Map-Aided Dead-Reckoning With Lane-Level Maps and Integrity Monitoring

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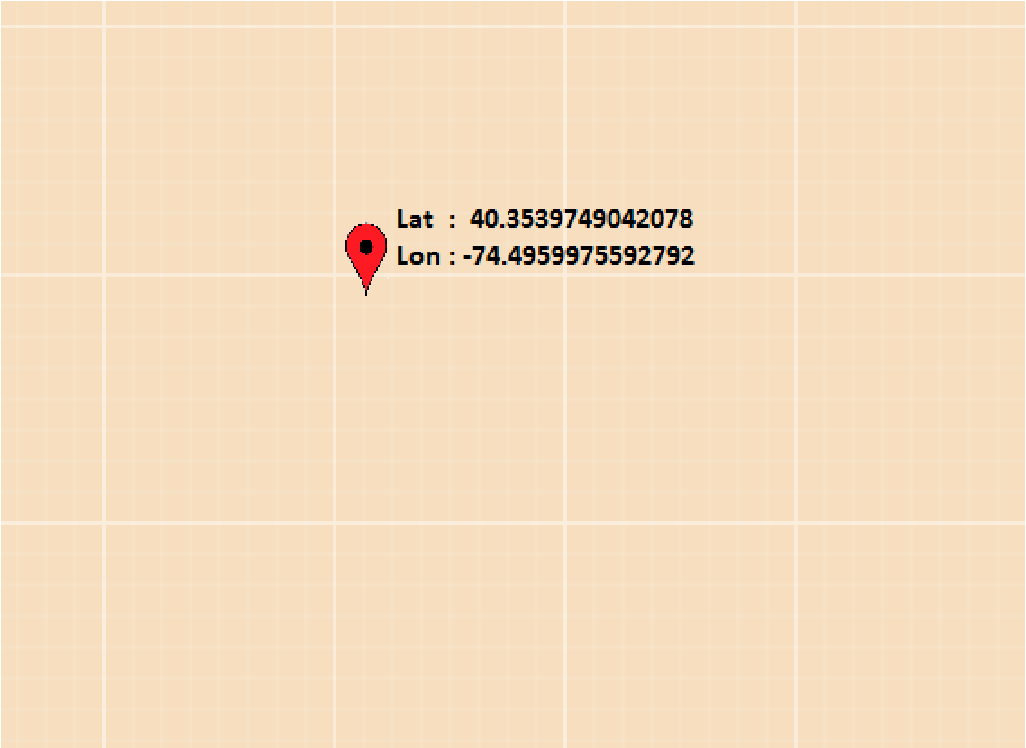
Contents

Localization For The Intelligent Vehicles

Knowing where the car is located

Absolute position is important

Provided by GNSS receivers



Source: Google Maps

Localization alone is insufficient

Requires a digital road map

- **Geographic Database**
- **Provides contextual information**

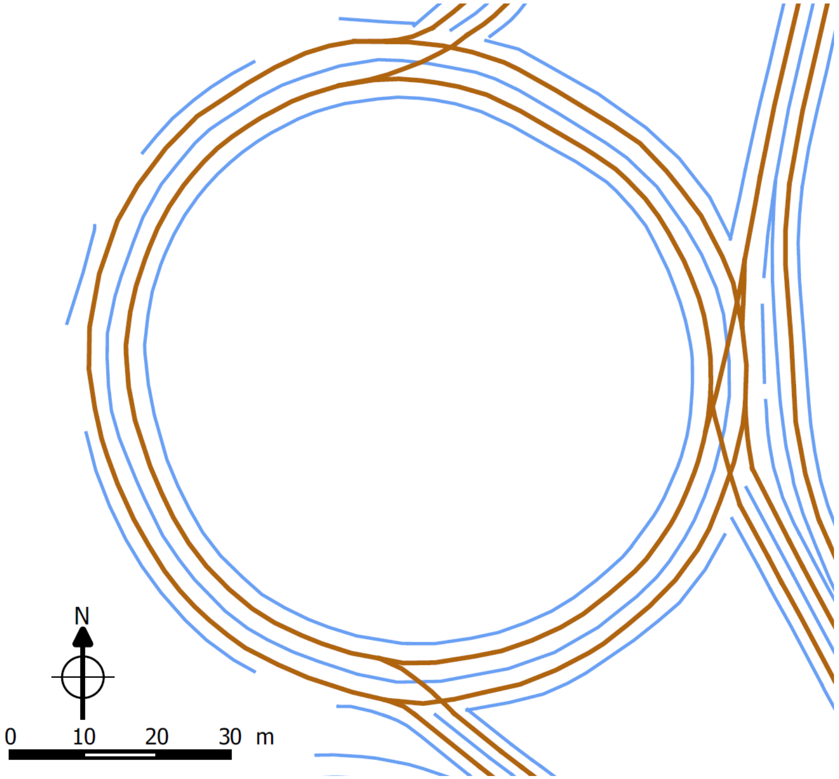
Road Map: a Source of Information

High accuracy road map (mesoscale)

