Vehicle Re-identification With Several Magnetic Sensors

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Outline

- Introduction
- Material
- Re-identification methods
- Experimental results
  - Evaluation method
  - Performances
- Conclusion and Future work

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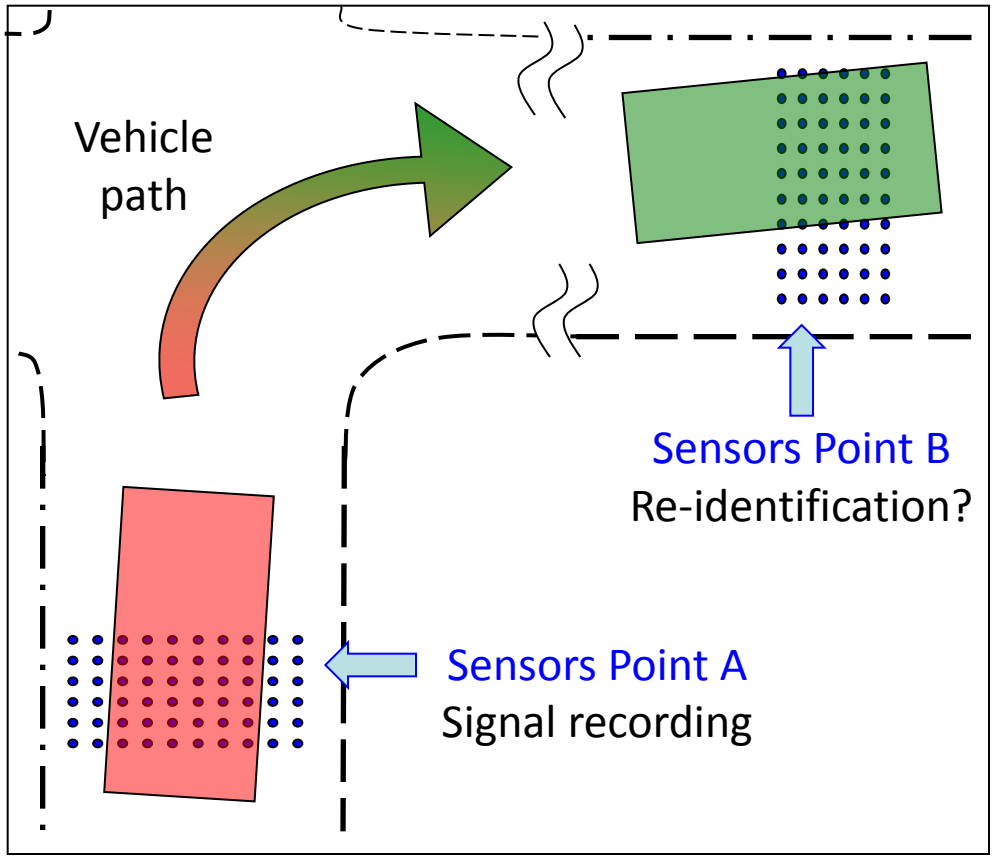
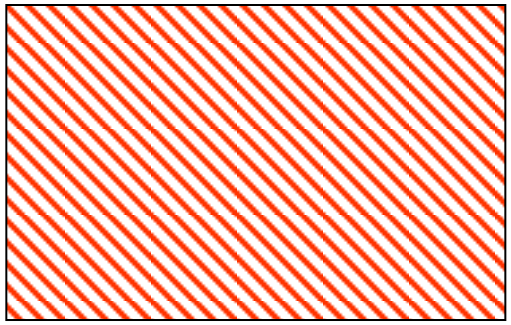
Introduction

- Traffic congestion
  - Economic and ecological inconveniences
- Vehicle re-identification
  - Travel Time estimation & Origin-Destination matrices
  - Current technological solutions



