International Association of Geodesy, Commission 4 Symposium
POSITIONING AND APPLICATIONS

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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

The role of multi-sensor systems within IAG, Commission 4

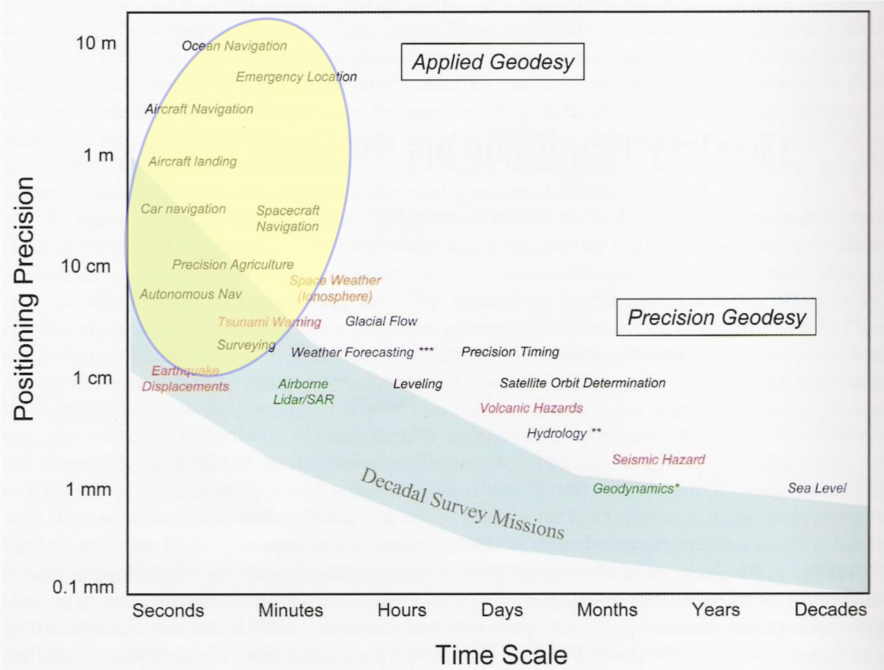
" … intends to bring together scientists, researchers and professionals dealing with emerging positioning techniques and technologies aiming to address practical and theoretical solutions for positioning, navigation and guidance, including spatio-temporal monitoring and tracking of objects at various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

The Geodesist's Handbook 2016

in practice and in short,

intends to provide, continuous and robust **P**ositioning, **N**avigation and **T**iming (**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?



NRC, USA

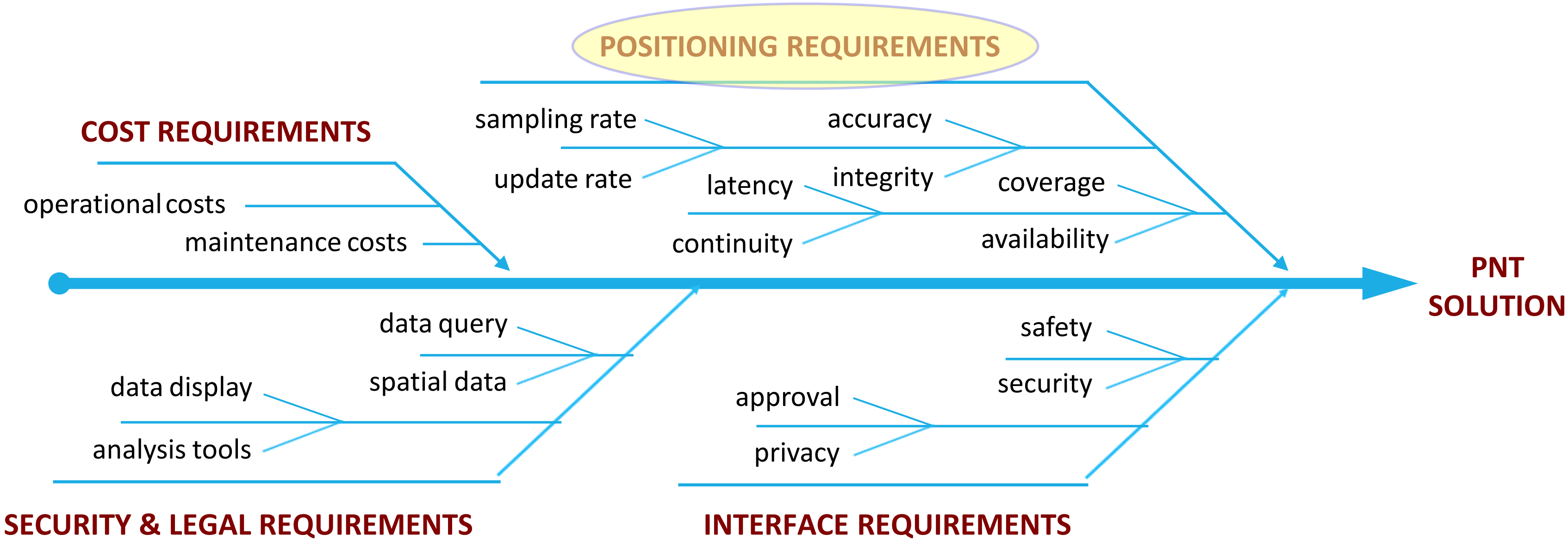
Application areas relying on PNT information