- A good description of the road network is needed
- Lane-level descriptions
- Contextual information

From absolute localization to relative position

Map-matching process



Accuracy

Ideal case

Positioning with the same level of accuracy as the map

Actual situation

GNSS Positioning cannot reach the accuracy of the road map in every situation (e.g. urban environment)

Uncertainty Characterization

Metrics such as Horizontal Protection Level (HPL)

It is however insufficient to use on lane-level maps

Approach

Purpose

To improve the confidence on the positioning system estimates, using additional information from the map and vehicle odometry

Rationale

Provide a coherence metric to the positioning system, in order to determine if it can be used on lane-level road maps

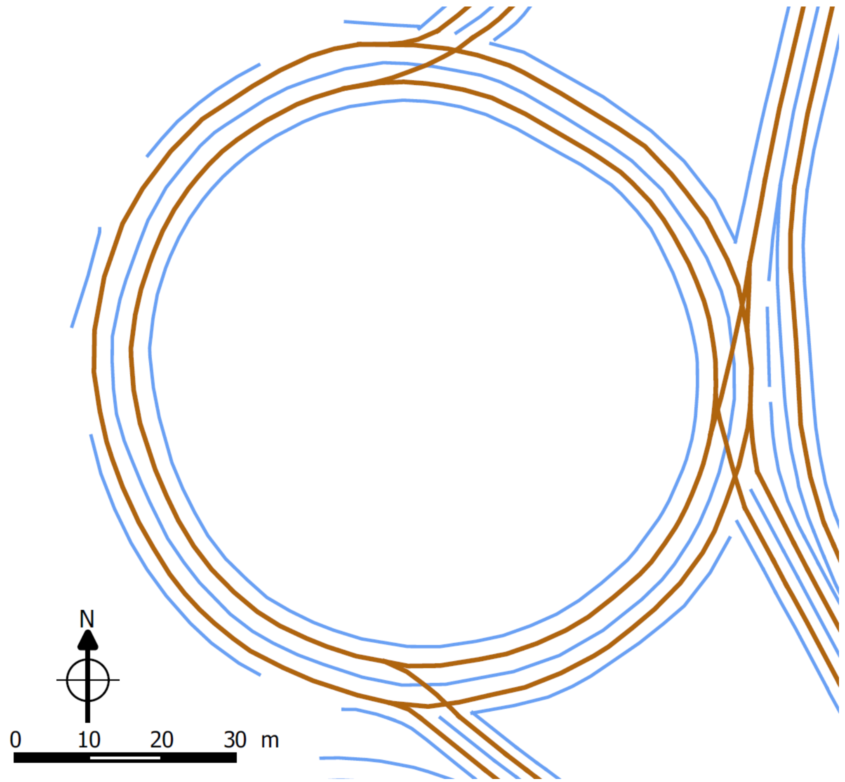
Contents

1. Introduction
2. **Lane-Level Map-Matching**
3. Coherence Checking
4. Conclusion

Approach

Determine a set of likely matching hypotheses

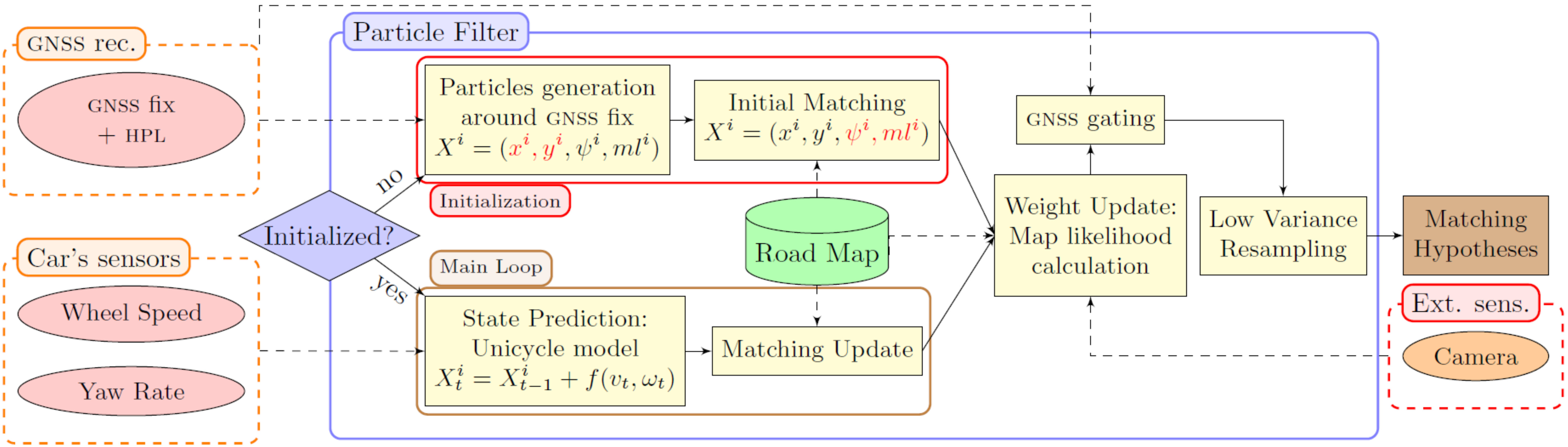
- Given the map and odometry
- With high probability:
  - **The set should contain the correct solution**
  - **Keep all likely solutions**



