WHU-GD: Smartphone-based Vehicle Positioning Algorithm Design for IPIN-2022 Competition (TRACK 6)

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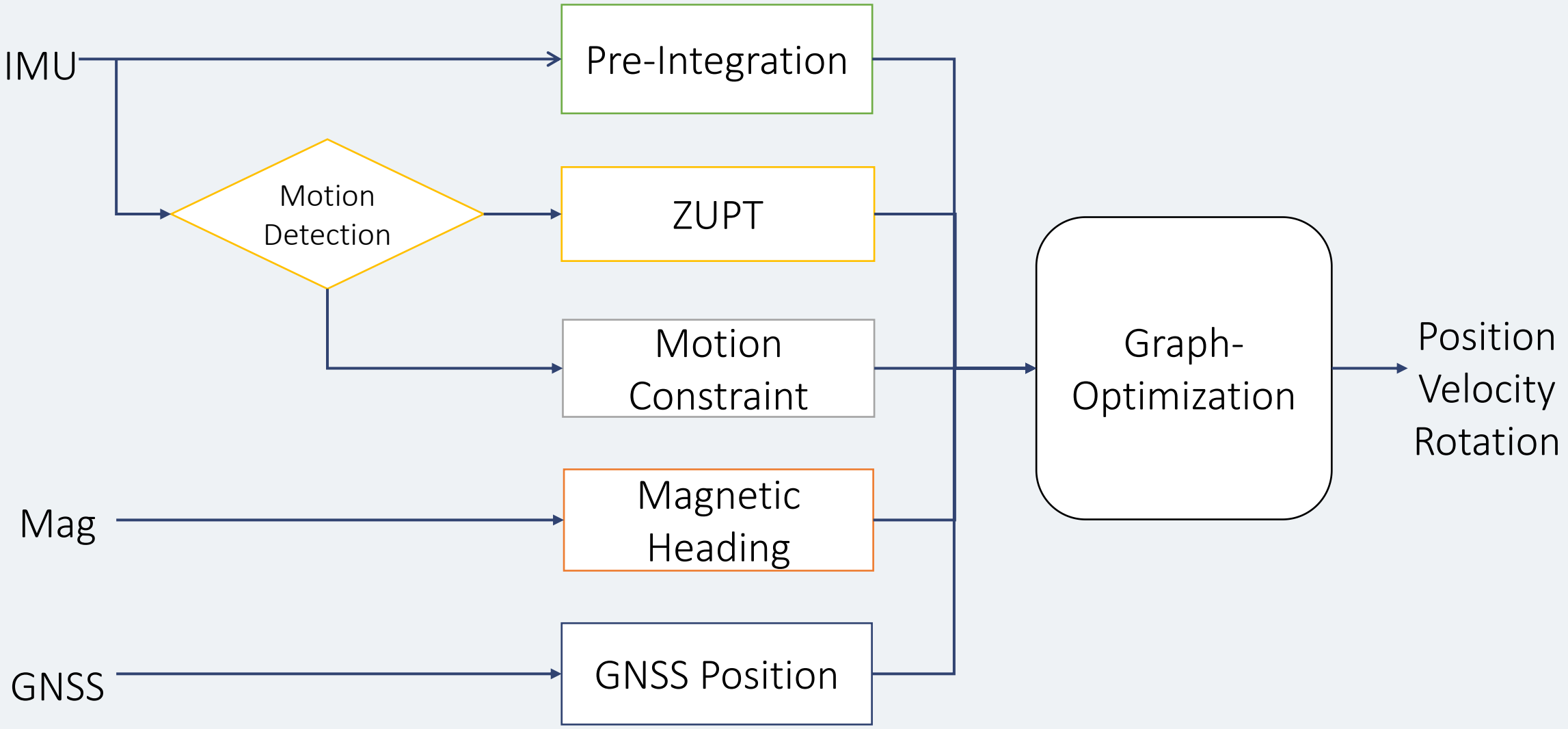
Smartphone Built-in Sensors

