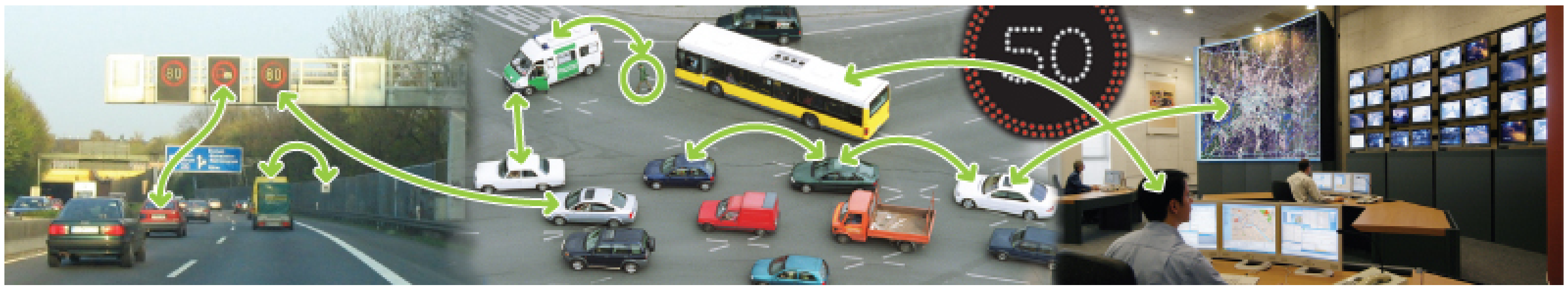
Multi-hypothesis Map-Matching using Particle Filtering

Ph. Bonnifait, J. Laneurit, C. Fouque
and G. Dherbomez
Heudiasyc UMR 6599,
University of Technology of Compiegne, France

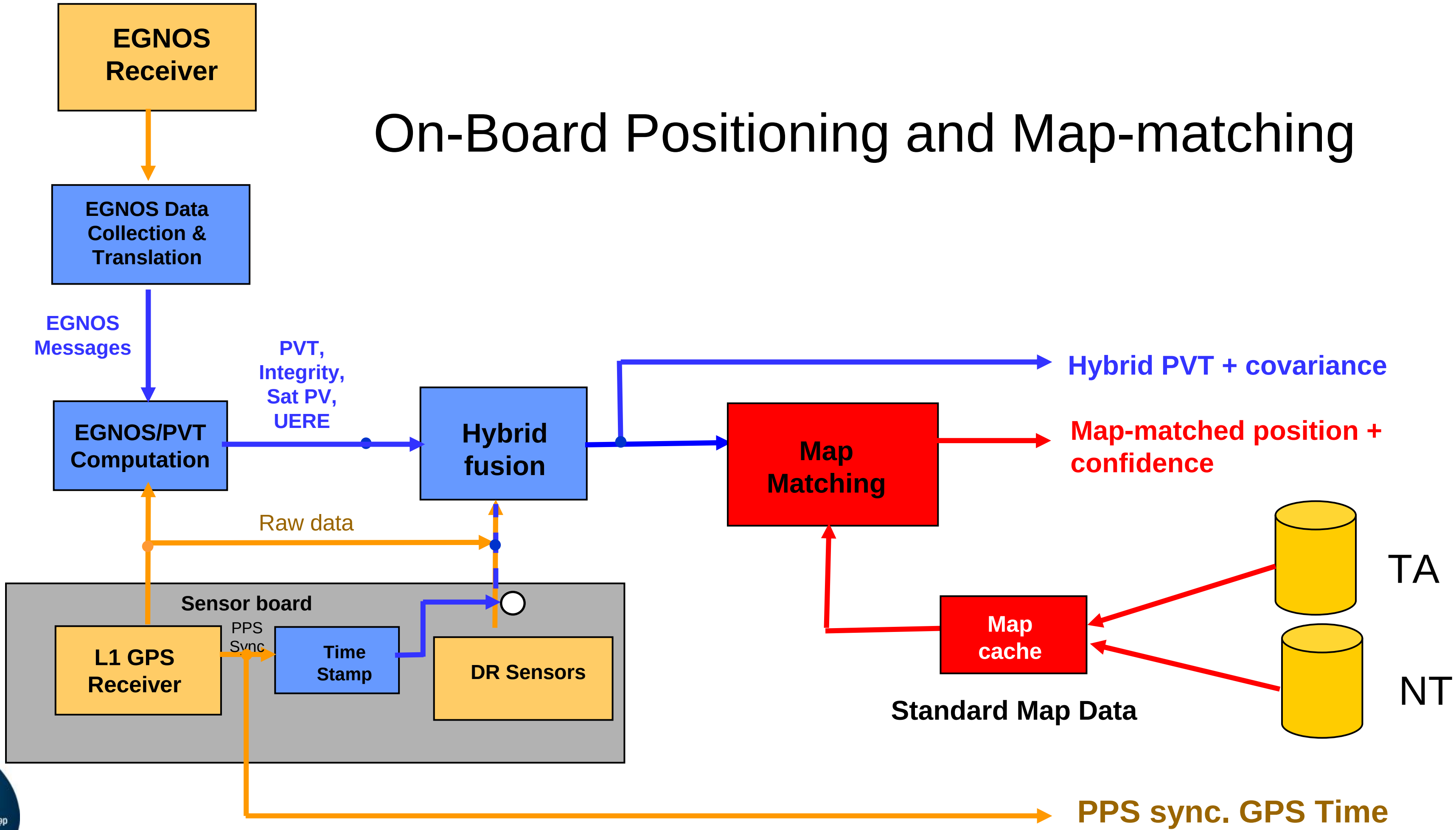


Outline

- Map-matching
  - specifications
  - method
  - integrity monitoring
- Validation method
- Experimental results