Introduction

- Magnetic sensor
  - Vehicles: metallic masses



Earth's magnetic field

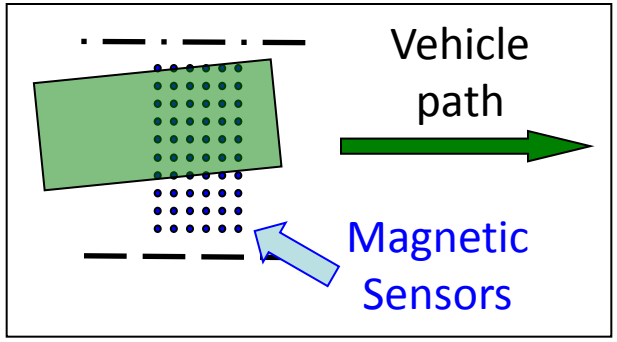
+

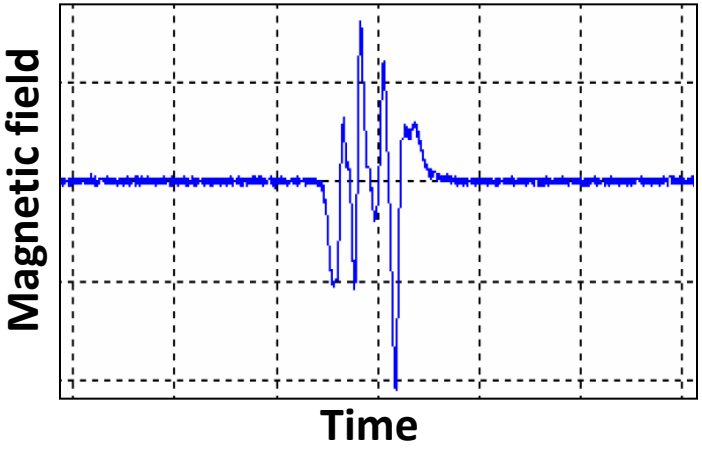
Ferrous object

=

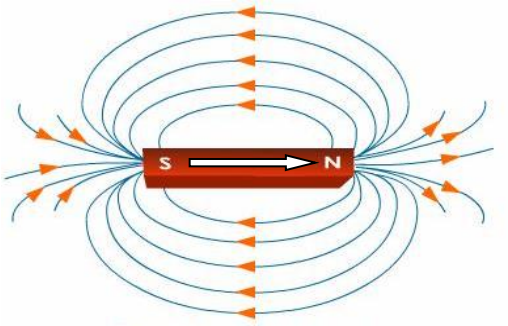
Disturbed field

  - → Vehicle "magnetic signature"



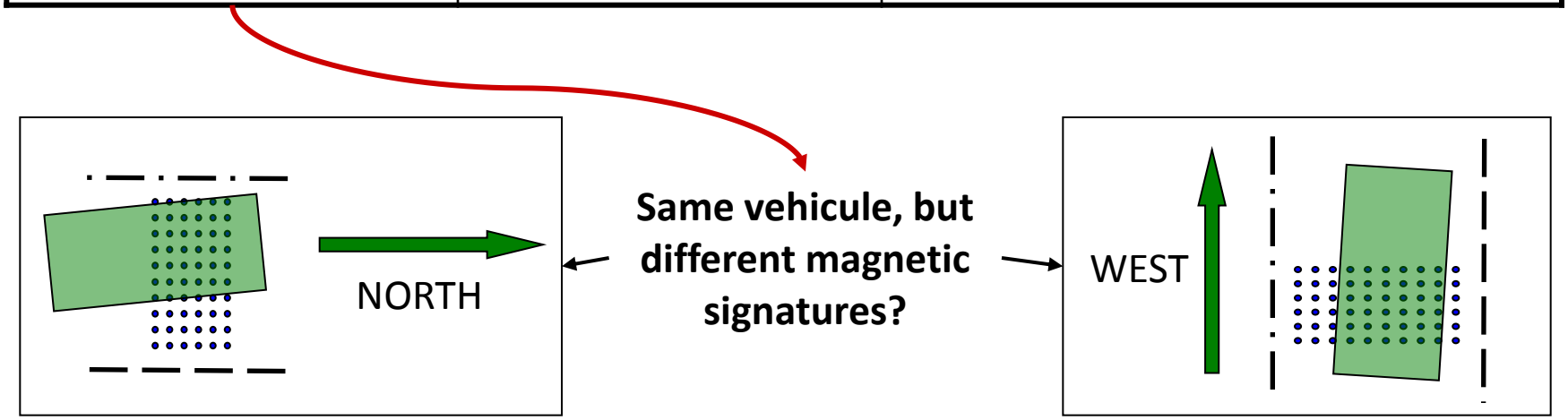


Introduction

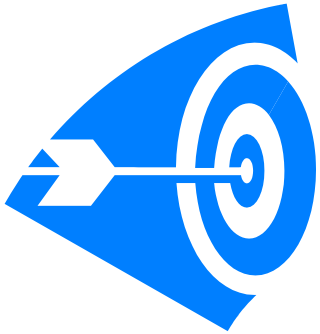


- Re-identification with magnetic sensors
  - Comparison of pairs of magnetic signatures
  - ⚠ Induced magnetization: problem?

Two magnetizations:	Varies with:	Consequence:
Permanent m_{perm}	vehicle history	≠ for 2 vehicles with the same model
Induced m_{ind}	outside magnetic field	Varies with vehicule direction



Introduction – Objectives



- Evaluate performances of re-identification methods

- Effects of a change in vehicule orientation ?