Assumption

The map is correct and accurate

Particle Filter Map-Matching

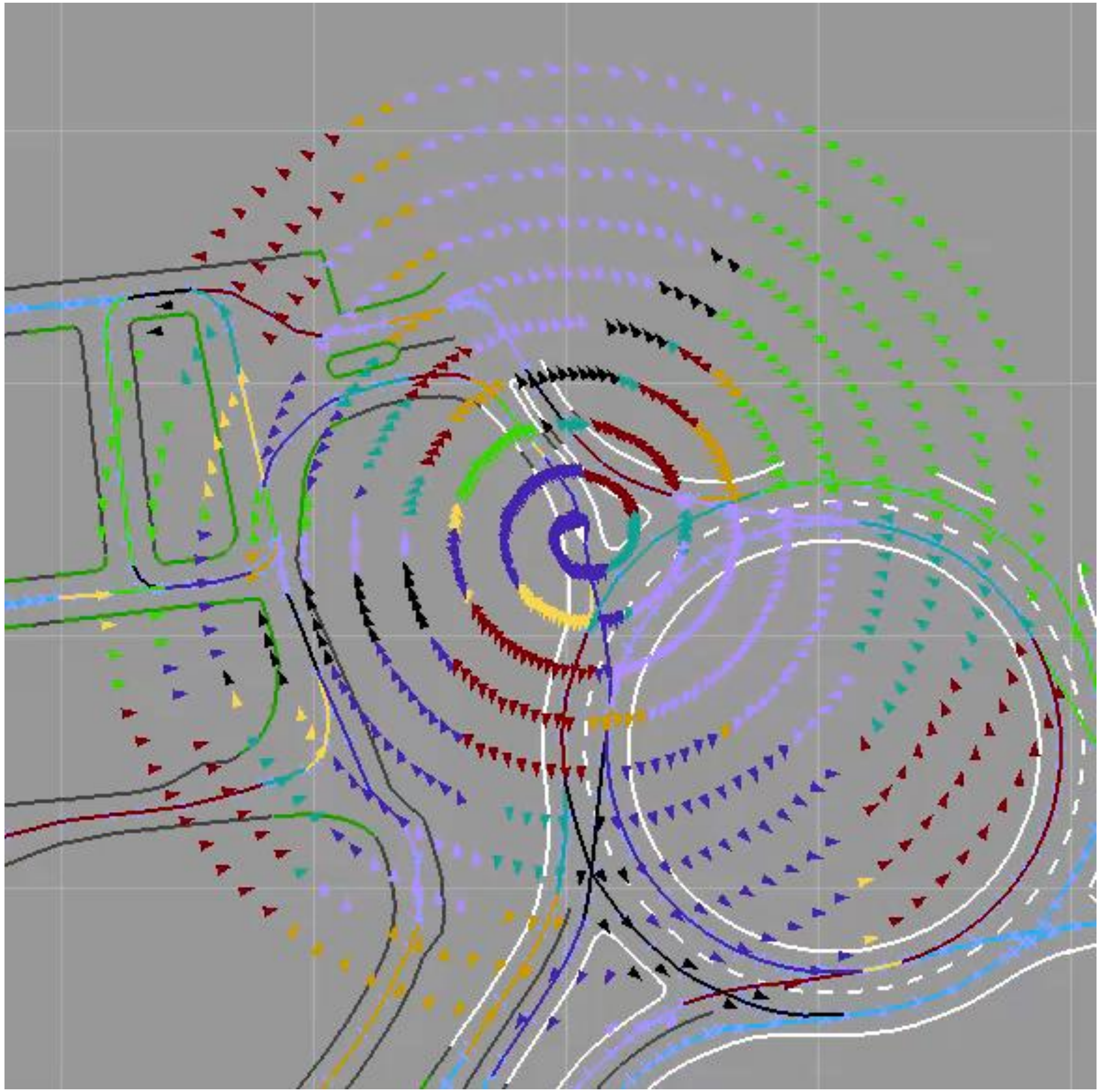


Safety-Oriented Design

Filter's result

- Returns a set of all the likely matching hypotheses, given the map and proprioceptive information

- Experiments have shown that the set includes the correct matching hypothesis



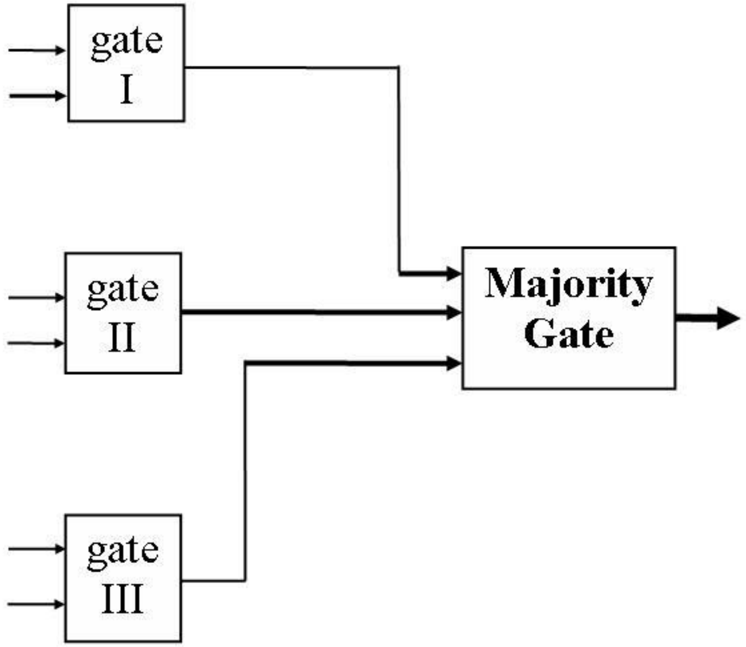
Contents

Assess The Coherence of the Positioning System

Inspired by Functional Safety

- Redundancy as a key element

Voting System



Sources available

On one hand: Map-Aided Odometry

- Mainly based on proprioceptive information and the road map
- Not strongly dependent on GNSS estimates