POMA / CVIS

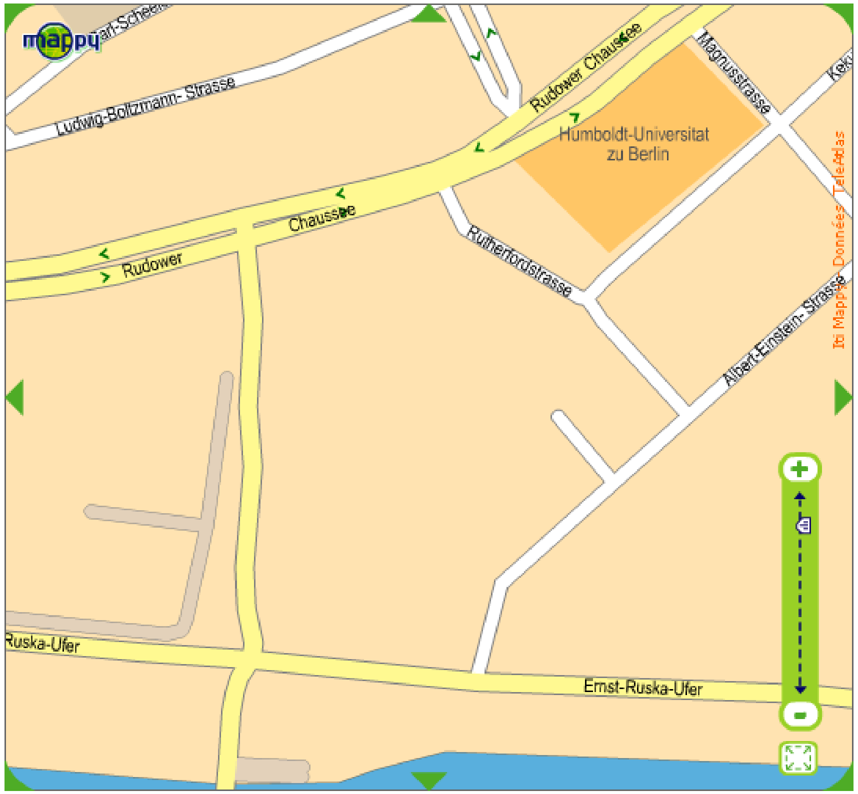
On-Board Positioning and Map-matching

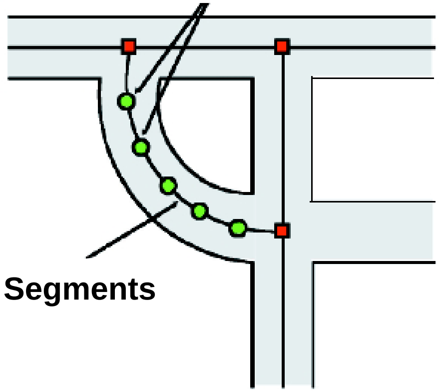


Standard maps

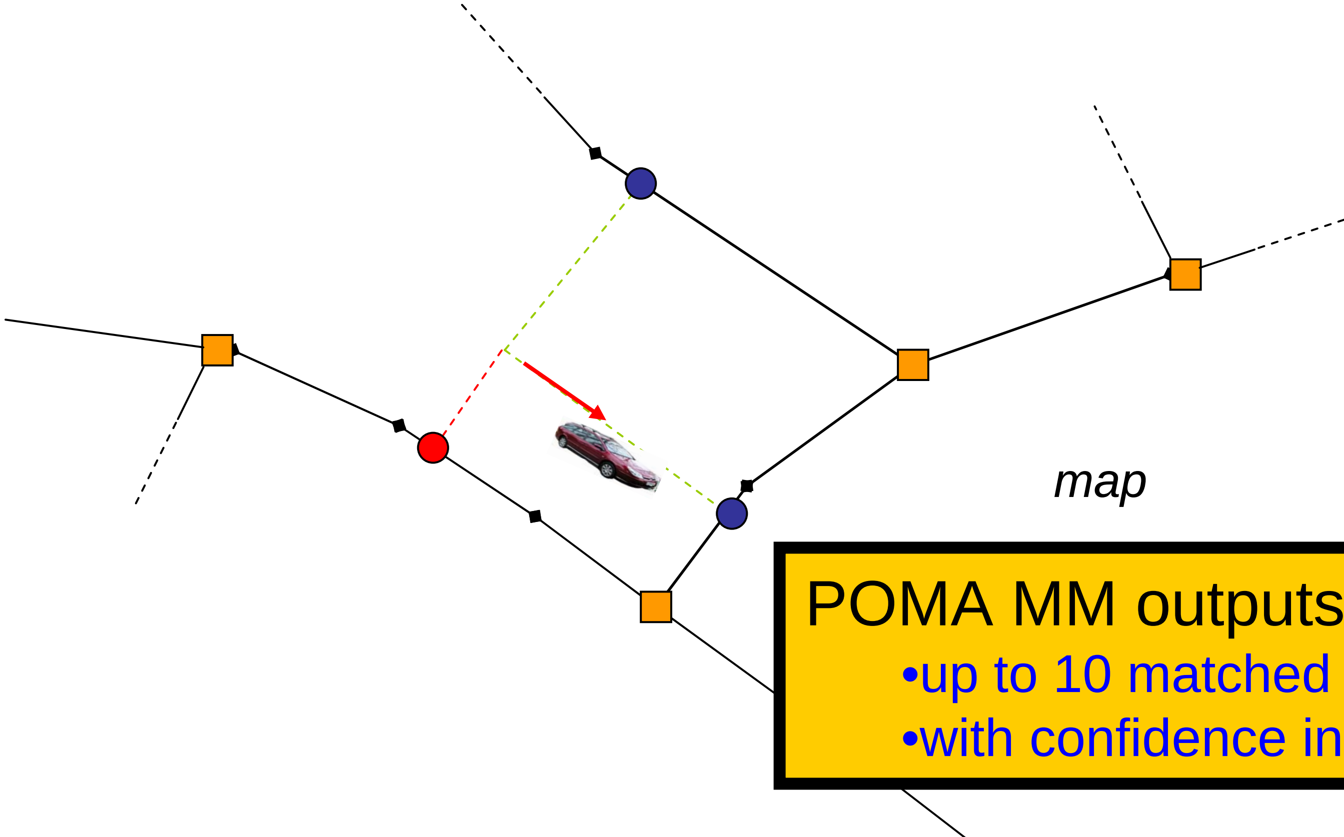
One carriageway = one polyline

Longitudinal topology





Map Matching Specifications

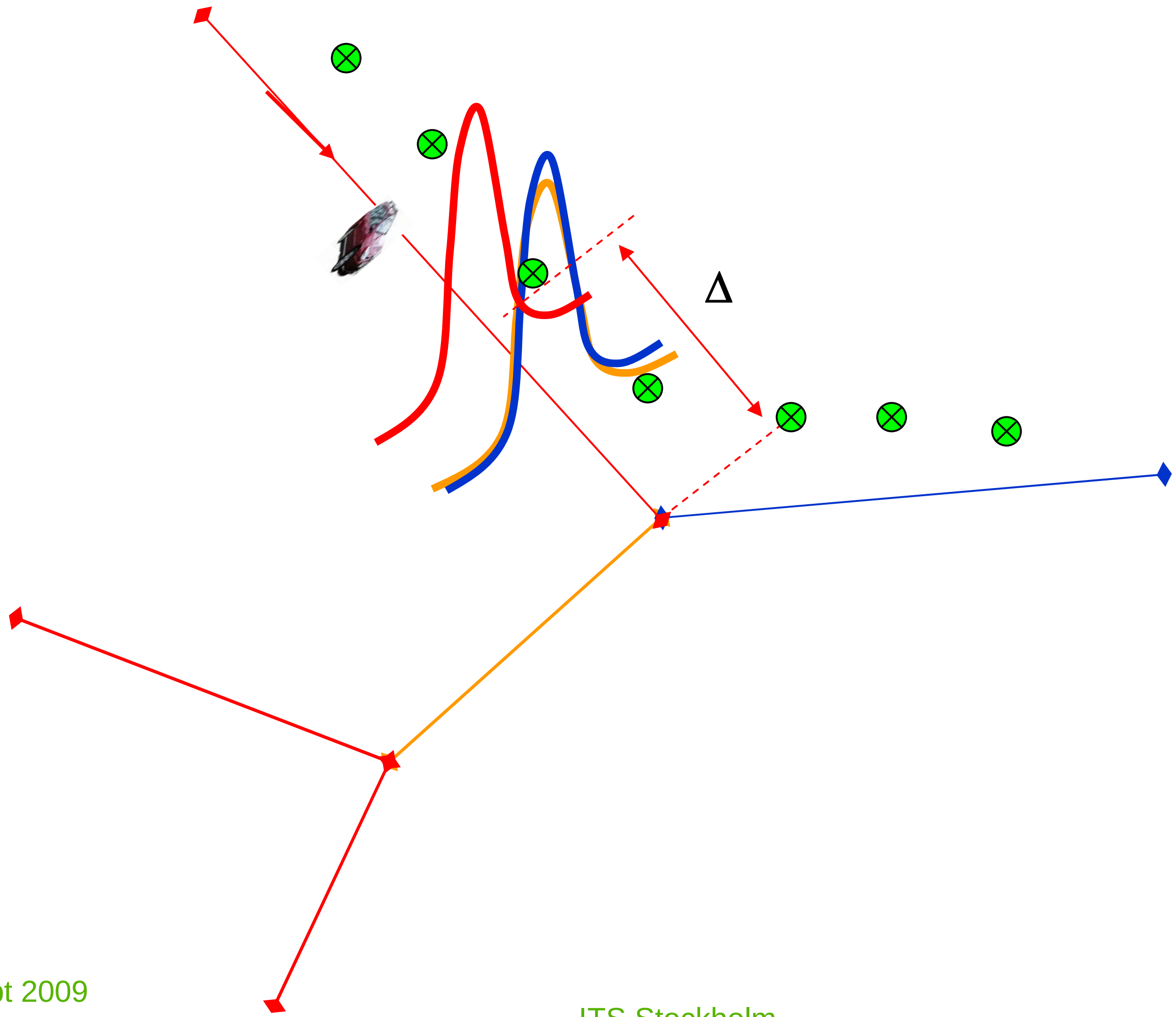


POMA MM outputs :