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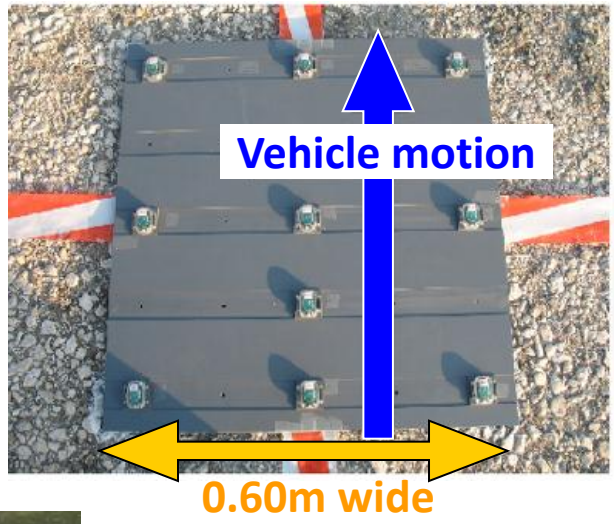
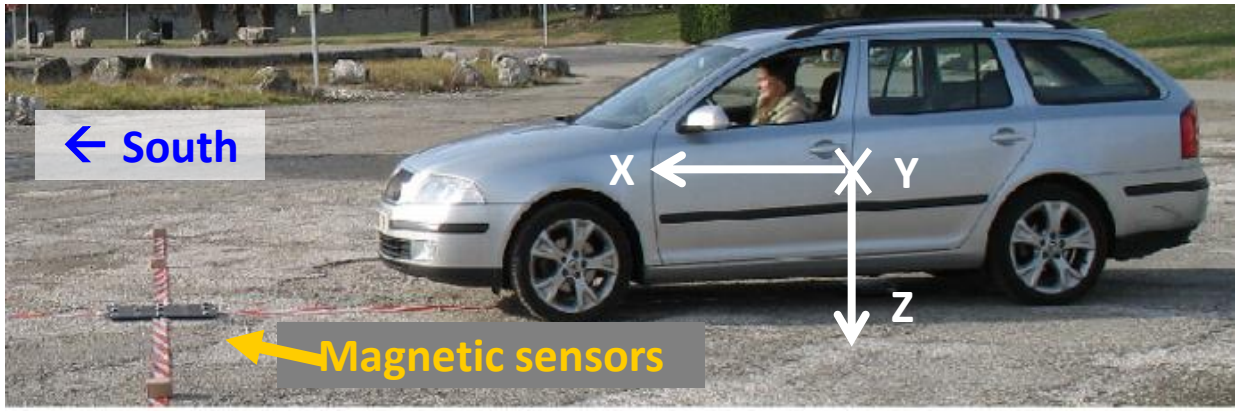
Material

- Data collection - A total of 261 signatures
  - 25 vehicles
  - 4 different orientations to the North
    - North to South (NS), SN, East to West (EW), WE
  - ~ 3 times in each traveling direction

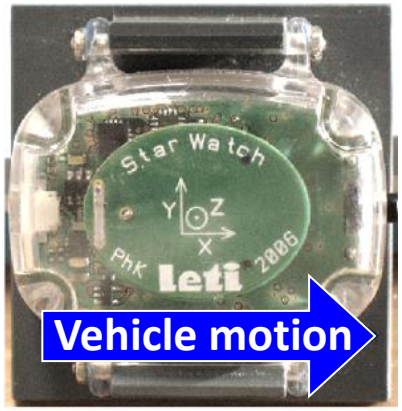




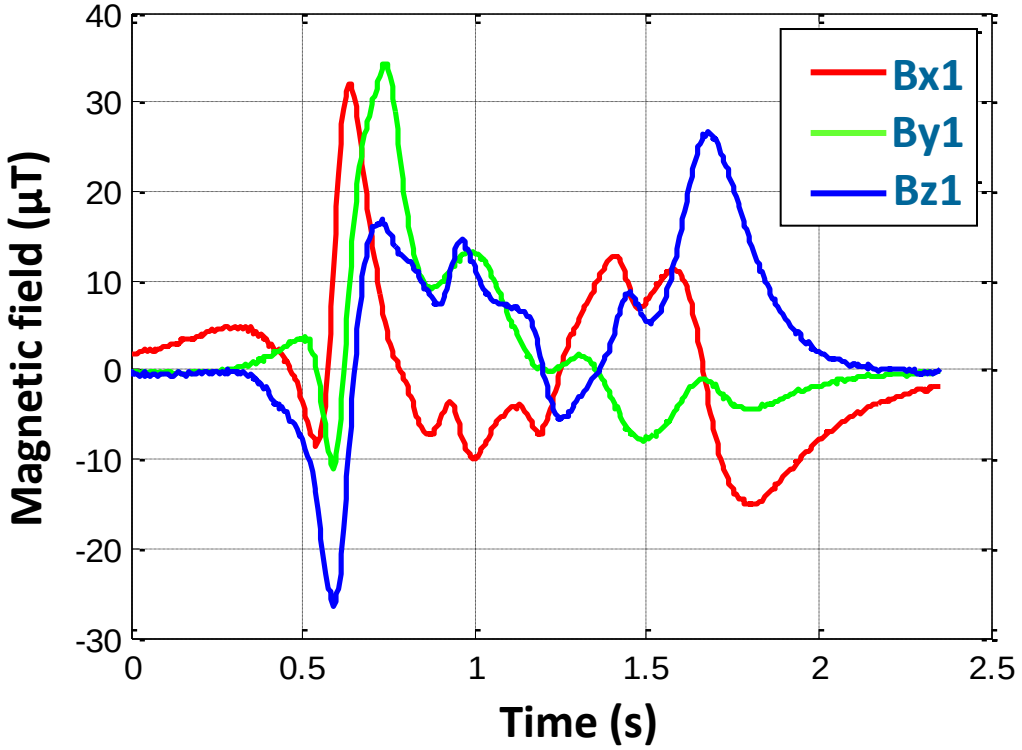
Recording of a North to South (=NS) 3-axis magnetic signature

Material

- Magnetic sensor
  - By CEA-Leti from AMR Honeywell
  - Sampling rate 200Hz
- Data post-processing
  - From Volts to Tesla
  - Temporal signature segmentation

