

Active transport: a new challenge for indoor navigation

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IFSTTAR



Few Words About IFSTTAR

Research for Sustainable Transport

General Public Navigation

Handheld Sensor Based
Pedestrian Dead Reckoning

Conclusion





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

1 250

employees

9

locations in France

5

departments

380

PhD students

120

M€ budget in 2012

17

M€ generated from research contracts

79

European projects

76

patents

350

publications in international reviews in 2010

50

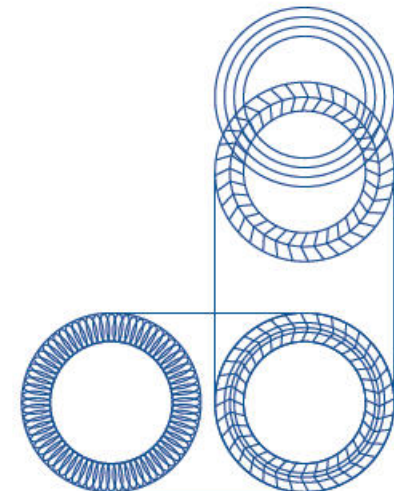
exceptional scientific facilities

5

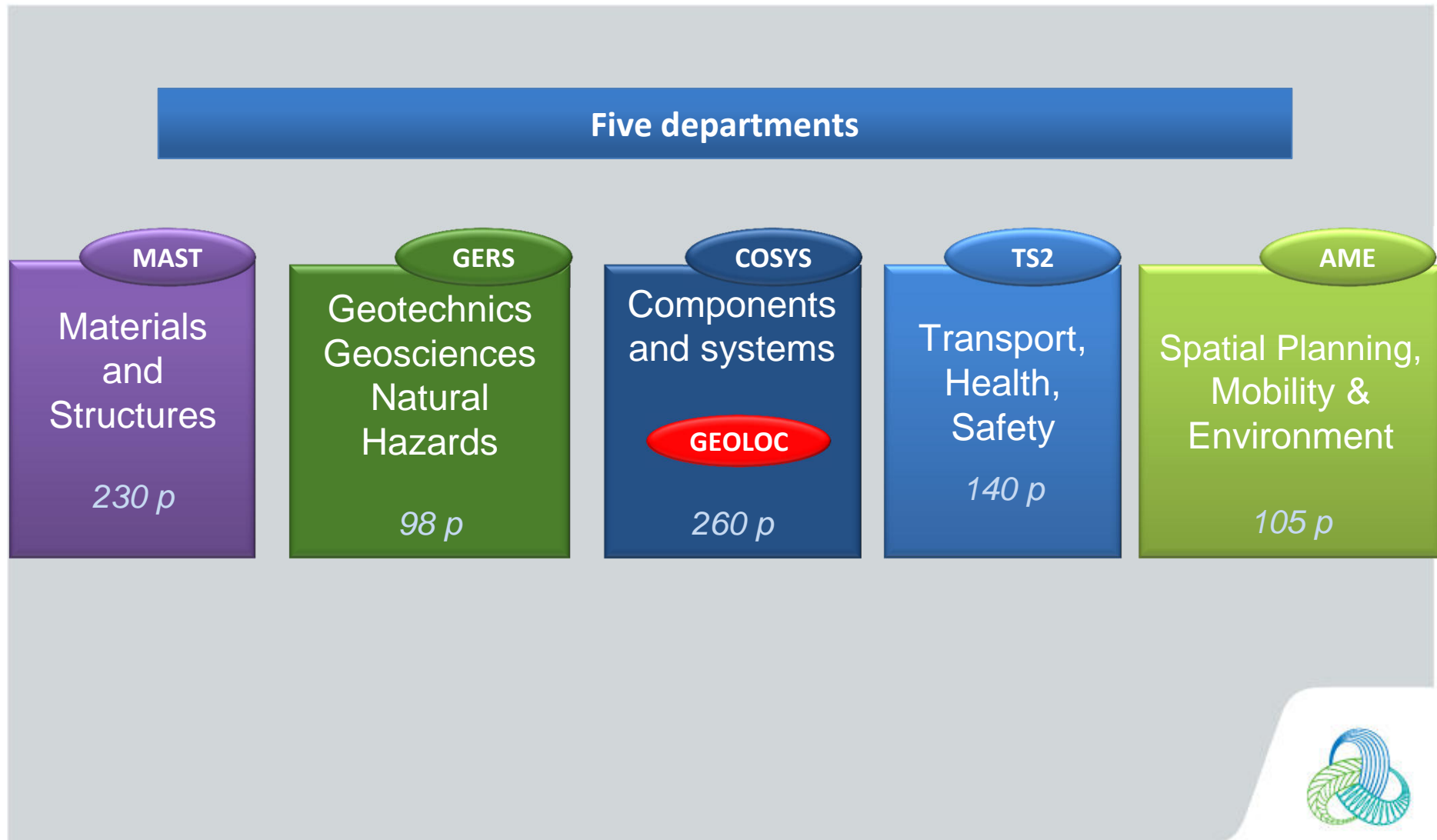
persons in GEOLOC laboratory



KEY FIGURES



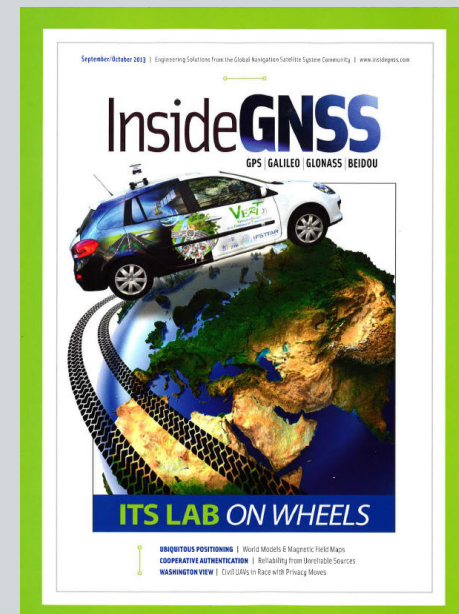
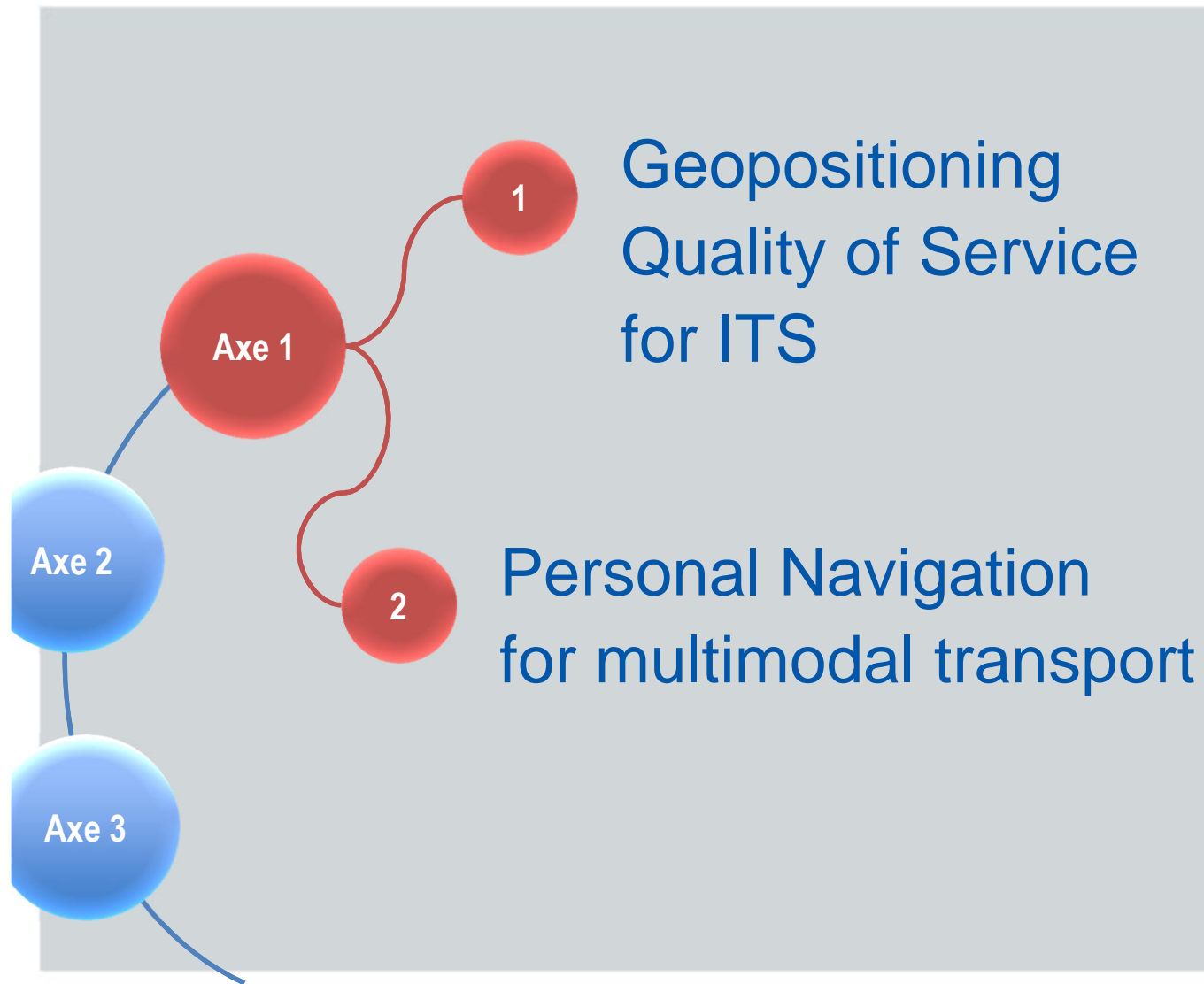
Governance and organization



Scientific Strategy for the Decade



Research in GEOLOC Lab



Source: www.republicain-lorrain.fr



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Background and Motivation

- The economic crisis around the globe & Europe raised new challenges: Next EU Framework Program for Research and Innovation (2014-2020) of targeting some of them
 - Tackle demographic trends: ageing phenomena
 - Propose an Inclusive Society
 - Develop Green Cities: promote sustainable transport, reduce energy consumption and low carbon emission
 - Improved safety in personal mobility: avoid car/bike/pedestrian collision



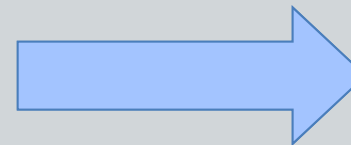
Invent solutions to get people moving



Source: www.lemonde.fr/sciences/article/2013/10/07/geolocalisation-naviguer-dans-les-murs_3491350_1650684.html

Definition

- **Active Transport:**
transport modes implying physical activity performed by foot, bicycle and other non-motorized vehicles
- It includes Public Transport
some walking/cycling to pick-up destinations & from drop-off points is needed



Multimodal Transport
Strategies



Active Transport: a solution?