- ✓ 2G/3G/4G/5G
- ✓ GNSS
- ✓ Wi-Fi/Bluetooth
- ✓ Microphone & Speaker
- ✓ Camera
- ✓ Light sensor
- ✓ Gyroscope & Accelerometer
- ✓ Magnetometer
- ✓ Barometer
- ✓ NFC

General scheme



Graph-Optimization

- **System State**

$$S_i = \{ t_{nb_i}, R_{nb_i}, V_{nb_i}, ba_i, bg_i, bm_i \}$$

Position, Rotation, Velocity, Acc Bias, Gyr Bias, Mag Bias

- **Installation Parameters**

$$\mathrm{R}_{vb}, l^b$$

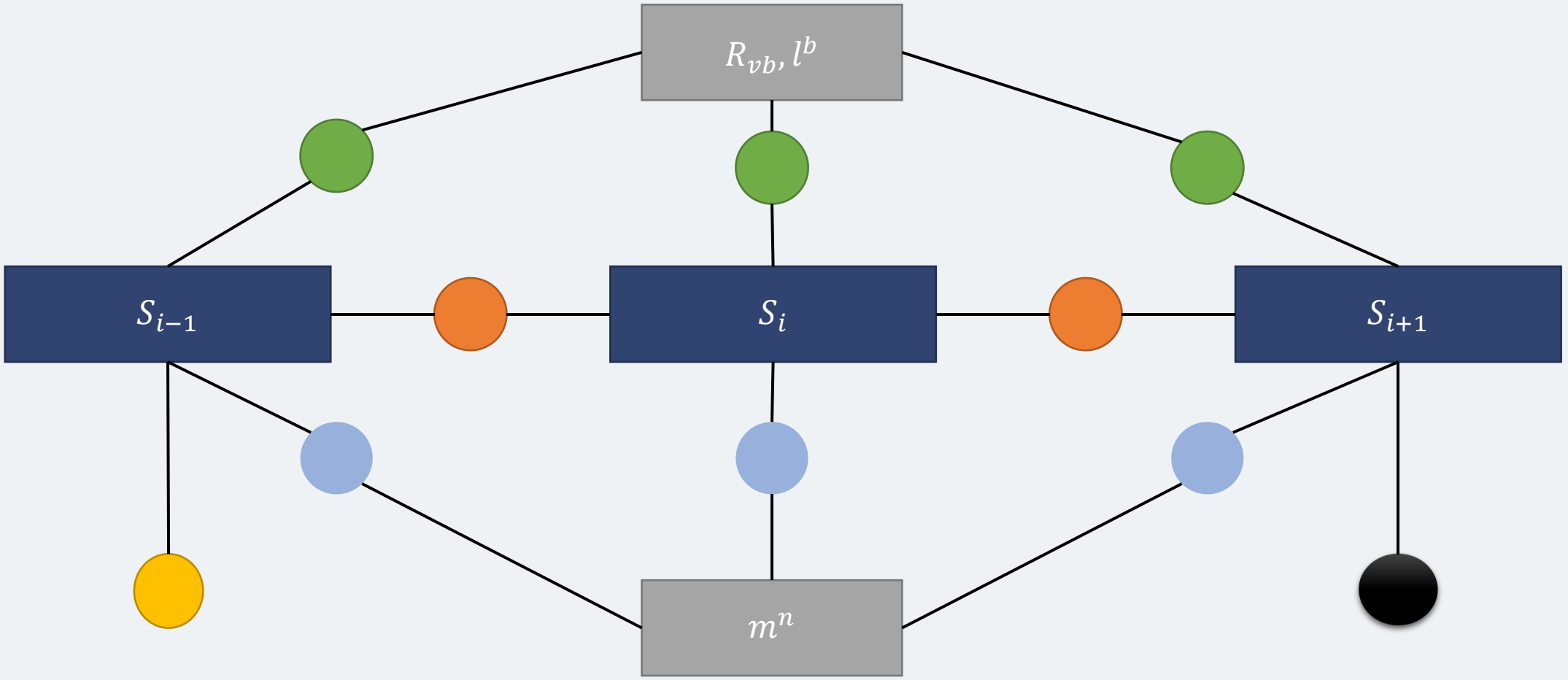
Translation between Vehicle Frame and Body Frame

