Navigation à l'estime: La marche intelligente

Valérie Renaudin
GEOLOC Lab
IFSTTAR

19 Novembre 2013
La localisation indoor – Angers

IFSTTAR

Research Motivation in IFSTTAR

Pedestrian Dead Reckoning: Smart Walk

Ubiquitous Solution with Sensor Fusion


French institute
of science and technology
for transport, development and networks

KEY FIGURES

1 250 **employees**

9 **locations** in France

5 **departments**

380 **PhD students**

120 M€ **budget** in 2012

17 M€ genereated from **research contracts**

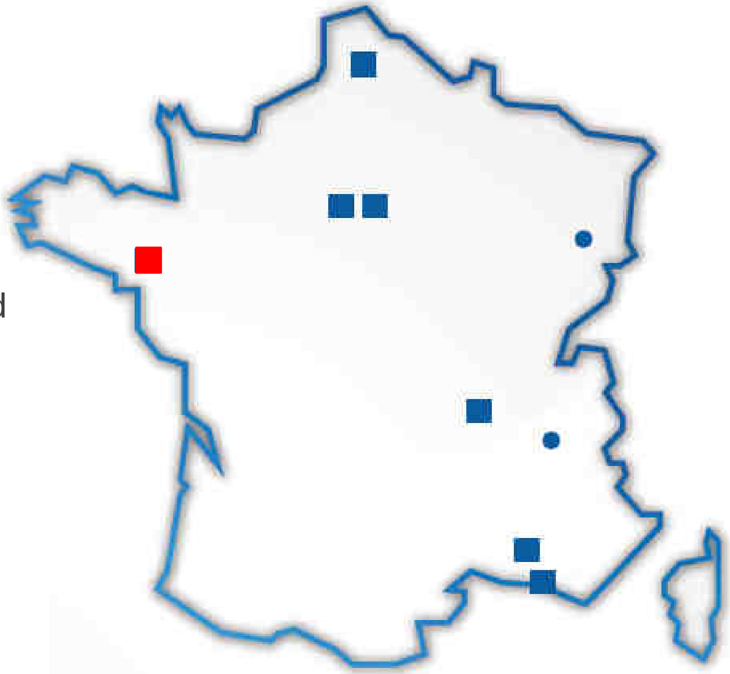
79 **European projects**

76 **patents**

350 **publications** in international reviews in 2010

50 exceptional **scientific facilities**

5 persons in **GEOLOC** laboratory



Scientific Strategy for the Decade

Axis 1 Imagining sustainable mobility

Axis 2 Adapting the infrastructure

Axis 3 Managing and controlling natural hazards impacts, environmental impacts

Axis 4 Imagining future cities and land use planning

Research in GEOLOC Lab

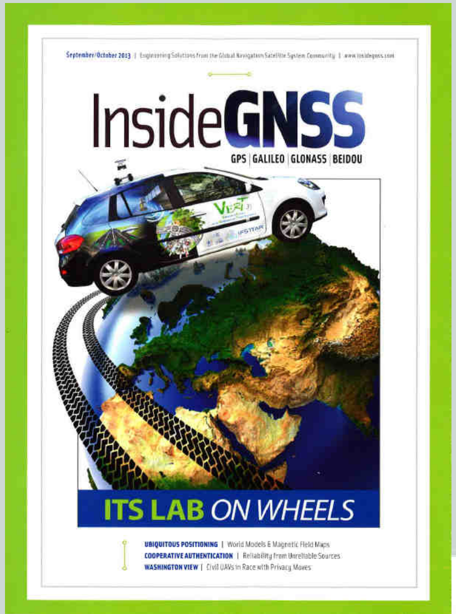
Axis 1

1 Geopositioning Quality of Service for ITS

2 Personal Navigation for multimodal transport

Axis 2

Axis 3



Source: www.republicain-lorrain.fr

Motivation & Objectives

- Develop accurate, available and continuous navigation services in GNSS denied environments for general public