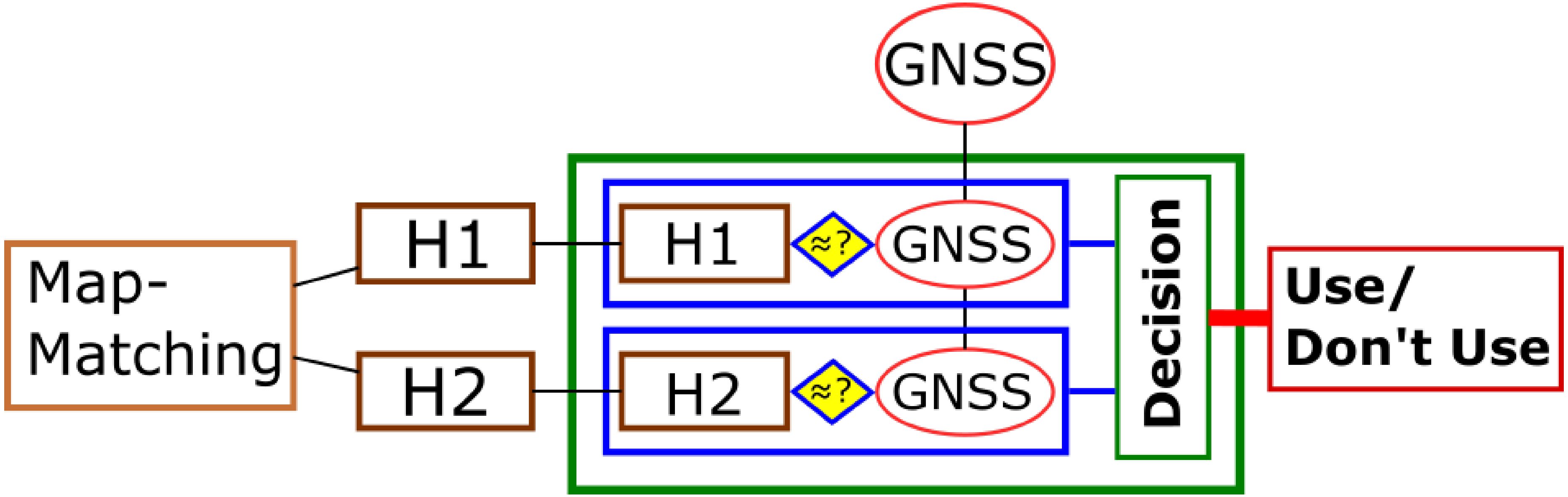
On the other hand: GNSS fix

- With covariances returned from the receiver

One multi-hypothesis source

Map-Aided Odometry

- Each hypothesis will be compared individually with the GNSS



Testing All Hypotheses: Use/Don’t Use

If no (or multiple) hypothesis remains after the test: Don’t Use

- No coherent hypothesis is found
- Or ambiguities still exist

If a single hypothesis remains after the test: Use