- The benefits of active transport are both for the individual and the city



Improved health



Reduce congestion



money-saving



environmental friendly

- The soft modes of transport



Geolocalization for Active Transport

Indoor positioning and navigation is a driving force for promoting active transport

- Encourage walking for a better health
 - Better life quality
 - Less noise and air pollution
 - Being less stressed
- Provide true complementarity between all modes of transport
 - Walk, bike, public transit and private cars
 - Secure the parts of traveling on foot
 - Improve public space sharing



Support Travelers

- **Support Multimodal Exchange Terminal**
 - Switch from one person in a private car to a wide range of transport services
 - Assist the pedestrian beyond signposting
- **Manage individual mobility at personal level**
 - Relieve the pressure on the roads
 - Encourage active transport with smart charging for the use of infrastructure and public transit at the scale of individuals



Source: <http://projets-architecte-urbanisme.fr/>



Geolocated Information



- Support Advanced Traveler Information System (ATIS)
 - Customize the information: too much info kills the info!
 - Contribute to data filtering from crowdsourcing: one location = one feature
- Privacy Issues?



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Location & Ethics

- European Parliament (LIBE commission) reforms General Data Protection Regulation to protect individual from personal identification through data processing
 - “**personal data** means any information relating to an identified or identifiable natural person (...) in particular by reference to (...) **location data** (...)”
 - >3000 amendments
 - LIBE committee vote planned in this month
- Scientific challenges
 - Different if technological or juridical solution: autonomous data processing or anonymous by software
 - Data provided by a “Trusted” Party