- Application field: Multimodal Transport Services: Promote Active Transport

Motivation & Objectives

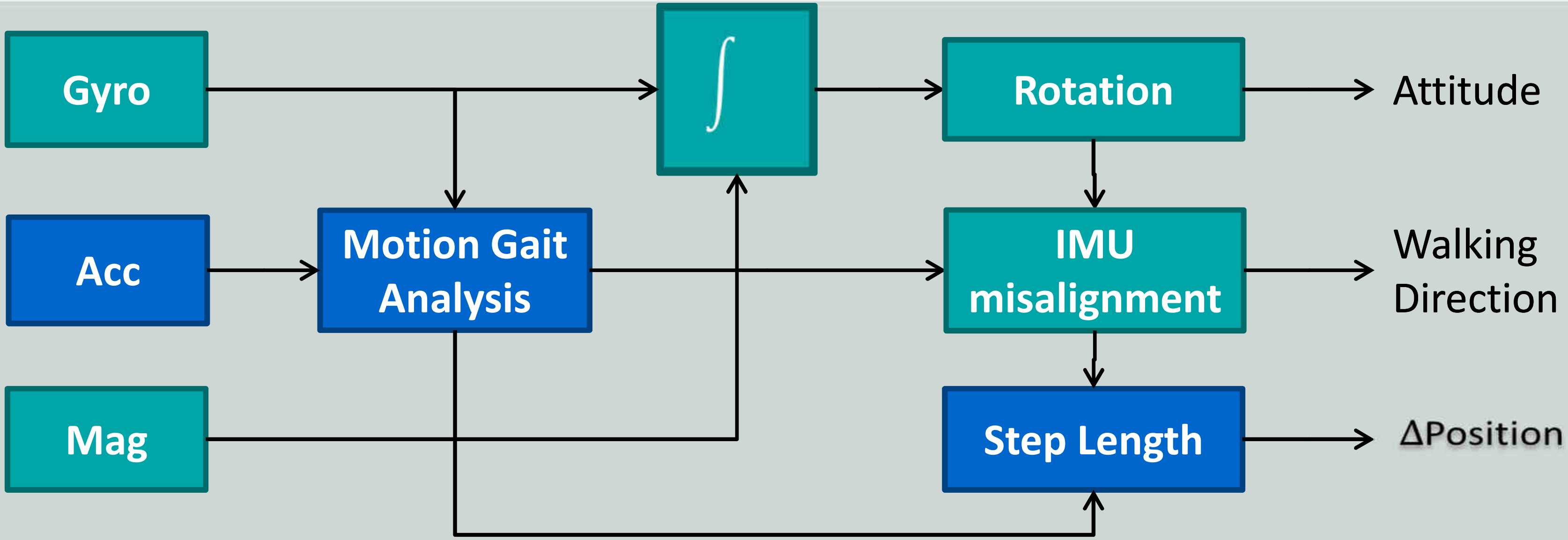
- Propose autonomous solutions based on Accelerations, angular rates and magnetic field signals
- Adopt a Pedestrian Dead Reckoning (PDR) navigation strategy with freely carried handheld devices
- Exploit walking gait features sensed with low cost inertial mobile unit (IMU) in hand
- Hybridize with GNSS signals prior to penetrating indoors or even inside buildings

Research Motivation in IFSTTAR

Pedestrian Dead Reckoning: Smart Walk

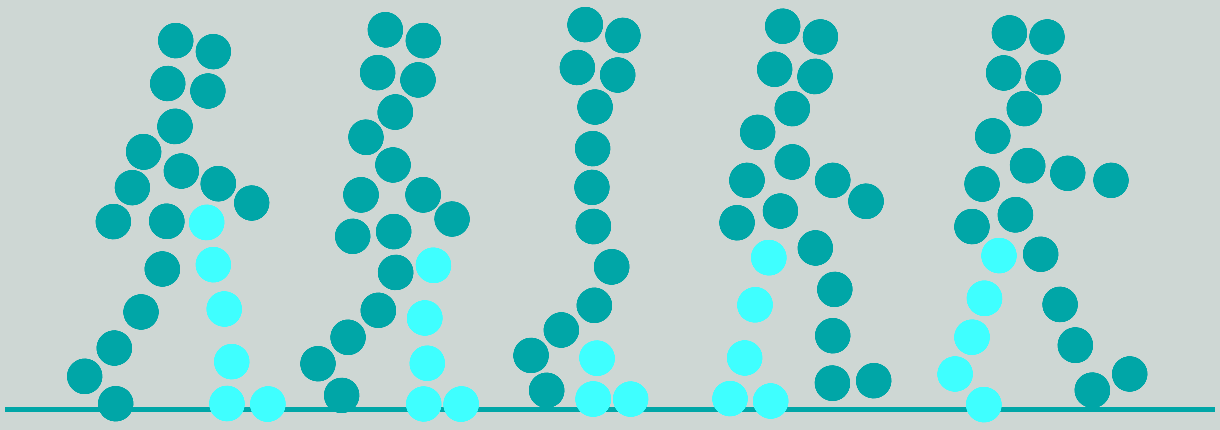
Ubiquitous Solution with Sensor Fusion

Pedestrian Dead Reckoning (PDR)



- Dead Reckoning (DR) based on traditional ‘strapdown’ mechanization equations for attitude estimation
- Changing misalignment between Attitude and Walking Direction with handheld sensor

Human Walking Gait

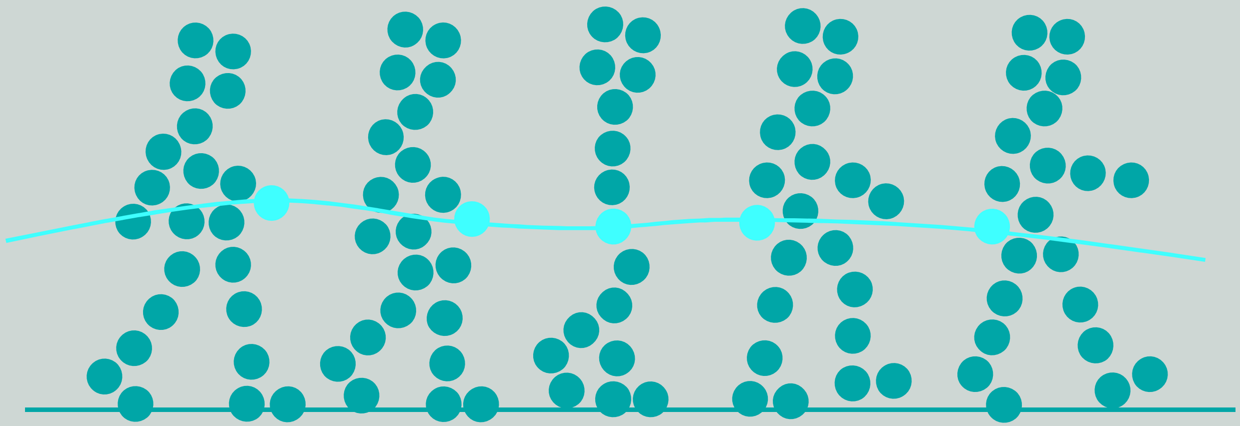


- PDR strategy exploits human walking gait features
- The closest to the foot the better:

  Waist, on foot: a mature technology
- Sensor calibration during stance phase:

  Zero Velocity Update (ZUPT), Zero Angular Rate Update (ZARU), Principal Building Directions, Trunk Roll Constraint

Biomechanics with Handheld Sensor



- Hand motion can hide the global pedestrian motion

  ‘body fixed’ methods can not be applied
- Handheld based PDR algorithms for freely carried devices can take several forms depending on the sensors and the context
- Common Assumption

  The user is watching the screen while walking ~ ‘body fixed’ like case

Limitations of PDR

Walking Direction

Body fixed like IMU

Attitude angles + Fixed Misalignment

Errors can be mitigated

by zero velocity updates

Handheld IMU

Attitude angles + Changing orientation relative to the Trunk

Errors can be mitigated by

GNSS signals, Magnetometers,

Sensor arrays, Opportune RF signals

Distance traveled

Body fixed like IMU

Step length estimation with “strapdown” mechanization

Errors can be mitigated

by zero velocity updates

Handheld IMU

→ Step length estimation with model relating steps to signal features, physiological parameters

Errors can be mitigated by

Complementary measurements

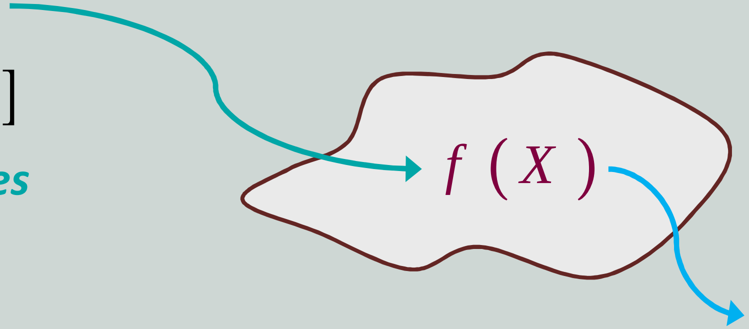
Adaptive modeling

Motion and Carrying Mode Recognition

Input Space

$$X = [x_1, x_2, \ldots, x_n]$$

IMU Signal Features



Decision Rule:

$$X \rightarrow f(X) \rightarrow y_k \in Y$$

mapping function

Classifier

Output Space

$$y_{k \in \{1,m\}} \in Y = [y_1, y_2, \ldots, y_m]$$

- Adapt the navigation algorithms to the user context to bound the pedestrian position
- A classification Problem

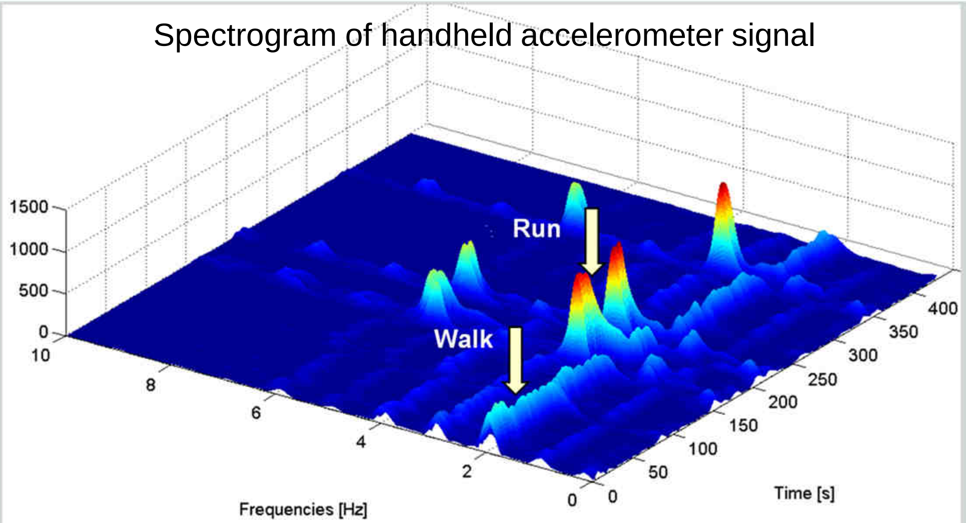
  Pre-processing → Feature extraction → Decision Making
- Motion States

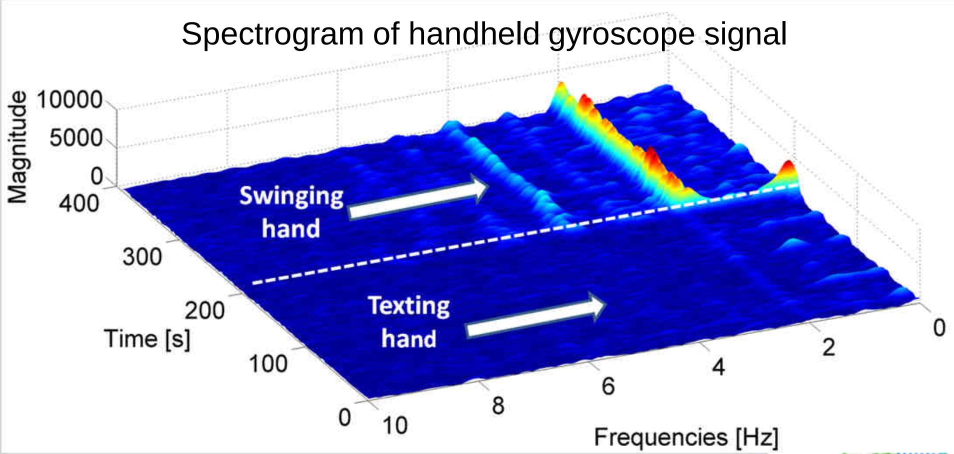
  User: Standing, Running, Walking, Up/Down Stairs