- **Magnetic Field Vector**

$$m^n$$

Magnetic Field Vector in the n-frame

Graph-Optimization



Zero-Velocity Factor

Magnetic Factor

Pre-Integration Factor

GNSS Factor

Non-holonomic Factor

Pre-Integration IMU Factor

- Due to the low accuracy of the built-in sensors in the mobile phone, the influence of angular rate and sculling effect caused by the rotation of the earth and motion speed can be ignored.
- The bias and noise parameters of the gyroscope and accelerometer are adjusted according to the two sets of training data given by the competition.
- **Residual Definition**

$$
\begin{aligned}
r_{\Delta R} &= Log(\Delta R_{ij} R_{nb_i}^{T} R_{nb_j}) \\
r_{\Delta v} &= R_{nb_i}^{T}\left(V_{nb_j} - V_{nb_i} - g\Delta \mathrm{T_{ij}}\right) - \Delta V_{ij} \\
r_{\Delta t} &= R_{nb_i}^{T}\left(t_{nb_j} - t_{nb_i} - V_{nb_i}\Delta \mathrm{T_{ij}} - 0.5 * \mathrm{g} * \Delta T_{ij}^{2}\right) - \Delta t_{ij} \\
r_{bg} &= bg_i - bg_j \\
r_{ba} &= ba_i - bg_j
\end{aligned}
$$

Zero-Velocity Factor

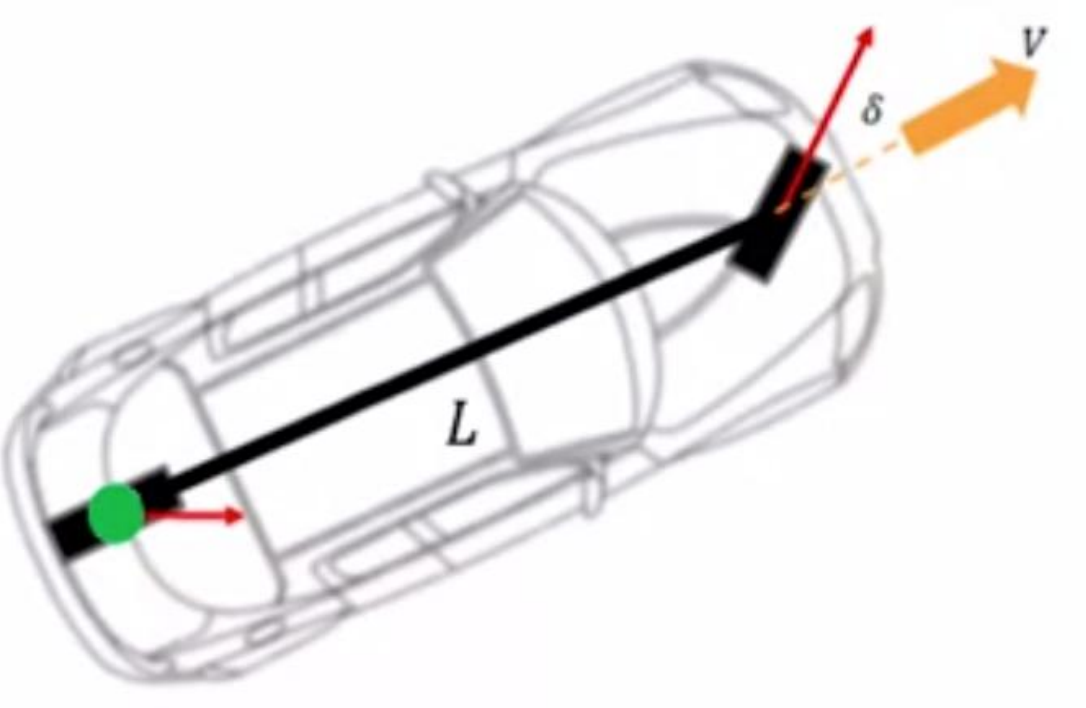
- Zero-velocity update technology (ZUPT) is a very effective means to control the accumulation errors of velocity. The raw output of IMU is used to determine the motion state of the vehicle. When the vehicle is detected to be stationary for one second, the virtual velocity observation of zero is employed to update the navigation state.