- up to 10 matched candidates
- with confidence indicators

« *map-matching* » : determining the vehicle's position % a digital road database

Multi-hypothesis Road Tracking

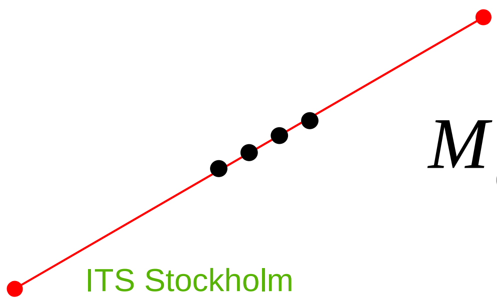


Solver Used

- Particle filter (PF)
- Sequential Bayesian state estimation technique that generalizes the Kalman filter
- Advantages
  - Can cope with non-linear systems and non Gaussian noises
  - Solves efficiently data association problems
  - Can track several hypotheses
  - Handles naturally uncertainty propagation

PF with Multiple Evolution Models

- Road tracking method
- Particles are constraint to follow the poly-lines representing the roads
- Noise is added at each prediction step in order to explore randomly the different hypotheses.
- A map matched position is a hybrid state

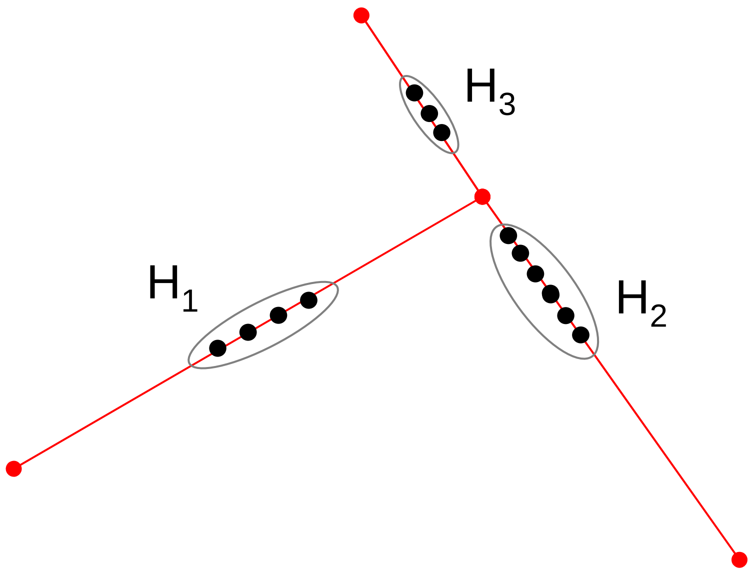


$$M_{(i)} = (s, ID)$$

Estimation stage

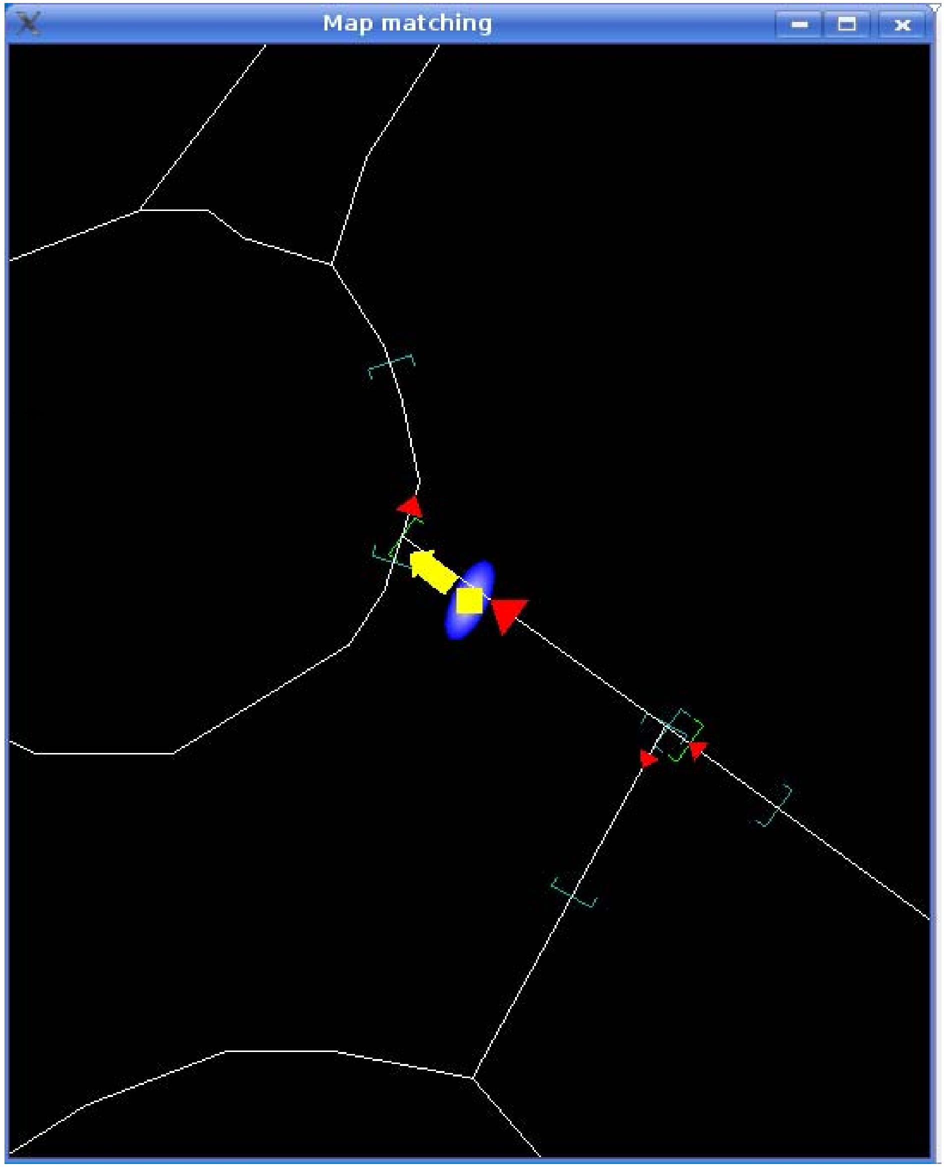
Hypothesis H_i : approximated by sub-particle sets

$$\chi_{h,t} = \{ \langle (s, ID)_t^n, w_t^n \rangle \mid ID = h \}_{n=1:N}$$



The system provides several candidates with confidence indicators

Map-Matching with confidence indicators

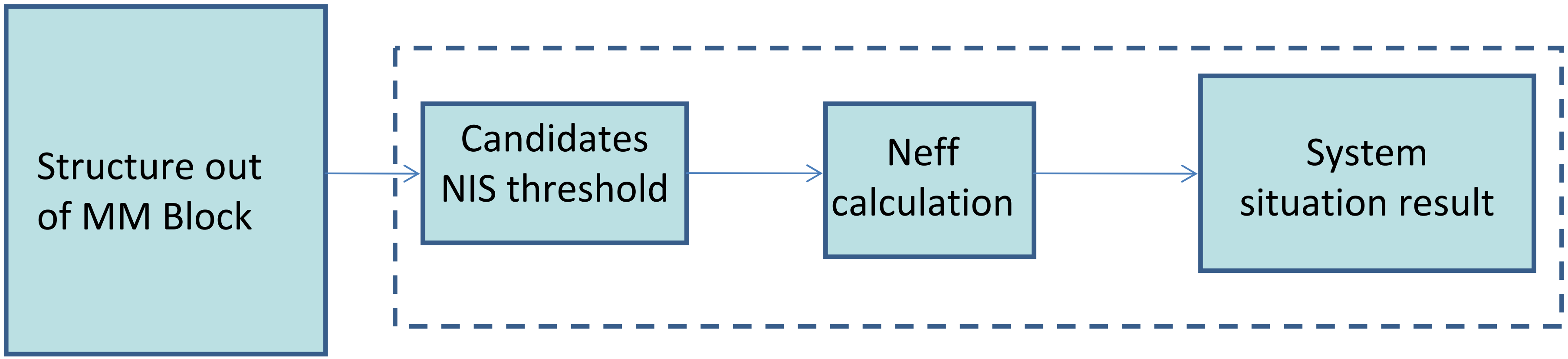


Map-Matching integrity monitoring

- Estimate the probability of each hypothesis with respect to the others
- Compute Normalized Residuals for each hypothesis
- Apply a decision rule for integrity monitoring
  - the risk depends on the application