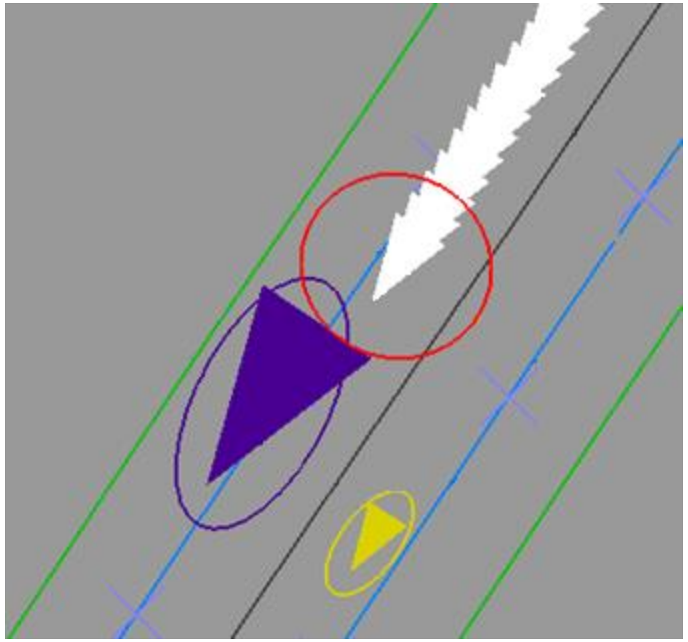
- All ambiguities resolved
- And coherent hypothesis

Test frequency: set on the GNSS reception (5 Hz)

Decision on hypothesis coherence

Considering GNSS and MM hypotheses as distributions

- Using covariances returned by GNSS receiver
- Or computed from the particles sets



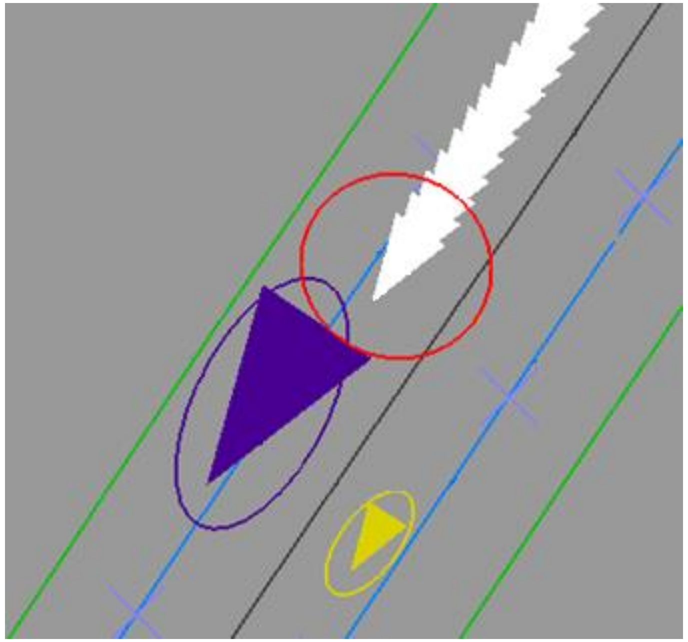
Idea: Assess the coherence of the positioning system using these distributions

