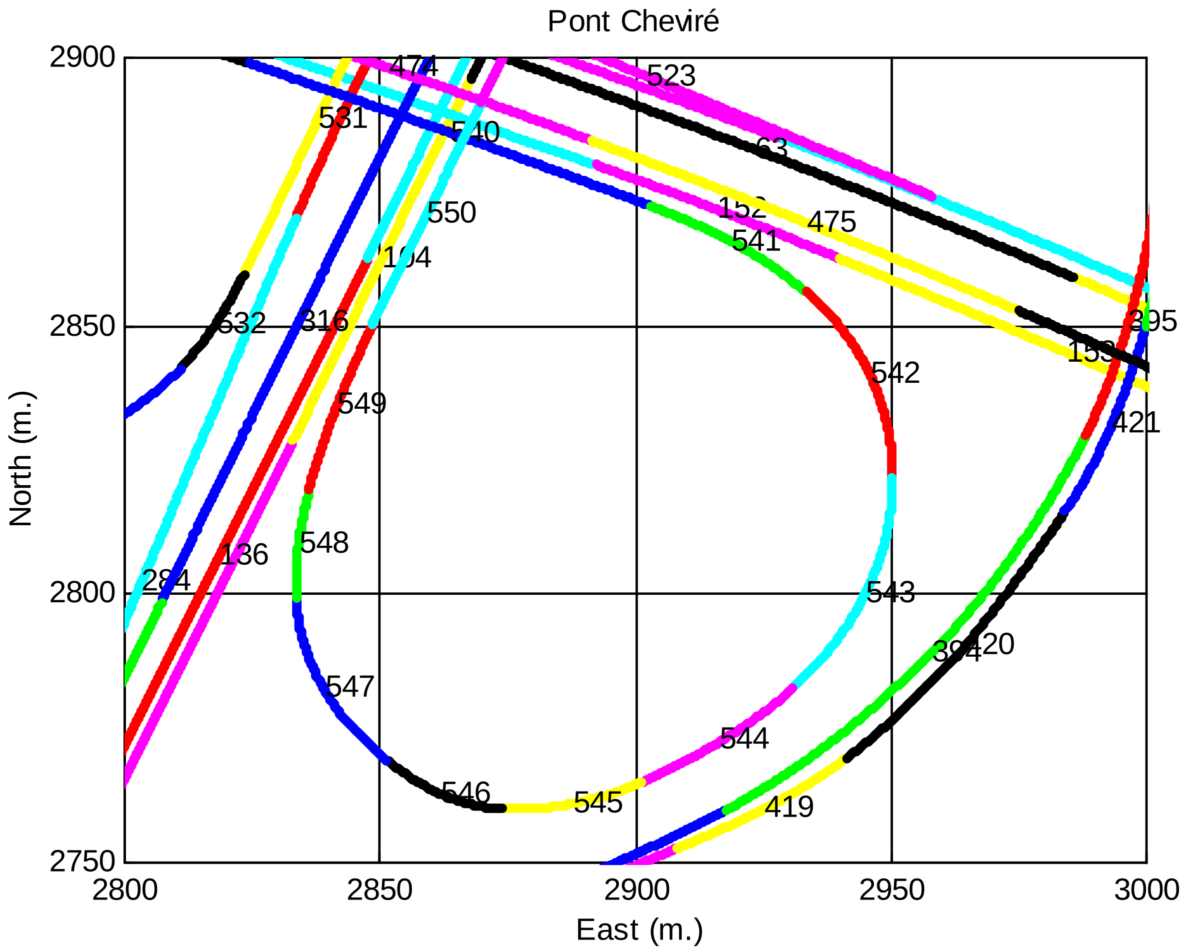


Standard map on the Berlin Emap area



Emap overview - Cheviré test site

Emap zoom (Cheviré test site)



