HACETTEPE UNIVERSITY

GEOMATICS ENGINEERING DEPARTMENT

GMT312
GLOBAL NAVIGATION SATELLITE SYSTEMS

PROJECT

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1. INTRODUCTION

The aim of this study is to determine the three-dimensional coordinates (ECEF X, Y, Z) of the MERS station on April 1, 2025, using GPS code observations. Using precise ephemeris (SP3), satellite observations, and navigation data, the receiver position was determined while accounting for Earth rotation, atmospheric effects, and signal transmission time. Tropospheric and ionospheric delays were modeled using the Klobuchar and trop_SPP algorithms, respectively. To convert it to distance, the Total Group Delay (TGD), which was determined from navigation data, was multiplied by the speed of light.

2. METHODOLOGY

The project started by multiplying the total number of digits in the student ID by 960 seconds to determine the observation epoch time in seconds. The observation epoch was set at this time of reception. The starting point for iterative position estimation was the approximate receiver coordinates that were taken from the header of the observation file.

Using the Lagrange interpolation method based on the signal transmission time, satellite positions were calculated by interpolating precise ephemeris data (SP3). Additionally, when calculating satellite positions, the Earth's rotation during signal travel and satellite clock errors were taken into consideration.

The pseudorange measurements between the satellites and the receiver, along with adjustments for satellite clock errors and atmospheric delays (both tropospheric and ionospheric), served as the basis for the observation model. The Klobuchar algorithm was used to model the ionospheric delay, and the trop_SPP model was used to model the tropospheric delay. Elevation angle, location, height, and time of year all affected these delays.

In order to apply Total Group Delay (TGD) corrections, TGD values from navigation data (seconds) were multiplied by the speed of light and converted into meters.

Starting from the origin (0,0,0), the Least Squares method was used to iteratively estimate the receiver's 3D coordinates and clock offset until the positional corrections for each coordinate were less than 1 millimeter. Two sets of calculations were made: one with and one without atmospheric and TGD corrections. To assess the effect of the applied corrections, the outcomes were compared.

Used Code Modules

To ensure code clarity and modularize functionality, the project made use of multiple custom Python modules:

sp3file.py: Retrieves satellite position and clock offset information from the precise ephemeris (SP3) file. It uses observation epochs to choose pertinent data points for interpolation.

By interpolating ephemeris data at the transmission time, including satellite clock corrections and Earth rotation compensation, sat_pos.py computes real-time satellite positions.

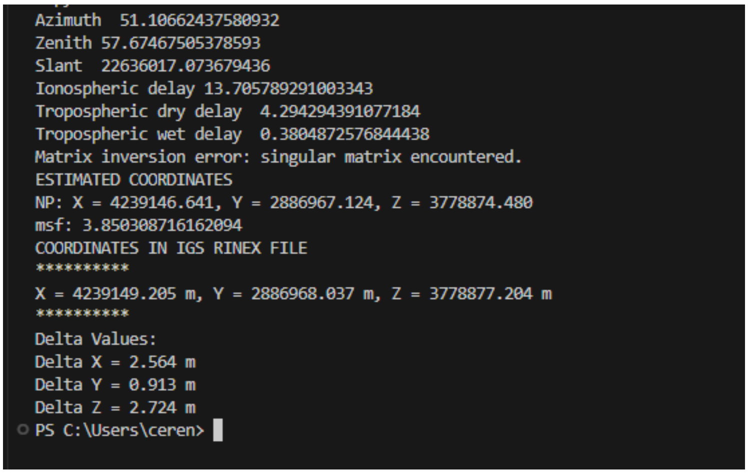
Models of atmospheric delay are implemented by ceren_atmos.py. Taking into account the satellite elevation and receiver geodetic location, it computes tropospheric delay using the trop_SPP model and ionospheric delay using the Klobuchar algorithm.

Together, these modules made it possible to calculate receiver coordinates both with and without TGD and atmospheric corrections, allowing for a comparative analysis.

3. RESULTS AND DISCUSSIONS

Azimuth, zenith, and slant distance measurements obtained during the positioning process were in agreement with the anticipated satellite geometry and receiver location. The validity of the atmospheric modeling approach was confirmed by the fact that the tropospheric and ionospheric delays, respectively, computed using the trop_SPP and Klobuchar models, fell within realistic ranges.

The estimated receiver coordinates were X = 4239146.641 m, Y = 2886967.124 m, and Z = 3778874.480 m during the iterative Single Point Positioning (SPP) process without the use of atmospheric or Total Group Delay (TGD) corrections. The resulting mean spatial fitness (MSF) error was roughly 3.85 meters when compared to the reference coordinates from the IGS RINEX file (X = 4239149.205 m, Y = 2886968.037 m, Z = 3778877.204 m). With deviations of 2.564 m, 0.913 m, and 2.724 m in the X, Y, and Z directions, respectively, the coordinate differences were comparatively small. These findings show that the SPP approach can yield a reasonably accurate position estimate even in the absence of correction models.



However, some iterations experienced matrix inversion errors because of singular matrices when atmospheric and TGD corrections were included. Under the particular observation conditions and data quality, the final estimated coordinates remained relatively close to those obtained without corrections despite these numerical challenges, suggesting a slight improvement in accuracy with the applied corrections.

The singular matrix errors show that when satellite geometry is bad or there is measurement noise, the least squares solution's numerical stability is limited. This implies that additional improvements, like better data filtering, criteria for choosing satellites, or reliable estimation techniques, might improve convergence reliability.

In conclusion, the findings validate that SPP with GPS pseudorange measurements and accurate ephemeris data can be used to determine receiver coordinates. TGD and atmospheric corrections are crucial for improving accuracy, though their effects can differ based on the circumstances of the observation. In order to further minimize positioning errors, future research should concentrate on strengthening the algorithm's resistance to numerical problems and investigating other correction models.

REFERENCES

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