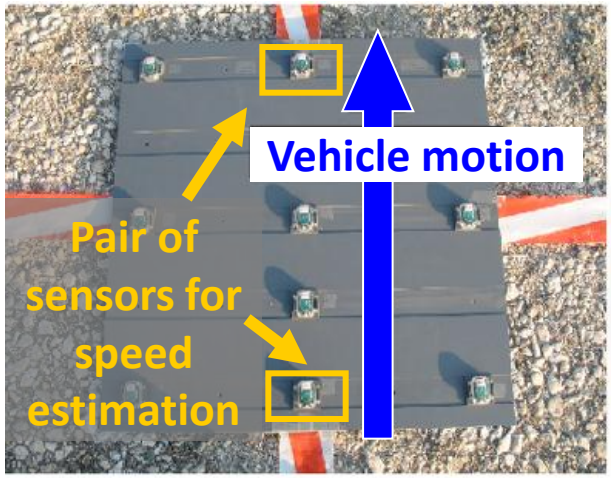


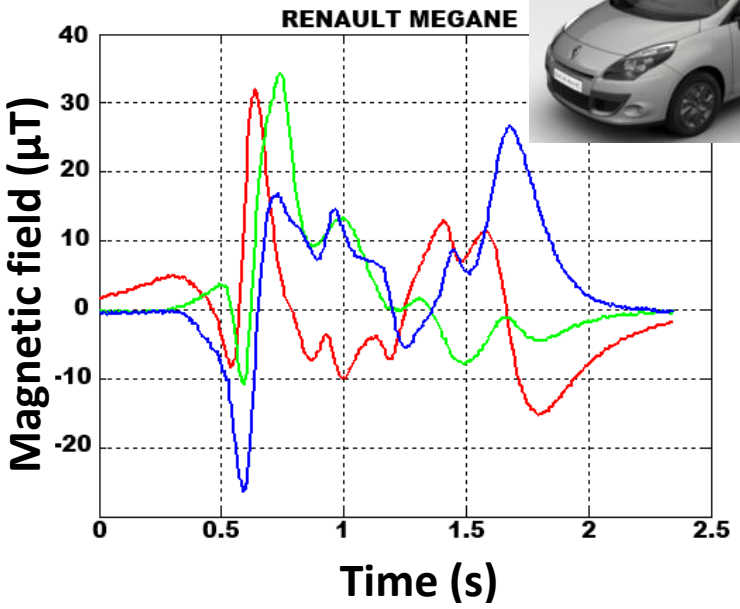
3-axis signature S1: Bx1, By1, Bz1



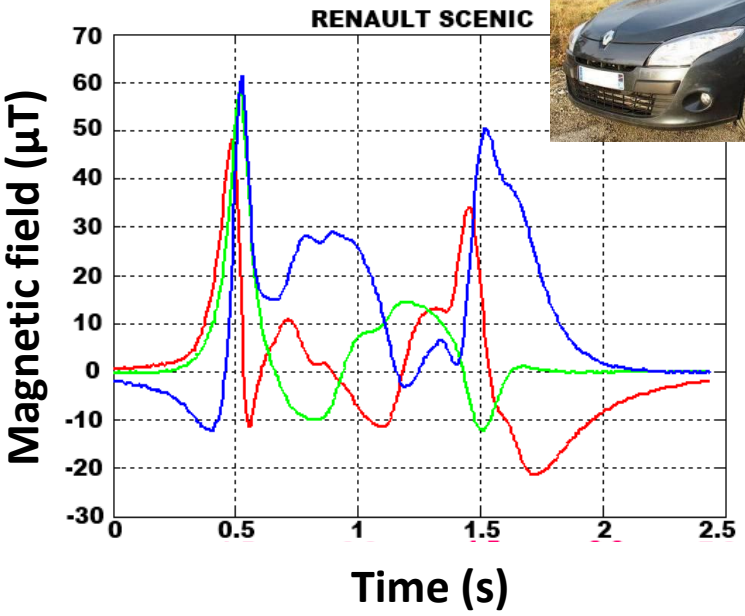
Material

- Data post-processing
  - From temporal to spatial signatures
  - Vehicle speed estimation