Emap-matching: particle filter using map constraints

Particle generation

↓

State propagation model ← ***DR measurements***

↓

Correction 1: geometrical and topological constraints ← ***Emap***

↓

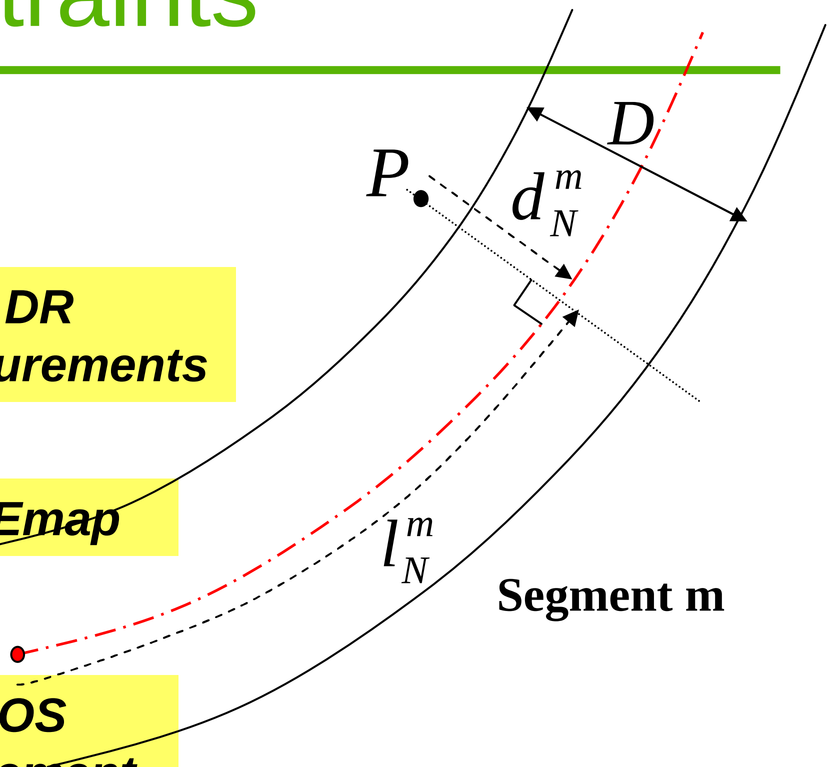
Correction2: weights modification ← ***EGNOS measurement***