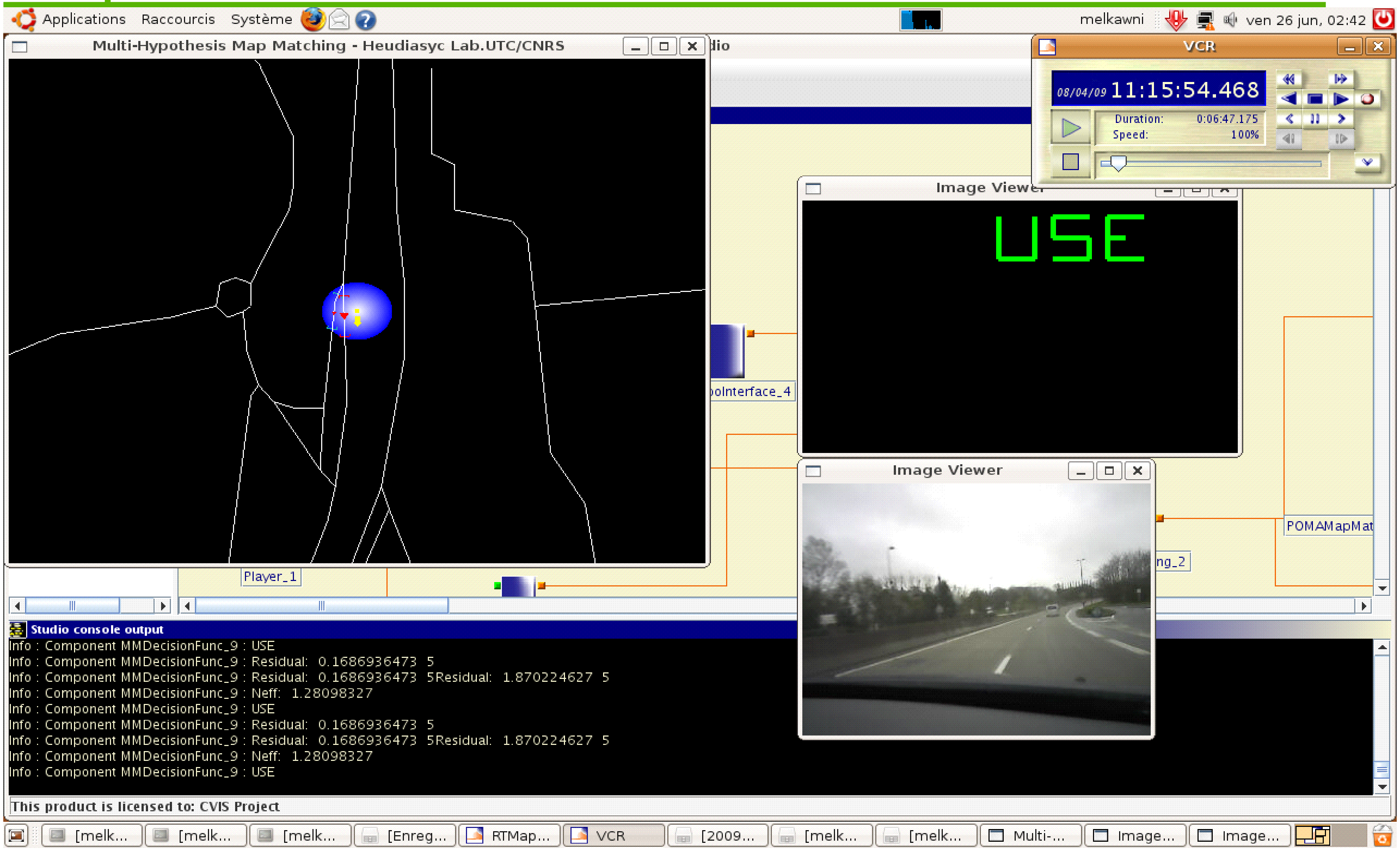
Decision Function

- Output:
  - use, don’t use, ambiguous
- Stages:
  - Eliminates unlikely candidates
  - Compute an estimate of the number of efficient candidates