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)

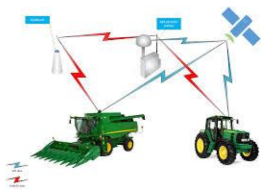
in conclusion,

- the focus always depends on specific application requirements

Evolution of PNT solution approaches through time

single-sensor

single-platform



GNSS
(GBAS, SBAS)

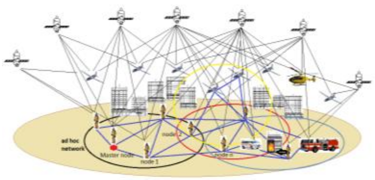
multi-sensor

single-platform

GNSS, RF, INS, optical, other

multi-sensor

multi-platform



network approach

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:

- 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 (inteliligent 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)

- …

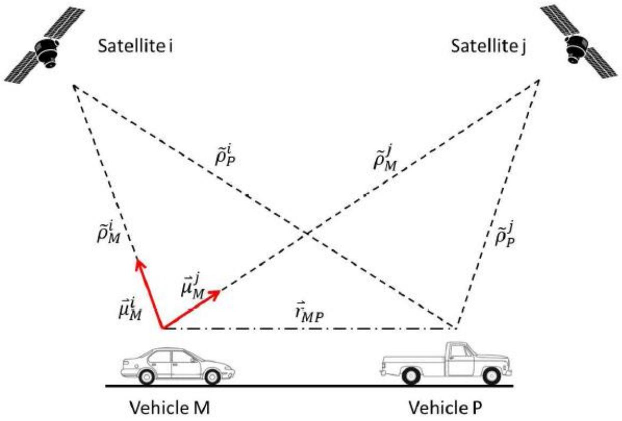
Campaign #1: Nottingham field trials - kinematic platforms & tests (1/3)

- 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

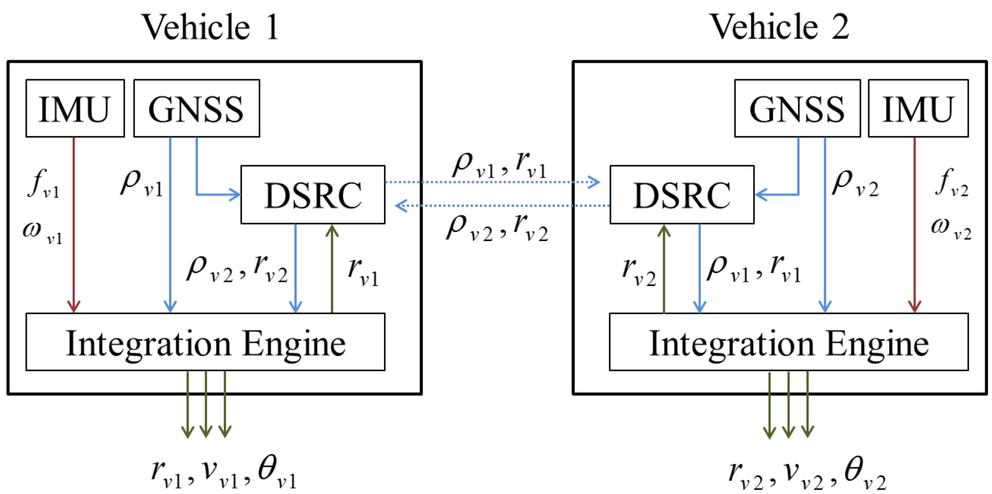
- employed five kinematic platforms
  - personal navigator (*Ohio State University*)
  - personal navigator (*The University of Nottingham*)
  - roof top train
  - two mobile mapping vans