  IMU/Hand: Phoning, Texting, Bag Carrying, Swinging, **Irregular Motion**

Frequency/Time Analysis

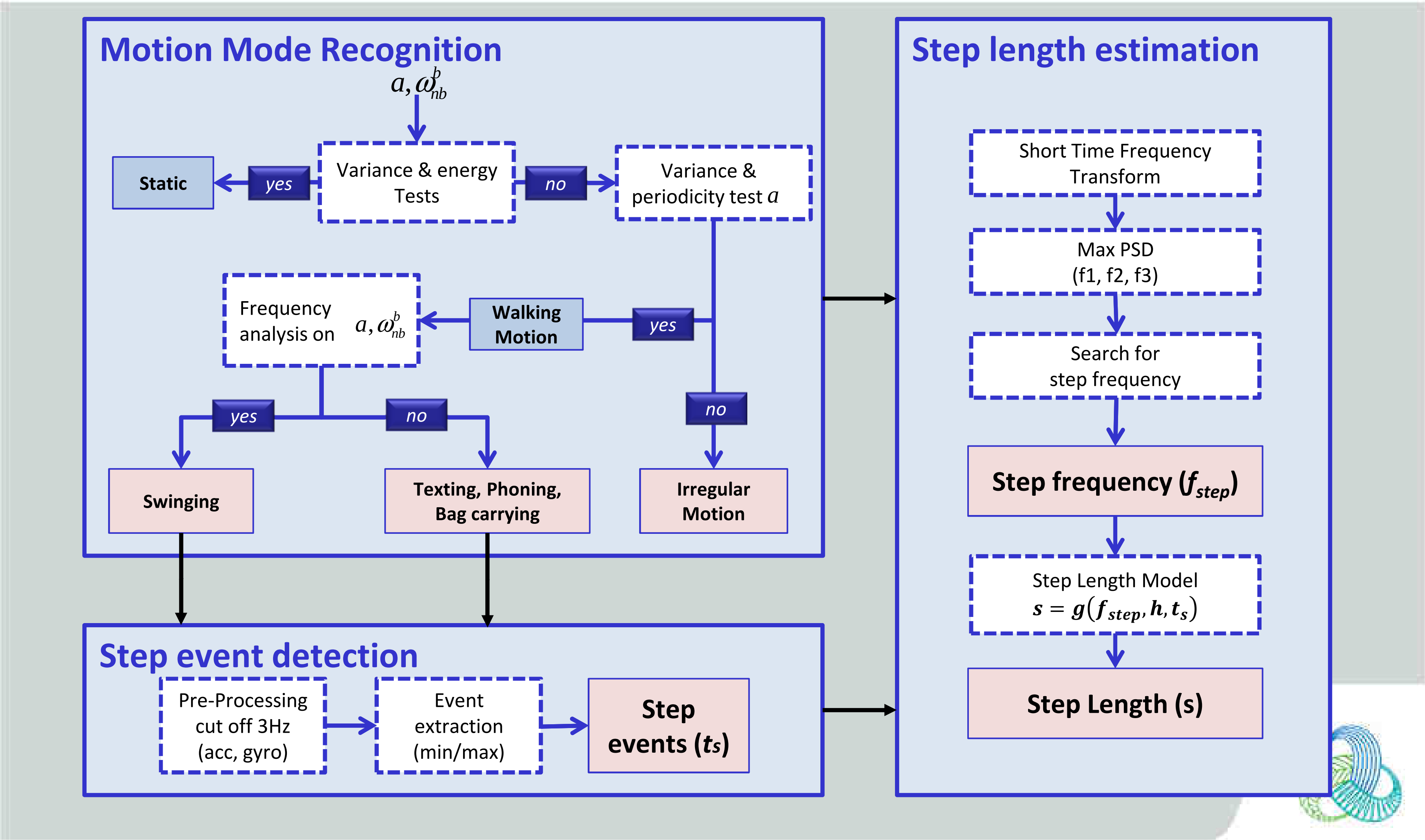
- Feature selection: energy, variance, standard deviation, frequencies in sub-bands
- Faster Motion modes migrate the signal energy toward highest frequencies (acc. signal)
- Periodic arm rotation induce frequency peaks (gyro signals)





Source: Ref [3]