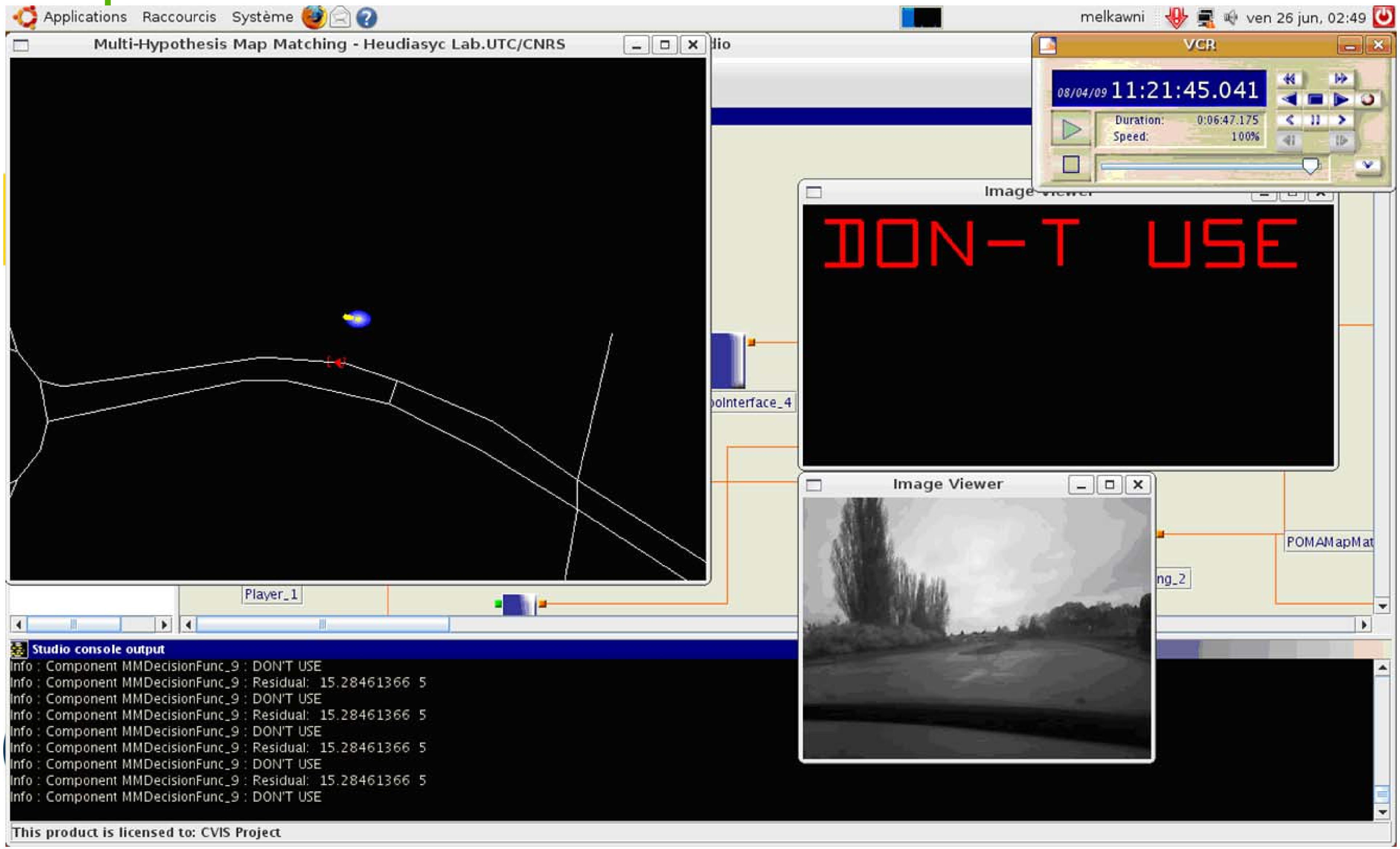


Decision Function Diagram

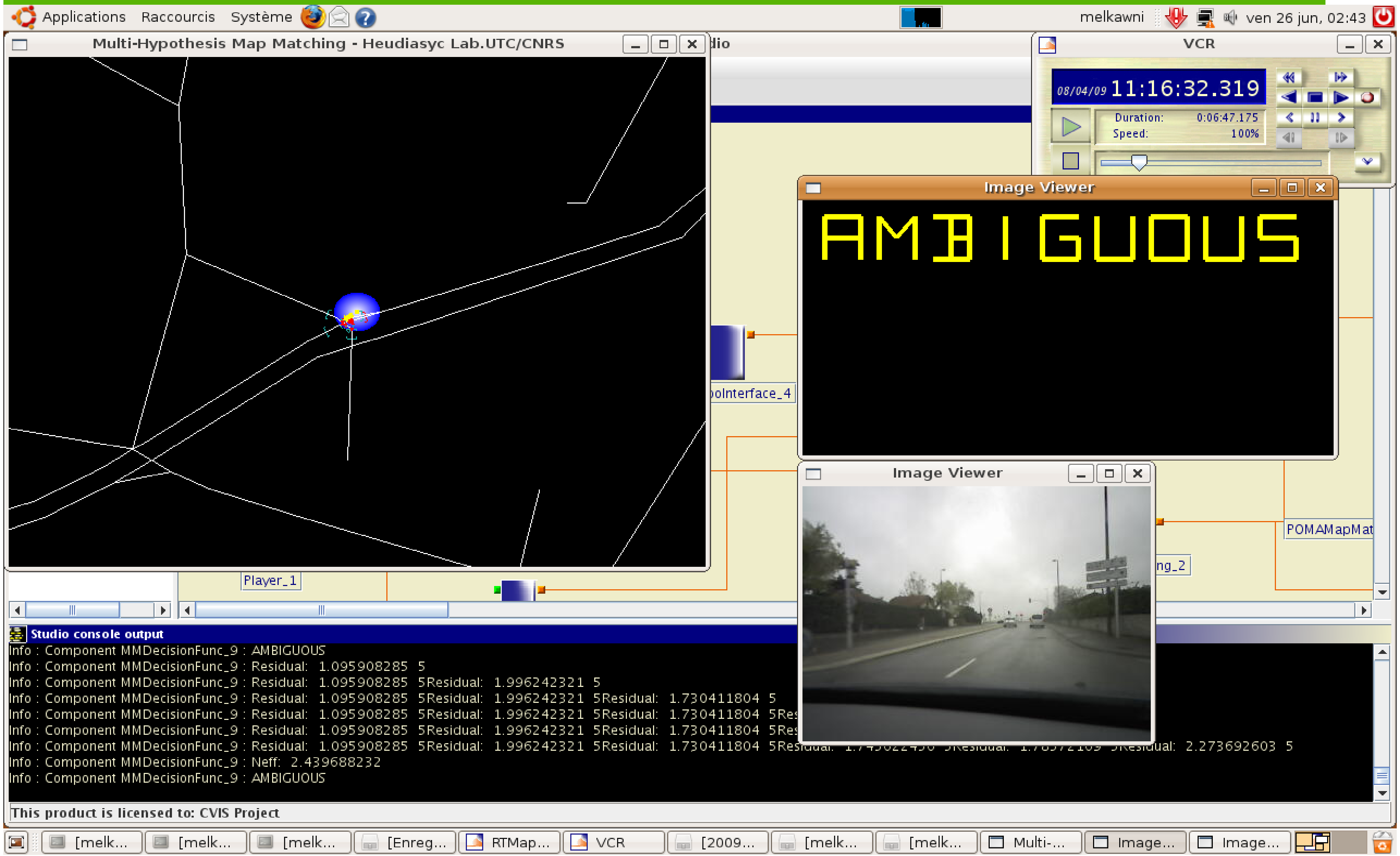
Normal conditions



The vehicle is in a parking lot



Approaching a junction



Map-Matching Validation

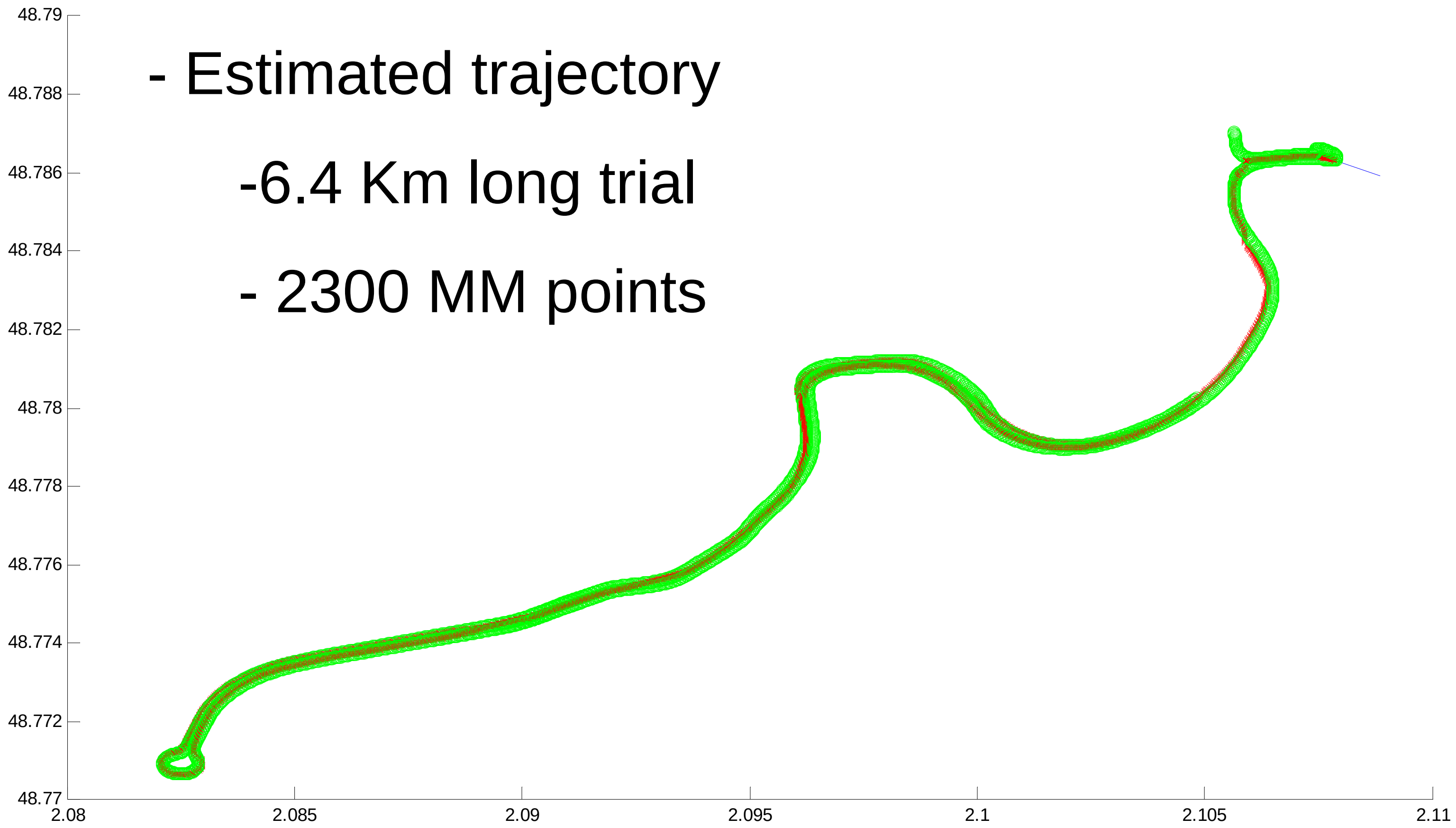
Proposed approach: to use a trajectometer

