Internship Description

1. Title: **INVESTIGATION OF FACTOR GRAPH OPTIMIZATION FOR GNSS**

2. Supervisors:

- Name: Paul THEVENON
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3. Description

3.1. Context

Factor graph optimization has been successfully used in order to compute GNSS solutions with accuracy performances exceeding those of more traditional approaches such as weighted least squares estimation or extended Kalman filter. Notably, it gained the first place in 2 editions of an open challenge organized by Google called the Google Smartphone Decimeter Challenge [1][2]. As such, the SIGNAV research team at ENAC has gained interest in this technique and launched a PhD study in 2022.

Factor graph is a convenient way to model a positioning problem with a graph, where nodes correspond to variables to estimate (position, velocity, receiver clock, etc) and edges to observations (GNSS pseudoranges, motion constraints, etc). Once the positioning problem is described using this factor graph formalism, a Least Squares estimation is used to obtain the solution of all the states over a large time window. It is a technique that is now routinely used in solutions using camera sensors (Simultaneous Localization and Mapping [3]), but not yet widely adopted in the GNSS domain. The combination of many GNSS observations and motion models promises to have an accuracy improvement, as well as improved outlier detection capabilities.

This student project will contribute to the investigation of attainable performances of GNSS solutions using factor graph optimization.

3.2. Objectives

The goal of this internship is to implement in python a factor graph optimization algorithm on real GNSS observations. To implement the graph, realistic state and observation models from the literature will be considered.

To validate the implementation of the algorithm, the comparison of a FGO solution will be compared to an existing Kalman Filter-based solution, to check that they are equivalent when considering only the last set of GNSS observations.

3.3. Work plan

The proposed work plan follows the following steps :

- State of the art on Factor Graph Optimization and its use for GNSS
- Contribution to software code performing FGO on simulated and real GNSS data

- Performance analysis of FGO and comparison with Kalman Filter performances

Depending on the progress, the algorithm will be tested against large GNSS datasets, such as the Google Smartphone Decimeter Challenge. Interactions with a PhD student from ENAC and experts from CNES and Institut de Robòtica i Informàtica Industrial (Barcelona) may also be possible.

3.4. Remarks

The intern will gain:

- knowledge on GNSS PVT algorithms
- methodology for contributing to and validating a large python software project
- experience on version control system (git)

3.5. References

[1] T. Suzuki, "First Place Award Winner of the Smartphone Decimeter Challenge: Global Optimization of Position and Velocity by Factor Graph Optimization," in ION GNSS+ 2021, Oct. 2021, pp. 2974–2985. doi: 10.33012/2021.18109.

[2] T. Suzuki, "1st Place Winner of the Smartphone Decimeter Challenge: Two-Step Optimization of Velocity and Position Using Smartphone's Carrier Phase Observations," presented at the 35th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2022), Denver, Colorado, Oct. 2022, pp. 2276–2286. doi: 10.33012/2022.18377.

[3] F. Dellaert and M. Kaess, "Factor Graphs for Robot Perception," FNT in Robotics, vol. 6, no. 1–2, pp. 1–139, 2017, doi: 10.1561/2300000043.

4. Period

- <u>Starting date:</u> March 1st 2023 (flexible)
- <u>Duration:</u> 6 Months (flexible)

5. Department

SINA/TELECOM/SIGNAV

The internship is proposed by the SIGNAV (SIGnals for NAVigation) research group. SIGNAV is one of three research groups of the TELECOM team in the SINA (Sciences et Ingenierie de la Navigation Aerienne) department at ENAC (Ecole Nationale de l'Aviation Civile).

6. Location

The internship will take place at main campus of ENAC in Toulouse, France. Adress: 7, avenue Edouard Belin BP 31055 Toulouse Cedex 4, building F.

7. Candidate's profile

Master student in electrical/telecommunications/electronic engineering with background in estimation theory and signal processing. Knowledge in GNSS, aerospace systems or robotics will be appreciated.