Navigation in urban areas using Geographical Information and rough GNSS measurements

Ph. Bonnifait

Lab Heudiasyc CNRS,
Université de Technologie de Compiègne
FRANCE
Outline

• Part One: introduction
  - UTC: Univ. of Technology of Compiegne
  - Heudiasyc: CNRS/UTC research lab
• Part two:
  - Intelligent Vehicles and robotic group
• Part three:
  - On the data fusion of Geographical Information and rough GNSS measurements
Part One: Introduction

UTC: Univ. of Technology of Compiegne
Heudiasyc: CNRS/UTC research lab
UTC
Compiègne
UTC figures

- 3380 Students
  - Ing Students: 2750
  - Master of science: 300
- 280 PhD Students
- Administrative and technical staff: 300
- Lecturers and researchers: 330
- 10 research laboratories
HEUDIASYC

HEUristic and DIAgnosis for Complex SYstems

UMR CNRS - UTC 6599
Lab Heudiasyc in figures

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academics</strong></td>
<td>38 (15 Pr + 23 MdC)</td>
</tr>
<tr>
<td>CNRS researchers</td>
<td>5 (1 DR + 4 CR)</td>
</tr>
<tr>
<td>CNRS technical and administrative</td>
<td>10</td>
</tr>
<tr>
<td>University technical and administrative</td>
<td>4</td>
</tr>
<tr>
<td><strong>Permanent staff</strong></td>
<td>57</td>
</tr>
<tr>
<td>Postgraduate students</td>
<td>74</td>
</tr>
<tr>
<td>Postdocs</td>
<td>16</td>
</tr>
<tr>
<td>Visitors</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>152</td>
</tr>
</tbody>
</table>
Research groups inside Heudiasyc

• ARO
  - Network Algorithms and optimization
• DoC
  - Documentation and Knowledge
• DI
  - Image, Decision
  - Statistical Learning, Pattern Recognition,
• ASER
  - Robotics and Automation,
  - Embedded Systems
DI Statistical Learning, Pattern Recognition, Image and Decision

Analysis of medical images

Analysis and tracking of facial expressions

Data analysis

Pattern recognition

Diagnosis

Separation using belief functions

Analysis of imprecise data via possibility theory
ASER
Robotics and Automation, Embedded Systems

• State observation
• Dynamic localization using GPS and digital cartography
• Under-actuated mechanical systems
• Modeling and control of UAV’s
• Systems with saturated inputs
Part two:
Intelligent Vehicles and robotic group
Intelligent vehicles: national CNRS platform
Scientific interests

• ADAS - Advanced Driver Assistance Systems
  - Techniques for Man-Machine cooperation assessment

• Perception
  - Observation of dynamic systems
  - Multi-sensor fusion in a dynamic context
  - Ego-localization using on-board sensors and GNSS associated with GIS information
  - Dynamic behaviour (tire/road contact characterisation)

• Embedded system
  - Distributed real-time systems and feedback scheduling
  - Safety systems and dependability
Intelligent Vehicles and human drivers

- An IV is a vehicle able to perform
  - driving assistance tasks
  - autonomous navigation
    - in the presence of uncertainty and variability in its environment
- Artificial Perception and Contextual Information analysis are key issues
- This can done using sensors and information computing
- HM cooperation needs Meta-data (confidence indicators) since no high enough reliability can be reached.
Meta-data

- The computing system needs
  - To fuse redundant information
  - To estimate unobserved parameters
  - To monitor itself
    - Fault detection and isolation
    - Diagnosis
    - Integrity tests
- Confidence indicators
  - Second order information
- Examples
  - Drift and slippage indicators + confidence
  - Visibility (fog, rain) indicators + confidence
  - Obstacles detection confidence
  - Localization integrity
DBITE

D-BITE : a distributed architecture for driver behavior analysis RoadSense [EU project 2001-2004]
- One computer is not enough for 4-5 videos acquisition, metrics processing, display…
- Distributed approach guarantees evolution ability
- Communication : modules exchange data
- Time reference : asynchronous data need the same timestamp reference
Detection and tracking in driving situation

- Detection and recognition
- Confidence indicators
  - Detection
  - Recognition
  - Tracking
- Four planes laser scanner

[Diagram of detection and tracking system]
Pedestrian detection
Multi-Hypothesis Tracking (real data)
Part three:
Ego-localization for Intelligent Vehicles