- **Residual Definition**

$$r_{zv} = t_{nb_i} - t_{nb_j}$$

Non-holonomic Factor

- The basic concept is that the vehicle rarely jumps and slides, so it can be considered that the lateral and vertical speeds in the vehicle frame are zero.



- The misalignment angle between the smartphone frame and the vehicle frame can be determined by the training data and estimated by scoring data online.
- Since the mobile phone is installed in front of the vehicle, the NHC lever arm can't be ignored, we add them to the system state.

Non-holonomic Factor

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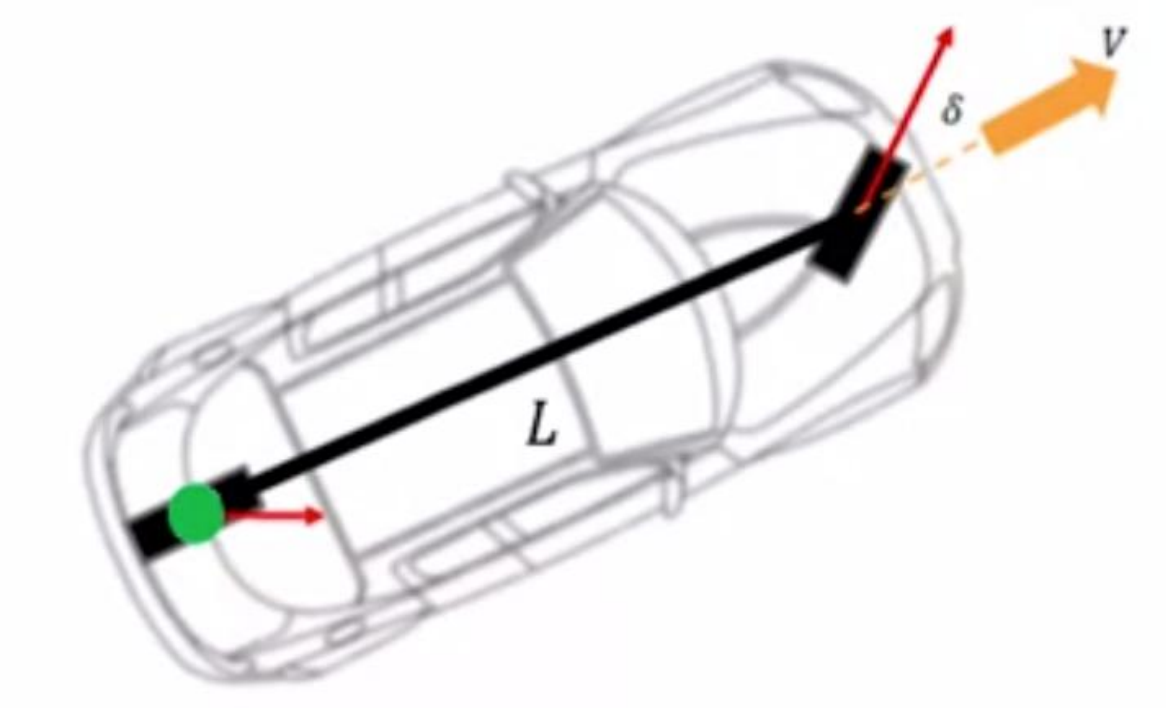
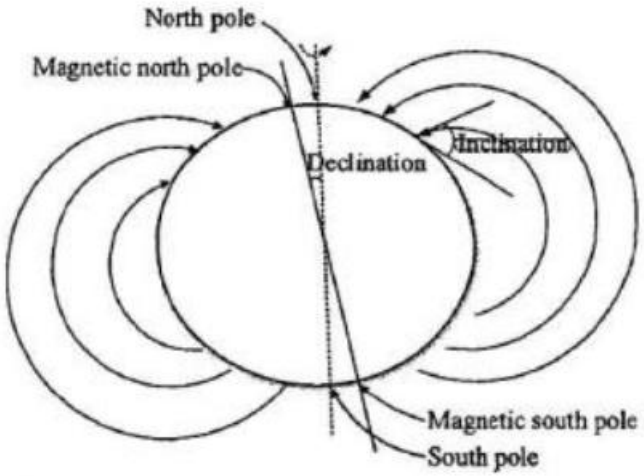


- **Residual Definition**

$$r_{NHC} = R_{vb}R_{nb_i}^{T}v_{nb_i} + R_{vb}\left(w_i^b \times l^b\right)$$

Magnetic Factor



- The absolute heading calculated by the magnetometer measurement to correct the heading estimated by the INS, which can still effectively improve the accuracy of the heading estimation.