Source: www.europarl.europa.eu/committees/en/libe/home.html



Inclusive Society

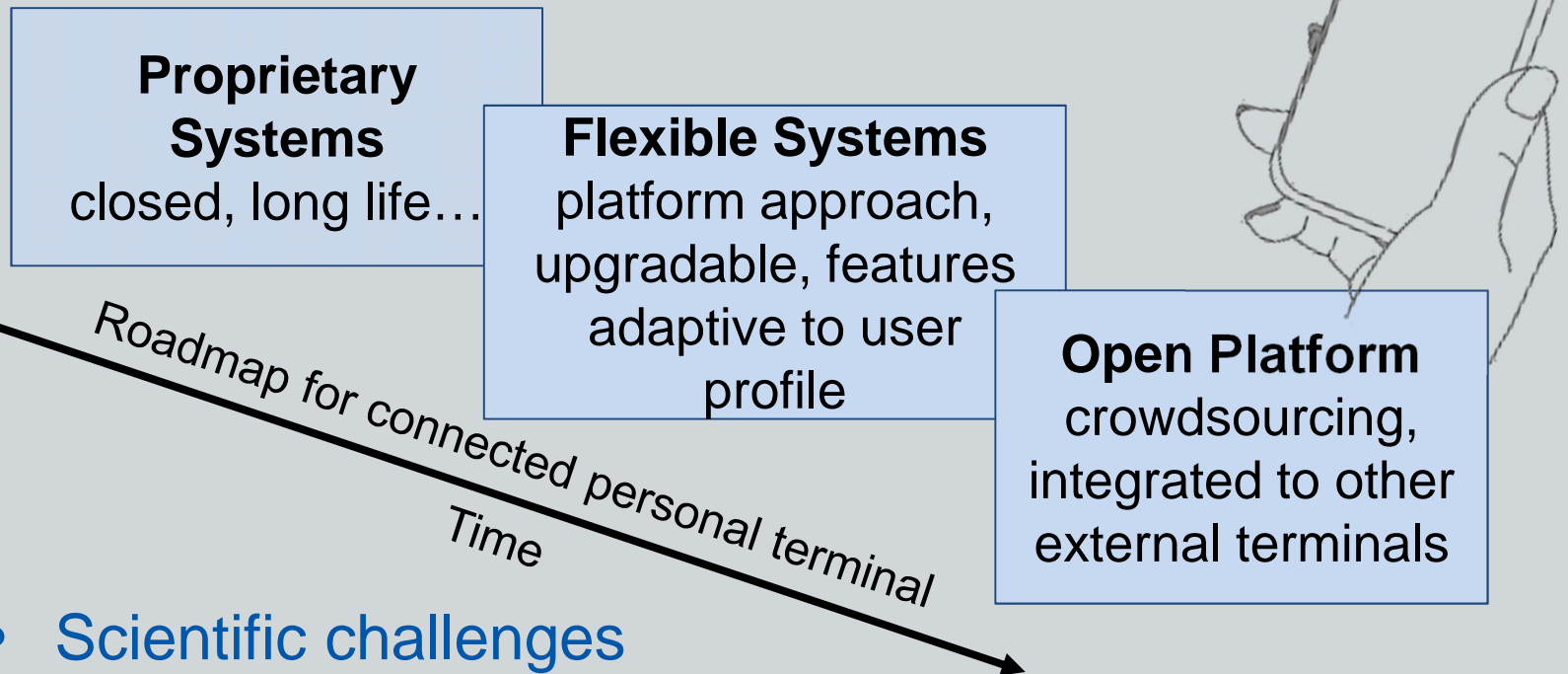


- Social Inclusion means:
 - People have access to needed services and facilities in their local area or via affordable transport services which meet the needs of those who do not drive
 - 20% drop of 19 years old drivers 1987 and 2010 - Ref [1]
 - Location Based Services for all including handicap people, senior, etc.
- Scientific challenges
 - Adaptive to wide range of behavior: **ubiquitous in time**
 - Inertial Pedestrian Dead Reckoning processing working also for “non-standard” walking
 - Platform independent: different information sources



A Single Device?

- An everyday device user-friendly for all ages



- **Scientific challenges**
 - Parasite motions from sensor's location
 - Customized equipment



Cost effective

- Affordable solution for general public and the city
 - Less infrastructure based localization
 - Toward zero maintenance & service cost
- Scientific challenges
 - **Ubiquitous in space** (measurements): signals of opportunities, Maps, Inertial Mobile Unit, GNSS
 - Right balance between accuracy, reliability and availability



Autonomous solution: **Inertial Pedestrian Dead Reckoning with Handheld Sensors**

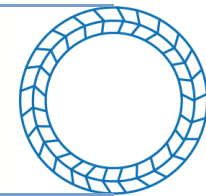


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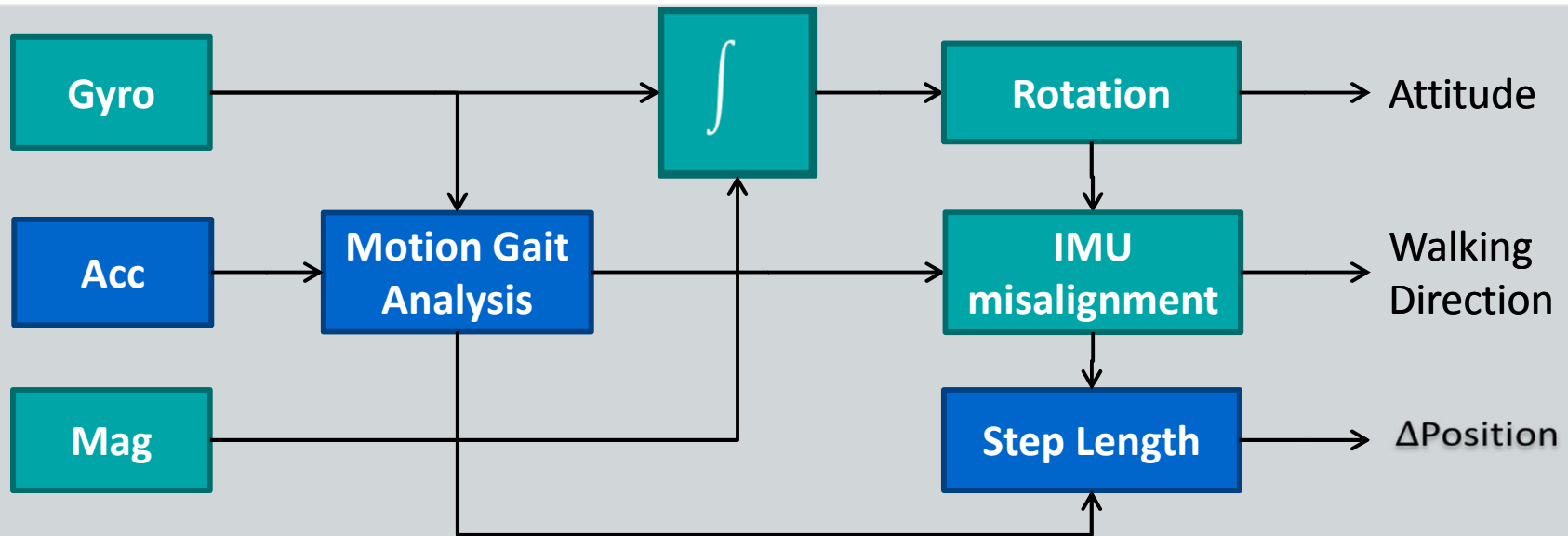
Handheld Sensor Based Pedestrian Dead Reckoning