Mahalanobis Distance

Given by:

$$D_{M_j}(\bar{X}_j) = \sqrt{(\bar{X}_j - X_{\text{GNSS}})^T \, \Sigma^{-1} \, (\bar{X}_j - X_{\text{GNSS}})}$$

- $\bar{X}_j$: mean particle position (for each hypothesis)
- X_{GNSS} : GNSS fix
- Σ : sum of the covariance matrices (independence assumption)

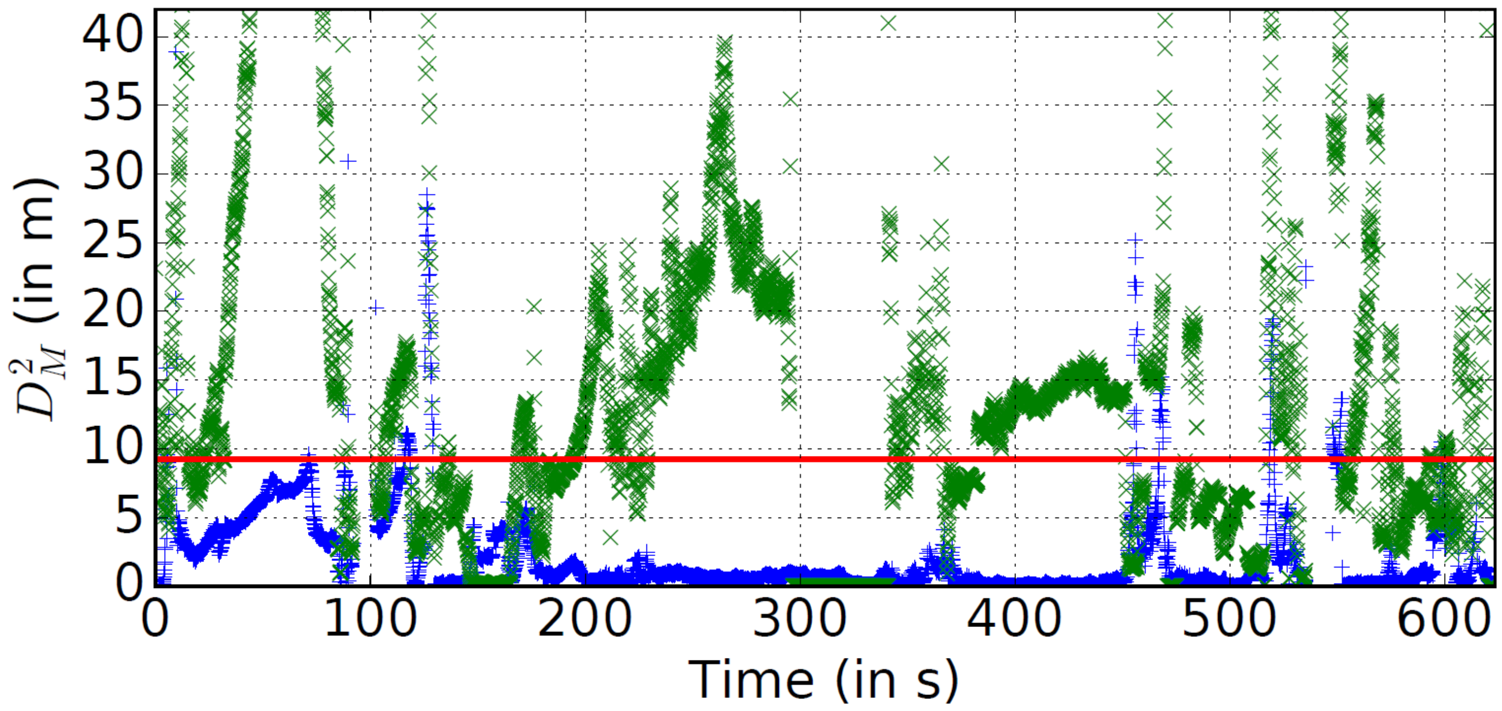


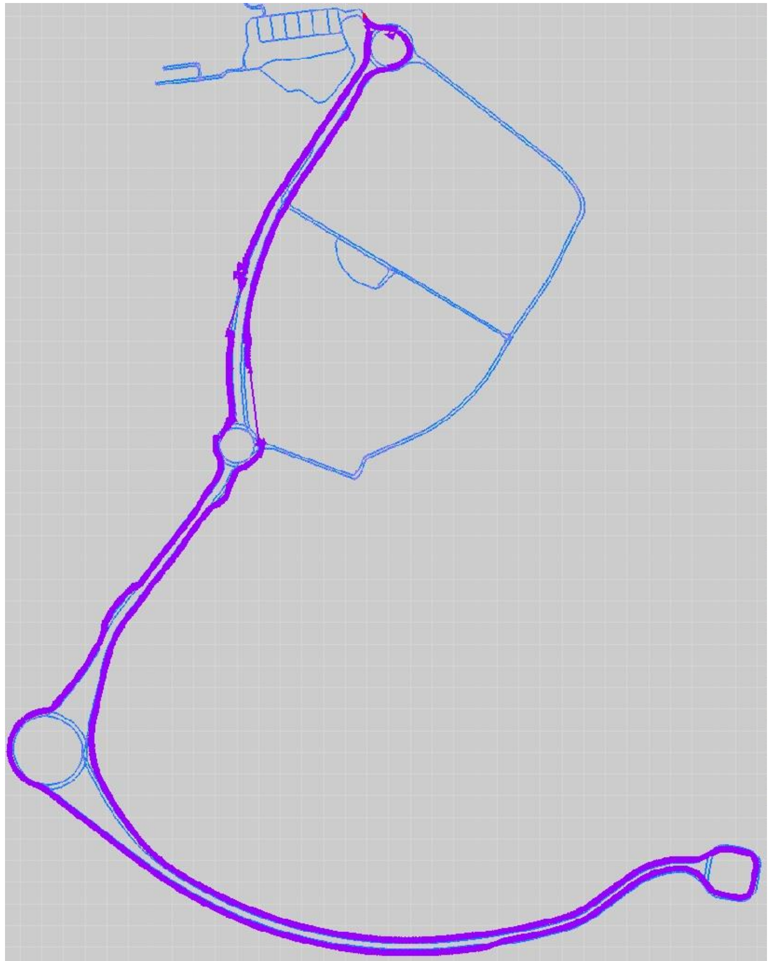