On the data fusion of Geographical Information and rough GNSS measurements
Localization for Intelligent vehicles

CVIS
FP6 IST EU project
4 years: 2006-2010
61 partners
All budget: 42 Millions euros budget
CVIS European project

Roadside System
- VMS
- Ant
- Roadside Gateway
- Access Router
- Roadside Host
- Border Router

Vehicle System
- Antenna
- Mobile Router
- Vehicle Host
- Vehicle Gateway

Central System
- Service Centre
- Authority Databases
- Control Centre

Tunneled IPv6

Internet
Autonomous navigation in urban environments

- VIP: intelligent vehicles
  - a new means of mobility in urban environments
- Precise localization using vision and laser

- GNSS based Localization

2003-2006
Standard positioning + map-matching process

GNSS sensor

X, Y, Z, V…

λ, φ, H

Sensor data fusion

You are here, on this segment, at this abscissa!

Digital road database

You are here!...

Position on the map

Relevant attributes of the road segment
GPS drawbacks in urban areas

- Bad visibility
  - Satellite masked by high rise buildings
- Bad satellite configuration
  - Urban canyons
- Multipaths
  - Reflexion on Non Line Of Sight (NLOS) satellites
- With less than 4 satellites, it is impossible to fix a point
How to deal with GPS outages?

• 1st idea:
• To use proprioceptive or dead reckoned (DR) sensors
  - Odometer and gyrometer

\[
\begin{align*}
    x_{v,k+1} &= x_{v,k} + \Delta_k \cdot \cos\left(\theta_{v,k} + \frac{w_k}{2}\right) \\
    y_{v,k+1} &= y_{v,k} + \Delta_k \cdot \sin\left(\theta_{v,k} + \frac{w_k}{2}\right) \\
    \theta_{v,k+1} &= \theta_{v,k} + w_k
\end{align*}
\]

• Drawbacks
  - Urban Canyoning can be long!
  - The Use of affordable sensors ➔ large drift
How to correct this DR drift?

- **2nd idea:**
- Digital maps of the road network are available in all cities!
- **Main characteristics**
  - **Poor**
    - geometry
    - absolute precision
  - **Good**
    - connectivity (for route planning)
    - relative precision
- The map can be interpreted as a constraint
- Very efficient to correct the lateral drift
On the use of rough GNSS measurements

• Often in a urban canyon, 1 or 2 satellites are still visible
• 3rd idea:
  • To use a tightly coupled approach for the data fusion process
    - Pseudo-ranges
      \[ \rho^i_c = R^i + c \cdot dt_u \]
    - Doppler measurements
    - Phase measurements
Tightly coupled GNSS/Map localization

GNSS sensor

Proprioceptive sensor 1

Proprioceptive sensor 2

Sensor data fusion and map-matching

Road database: map

Position on the map

Relevant attributes of the road segment
Tightly Coupling GPS and 2D map data
Static Localisation

- Variable elimination
- Weighted Least Squares
Dynamic Localisation

Initial localisation

Dynamic localisation

- Gyro + odo
- Rough GPS data
- Map

Pose tracking
Kalman Filtering
Our European Maps!
How to handle GPS and Map troubles

• GPS: multi-paths and interferences
• Maps: Inaccurate (bias), obsolete, rough representation of the reality, Ambiguous at junctions

• Proposed strategy:
  To rely on dead reckoning and consider that integrity problems come from the GPS data and/or form the map

• Implementation:
  - Mono-hypothesis road tracking
  - Map used as a heading observation
  - Integrity tests on pseudo-ranges and on the map observation (NIS – Normalized Innovation Squared and Ch2 threshold)
Experimental results

L1 GPS receiver
Odometer
Gyro
2D map
Multiple models observation Kalman filter (real data)

Only 7 states Kalman Filter
Conclusion and perspective

• Tightly fusion of GNSS and Map has many advantages
  - Use of few satellite in LOS
  - Possibility to apply efficient integrity tests
  - Map-Matching is a sub-product of the method

• Perspectives
  - Galiléo measurements (2013)
  - 3D maps (CityVIP new French Predit project)
  - Validate the confidence indicators that are useful for integrity monitoring
Thank you for your attention!

Philippe Bonnifait
Professor at
Lab Heudiasyc CNRS,
Université de Technologie de Compiègne
FRANCE
philippe.bonnifait@hds.utc.fr
www.hds.utc.fr