Step Length Estimation in 3 phases

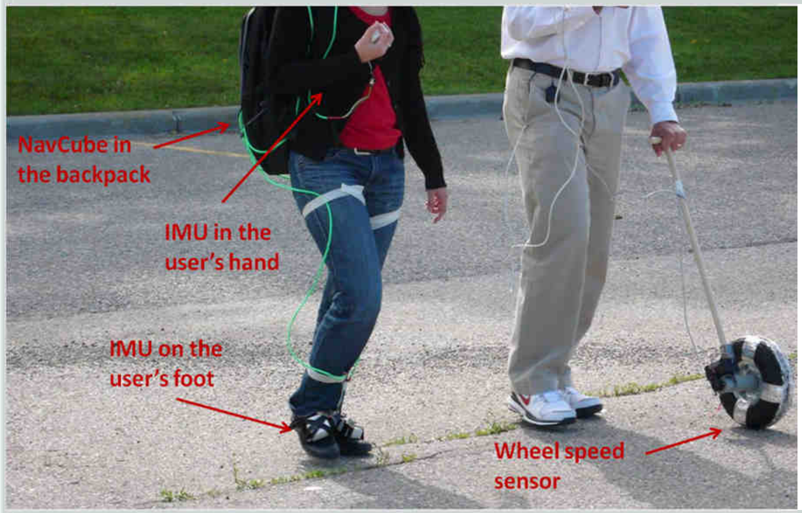


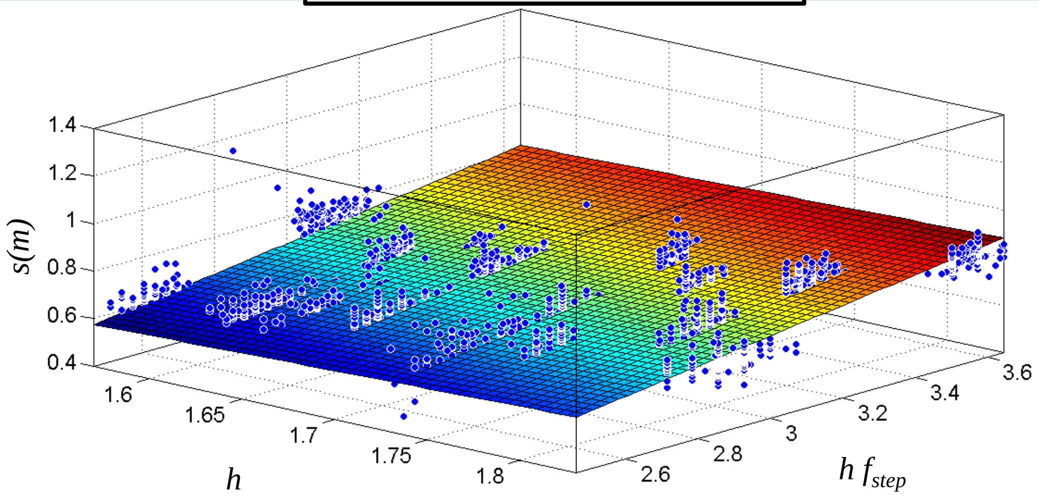
Step Length Model

- Step length model performance depend on the sensor fixation point
- Experimental approach with controlled walking pace

$$s = h \cdot (a \cdot f_{Step} + b) + c \text{ with } K = \{a, b, c\} \in \mathbb{R}$$

- Universal
- Calibrated





Step Length Model Assessment

Subject	%P_{det} (motion)	%P_{det} (steps)	% Distance Travelled		Covergence Iterations
			Universal Model	Fitted Model	
M1	100	99	5.8	5	4
M2	100	100	4.8	4.3	3
M3	99	100	5	4.5	3
M4	100	99	8	4.2	6
M5	100	100	9	3.8	7
W1	98	97	5.2	4.3	4
W2	100	100	3.2	2.5	3
W3	98	99	4.5	4	3
W4	100	98	5.6	5	3
W5	100	100	5.8	5	4
Mean	99.6	99.2	5.7	4.2	4

- Reference path and estimated trajectories for the test subject with the worst performance (M5)
- Mean error of 5.7% over 600 m distance travelled

Research Motivation in IFSTTAR

Pedestrian Dead Reckoning: Smart Walk

Ubiquitous Solution with Sensor Fusion

Ubiquitous in time

- Walking Gait influenced by varying physiological conditions tiredness, injuries, carrying a bag, …

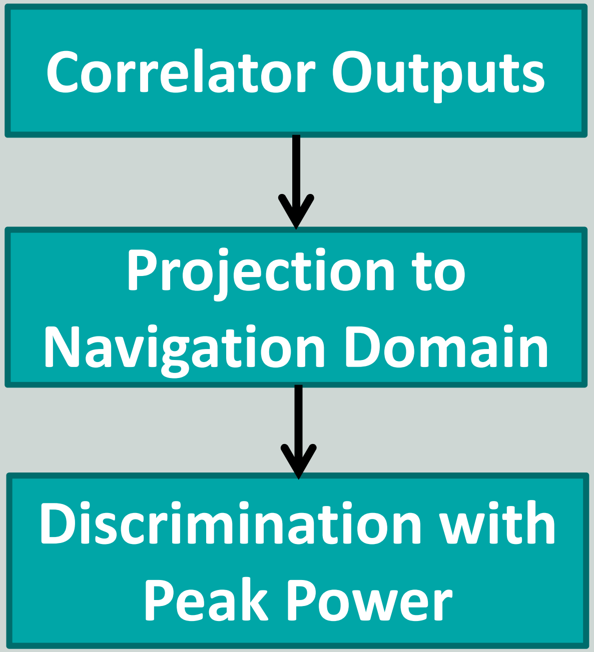
Source: http://www.blogtrepreneur.com/

→ **Frequent calibration is needed**

- Several approaches are possible depending on the application
  - Walking along a known footpath
  - Use departure / destination info
  - Hybridization with opportune signal