↓

Corrected particle set

↓

Corrected estimated state

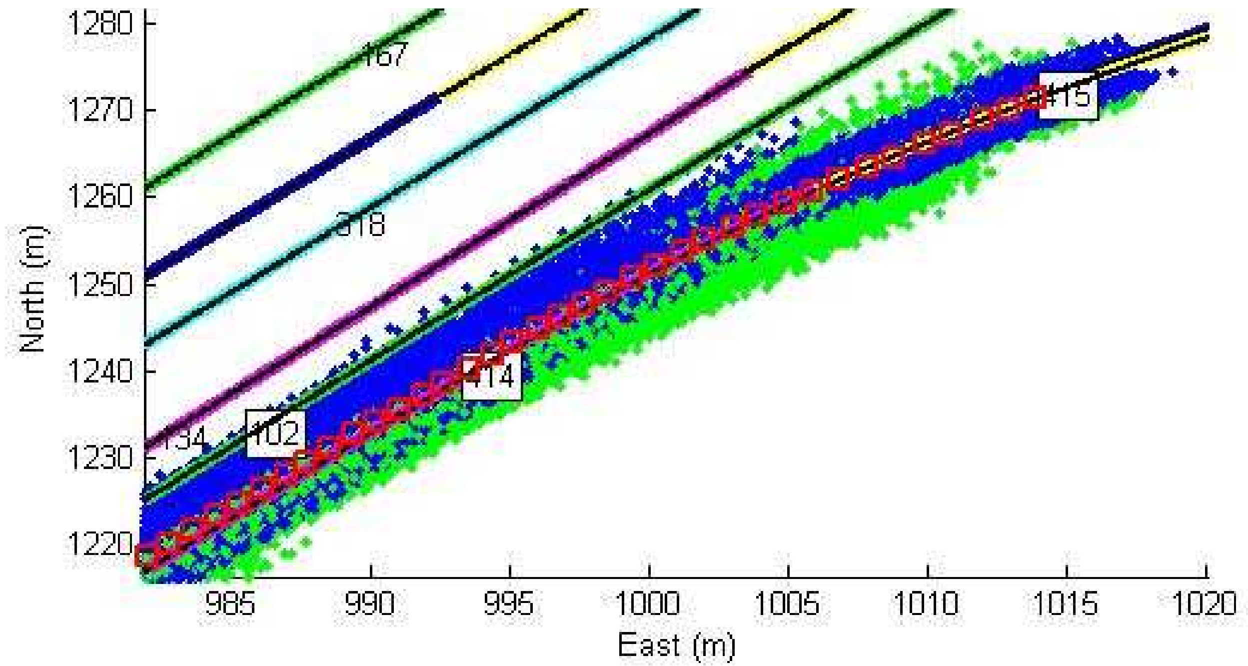


Composite state vector:

$$X = ({}^{C}X, {}^{F}X)^T = \left(\left[x, y, \gamma\right], \left[l_N^m, d_N^m, m\right]\right)^T$$

Emap-matching: particle filter using map constraints

- Green: particles that figure out the possible vehicle predicted positions (using vehicle dynamics)
- Blue: particles that remain after applying Emap constraint (removing the particles out of the road)



Confidence indicators

- Apply integrity concept onto map-matched position, with 2 indicators:
  - Correct lane assignment:

*Probability of lane occupancy (**μLO**)*

  - Confidence on the position of the vehicle on the assigned lane:

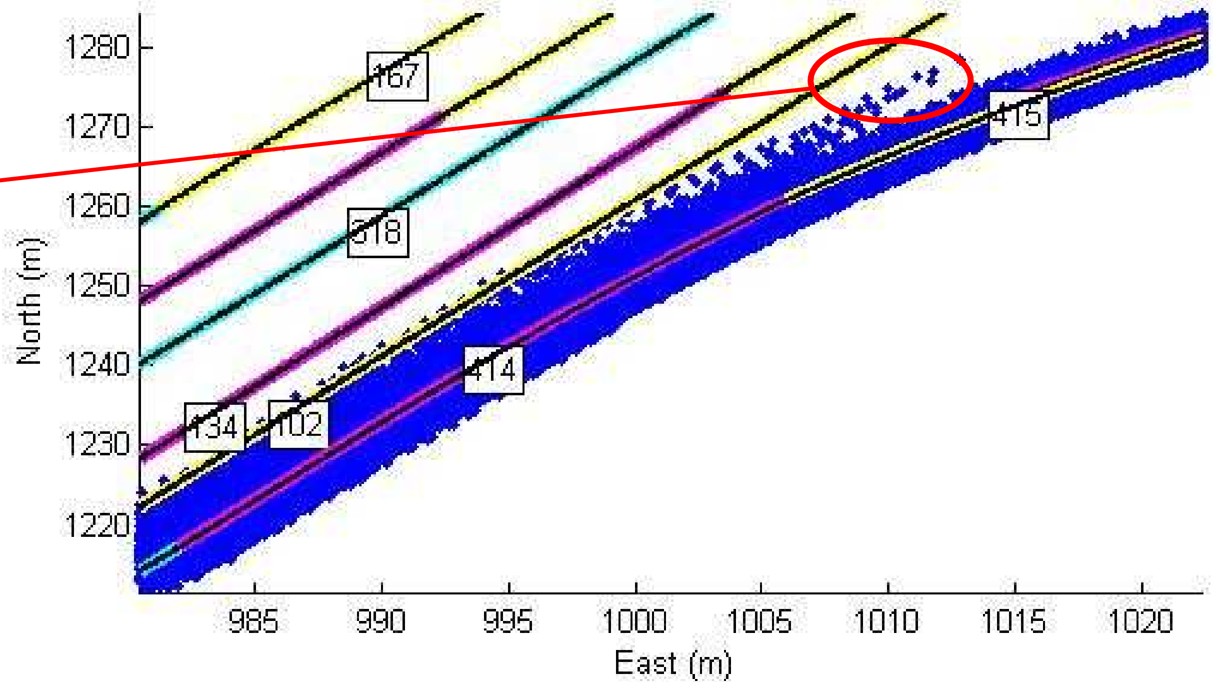
*Lane Positioning Protection Level (**LPPL**)*

