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XXXII Cycle

GNSS-only Collaborative Positioning for Networked Receivers

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Research context and motivation

Positioning and Navigation Technologies play a determinant role in smart cities as the basis for mobility services. In harsh environment, the standalone **Global Navigation Satellite Systems (GNSS)** such as **GPS** and **Galileo** are not capable to satisfy the requirements of **precision**, **accuracy** and **continuity** of the estimated position.

Such limitations can be mitigated by:

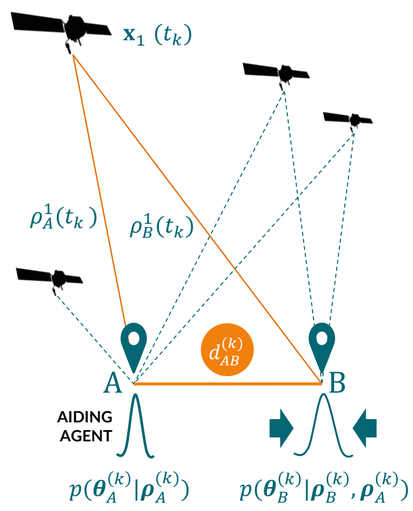
- **Proprioceptive** or **exteroceptive sensors** integrated with **GNSS**.
- **Cooperative Positioning (CP)** using network connectivity (i.e. LTE/5G, ad-hoc networks) among GNSS receivers.

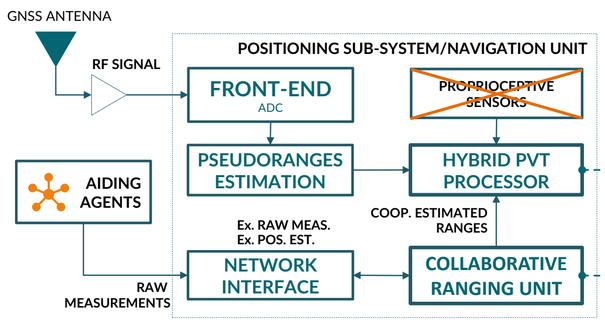
The concept can be applied to:

- Smartphones
- Drones
- Vehicular Networks

GNSS-based CP overcomes:

- Complexity, weight and size of high-end GNSS receivers
- Line of Sight (LoS)



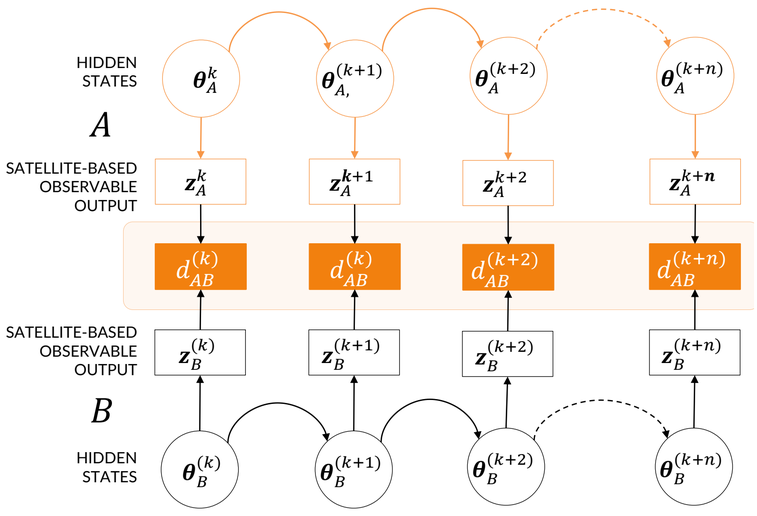


Which **Bayesian navigation filter** is more suitable for **GNSS-based CP**?

Which **GNSS-based ranging** techniques gurantees the proper performance?

