ASEN 5090-001 Homework #07

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Executive Summary

This document outlines the problem solving process and results for the set homework assignment. The document is broken down into several sections. The first section is the objective section. One objective has been identified. Following the objective section is the methods and procedures. The work completed is straightforward. The results section follows the method/procedure section. The results obtained are consistent with the expected results. The analysis and discussion section describes in detail how each of the results are obtained. Following the analysis and discussion section is the conclusion and recommendation section. This section is short, again, this assignment is straightforward and does not necessarily require a large report to show results. The final sections are the references and the appendix. All MATLAB code generated to complete the assignment has been submitted to the reader in the appendix.

Objective

The objective of this document is to fully demonstrate adequate understanding of the covered course material as well as present solutions to assigned problem using proper engineering problem solving processes. Specifically, the main learning outcome of this homework assignment is to gain a thorough understanding of concepts of RINEX files and accuracy of GPS point positioning.

Methods and Procedures

The methodology and procedures followed are straight forward and concise. All procedures used to solve the problem are from either course notes or the course textbook. The most direct approach was used to solve all of the problems. All computations, used MATLAB as the programming language to compute the solution.

Results and Discussion

Problem 1: RINEX files start with a special header.

a) Look at the test file with a text editor and examine the header. How many types of observations are available in the sample file? Which one is P1? What is C1?

   There are a total of 7 types of observations in the RINEX file. They are L1, L2, P1, P2, C1, S1 and S2.

   P1 is the third type of observation, specifically, P1 is the pseudorange of the P code on L1 frequency measured in meters.

   C1 is the pseudorange C/A code on L1 frequency measured in meters.

b) Read the obs file header and extract the approximate receiver position. Use this for your assumed receiver position coordinates.

   The Earth-Centered-Earth-Fixed wgs84 coordinates found from the obs header file are:

   X: 1.112162136E6 meters
   Y: -4.842854662E6 meters
   Z: 3.9854970649E6 meters

   Converting the ECEF position to latitude, longitude and altitude, the assumed position is:

Latitude:	38.921°
Longitude:	-77.066°
Altitude:	58.92 meters

Problem 2: Read the set of observation records using read_rinex_obs5. For each of the observed satellites record calculate, print, and check the following values:

a. The ionosphere free pseudorange observable P3 in meters
b. The expected range in meters
c. The elevation and azimuth in degrees
d. The satellite clock correction in meters
e. The relativistic correction in meters

Table 1: Solution to Question 2

PRN	P3 [m]	Expected Range [m]	Elevation [deg]	Azimuth [deg]	Sat Clock [m]	Relativity Correction [m]
31	20870599.20	20942669.19	54.838	240.130	72078.54	4.30
22	24331228.58	24393714.85	15.084	315.359	62497.63	-0.55
32	20571454.93	20520489.82	69.189	032.525	-50962.44	-0.39
01	23972570.48	23984068.55	17.272	300.662	11509.77	4.09
25	21435555.97	21354525.82	47.624	095.938	-81028.67	-0.57
26	25332020.32	25184443.50	05.037	188.764	-147554.48	-0.38
14	21137165.75	21124589.15	59.150	317.814	-12574.72	-1.13
10	21281236.84	21248114.95	51.061	161.746	-33120.68	-0.52
18	23287327.85	23458291.92	19.599	151.214	170962.81	-9.82
12	22790632.51	22907354.84	27.061	051.645	116733.01	1.58

Problem 3: Construct and print the A-Matrix as discussed in lecture or in your book.

The formula to construct the A-Matrix

$$[A] = \left[-\frac{x^s - x_0}{R_0^s}, -\frac{y^s - y_0}{R_0^s}, -\frac{z^s - z_0}{R_0^s}, 1 \right]$$

A =

0.304025395515536	0.907303506795513	-0.290463260048816	1
0.712519735015933	-0.071473177213792	-0.698002300964539	1
-0.306836324518498	0.482622798040554	-0.820321098575116	1
0.817332392843283	0.110816921949193	-0.565409028419939	1
-0.791812662782458	0.452823973695296	-0.409857482430363	1
-0.005797313672808	0.703367898679099	0.710802356680060	1
0.239554432533278	0.495413836726354	-0.834972337406295	1
-0.411247073379375	0.911200319450098	-0.024286260950136	1
-0.616641007694983	0.658362640842201	0.431639317917401	1
-0.682134441640853	-0.149689367669224	-0.715741361620320	1

