Recent Developments on Multi-Sensor Systems within the IAG as a Driver for Robust Positioning and Navigation

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Presentation structure

- The role of multi-sensor systems within IAG, Commission 4
- Application areas asking for PNT information
- User requirements for PNT solutions
- Evolution of PNT solution approaches through time
- Key projects undertaken on multi-sensor systems in the past period (2011-15)
  - Campaign #1: Nottingham field trials - kinematic platforms & tests (1/3)
  - Campaign #1: Nottingham field trials - vehicle test (2/3)
  - Campaign #1: Nottingham field trials - vehicle test (3/3)
  - Campaign #2: Melbourne field & indoor navigation trials (1/2)
  - Campaign #2: Melbourne field & indoor navigation trials (2/2)
- New structure of IAG, SC 4.1 (2015-19)
- Concluding remarks and outlook for the running period
Recent developments on multi-sensor systems within IAG, Commission 4

“... intends to bring together scientists, researchers and professionals dealing with emerging positioning techniques and technologies aiming to address practical and theoretical solutions for positioning, navigation and guidance, including spatio-temporal monitoring and tracking of objects at various scales.”

The Geodesist’s Handbook 2016

in practice and in short,

intends to provide, continuous and robust **Positioning, Navigation and Timing (PNT)** solutions to serve a wide spectrum of applications ranging from the transportation and personal mobility to industrial and environmental sector

where do we stand in geodetic science?

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Application areas relying on PNT information

List of emerging application examples:

- Location-Based Services (LBS)
- Personal / Pedestrian Navigation (PN)
- Intelligent Transportation Systems (ITS)
- Air traffic management
- Asset location and tracking
- First responders and fire-fighters
- Unmanned Autonomous Vehicles (UAVs) for mapping and surveillance
- Emergency response and rescue operations in large warehouses, multi-storey buildings, train/metro stations, airports, etc.
- Dismounted soldier navigation
- Vehicle collision avoidance systems
- Navigation and guidance of teams of robots, etc.
- Precision Farming (PF)

what about user requirements?
User requirements for PNT solutions

User requirements can be listed in a “fish plot”, in which four basic categories can be recognized:

- Positioning, interface, cost, security & legal requirements

What is most relevant & critical category for IAG?

- Positioning requirements
- All other requirements (albeit of lesser importance)

In conclusion,

- The focus always depends on specific application requirements
Evolution of PNT solution approaches through time

key components of CP networks:
- inter-nodal ranging sub-system a dynamic network
- optimisation of dynamic network configuration
- time synchronisation
- optimum distributed GNSS aperture size
- communication sub-system
- selection of master or anchor nodes
- network topology

fully integrated approach:
sensors, signals, techniques
- Kalman filter
- Monte Carlo Localization
- Sum product Algorithms
Recent research undertaken within SC4.1 on multi-sensor systems in the past term (2011-15)

- **WG 4.1.1, Ubiquitous Positioning (IAG / FIG / ISPRS) [www.ubpos.net]**
  - two major field campaigns & follow-up processing and analysis on CP
  - Nottingham, UK, May 2012 & Melbourne, AU, July 2013
  - multi-institutional effort:
    - [www.ubpos.net](http://www.ubpos.net)
    - [www.emparco.wordpress.com](http://www.emparco.wordpress.com)
    - [www.e-ubpos.net](http://www.e-ubpos.net)
    - [www.inko9motover.org](http://www.inko9motover.org)
    - [www.rowingperformanceassessment.org](http://www.rowingperformanceassessment.org)

- **EMPARCO (Efficient Management of Parking under Constraints) [www.emparco.wordpress.com]**
  - aims at management of large-scale parking facilities under constraints (NTUA, UM, TUV, OSU)

- **InKoPoMoVer (intelligent Cooperative Positioning at Multimodal Public Transit Junctions)**
  - studies passenger movement at multi-modal transit situations – WLAN & RFID CP (TUV)