The distance compares the characteristics of the distributions

Mahalanobis Distance

χ^2 test

- Under Gaussian assumption: $D_M^2 \sim \chi^2$





Meaning of the test

If the test fails (value greater than threshold)

- Does **NOT** mean the hypothesis wrong
- Does **NOT** mean the GNSS wrong

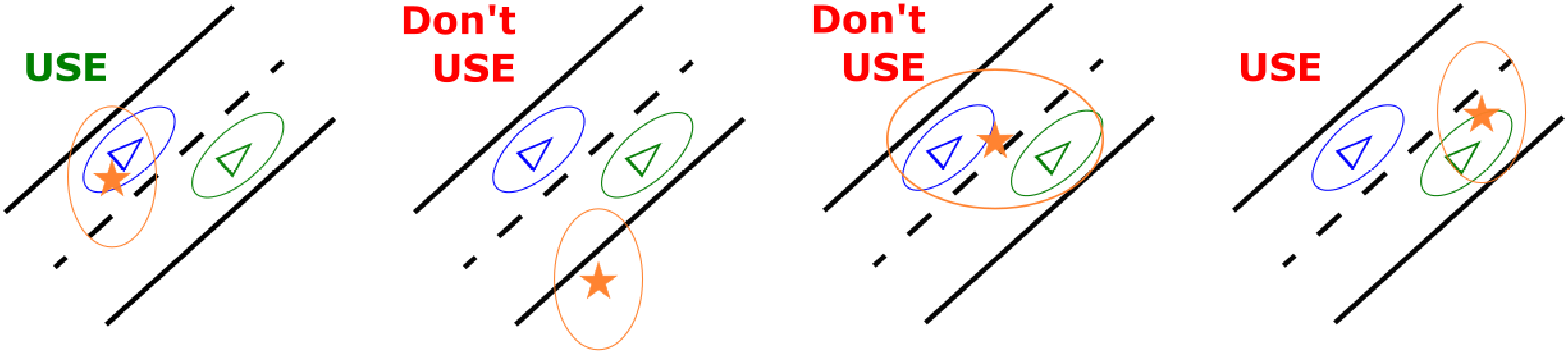
It means that the hypothesis is not coherent with the GNSS fix