µLO

- µLO: probability of Lane Occupancy
  - particles here match id 414, 102, and next 415
  - at any time, µLO(id) = normalized cumulated weights of all particles that match this lane id

These particles prove that matching id 102 remains a possible hypothesis for a while, with µLO decreasing.

In the meanwhile, id 415 µLO is increasing.

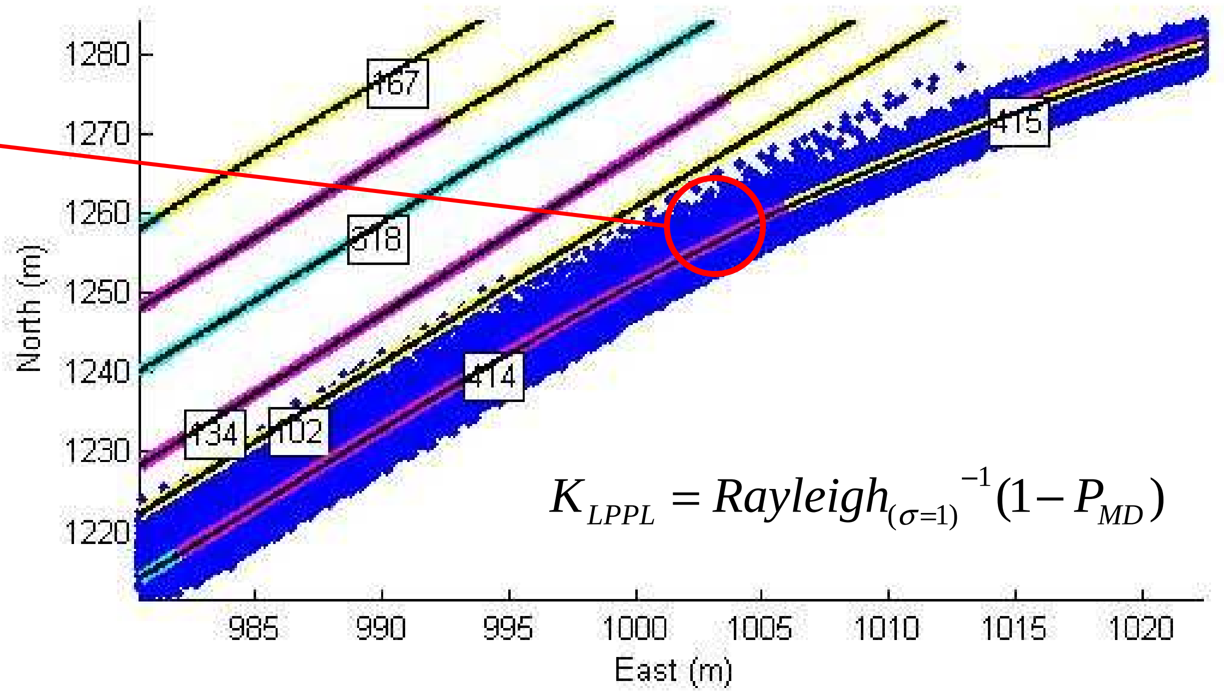


LPPL

- LPPL : Lane Positioning Protection Level
  - similar to aircraft navigation : LPPL = K σ
  - maximum eigenvalue σ of the covariance matrix for the plane position obtained with the weighted mean of the particles, multiplied by a K factor