Method:

1. Extract the traveled roads
2. Match the trajectometer on this path
   This is the ground truth for MM
3. Compare the outputs of the real-time
   Decision Function with the ground truth

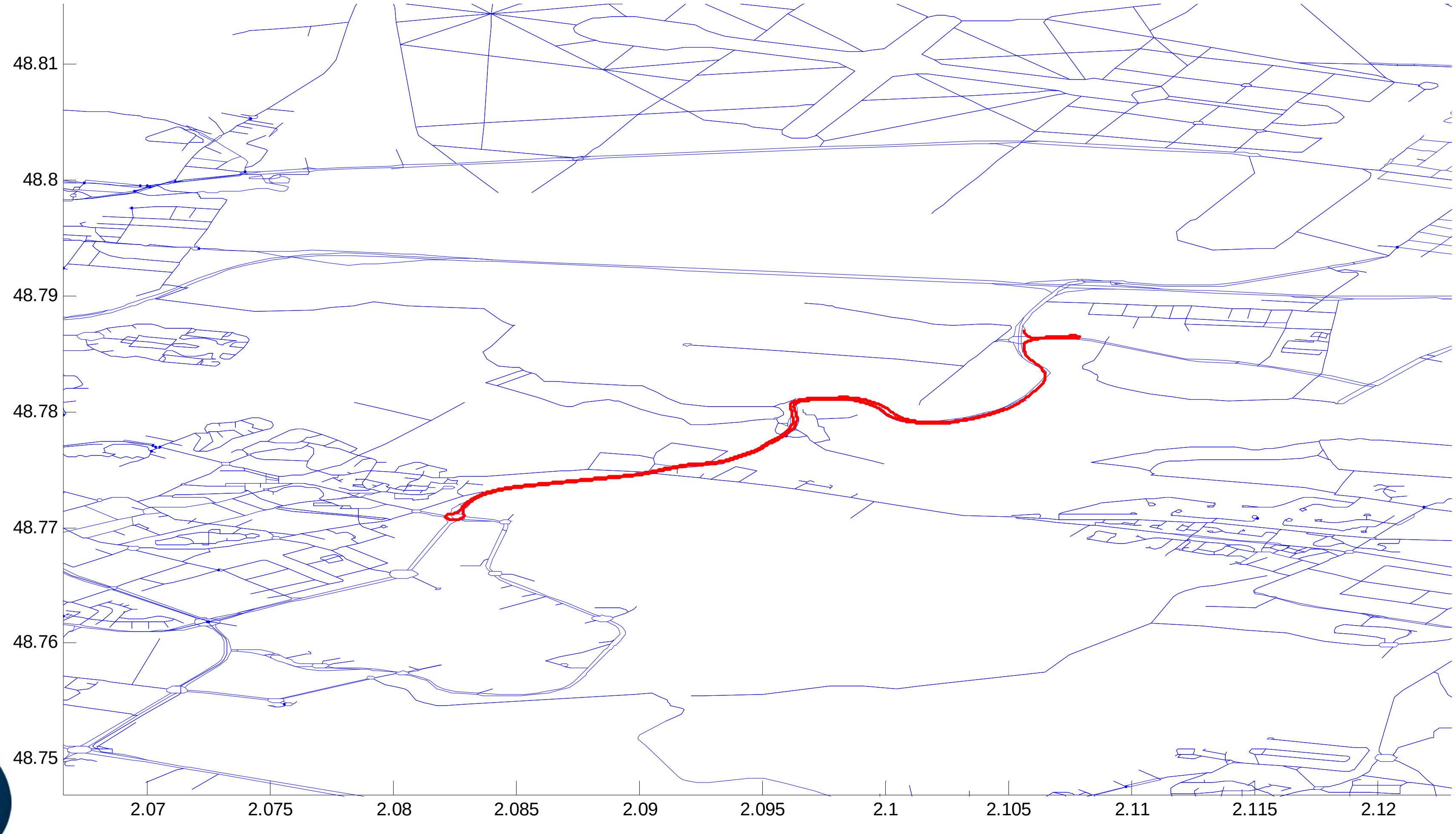
Versailles experiment (March 2009)