Problem 4: Compute and print the prefit residuals (dy) correcting for ionospheric errors, satellite clock, and relativity.

$$dy = P3 - geometric_{range} + Satellite_{Clock} - Relativity_{Correction}$$

dy =

4.24922355758618
11.9122018521399
3.05746280341697
7.60610440373357
2.06020666926426
22.7166908326313
3.00556587296223
1.72767984290069
8.55124094124630
9.10419624908146

Problem 5: Plot these residuals as a function of the satellite elevation angle. What do you think is the cause of the residuals? Use the simple model for the dry component of the troposphere given in class and compare it with these residuals.

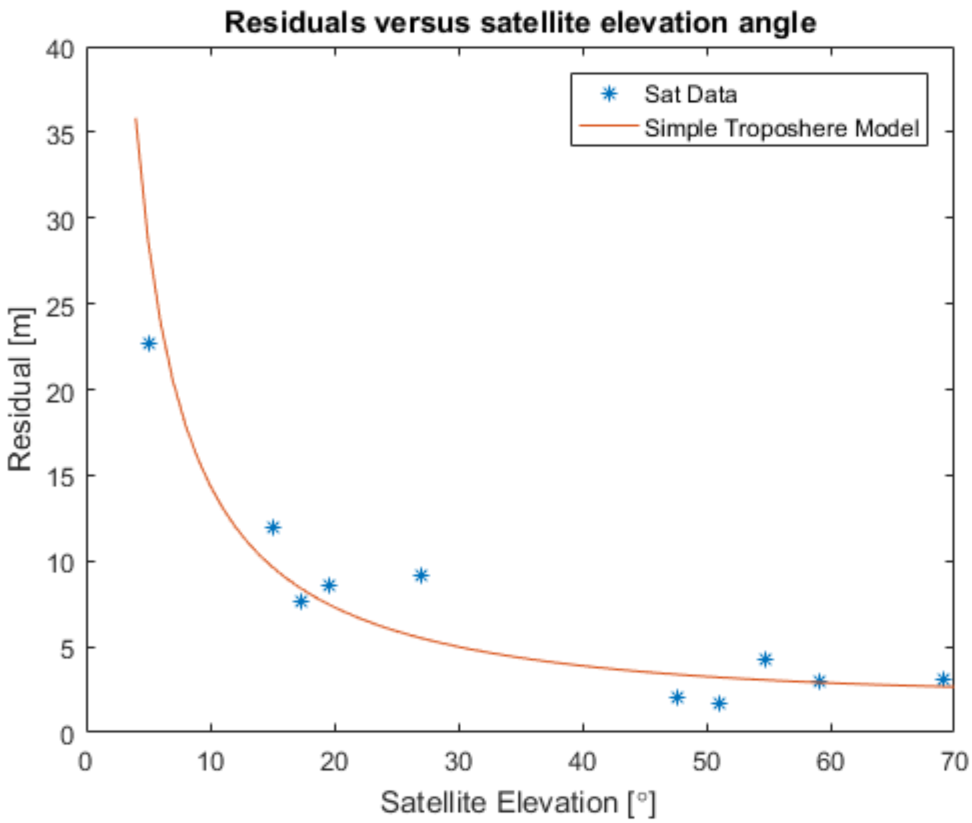

Figure 1: Plot of Residuals versus Satellite Elevation

One of the sources of error that causes the residuals is that the mathematic model used is not perfect and does physically capture the entire picture. Since there is missing information in the model, there are residual differences. By inspecting the above graph it is clear that, the simple tropospheric model does a good job of capturing and modeling atmospheric disturbances. If the model were more accurate it could drive the residuals down to zero creating a problem with a homogeneous solution.

Problem 6: Form the least squares solution for dx based on dy = A dx + e. Print the dx, dy, dz, and db to a precision of 1 cm. If the information in the header is correct, this will be the point solution error.

$$[d\vec{x}] = \begin{bmatrix} dx \\ dy \\ dz \\ db \end{bmatrix} = \begin{bmatrix} 3.58 \\ -11.87 \\ 12.40 \\ 17.00 \end{bmatrix}$$

Problem 7: Now, instead of using the correct location from the RINEX header, use an initial estimate that is way off – for example try Boulder, CO. Compute the A matrix and the pre-fit residuals. Compute the least squares correction and iterate your solution 5 times. For each iteration print the position correction, and your new estimate. Does it converge to the correct answer?