Something is wrong

No matter what, this hypothesis should not be used

Different Situations

Varying dispositions

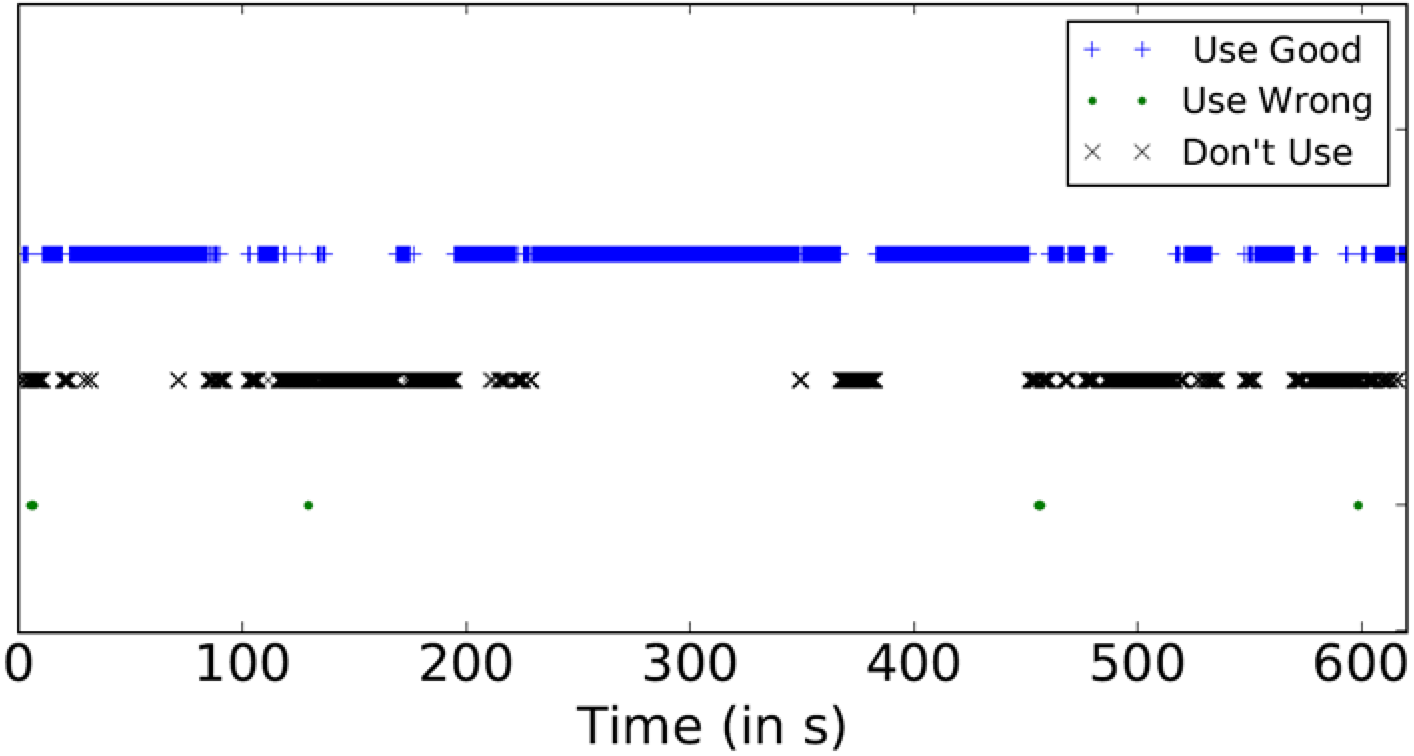


- Correct Hypothesis
- Other Hypothesis
- GNSS Fix

Testing All Hypotheses: Use/Don't Use

Results

	Don't Use	Correct Use	Incorrect Use
%	33.9	65.6	0.5



Contents

Conclusion

Developed a Map-Aided Odometry

- Multi-hypothesis map-matching, using a particle filter
- Minimal use of GNSS, only with an HPL

Coherence checking of the positioning system

- Use/Don’t Use Classification
- Using Mahalanobis Distance

Application: Learning maps

- Add information about the positioning quality at a given place

Thank you for your attention