- Estimated trajectory
  - -6.4 Km long trial
  - - 2300 MM points

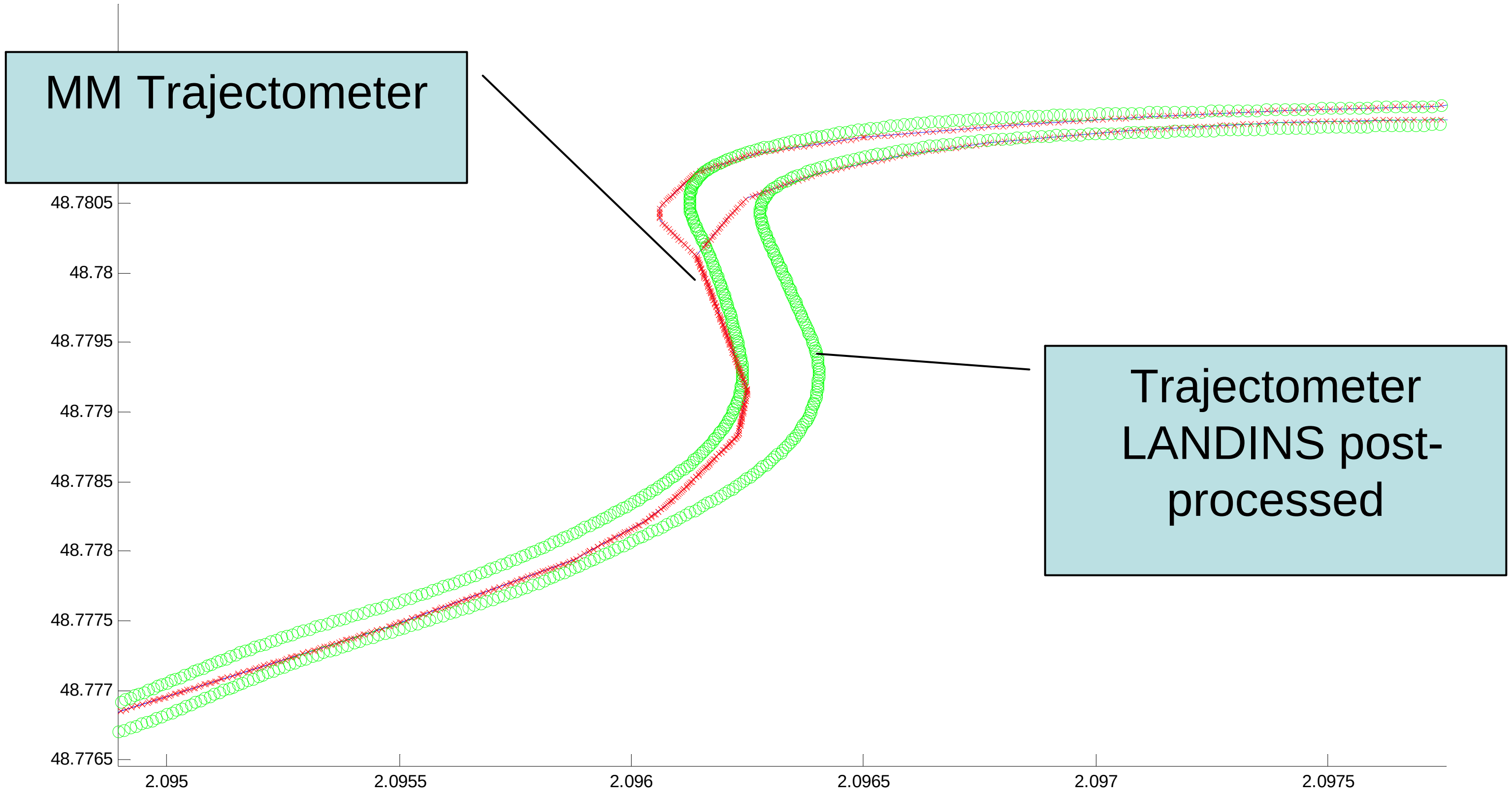


Result of the map path selection

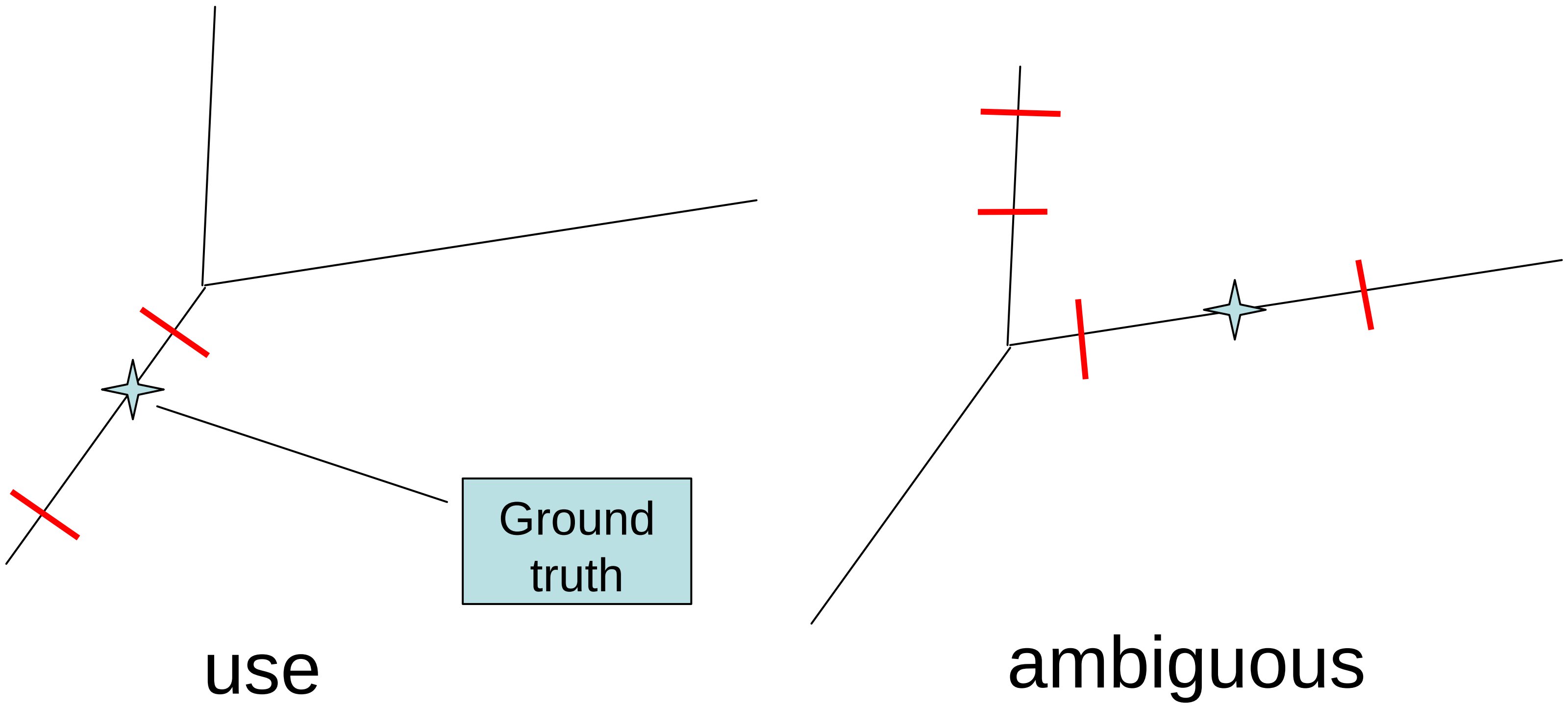
Goal: to select the roads traveled by the vehicle (and only them)