Signatures clearly different



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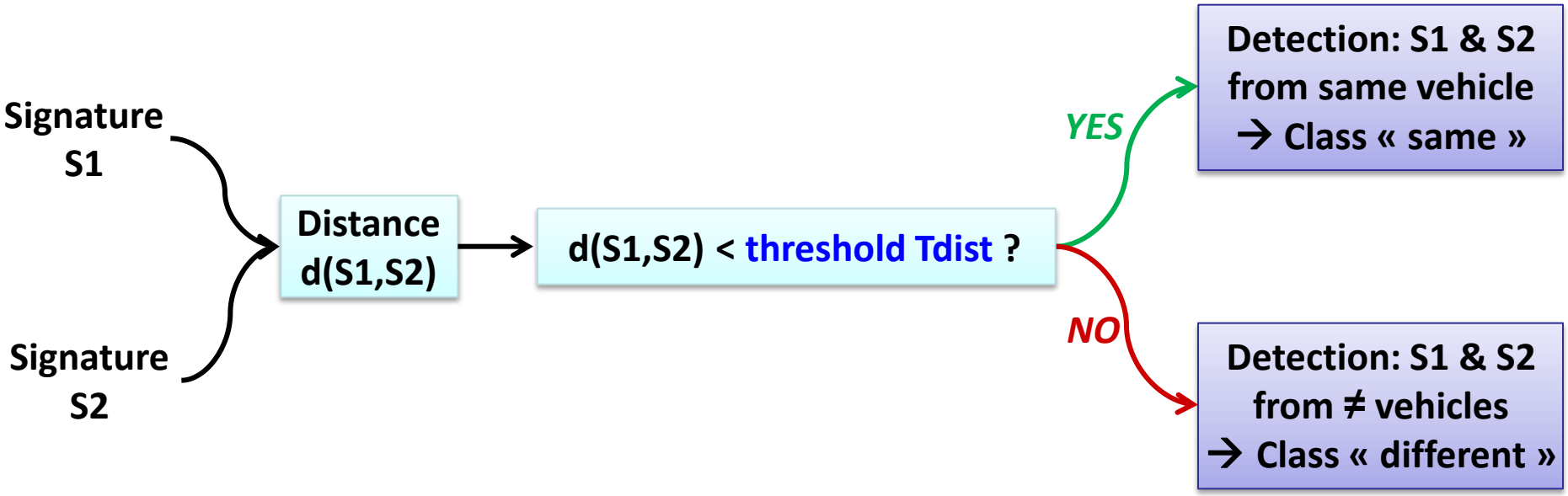
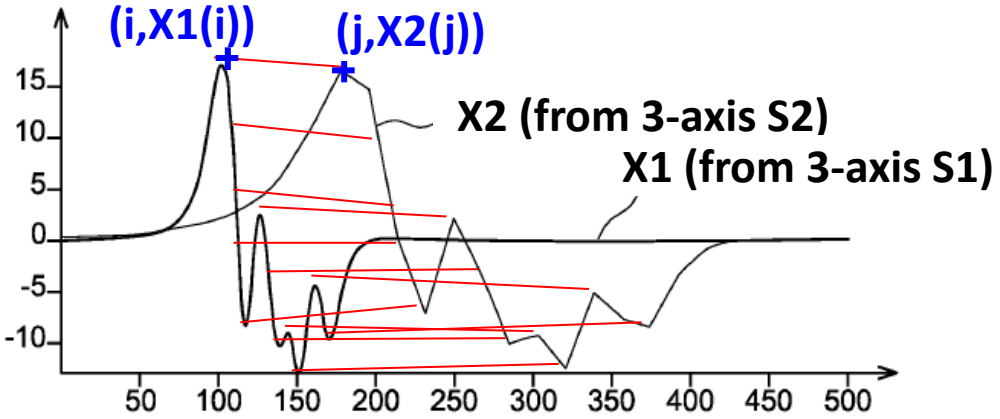
Re-identification methods

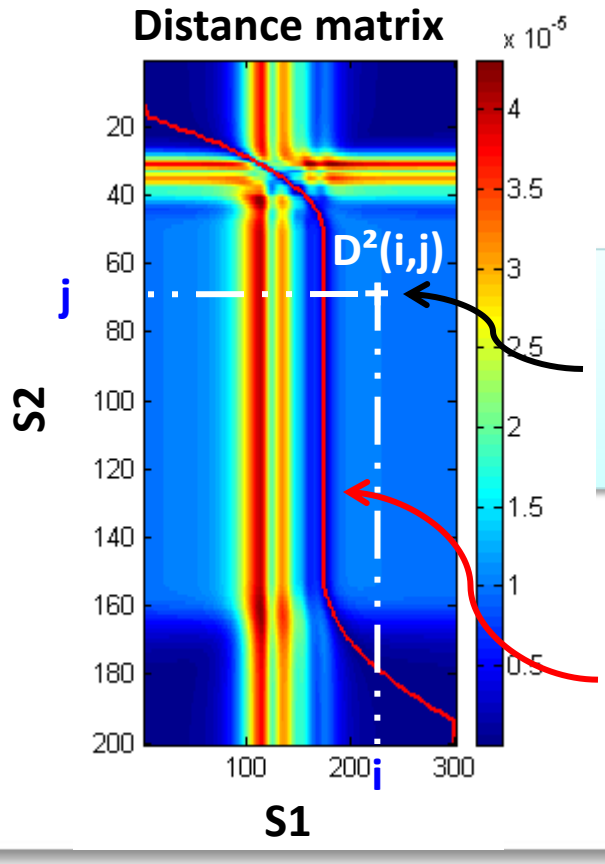
- Detectors
  - Two classes: « same » & « different »
  - Decision rules:



Re-identification methods

- Distances
  - DTW – temporal S1,S2





Three-dimensional:

$$D^2(i,j) = \frac{\left(X_1(i) - X_2(j)\right)^2 + \left(Y_1(i) - Y_2(j)\right)^2 + \left(Z_1(i) - Z_2(j)\right)^2}{3}$$

Optimal path between S1 and S2

DTW distance: $\sum_{optimal\,path} D^2(i,j)$

Re-identification methods

- Distances
  - Euclidean distances – spatial S1,S2

Three Mono-dimensional: X,Y,Z
Three Bi-dimensional: XY,YZ,XZ
A Three-dimensional: XYZ

Mono-dimensional:

$$distX = \frac{1}{lsign} \cdot \sum_{i=1}^{lsign} \left| Bx_1(i) - Bx_2(i) \right|$$

Bi-dimensional:

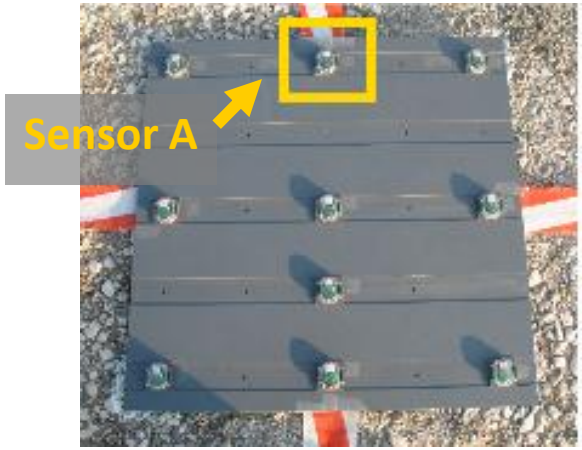
$$distXY = \frac{1}{lsign} \cdot \sum_{i=1}^{lsign} \sqrt{\left((Bx_1(i) - Bx_2(i))^2 + (By_1(i) - By_2(i))^2 \right)}$$

Three-dimensional:

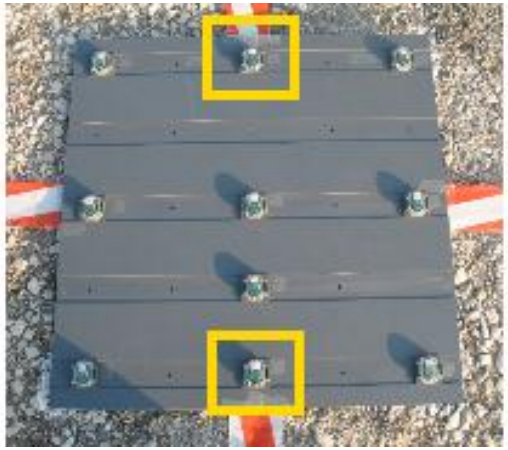
$$distXYZ = \frac{1}{lsign} \cdot \sum_{i=1}^{lsign} \sqrt{\left((Bx_1(i) - Bx_2(i))^2 + (By_1(i) - By_2(i))^2 + (Bz_1(i) - Bz_2(i))^2 \right)}$$

Re-identification methods

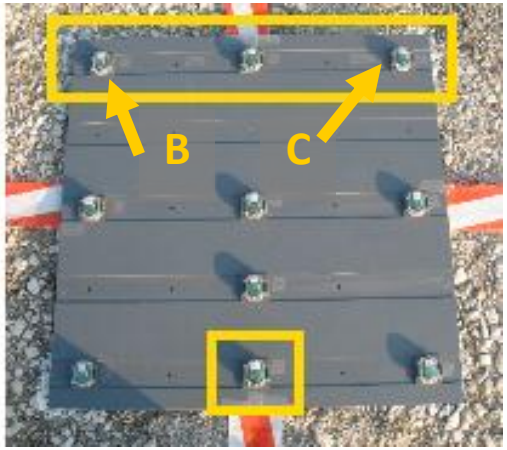
- Distances
  - Euclidean distances – spatial S1,S2
  - Two or four sensors:



DTW distance
A single sensor
S1 <= s(A)



Euclidean distances
Two sensors
S1 <= s(A)



Euclidean distances
Four sensors
S1 <= sum(s(A), s(B), s(C))

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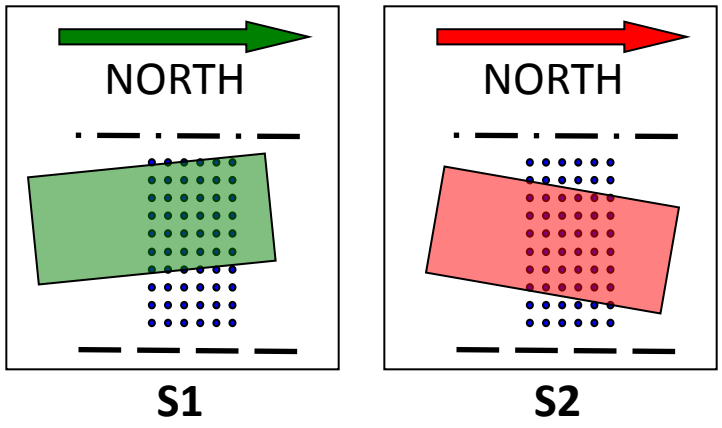
Experimental results
Evaluation methods

- Pairs of signatures (S1, S2): measured…
  - … from the same vehicle, or not

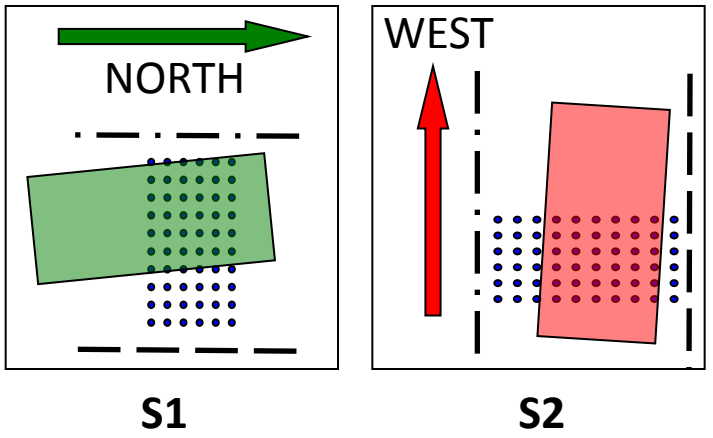
eg. 66 NS signatures:
92 « same » pairs
2053 « different » pairs