Addressed research question/problems

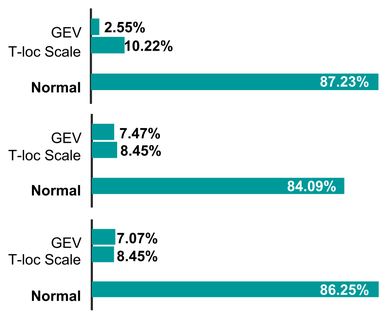
Determination of collaborative **inter-agent distances** by combining independent observables in a joint **Hidden Markov Model**



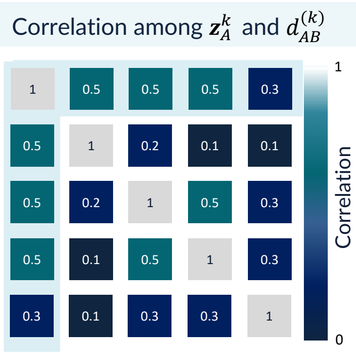
➡ **How much information does d_{AB} bring about $p(\theta_A)$?**

While ranging information provided by sensors (e.g. UWB, Lidar, Ultrasound) are **independent** from GNSS, **collaborative baseline measurements**, $d_{AB}^{(k)}$, are **dependent** from agents' pseudorange measurements, $\mathbf{z}_A^k$, and position estimates, $\boldsymbol{\theta}_B^{(k)}$.

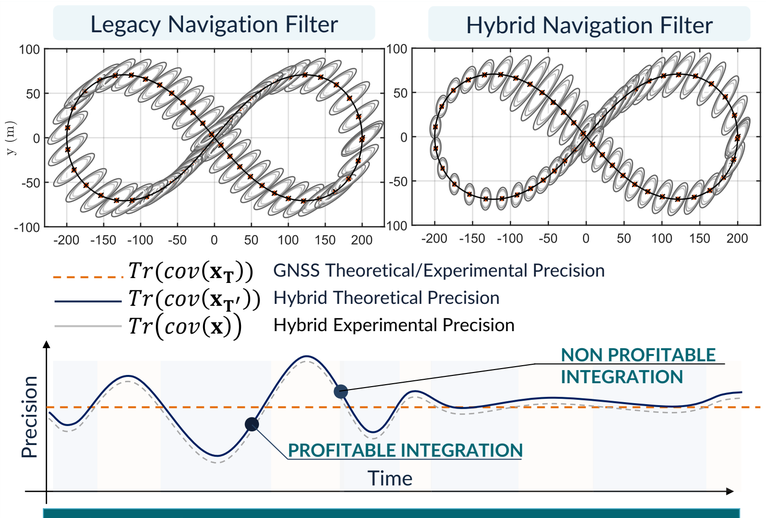
BIC fit test for baseline length, $d_{AB}^{(k)}$, statistical distribution



Correlation among $\mathbf{z}_A^k$ and $d_{AB}^{(k)}$



Contributions & methodology



Trajectory Shape	$\tau_{EXP}(\%)$	$\tau_{CRLB}(\%)$	$\Delta\tau(\%)$
Squircle	72.21 %	81.90 %	9,69 %
Circular	73.11 %	79.46 %	6,35 %
Rose Lemniscate	74.57 %	77.50 %	2,93 %
Archimedean Spiral	75.41 %	80.67 %	5,26 %
Bernoullian Lemniscate	89.73 %	91.93 %	2,20 %

Theoretical vs experimental profitability of GNSS-based CP

LEGACY NAVIGATION FILTER VS HYBRID NAVIGATION FILTER

CRLB $[F_T(\boldsymbol{\theta})]_{i,j}^{-1} = \left[-\mathbf{E}\left(\frac{\partial^2}{\partial\theta_i\partial\theta_j}\log f(\boldsymbol{\mu};\boldsymbol{\theta})|\boldsymbol{\theta}\right)\right]^{-1}$