Conclusion



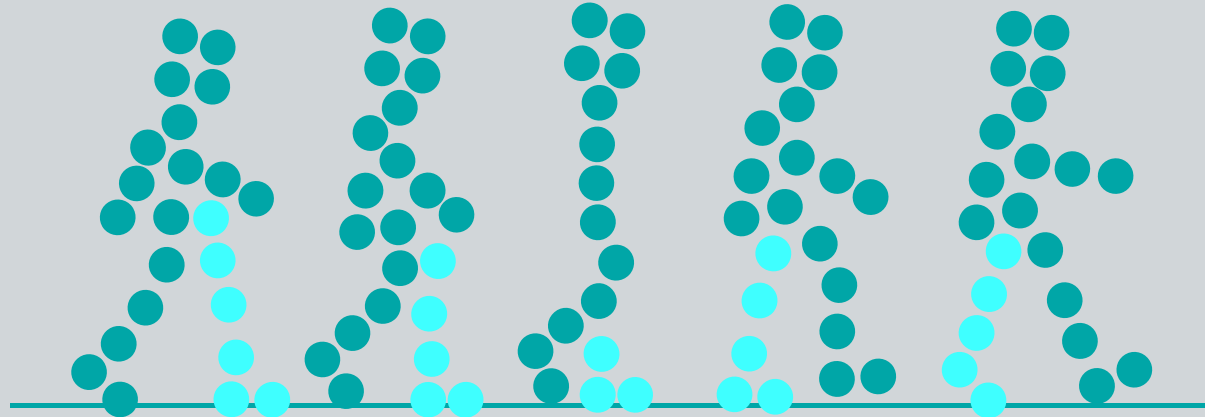
Pedestrian Dead Reckoning (PDR)



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



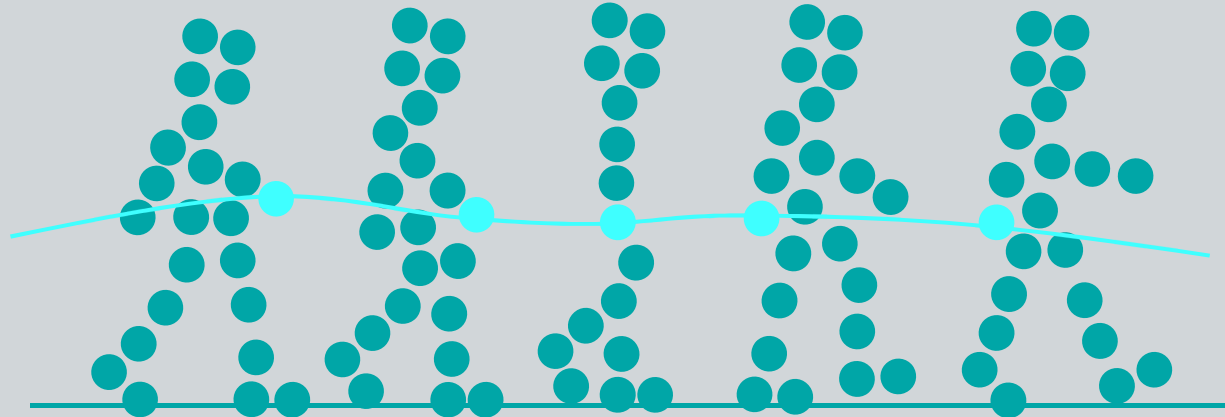
Human Walking Gait



- 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



Motion and Carrying Mode Recognition

Input Space

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

IMU Signal Features

Classifier

$f(X)$

Decision Rule:

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

mapping function

Output Space

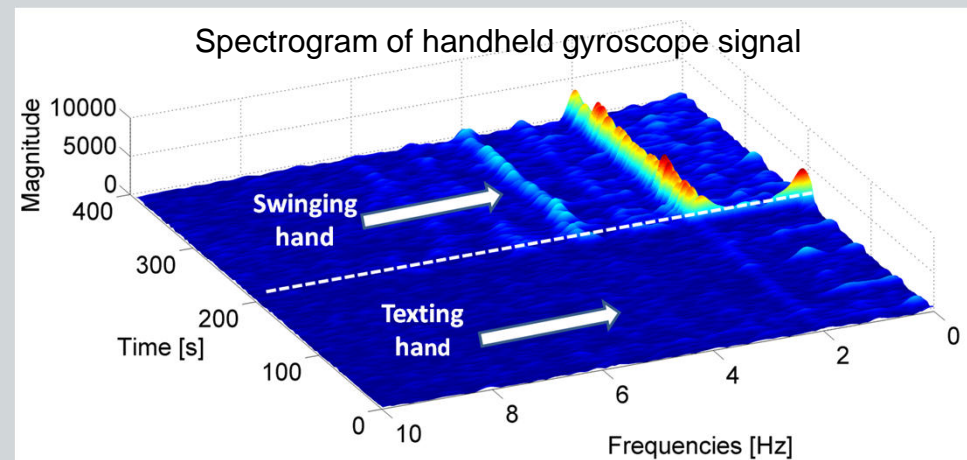
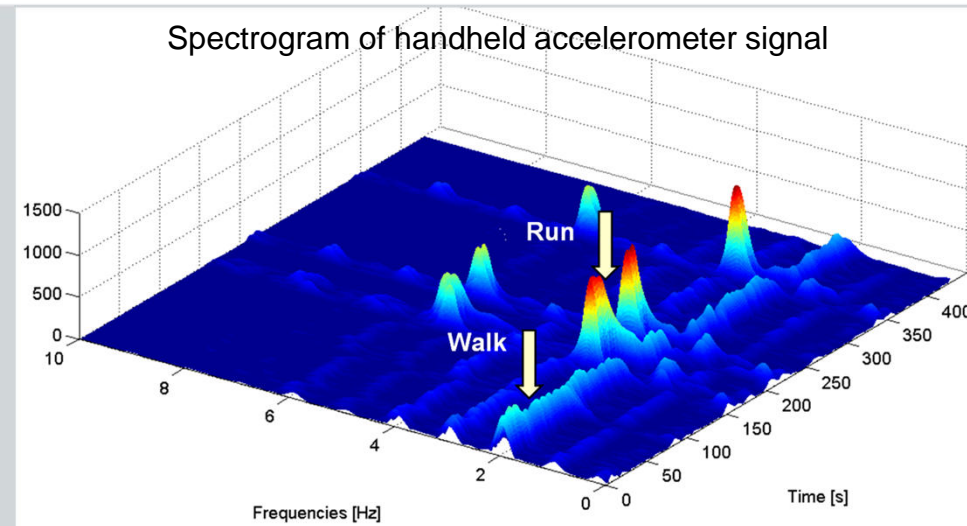
$$y_{k \in \{1, m\}} \in Y = [y_1, y_2, \dots, y_m]$$