GNSS Doppler Update

- PDR/GPS Doppler EKF designed for handheld device
  - Pseudorange measurements strongly perturbed indoors (multipath, echo only)
  - Doppler (phase rate) errors depend on pedestrian velocity in the presence of multipath
  - Direct Vector GNSS Receiver architecture proposed with discriminator implemented in the position/velocity domain



Adaptive to Physiological Variations

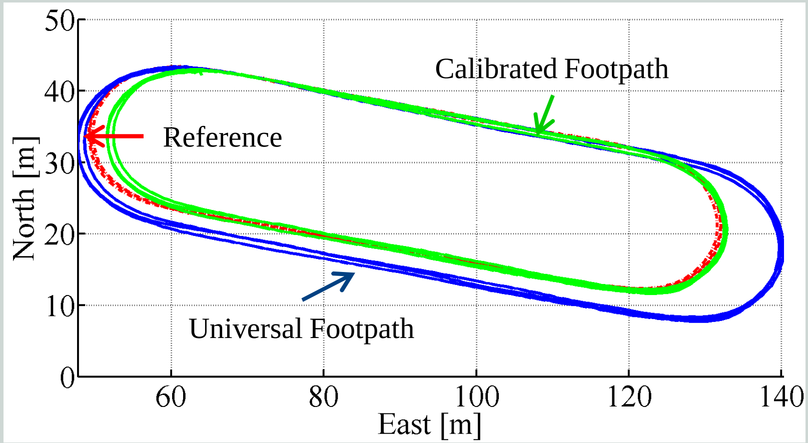
- 10 sec. PDR/GPS Doppler calibration prior to penetrating indoors

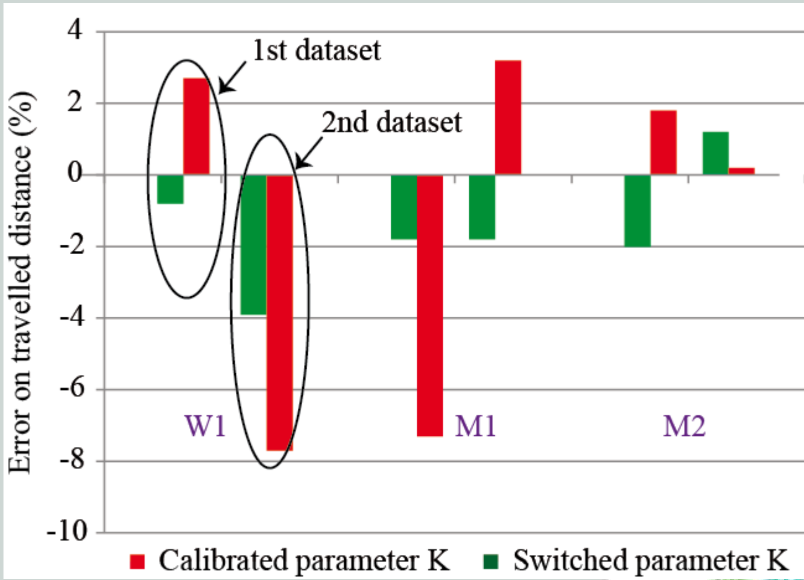
- Free inertial PDR trajectory estimated with