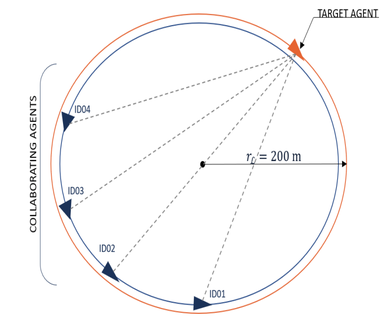
QUALITY | GEOMETRY | CORRELATION

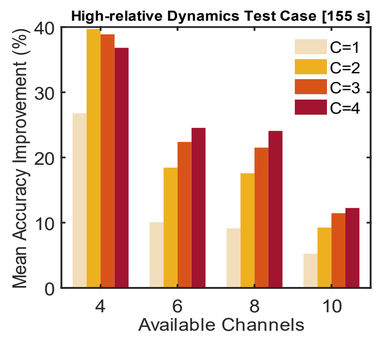
- New **non-linear GNSS-based estimation** algorithm for ranging measurement in GNSS partial unavailability of positioning service [1][2].
- Theoretical study on the benefits of the collaborative measurements in the hybrid positioning solution [4][14].
- Tight integration of collaboratively generated ranging measurements (IAR) based on advanced **Bayesian Estimation** (EKF,PF) [6][11].
- Real Implementation of the GNSS-based CP paradigm in Android devices. [10][12].

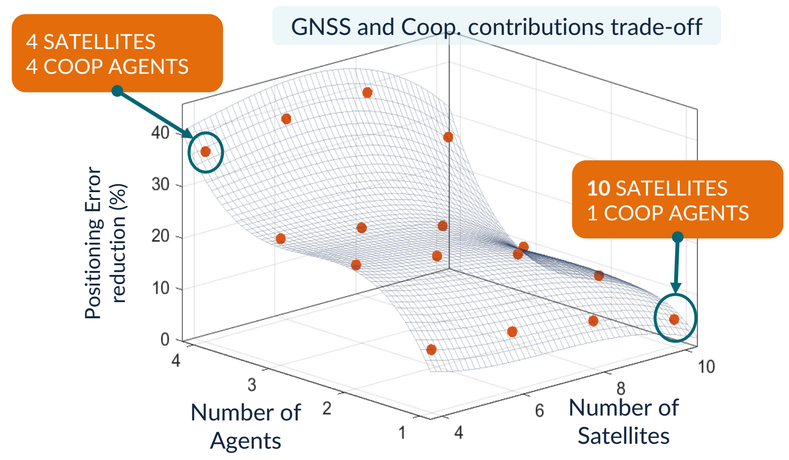
Research Results

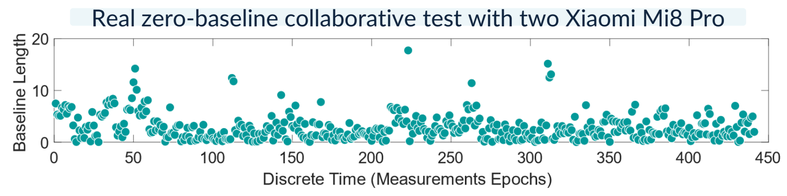
Considering the Hybrid EKF, the performance in term of the average accuracy can be optimized in terms of **position and number of aiding agents**, given the **number and position of the visible satellites**.

Experimental results obtained by means of realistic GNSS signals on analytic trajectories.
Realistic motion kinematics modelled for the whole network of agents (platoon).









➡ **FURTHER WORKS**: Performance optimization of satellite and aiding agents ranging maximizing the quantity of collaborative information in multi-agent scenarios.