- **Residual Definition:**

$$r_{mag} = R_{nb_i}(m_i - bm) - m^n$$

GNSS Factor

The GNSS position is the most important absolute information. Due to the GNSS signal being easily affected by the external environment, the chi-square test determines whether the GNSS position with significant error.

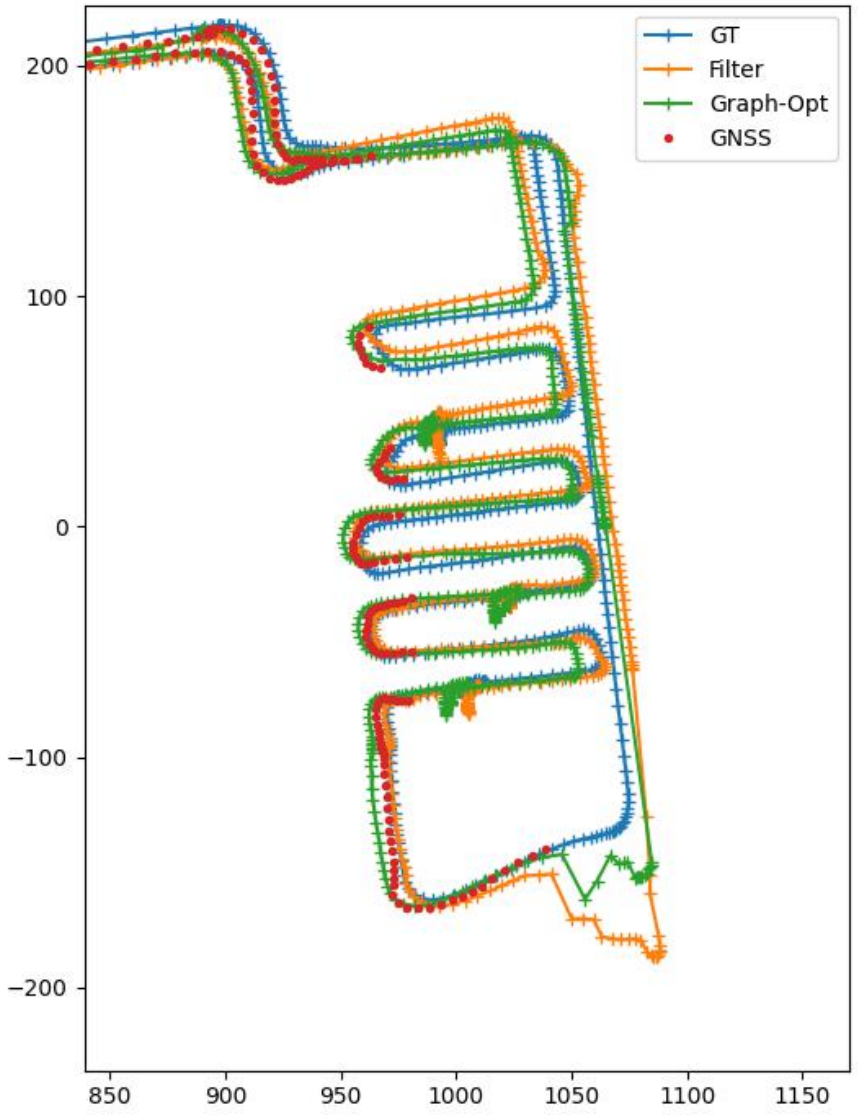
Furthermore, for better reliability, we first use **relative distance** constraint between keyframe and then adopt **absolute position** constraint.