$$s = h \cdot (a \cdot f_{Step} + b) + c$$

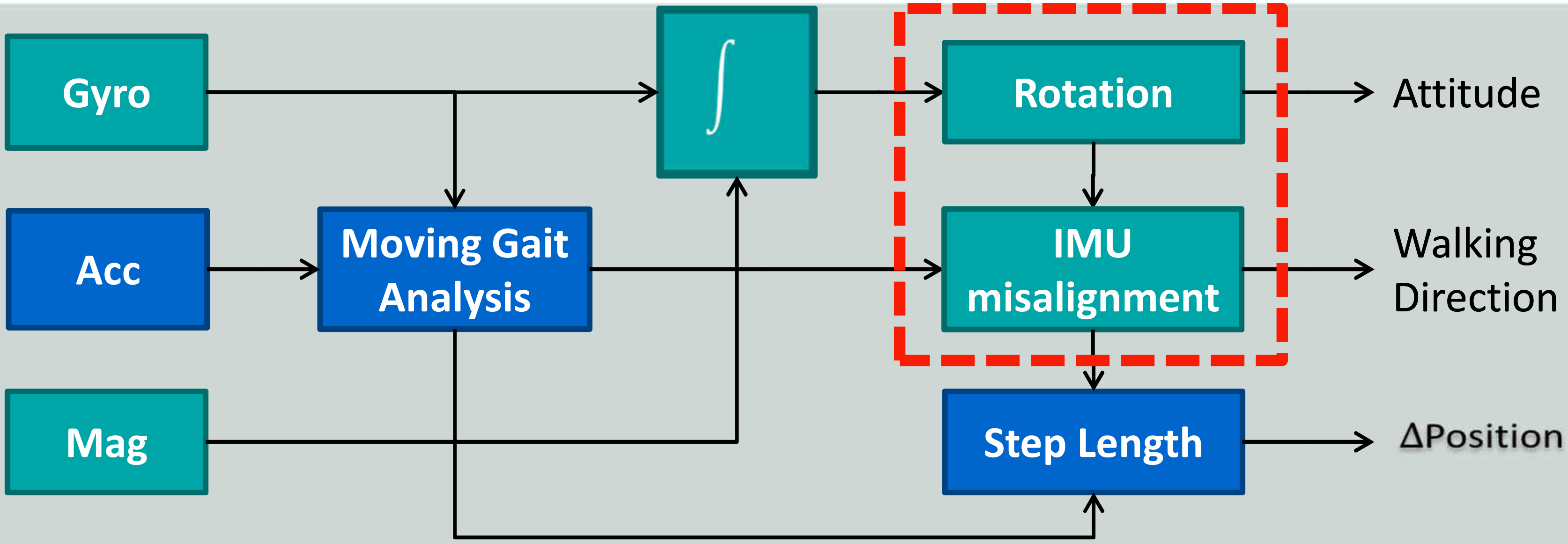
$$K = \{a, b, c\} \in \mathbb{R}$$

- 700 m with freely carried device (texting, swinging): 2% mean error over traveled distance