For this problem an initial position of Boulder, CO with an initial position:
Latitude: 40 degrees Longitude: -105 degrees Altitude: 1631 meters

Table 2: Position Correction

Iteration	dx [m]	dy [m]	dz [m]	db [m]
1	2371324.30	-198729.08	-65176.14	-40422.86
2	7511.01	83213.41	-28399.23	-176.33
3	-20.32	-151.39	50.88	17.00
4	-2.01 E-3	290.47 E-6	-472.52 E-6	17.00
5	7.96 E-9	38.48 E-9	4.84 E-9	17.00

Table 3: Position Estimate

Iteration	Latitude	Longitude	Altitude
1	38.6733	-77.3601	79677.36
2	38.9210	-77.0656	-66.89
3	38.9206	-77.0662	76.33
4	38.9206	-77.0662	76.33
5	38.9206	-77.0662	76.33
Actual	38.9206	-77.0662	58.92

Inspecting the results in tables two and three it is clear that the results converge to the proper latitude and longitude but do not converge to the correct altitude. Increasing the number of iterations does not change the altitude difference. Furthermore, changing the initial location does not change the altitude difference either.

Conclusions and Recommendations

Concluding, this homework set has been successful and has meet the objective of the assignment. Overall, the assignment was straight forward and not very challenging, it allowed the author to think critically about the real GPS data and how error can affect position determination.

References

1. Misra, Pratap, and Per Enge. *Global Positioning System: Signals, Measurements, and Performance*. Lincoln, MA: Ganga-Jamuna, 2011. Print.

