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# An Improved Measurement and Visualization System for High Precision Positioning with GPS-RTK*

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## Abstract

In this work we present a GPS measurement and visualization system that enables real-time tracking, saving, and analysis of measurement data. We made measurements with a u-blox receiver GNSS (Global Navigation Satellite System) module connected to a `Raspberry Pi 5` microcomputer, to find out if the out-of-the-box solution can be used for high precision GPS positioning that usually means centimeter level in RTK (Real Time Kinetics) applications. We provided a modular user interface for the device supporting graphical visualization, database management and point separation. Based on repeated measurements, the system reproduces the coordinates of measurement locations. Overall, the software assists in handling GPS data and analyzing information collected during experiments. The primary goal is to maximize measurement accuracy and simplify the experimental workflow.

## Introduction and Methodology

Real Time Kinetics by high precision positioning is widely used in several practical areas [1, 2]. Our objective is to visualize, store, and analyze data obtained from an RTK GPS measurement device in order to maximize measurement accuracy.

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The measurement system is built on reliable, industry-grade GNSS hardware. The RTK processing is performed by the `u-blox ZED-F9P-04B-01` receiver, a high-precision, multi-frequency GNSS module capable of centimeter-level positioning. The `u-blox ANN-MB-00-00` active antenna provides stable multi-band reception, ensuring consistent signal quality even in challenging environments. Data acquisition and real-time processing are handled by a `Raspberry Pi 5`, which offers sufficient computational performance for visualization, database operations, and communication with the GNSS hardware.

The measurement algorithm selects the coordinates with the smallest error from a set of pre-collected GPS points noted by $lat_{\text{best}}$ and $lon_{\text{best}}$ respectively for the latitude and longitude. Since in our current measurements they are not needed, height and velocity values are simply averaged. We formulize the above as:

$$lat_{\text{best}} = \min_i \sigma_{lat}(i), \qquad lon_{\text{best}} = \min_i \sigma_{lon}(i) \tag{1}$$

$$alt_{\text{avg}} = \frac{1}{N}\sum_{i=1}^{N} alt(i), \qquad v_{\text{avg}} = \frac{1}{N}\sum_{i=1}^{N} v(i), \tag{2}$$

where $\sigma_{lat}(i)$ and $\sigma_{lon}(i)$ are the accuracy errors in meters of the latitude and the longitude for the measurement $i$. The total 3D error $H_{3D}$ is:

$$H_{\text{3D}} = \sqrt{(\sigma_{\text{lat}})^2 + (\sigma_{\text{lon}})^2 + (\sigma_{\text{alt}})^2} \tag{3}$$

Repeated measurements confirmed that the actual positions lie very close to each other, although the estimated error is typically exaggerated (the real deviation is approximately 5 cm).

## Results

Initial measurements showed errors of $100 - 170$ cm, while the improved algorithm typically achieves around 70 cm, with best cases reaching 30˘40 cm. Measurements were performed in Debrecen and Mátészalka under various environmental conditions (forest, open sky, cloudy and clear weather). In order to further improve accuracy we plan refinement of the algorithm, particularly the averaging of coordinates while incorporating error metrics,

# References


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