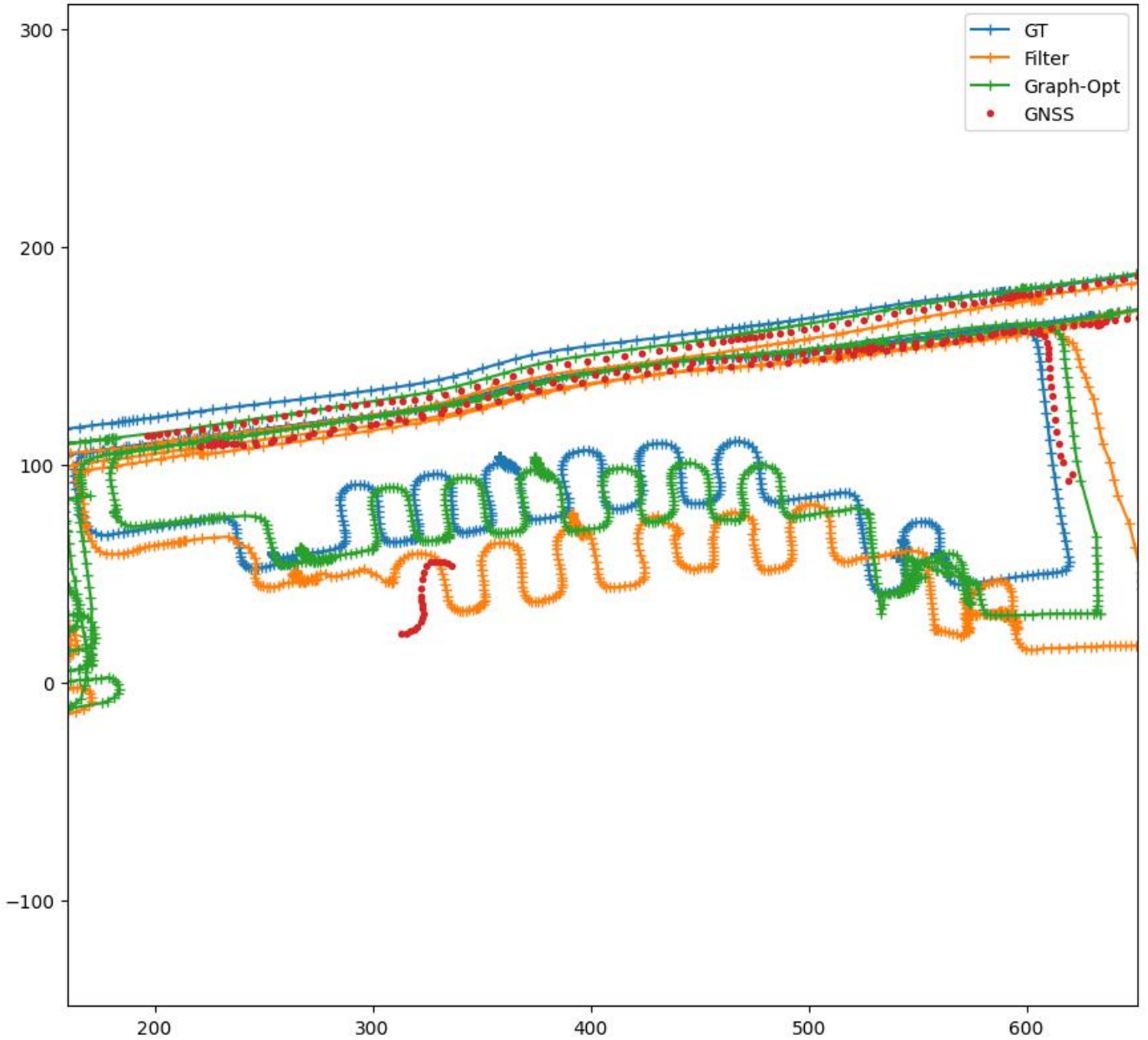
- **Residual Definition :**

$$r_{gnss_{distance}} = ||t_{nb_i} - t_{nb_j}||_2^2 - ||t_i^{GNSS} - t_j^{GNSS}||_2^2$$