- **RoPASS (Rowing Performance Assessment)**
  - develop integrated acquisition system and analysis tools for competitive rowing (NTUA)

- ...
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Campaign #1: Nottingham field trials - kinematic platforms & tests (1/3)

- a multitude of sensor types employed
  - geodetic & low-cost, high-sensitivity GNSS receivers
  - tactical grade IMUs, MEMS-based IMUs
  - magnetometers, barometric pressure, and digital cameras, Flash LIDAR, UWB receivers to realize a number of CP scenarios

- employed five kinematic platforms
  - personal navigator (Ohio State University)
  - personal navigator (The University of Nottingham)
  - rooftop train
  - two mobile mapping vans
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Campaign #1: Nottingham field trials - vehicle test on CP (2/3)

- **sensors & testing scenario**
  - involves two vehicles M and P (vehicle of interest)
  - equipped with geodetic GPS, two INS, DSRC
  - the navigation solution is obtained separately and in CP mode
  - each vehicle solves for its own position, velocity and attitude, while receiving pseudoranges, position @ variances

Here, of interest is an assessment of the improvement of navigation solution of vehicle P in adverse GNSS conditions
CP algorithm results

- show an improvement in the horizontal position of the target vehicle by 50% @ 24% for 300 s partial GPS outage of 3 SV and 2 SV respectively
- indicate the high potential of the approach
- efficiency of the method depends heavily on IMU data and the quality of adding vehicle information

![Graph showing CP algorithm results with 3 SVs and 2 SVs at 300 s](image-url)

- **3 SVs @ 300 s**
- **2 SVs @ 300 s**
Campaign #2: Melbourne field & indoor navigation trials (1/2)

- Melbourne campaign deals with testing of UWB capabilities, etc.
- Indoor navigation trials for PM
  - Emphasis was placed on Wi-Fi & RFID testing
  - New algorithms for localization improvement were proposed and tested
- Modified Wi-Fi fingerprinting method was proposed
  - Implements a two stage (training & location detection) steps
  - Novelty relies in computing two-distance correction factors while eliminating systematic errors from the path-loss models using differentiation techniques
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Campaign #2: Melbourne field & indoor navigation trials (2/2)

- snapshots of the testing scenarios and the tracking software was developed
- testing took place at Indoor Lab., RMIT, Melbourne
- results obtained show considerable improvement compared to standard fingerprinting and other RTLS
New structure of IAG, SC 4.1 (2015-19)

it consists four Working Groups

- WG 4.1.1: Multi-Sensor Systems (Joint IAG/FIG)
  Allison Kealy, Guenther Retscher
- WG 4.1.2: Indoor Positioning and Navigation
  Kefei Zhang, R. Chen
- WG 4.1.3: 3D Point Cloud-Based Spatio-Temporal Monitoring
  J-A. Paffenholz, C. Harmening
- WG 4.1.4: Robust Positioning for Urban Traffic
  L. Ruotsalainen, F. Dovis

- currently WG structure completed
- SC webpage close to finalize
  (internal distribution within Sept.)
- various research activities (funded & un-funded) are under way
- new field campaigns are planned
- initiatives to enforce collaborations under way
Concluding remarks and outlook

Main areas of interest in the context of “multi-sensor systems” in the running period:

- transportation
- personal mobility
- industrial & indoor applications
- environmental monitoring

Regarding “specific projects” the focus will be specified by the respective WGs:
(examples only)

- to address / evaluate new algorithms & multi-sensor systems for CP for land and airborne navigation applications including UAV systems
- to examine the potential & capabilities of low-cost sensors including GNSS systems & smartphone navigation sensors
- to follow the technical advances in wireless systems (RFID, UWB, WiFi, LED, DSRC) for PM and road applications
- to evaluate the usability of emerging positioning technologies for urban traffic navigation & improved routing using collaborative driving systems and crowdsourcing traffic information
- to study vision-based and optical systems including cameras and laser scanning both for navigation and object tracking and monitoring purposes
- ...

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