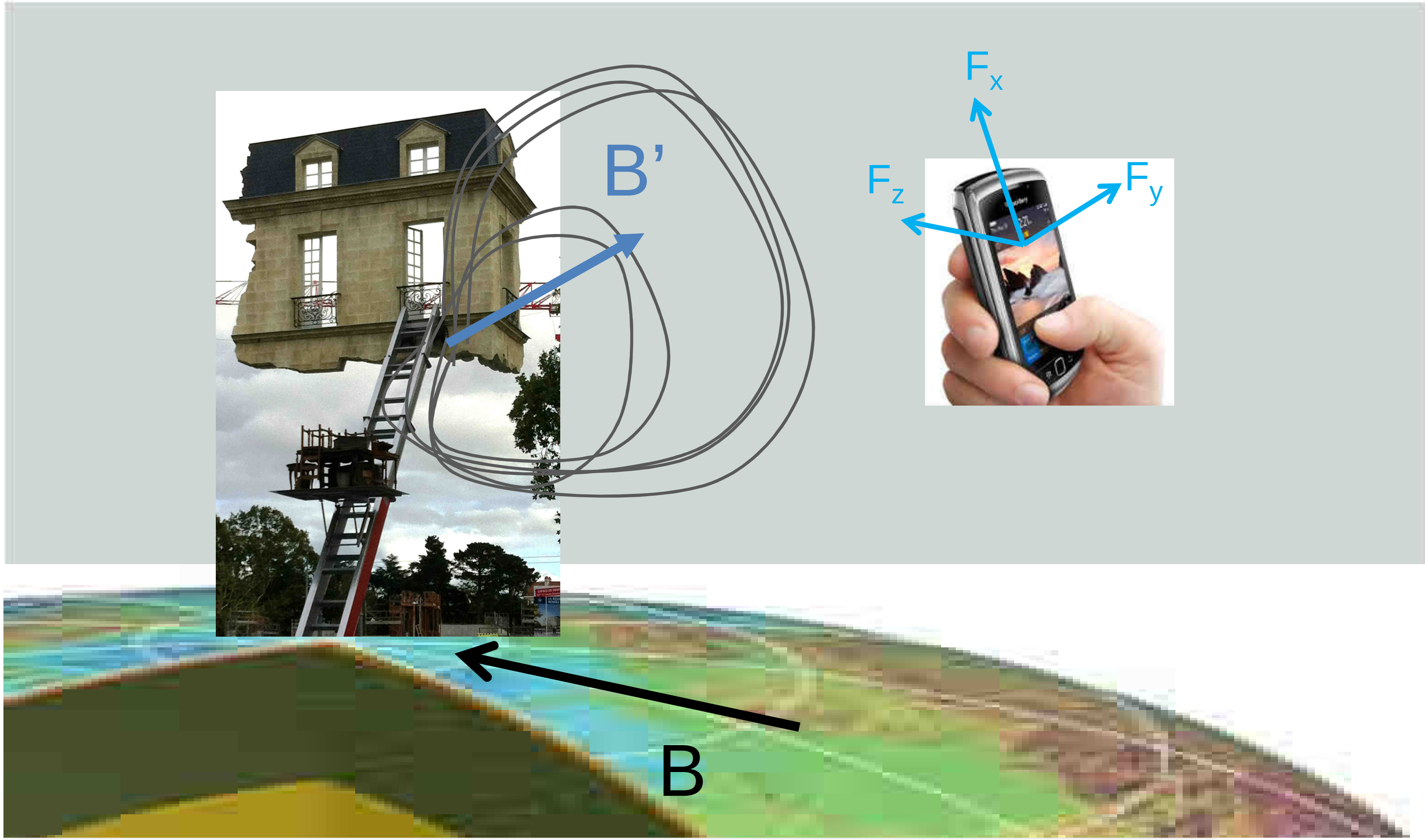


Walking Direction Estimation

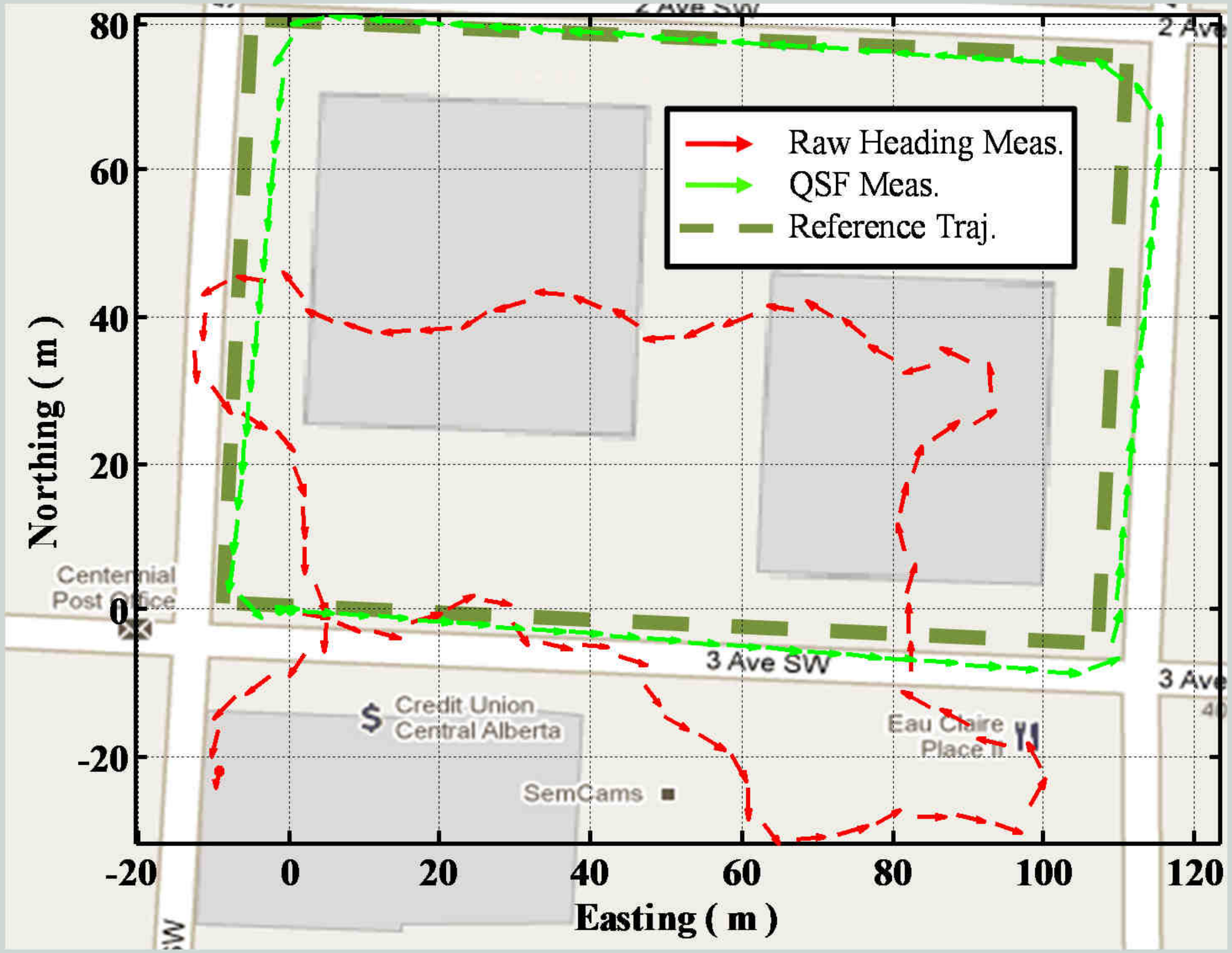


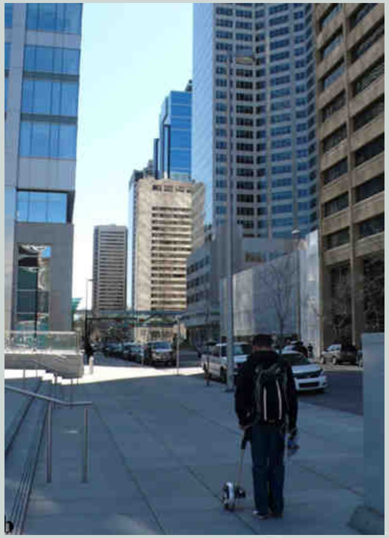
- PDR performance is limited by
  - azimuth which can be controlled by GNSS updates, Map constraints and **Magnetic Field**
  - IMU misalignment which requires dynamic estimation

Use perturbed magnetic field to mitigate gyroscope's errors



Magnetic Angular Rate Update





La navigation à l'estime va t-elle bouleverser nos habitudes ?

Valérie RENAUDIN
Ifsttar
GEOLOC Lab
Route de Bouaye - CS 4
44344 - Bouguenais Cedex
www.ifsttar.fr
valerie.renaudin@ifsttar.fr

IFSTTAR

References

1. Sivak, M. and Schoettle, B. *Update: Percentage of young persons with a driver's license continues to drop*. Traffic Injury Prevention, 13, 341, 2012
2. Susi, M., Renaudin, V., Lachapelle, G. *Motion Mode Recognition and Step Detection Algorithms for Mobile Phone Users*. Sensors 2013, 13, 1539-1562.
3. Renaudin, V., Susi, M., Lachapelle, G. *Step Length Estimation Using Handheld Inertial Sensors*. Sensors 2012, 12, 8507-8525.
4. Z. He, V. Renaudin, M. G. Petovello, and G. Lachapelle, "Use of High Sensitivity GNSS Receiver Doppler Measurements for Indoor Pedestrian Dead Reckoning," Sensors 2013, 4303-4326.
5. M. H. Afzal, V. Renaudin, and G. Lachapelle, "Use of earth's magnetic field for mitigating gyroscope errors regardless of magnetic perturbation," Sensors 2011, 11390-11414.