  - … with the same traveling direction, or not

… *same* orientation: eg. SN / SN



… *different* orientations: eg. SN / EW



Experimental results
Evaluation methods

- Detection curves: TD-PE curves
  - For each threshold Tdist:

(S1,S2) … Reality / … Decision	92: same vehicle	2053: ≠ vehicles
Є "same"	a	b
Є "different"	c	d

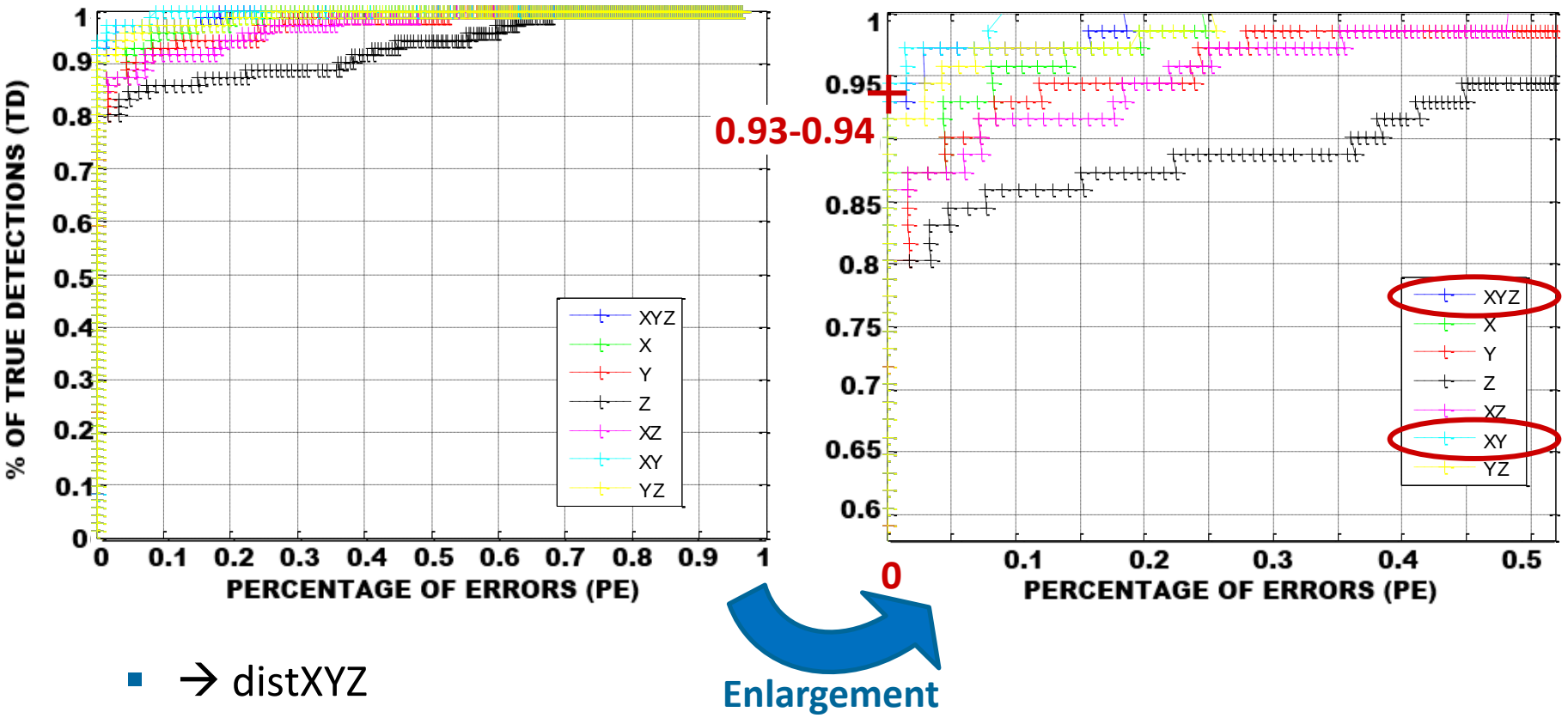
PE = b/(b+a)

TD = a/(a+c)