- Adapt the navigation algorithms to the user context to bound the pedestrian position
- A classification Problem
Pre-processing \rightarrow Feature extraction \rightarrow 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)

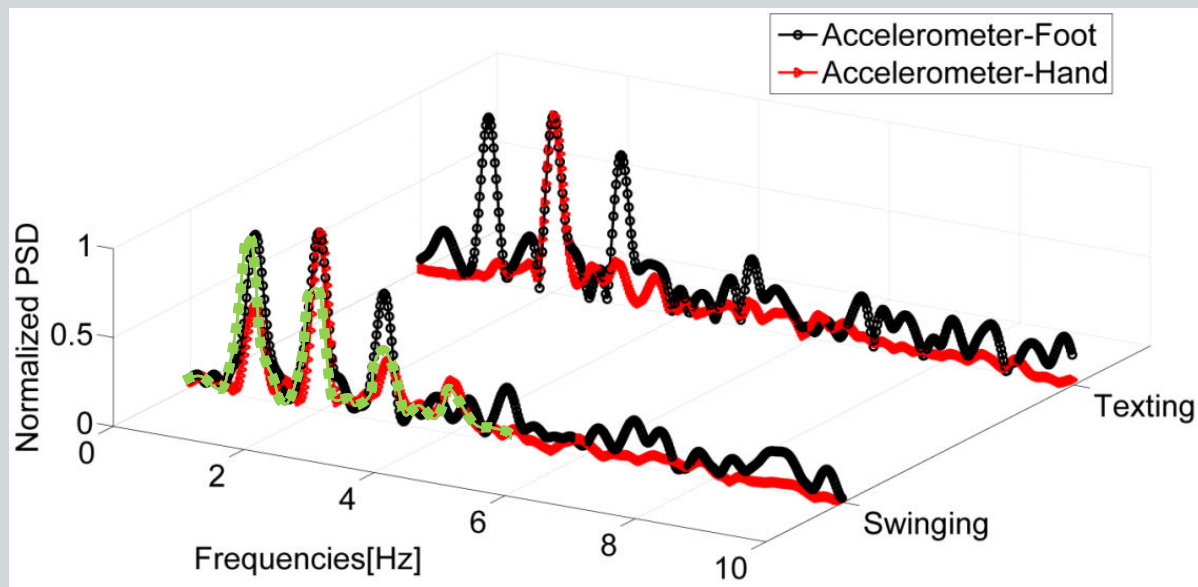


Source: Ref [3]



Step Frequency Extraction

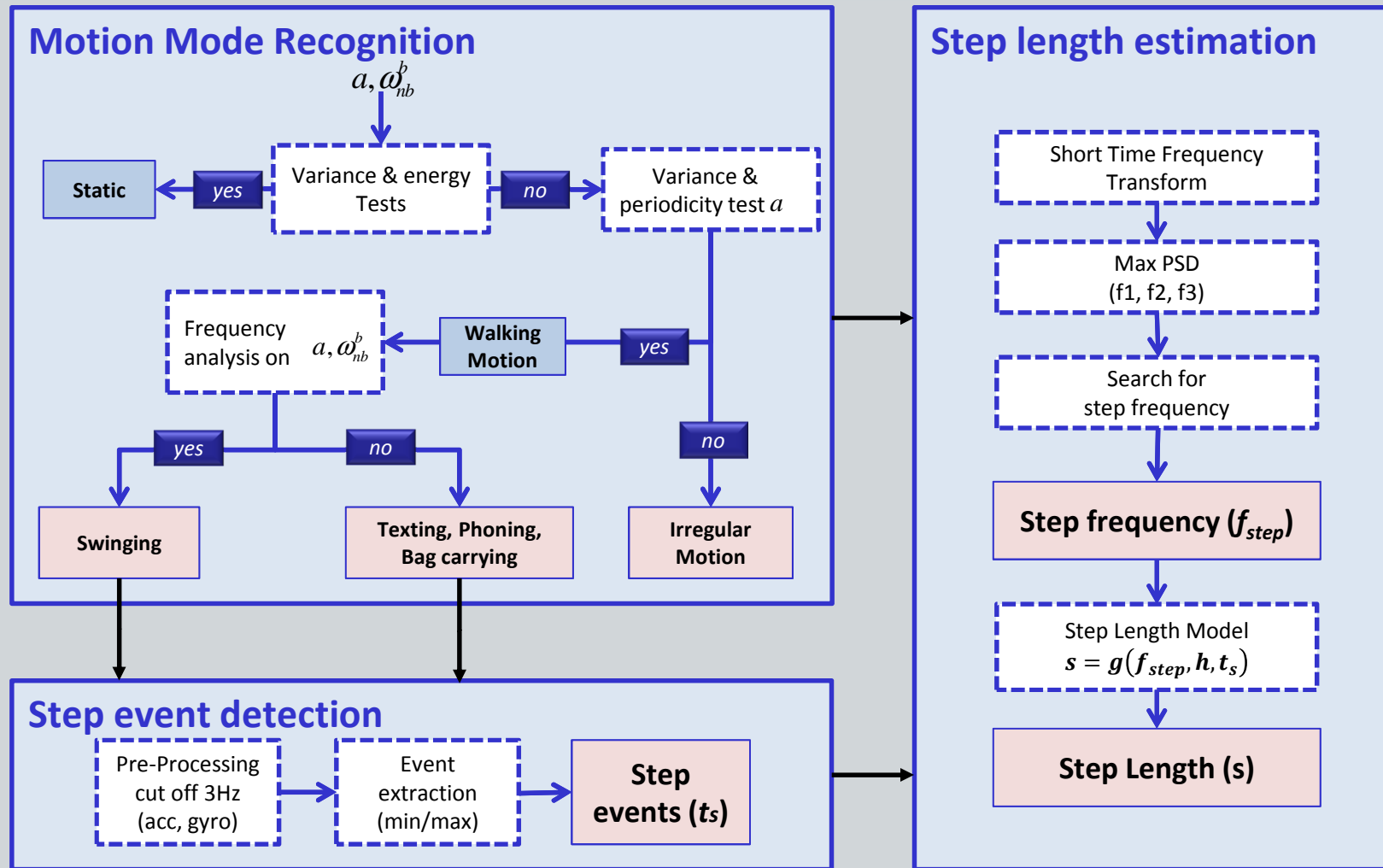
- Needed for the PDR mechanization and step length estimation
- Estimated independently from step detection: remove correlation in the filter, more robust
- Extraction of dominant frequencies with Short Time Fourier Transform (STFT) over 2 sec. sliding window → Three peaks
- Coupling problem of strongest hand frequency with **step** or **stride** even → **Binary Detector** based on biomechanics feature of walking gait