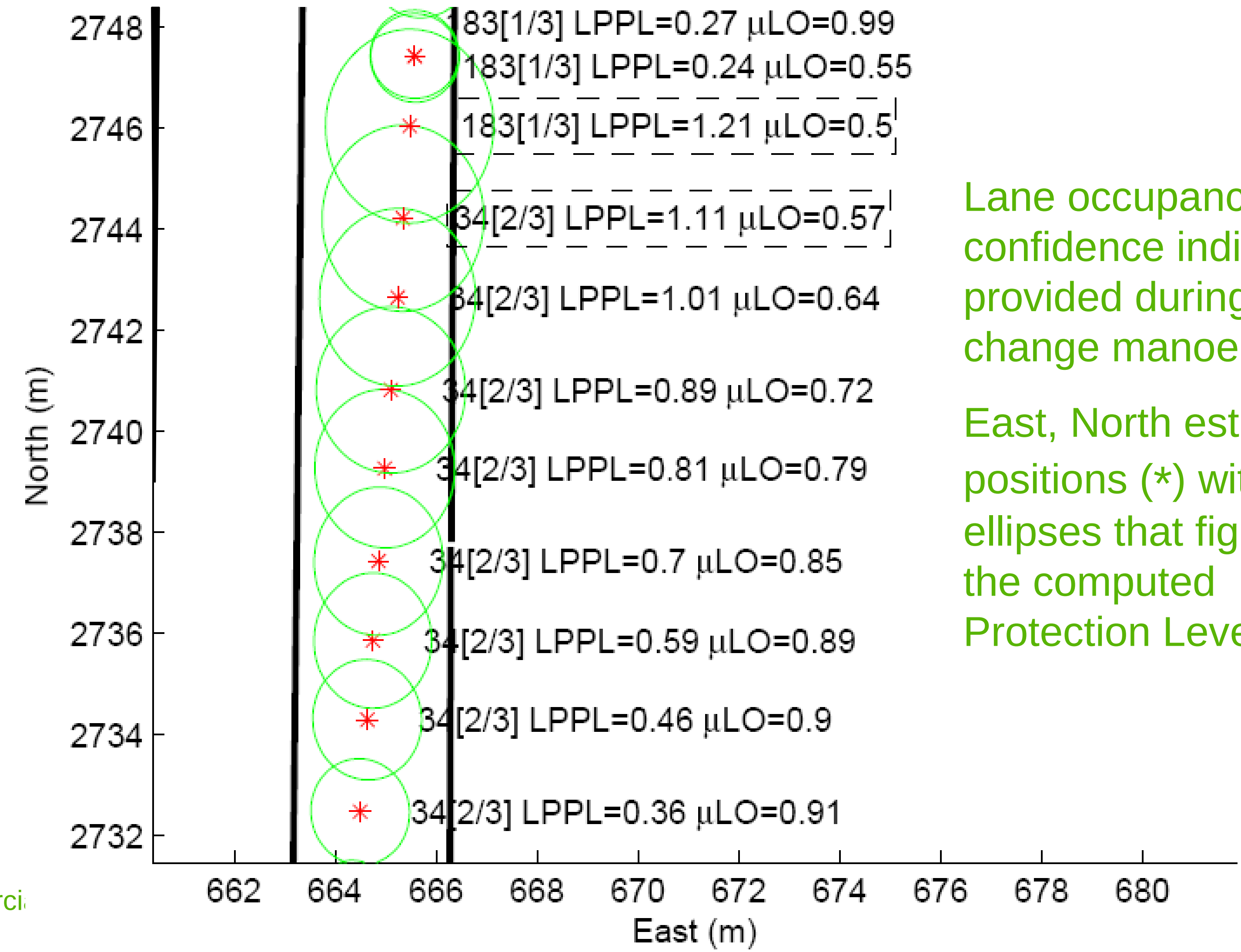
LPPL : a circle that contains most of the particles.

K is fixed with respect to the probability of missed detection (risk of not encompassing a position despite it is acceptable).



$$K_{LPPL} = Rayleigh_{(\sigma=1)}^{-1}(1-P_{MD})$$

Lane occupancy + confidence



Lane occupancy and confidence indicators provided during a lane change manoeuvre.

East, North estimated positions (*) with ellipses that figure out the computed Protection Level

Thanks for your attention…

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