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

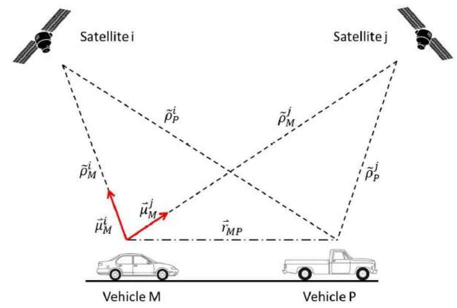


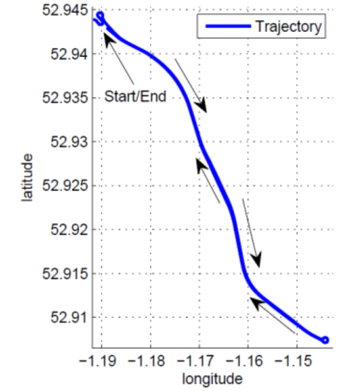
Here, of interest is an assessment of the improvement of navigation solution of vehicle P in adverse GNSS conditions

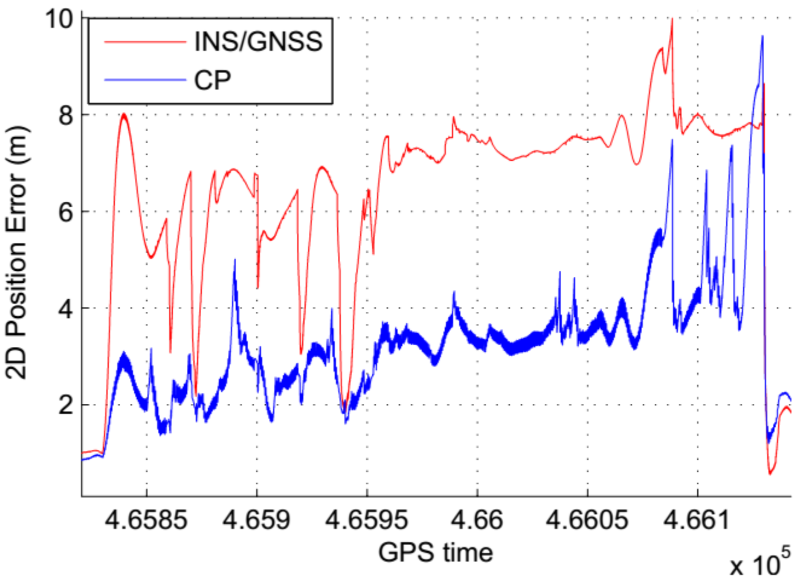


Campaign #1: Nottingham field trials - vehicle test (3/3)

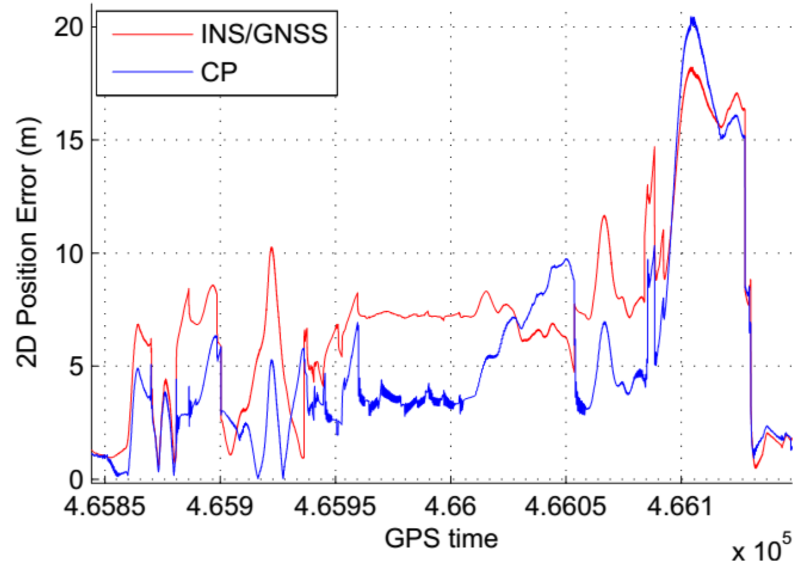
- CP algorithm results
  - show an improvement in the horizontal positionof the target vehicle by 50% @ 24% for 300 s partial GPS outage of 3 SV and 2 SV respectively
  - indicate the high potential of the approach
  - efficiency of the method depends heavily on IMU data and the quality of adding vehicle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