Source: Ref [4]



Step Length Estimation in 3 phases

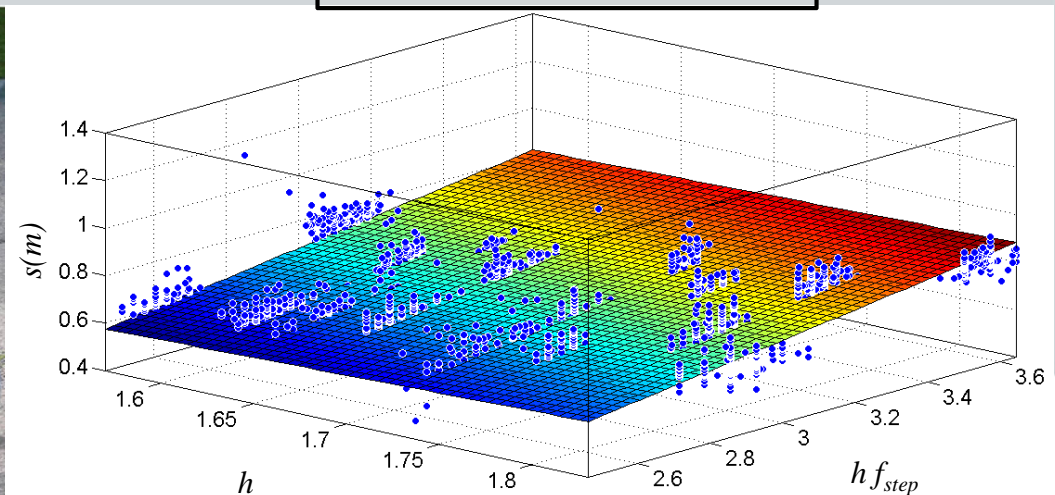
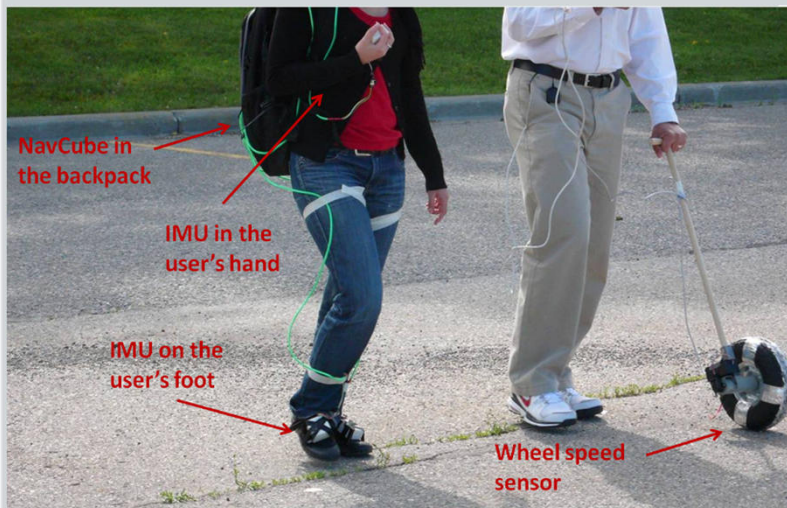


Step Length Model

- 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		Coverage 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



Ubiquitous in time

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

Source: <http://www.blog.trepreneur.com/>



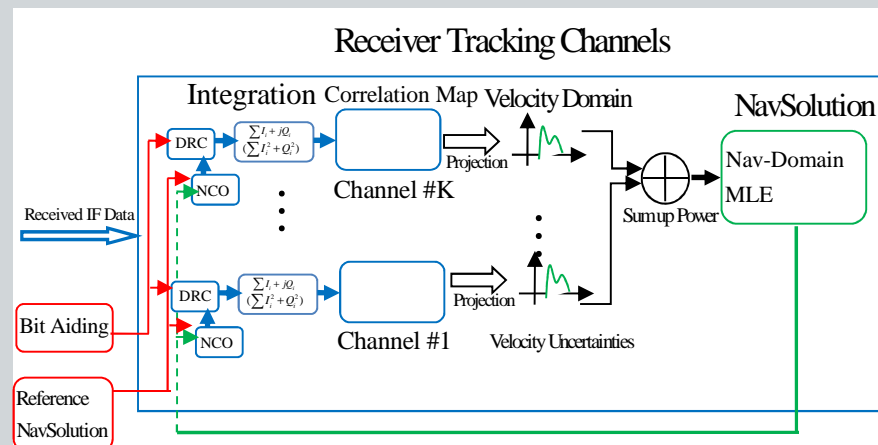
→ **Frequent calibration is needed**

- 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



Source: Ref [5]