$$r_{gnss} = t_{nb_i} - t_i^{GNSS}$$

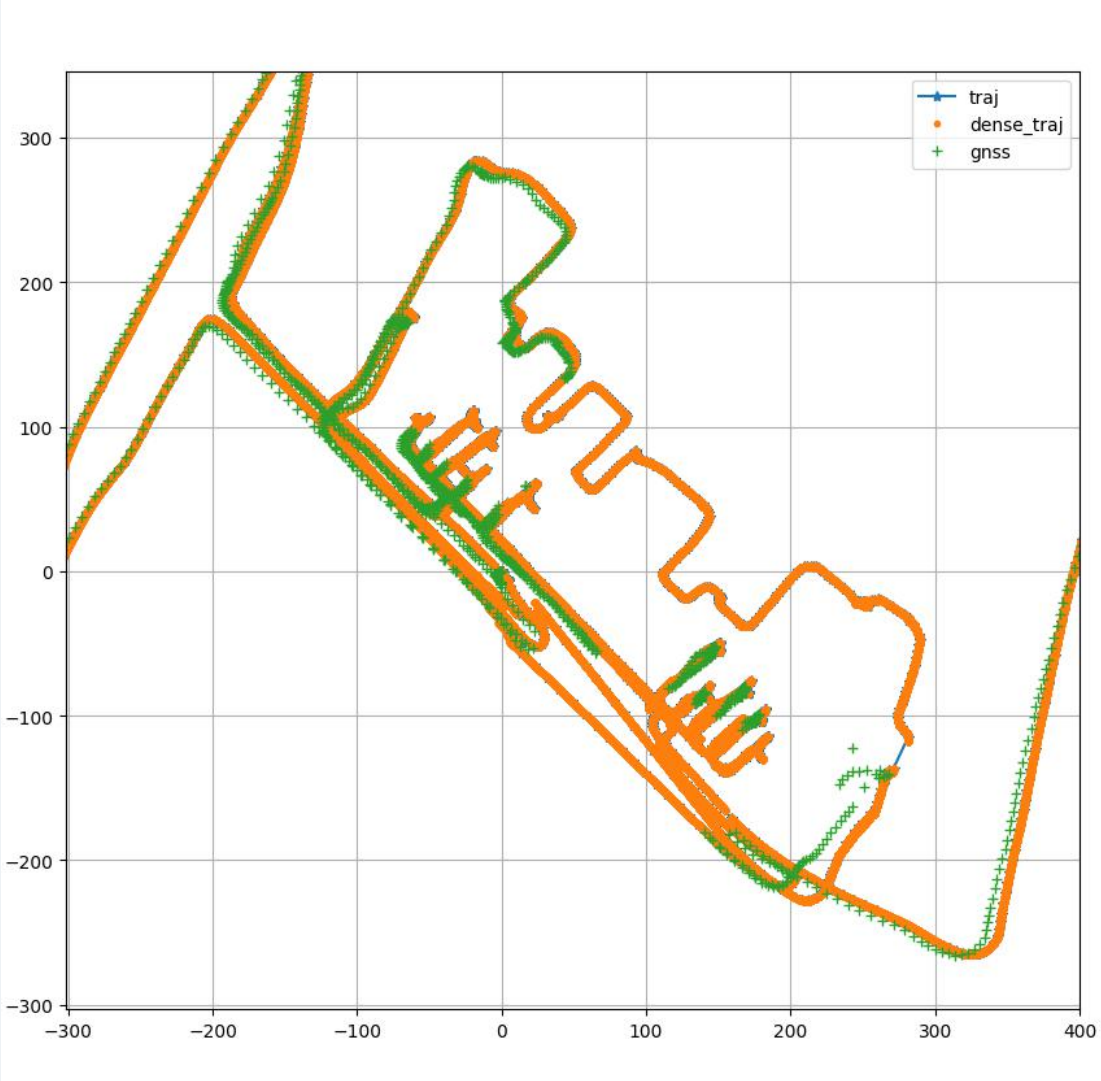
Result [Train]





Result [Score]

Trajectory 1



Trajectory 2

THANK YOU FOR YOUR ATTENTION!

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