3 SVs @ 300 s

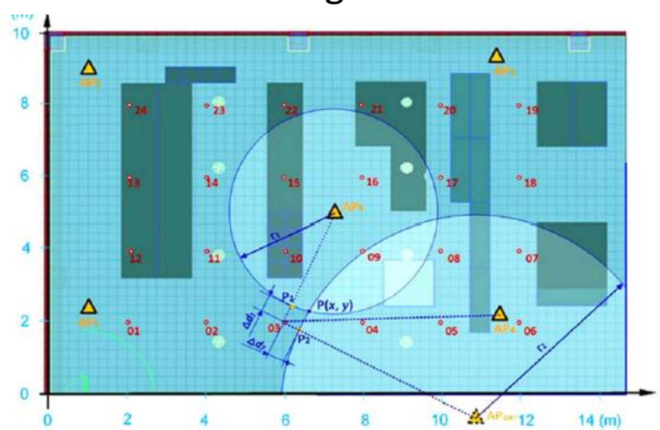


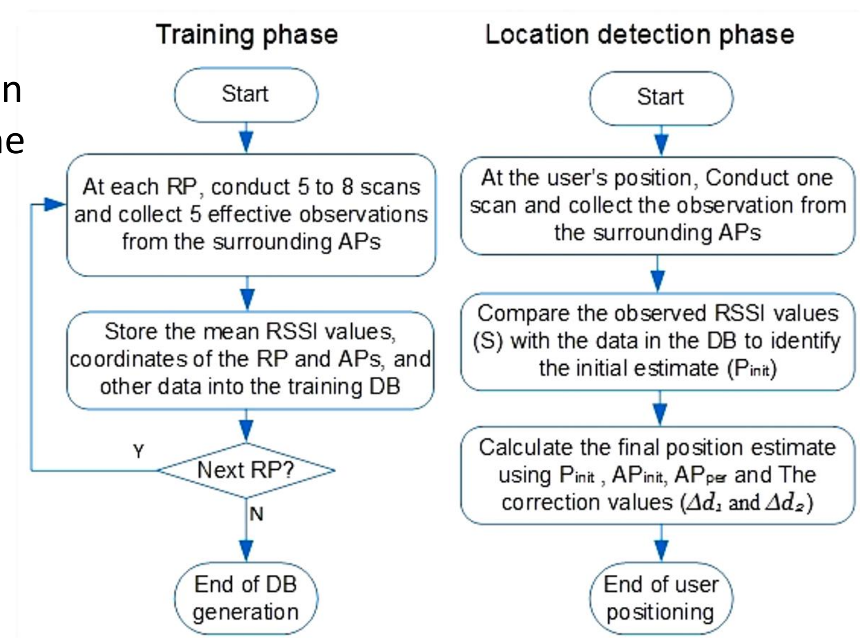
2 SVs @ 300 s

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

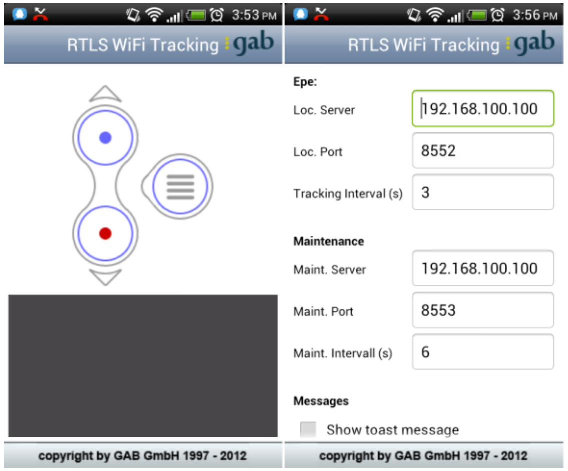
- modified Wi-Fi fingerprinting method was proposed
  - implements a two stage (training & location detection) steps
  - novelty relies in computing two-distance correction factors while eliminating systematic errors from the path-loss models using differentiation techniques