  - → plotting TD-PE curves by varying the threshold Tdist

Experimental results
Evaluation methods

- Detection curves – example on NS/NS signatures
  - Euclidean distances



  - → distXYZ

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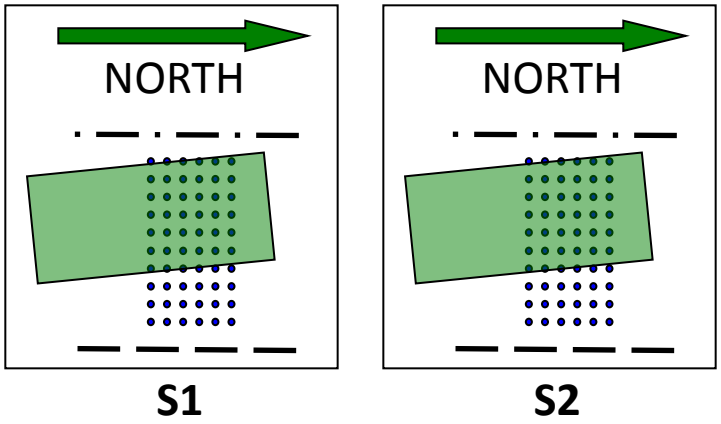
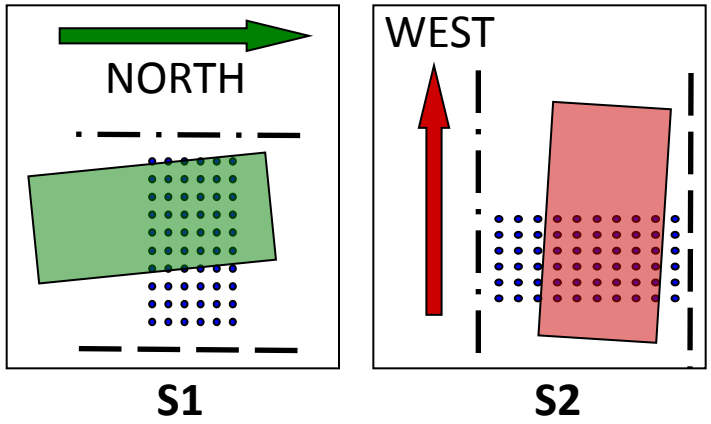
Experimental results
Performances

- Parameters
  - Effect of the number of sensors?
  - Effect of a change in vehicle orientation?
    - → Comparison: Results on pairs of signatures with ...

... *same* orientation: eg. SN / SN



... *different* orientations: eg. SN / EW

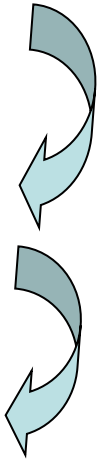


  - Effect of a change in the lateral position of the vehicle on the road?

Experimental results
Performances

- Number of sensors?

Method	*Number of sensors*	*Same orientation*	
		TD	*PE*
3D DTW	1	84%	1%
3D Euclidean distance	2	90%	0%
	4	100%	0%



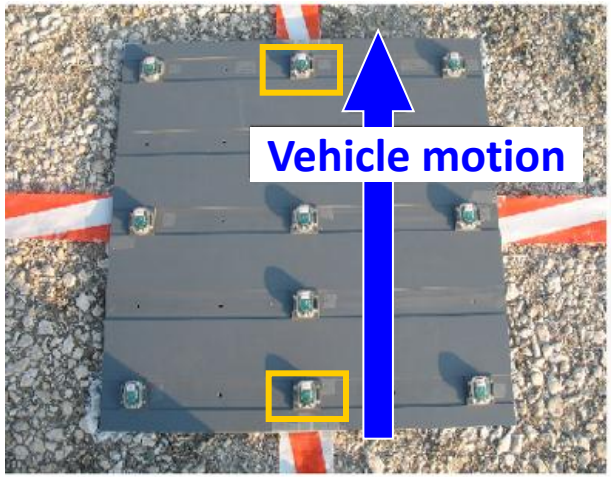
Experimental results
Performances

- Change in direction?

Method	*Number of sensors*	*Same orientation*		*Different orientations*	
		TD	*PE*	*TD*	*PE*
3D DTW	1	84%	1%	70%	5%
3D Euclidean distance	2	90%	0%	80%	0%
	4	100%	0%	90%	0%

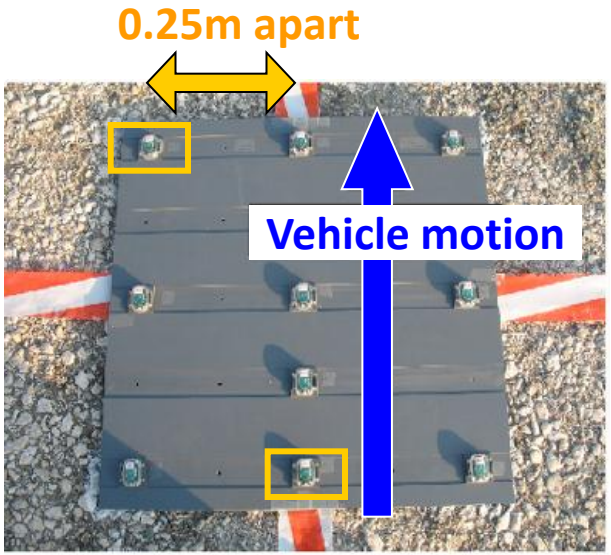
Experimental results
Performances

- Effect of a change in the lateral position of the vehicle on the road?
  - Simulation: shift of 0.25m



S1

Versus



S2

  - ➔ TD rate falls by about 60%

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Conclusion and Future work

- Vehicle:
  - Permanent magnetization: dominant
- Comparison DTW / Euclidean distances:
  - Best results with 3D Euclidean distance
  - ⚠ at least two sensors
- ⚠ Affected by variations in lateral position:
  - Solved with sensors closer to each other?
  - ➔ Two new experiments:
    - Sensors 0.1m apart (March 2012)
    - Real traffic flow (June 2012)

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Thanks for your attention ☺

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Experimental results
Performances

- Detection curves – example on NS signatures
  - Euclidean distances & DTW3D distance