** AE4872 (2024) – SATELLITE ORBIT DETERMINATION**

A satellite in space above earth

Description automatically generated

**Assignment 2 – Point Positioning**

Instructor: Christian Siemes

Email: [C.Siemes@tudelft.nl](mailto:C.Siemes@tudelft.nl)

Group size: 1 student

Due: Wednesday, 18 December 2024, 18:00

Page limit: 6 pages

Estimated time: 20 hours

*In your report, explain how you solve the tasks and use figures where appropriate. Describe the intermediate steps and give the intermediate results so we may award partial points (no intermediate results = no full score). Attach your code in the appendix of your report. We will check the code for plagiarism but not grade it.*

We want to determine the position of the GOCE satellite from GPS tracking data (pseudoranges derived from the C/A code) using iterative least squares. The data and Matlab/Python scripts to read the data files are provided on Brightspace. The last instruction slide clarifies the contents of the files, including the units and reference frames. Use these values for the speed of light and Earth's rotation rate:

c = 299792458 m/s

= 7.292115e-5 rad/s

a) For this question, do not use any of the data in the files. Instead, assume a GPS receiver on an arbitrary satellite in a circular orbit at an altitude of 500 km. Further, assume a GPS transmitter clock error of 0.1 ms and that the GPS satellites are in near-circular orbits with an eccentricity up to 0.01 and a semi-major axis of 26560 km. How large are the following effects on the pseudoranges measured by the GPS receiver?

1) GPS clock offsets **(4 points)**

2) Light time effect **(10 points)**

3) Relativistic effect caused by the eccentricity of the GPS orbits **(6 points)**

Give the approximate size or range of values and explain how you reached that conclusion.

b) Now consider the specific case of the GOCE satellite. Inspect file PRN\_ID.txt and explain why the PRN IDs change over time. **(5 points)**

c) Assume that the pseudorange observations have a standard deviation of 3 m and a correlation of 0.2. Describe how you construct the observation covariance matrix and report the matrix. **(5 points)**

d) Linearize the observation equation for one pseudo-range observation. The parameters are the GOCE position and the receiver clock offset. Select values for the initial parameter vector that are not zero, i.e., ***x***0 ≠ 0. Report the values of the linearised observation equation for the first epoch (vectors ***x***0, ***f***(***x***0), ***y***, and matrix ***H***). **(10 points)**

e) Implement your code for the least-squares adjustment based on tasks c and d. Use your code to estimate the GOCE positions at all epochs. Include only the corrections for the transmitter and receiver clock offsets in the model for the pseudoranges. Use all pseudorange measurements and consider that the GOCE GPS receiver tracks different GPS satellites over time. In the provided files, the PRN ID is zero when no GPS satellite is tracked. **(20 points)**

* Show the difference between your estimated positions and the precise orbit in a figure. Briefly describe the figure.
* Report the estimated positions for the first four epochs in a table with cm precision.
* Describe how you decide when to stop the iterations of the iterative least squares procedure.

*Hint: The precise positions of the receiver are provided at the epochs specified in file t.txt. The estimated positions (your solution) are valid at the epochs specified in file t.txt, corrected for the receiver clock offset. Thus, you must calculate the precise positions at those epochs. You can do this by multiplying the receiver clock offset with the precise orbit's velocity and adjusting the precise positions accordingly.*

f) Do the same as in task e, but now include the light time correction and the correction for relativistic effects. **(14 points)**

* Show the difference between your estimated positions and the precise orbit in a figure. Briefly describe the figure.
* Report the estimated positions for the first four epochs in a table with cm precision.
* Show the size of the residuals in the observation equations from tasks e and f. Describe what you show and justify if the change in size is as expected.

*The hint for task e also applies here.*

g) Show the estimated receiver clock offset from task f in a figure. Describe what would happen if we did not model the receiver clock offset in task f. **(12 points)**

h) For task f, calculate the PDOP values using the equation from the instruction slides. Compare the PDOP values to the difference between your estimated positions and the precise orbit in a figure. Discuss if the size of the PDOP values agrees with the size of the differences and what you can conclude from that, considering task c. **(9 points)**

i) Mention the remaining error/noise sources affecting your solution from task f. Specify and briefly justify their size. Only error and noise sources larger than 10 cm give points. Also, exclude the possibility of mistakes in your solution. **(5 points)**

*Please mention how many hours you spent approximately on the assignment. We will use the information to improve the assignments for next year.*