Adaptive to Physiological Variations

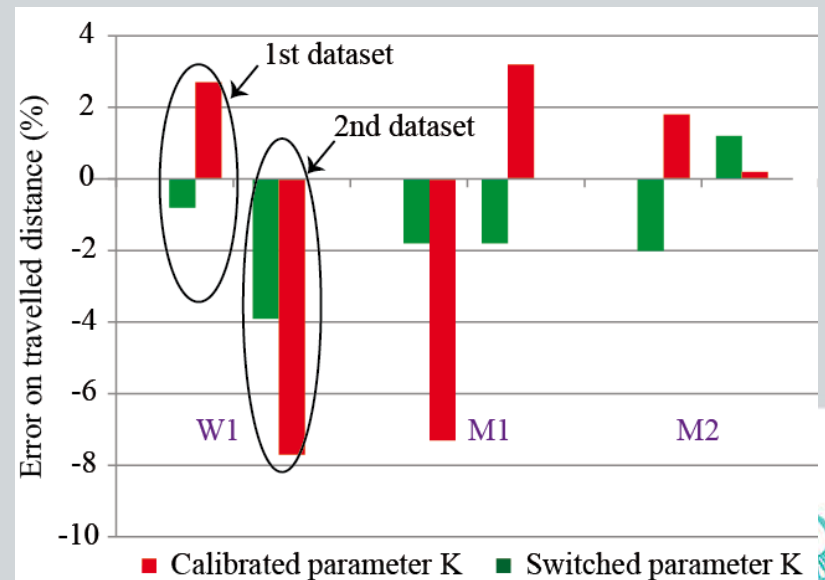
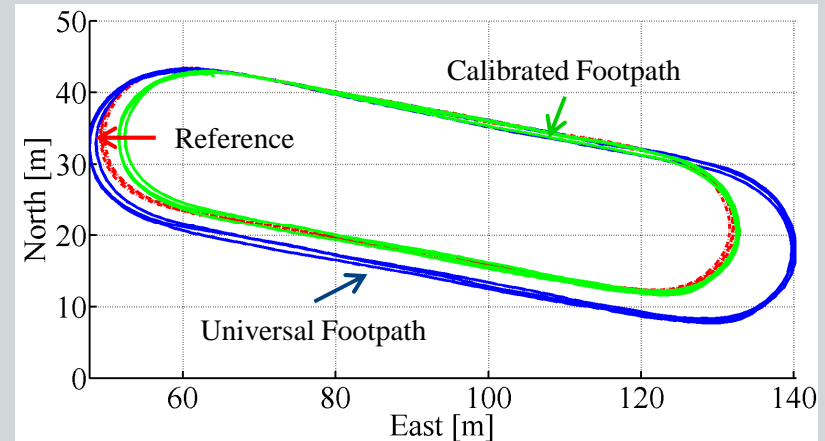
- 10 sec. PDR/GPS
Doppler calibration prior to penetrating indoors

- Free inertial PDR trajectory estimated with

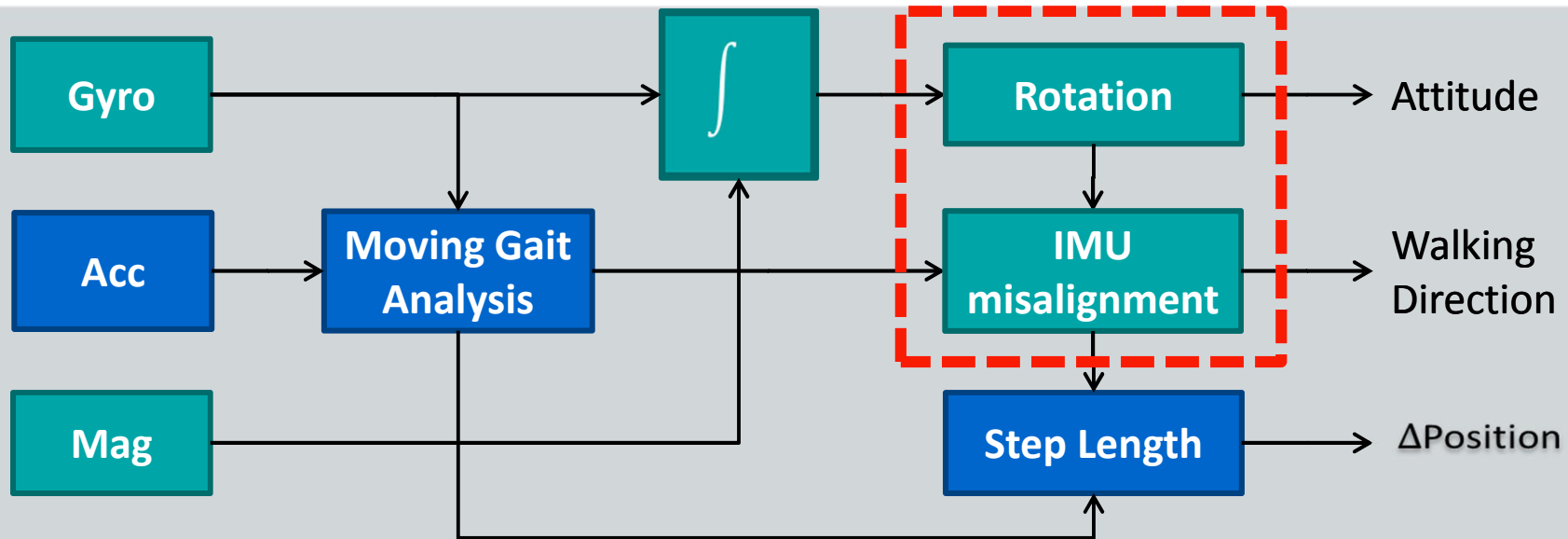
$$s = h \cdot (a \cdot f_{Step} + b) + c$$