Appendix A: MATLAB CODE

```
% ASEN 5050 HW # 7
% Author: CG

close all; clear all; clc;

% Problem 1:

wgs84.ellipSemi = 6378137.0;
wgs84.reciFlat = 298.257223563;
wgs84.f = 1/wgs84.reciFlat;
wgs84.earAngVel = 7292115.0E-11;
wgs84.GM = 3986004.418E8;
wgs84.spdLite = 2.99792458E8;

meanSolarDay = 86400;
meanSiderealDay = 86164.09954;

% Part A

% How many types of observations are avialable in the sample file? 7
% Which one is p1? The 3rd
% What is c1? Pseudorange for C/A L1 code

% Part B: Read the obs file header and extract the approximate reciever
% position. Use this for your assumed reciever position coordinates.

    [fid, obsECEF, observables] = read_rinex_header('test.16o');
    rinexv3 = read_rinex_obs5('test.16o',1:1:32,86400);
    clc;
    data = rinexv3.data;
    disp('Problem 1 Part B')
    fprintf('The assumed reciever position is %.4f %.4f %.4f m\n',obsECEF)
    disp(' ')

% Read the set of observation records using read_rinex_obs5. (One time or
% epoch 01:03:00 GPS time, all the observed satellites.) For each of the
% observed satellites record calcualte, print, and check the following
% values:
%   a) the ionosphere free pseudorange ovservable P3(using P1 and P2) in
%   meters
%   b) the expected range in meters
%   c) the elevation and azimuth in degrees
%   d) the satellite clock correction in meters
%   e) the relativistic correction in meters

    tStart = data(1,2);
    epoch = tStart + 60*63;
    aa = find(data(:,2) == epoch);
    newDat = data(aa,:);

    % Ionosphere free pseudorange observable P3
        %p3 = 2.546*newDat(:,6) - 1.546*newDat(:,7);
```

```
        p3 = ((1575.42^2)/(1575.42^2 - 1227.6^2))*newDat(:,6) -
((1227.6^2)/(1575.42^2 - 1227.6^2))*newDat(:,7);

    % Expected range in meters
    [brdc3000,ionoparams3000] = read_GPSbroadcast('brdc3000.16n');
    for ii = 1:1:length(newDat)
        [health,x,v,relcorr,satClkCorr] = broadcast2xv(brdc3000,[data(1)
epoch],newDat(ii,3), 'eph');
        satECEF = x;
        lla = ecef2lla(obsECEF');
        [range, az,ele] = ecef2topo( obsECEF, satECEF', lla(1), lla(2), wgs84
);
        [range0, range1,] = compute_range(brdc3000, newDat(ii,3), [data(1)
epoch], obsECEF, wgs84);
        rangeTopo(ii,1) = range;
        azimuth(ii,1) = az;
        elevation(ii,1) = ele;
        geoRange(ii,1) = range0;
        expRange(ii,1) = range1;
        relativity(ii,1) = relcorr;
        satClock(ii,1) = satClkCorr;
        satPos(ii,:) = x;
    end

quest2 = [newDat(:,3), p3, expRange, elevation, azimuth, satClock,
relativity];

% Question 3: Construct and print the A-Matrix as discussed in lecture or
% in your book.

    %A = ones(length(newDat),4);
    for jj = 1:1:length(newDat)
        A(jj,:) = [-(satPos(jj,1)-obsECEF(1))/geoRange(jj), -(satPos(jj,2)-
obsECEF(2))/geoRange(jj), -(satPos(jj,3)-obsECEF(3))/geoRange(jj), 1];
    end
% Problem 4: Compute and print the prefit residuals (dy) correcting for
% ionospheric errors, satellite clock, and relativity.

    %dy(ii) = p3(ii) - range0 + satClkCorr - relcorr;
    dy = p3 - expRange + satClock - relativity;

% Problem 5: Plot these residuals as a function of the satellite elevation
% angle. What do you think is the cause of the residuals? Use the simple
% model for the dry component of the troposphere given in class and compare
% it with these residuals.

    eleAng = 4:1:70;
    dryMod = 2.5./sind(eleAng);

    figure()
    plot(elevation,dy,'*')
    hold on
    title('Residuals versus satellite elevation angle')
    ylabel('Residual [m]')
    xlabel('Satellite Elevation [\circ]')
```

```matlab
    plot(eleAng,dryMod)
    legend('Sat Data','Simple Troposhere Model')


% Problem 6: Form the least squares solution for dx based on dy = Ax + e.
% Print the dx, dy, dz, and db to a precision of 1cm. If the information in
% the deader is correct, this will be the point solution error.

    dx = inv(transpose(A)*A)*transpose(A)*dy;

% Problem 7: Now, instead of using the correct location from the RINEX
% header, use an inital estimate that is way off. Compute the A matrix and
% the pre-fit residuals. Compute the least square correction and iterate
% your solution 5 times. For each iteration print the position correction,
% and your new estimate. Does it converge to the correct answer?

    % Start in Boulder
        lat = 40; long = -105; alt = 1631;
        newObsECEF = lla2ecef([lat, long, alt]);

    for kk = 1:1:5
        for ii = 1:1:length(newDat)
        [health,x,v,relcorr,satClkCorr] = broadcast2xv(brdc3000,[data(1)
epoch],newDat(ii,3), 'eph');
        satECEF = x;
        lla = ecef2lla(newObsECEF);
        [range, az,ele] = ecef2topo( newObsECEF', satECEF', lla(1), lla(2),
wgs84 );
        [range0, range1] = compute_range(brdc3000, newDat(ii,3), [data(1)
epoch], newObsECEF', wgs84);
        rangeTopo2(ii,1) = range;
        azimuth2(ii,1) = az;
        elevation2(ii,1) = ele;
        geoRange2(ii,1) = range0;
        expRange2(ii,1) = range1;
        relativity2(ii,1) = relcorr;
        satClock2(ii,1) = satClkCorr;
        satPos2(ii,:) = x;
        end

        for jj = 1:1:length(newDat)
            A2(jj,:) = [-(satPos(jj,1)-obsECEF(1))/geoRange(jj), -
(satPos(jj,2)-obsECEF(2))/geoRange(jj), -(satPos(jj,3)-
obsECEF(3))/geoRange(jj), 1];
        end

        dy2 = p3 - expRange2 + satClock2 - relativity2;

        dx2 = inv(transpose(A2)*A2)*transpose(A2)*dy2;
        aaa(kk,:) = dx2;

        newObsECEF = (newObsECEF(1:3)' + dx2(1:3))';
        lla2(kk,:)  = ecef2lla(newObsECEF);
    end
```