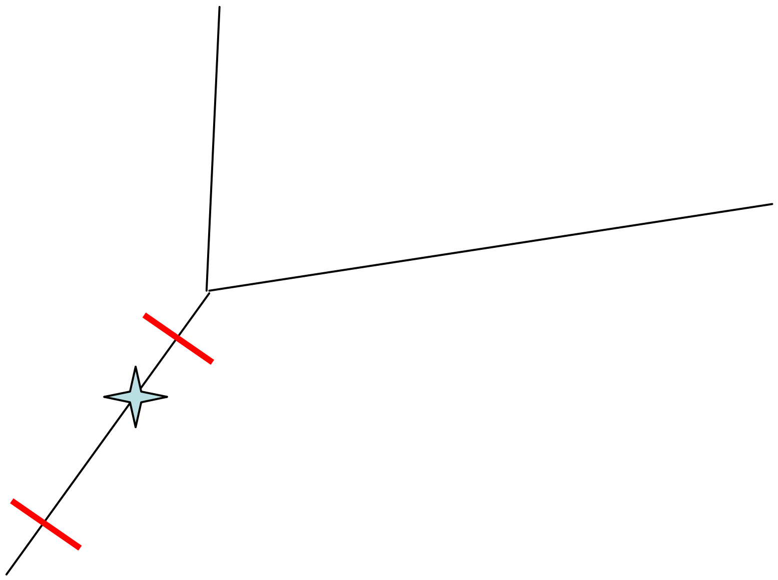
Map-matched reference trajectory



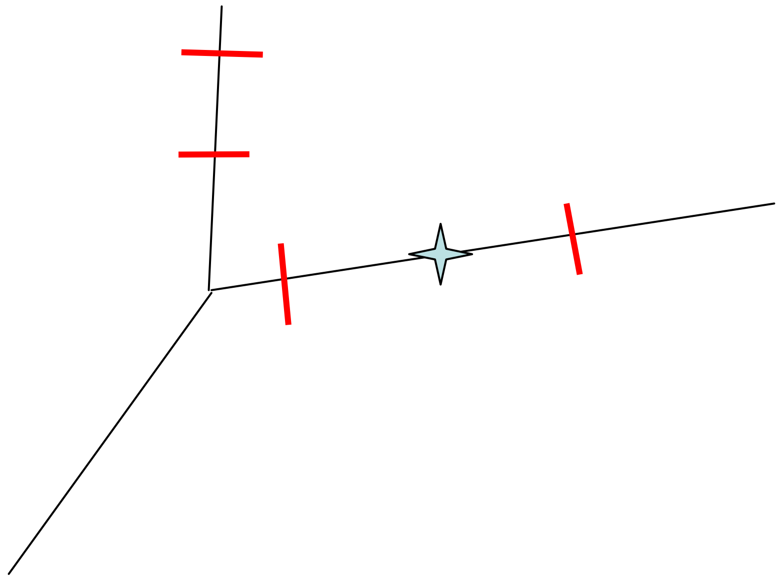
Good match



False Alarm

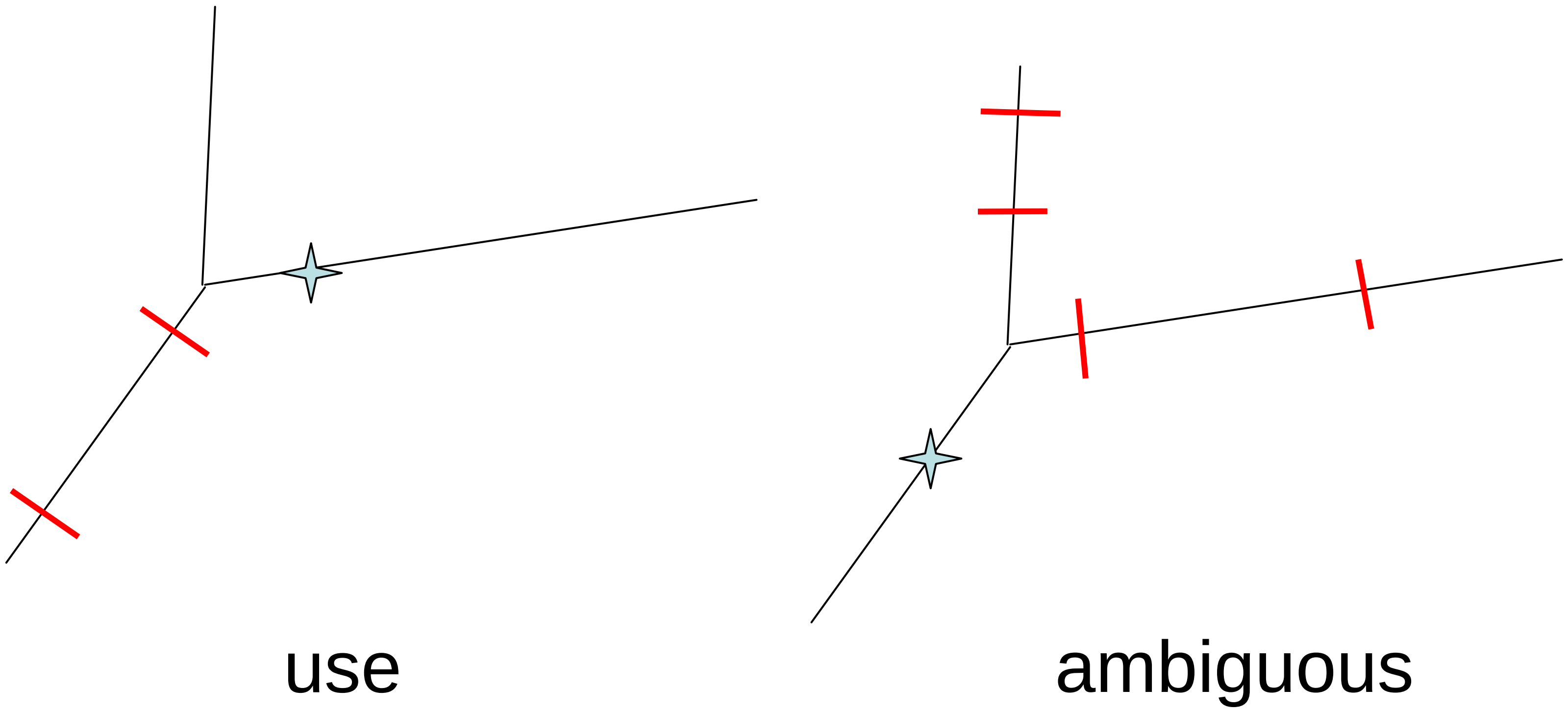


Don't use

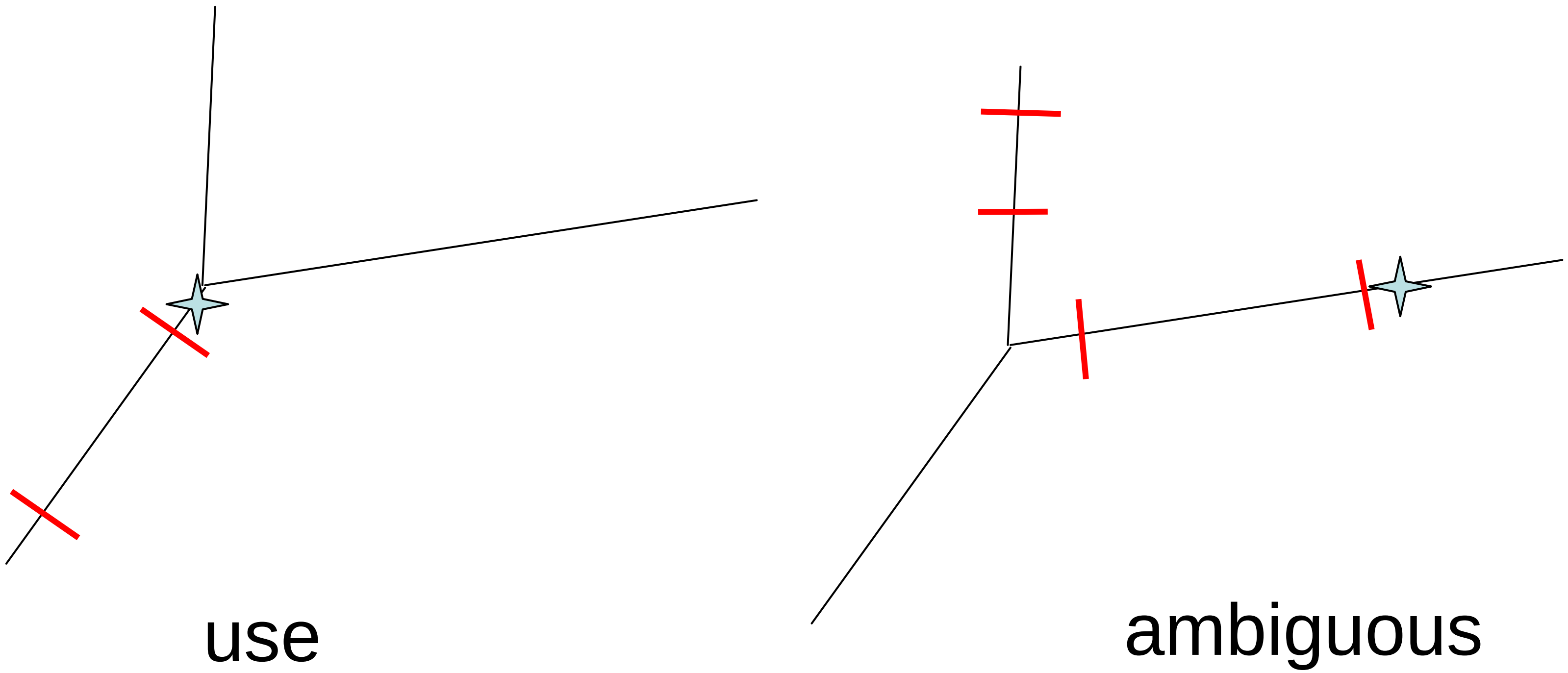


Don't use

Miss match (miss detection)



Miss match but good ID selection



GIDS = Good ID selection

Performance Analysis

~2300 Map-Matched positions

OCDR (overall correct detection rate)

GIDS (Good ID selection)

Map	FAR (%)	MDR (%)	OCDR (%)	GIDS (%)
Map *i*	0.4	4.3	95.3	99.7
Map *j*	0.2	6.3	93.6	99.9

Conclusion

- Integrity monitoring is crucial for ITS applications where safety is important
- Multi-hypothesis Map-Matching is essential for integrity monitoring
- This talk has presented
  - an MHMM implementation using PF
  - a decision function for integrity monitoring
  - a validation method