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

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



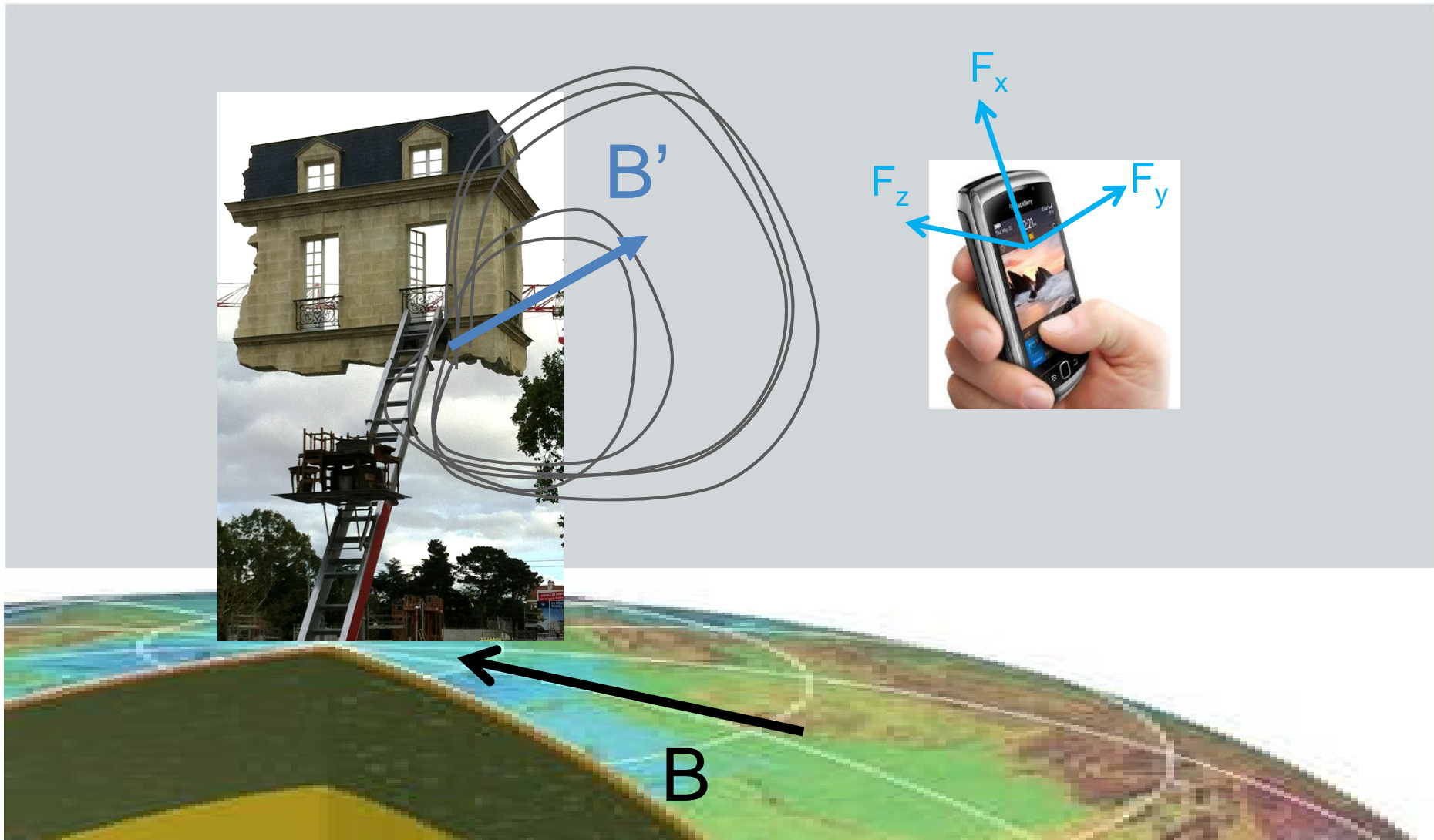
Walking Direction Estimation



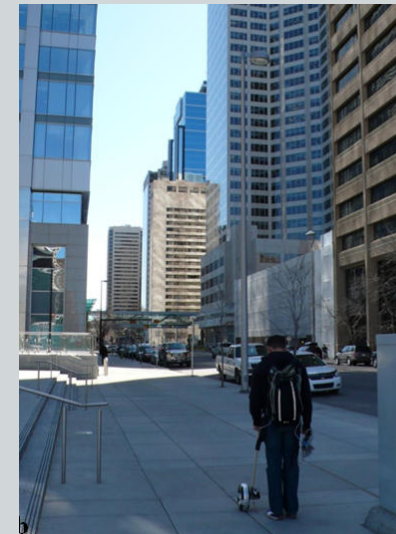
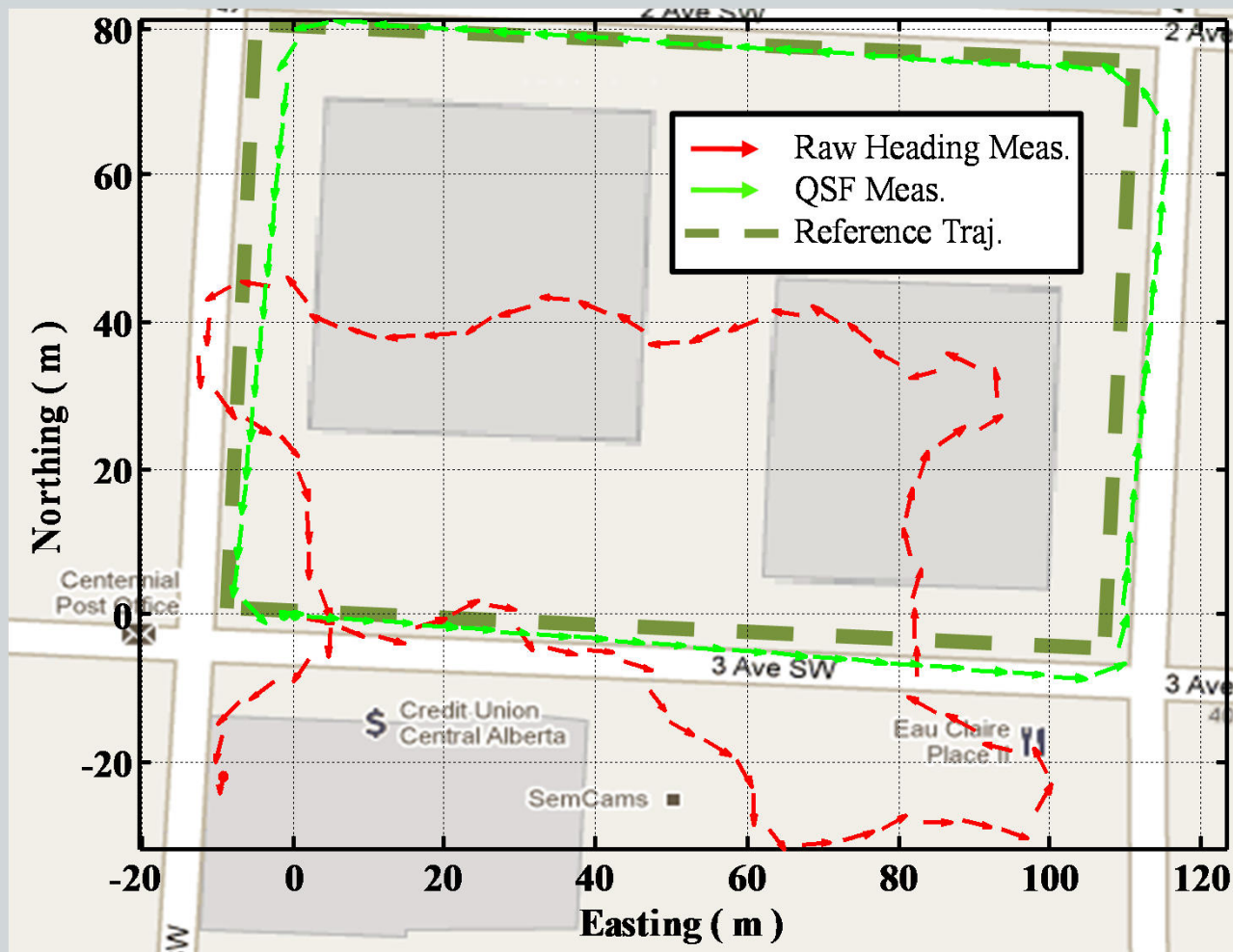
- PDR performance is limited by
 - azimuth which can be controlled by GNSS updates, Map constraints and **Magnetic Field**
 - IMU misalignment which requires dynamic estimation



Use perturbed magnetic field to mitigate gyroscope's errors



Magnetic Angular Rate Update



Source: Ref [6]



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Is reliable Pedestrian Dead Reckoning the next revolution for Sustainable Transport?



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