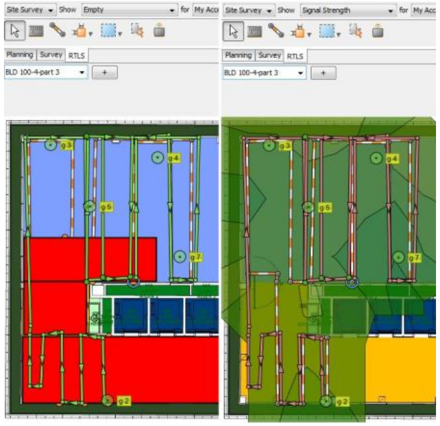


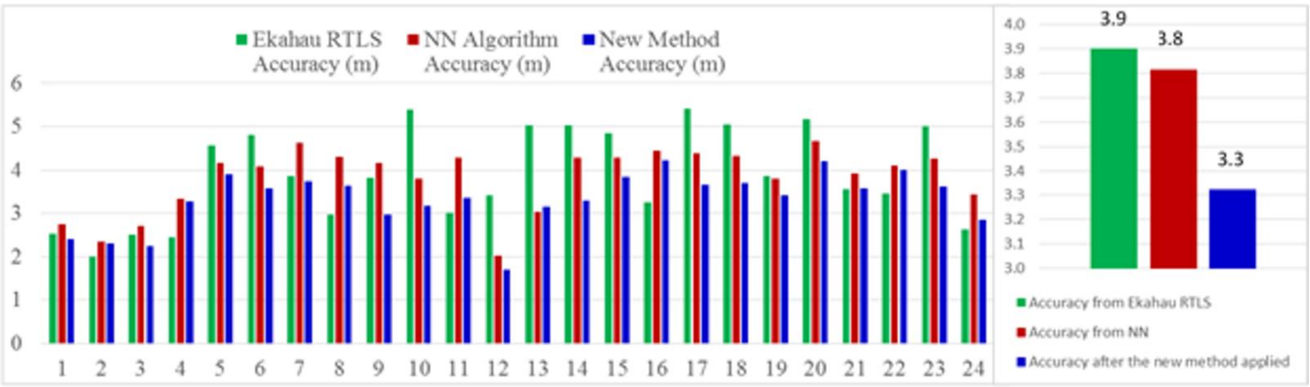


Campaign #2: Melbourne field & indoor navigation trials (2/2)

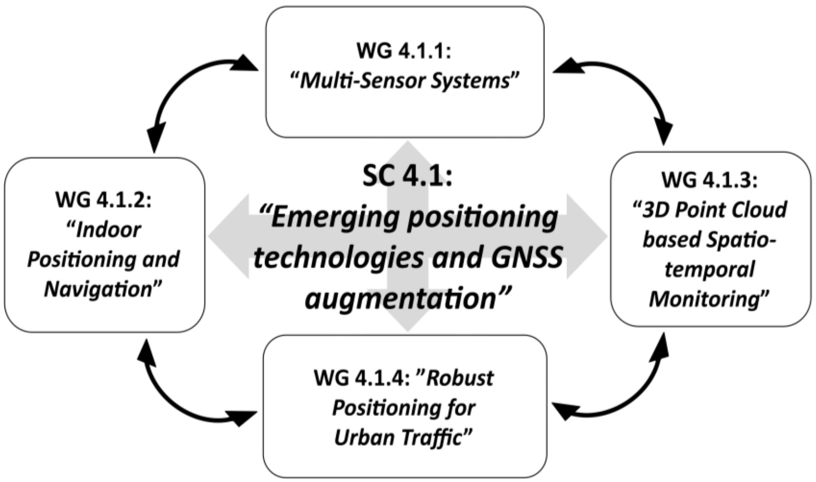
- snapshots of the testing scenarios and the tracking software was developed
- testing took place at Indoor Lab., RMIT, Melbourne
- results obtained show considerable improvement compared to standard fingerprinting and other RTLS







New structure of IAG, SC 4.1 (2015-19)

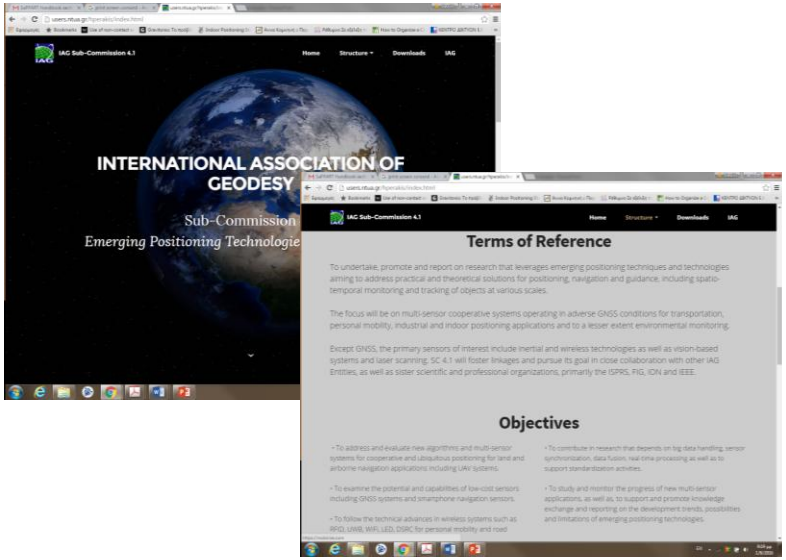


Chair: Vassilis Gikas
Co-chair: Guenther Retscher

- 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

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



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