Journals and Conferences Publications

- [1] A. Minetto, C. Cristodaro and F. Dovis, "*A Collaborative Method for GNSS-based InterAgent Range Estimation and Hybrid Positioning Algorithm in Harsh Environment*," in Proceedings of the 2017 International Technical Meeting of The Institute of Navigation (ION GNSS+ 2017), Portland, Oregon (USA), September 2017.
- [2] A. Minetto, C. Cristodaro and F. Dovis, "*A Collaborative Method for Positioning based on GNSS Inter Agent Range Estimation*," 2017 25th European Signal Processing Conference (EUSIPCO), Kos island, Greece, 2017.
- [3] F. Dovis et al., "*Anomalous GPS Signals from SVN49*", in GPS World, July 2017.
- [4] A. Minetto, F. Dovis, "*A Theoretical Framework for Collaborative Estimation of Distances Among GNSS Users*", in ION PLANS 2018, Monterey, California
- [5] **N. Linty, A. Minetto, F. Dovis, L. Spogli, "*Effects of phase scintillation on the GPS positioning error during the September 2017 storm at Svalbard*", in AGU Space Weather, 2018.**
- [6] A. Minetto, A. Nardin, F. Dovis, "*Tight Integration of GNSS Measurements and GNSS-based Collaborative Virtual Ranging*", ION GNSS+ 2018, Miami, Florida (USA)
- [7] N. Linty, A. Minetto, F. Dovis, V. Romano, I. Hunstad, "*Investigation into the Space Weather Event of September 2017 through GNSS Raw Samples Processing*", ION GNSS+ 2018, Miami, Florida (USA)
- [8] Minetto, Alex, Andrea Nardin, and Fabio Dovis. "*GNSS-only Collaborative Positioning Among Connected Vehicles*" Proceedings of the 1st ACM MobiHoc Workshop on Technologies, mOdels, and Protocols for Cooperative Connected Cars. ACM, 2019. [9] F. Dovis, A. Minetto, A. Nardin, E. Falletti, D. Margaria, M. Nicola, M. Vannucchi, "*Analysis of the Signal Outage*", GPS World, August 2019.
- [10] **A. Minetto, "*A Theoretical Study on the Benefits of Integrating GNSS and Collaborative Relative Ranges*", International Technical Meeting of The Institute of Navigation (ION GNSS+ 2019), Miami, Florida (USA), September 2019**.
- [11] A. Minetto, G. Falco, F. Dovis, "*On the Trade-off Between Computational Complexity and*
- *Collaborative GNSS Hybridization*", VTC-2019 Fall, Honolulu, Hawaii (USA), September 2019.
- [12] N. Gogoi, A. Minetto, F. Dovis, "*On the Cooperative Ranging between Android Smartphones Sharing Raw GNSS Measurements*", VTC-2019 Fall, Honolulu, Hawaii (USA), September 2019.
- [13] N. Gogoi, A. Minetto, N. Linty, F. Dovis, "*A Controlled-Environment Quality Assessment of Android GNSS Raw Measurements*", MDPI Electronics, 2019.
- [14] **Under revision: A. Minetto, F. Dovis, "*On the Information Carried by Correlated Collaborative Ranging Measurements for Hybrid Positioning*", IEEE Transactions on Vehicular Technology. 2019**

Other Activities and Awards

Research and Teaching Activities

- **HANSEL:** Navigation and GNSS in Smart Cities Testbed Concept Definition
- **AGRITECH CHALLANGE** Tutoring in GNSS technologies applied to precision agriculture
- **PIC4SER RESEARCH** Research Activities about navigation in collaborative multi-agent systems

Awards and Public Speaking Events

- FRANCESCO CARASSA AWARD 2018
- my research in three minutes
- GNSS summer school
- STUDENT PAPER AWARD ION
- ASI Agenzia Spaziale Italiana
- TEDx

List of attended classes

- 01RYHRV - Disruption Tolerant Networks: Routing Algorithms and Protocols
- 01NSGGN - Front-end technologies and antennas
- 01NSJGN - Integration of satellite navigation and other positioning technologies
- 01QRXIU - Multimedia communications: technological advances and social implications
- 01QUMRU - Pattern recognition and neural networks
- 01PJMRV - Communication I
- 08IXTRW - Public Speaking
- 08IXTRV - Project Management
- 01SWQRV - Responsible Research and Innovation, the impact on social challenges
- 02RHORV - The new Internet Society: entering the black box of digital innovation
- 01SWPRV - Time Management
- 01QORRV - Writing Scientific Papers in English
- TRAINING - ESA/JRC Summer School on GNSS 2017 – Longyearbyen (Svalbard)
- TRAINING - E-knot PhD training, FAF Munich, Germany

POLITECNICO DI TORINO

PhD program in
Electrical, Electronics and Communications Engineering