ENAE441 Fall 2019

GNSS Orbit Group Project

Due December 5, 2019 at 5PM

1 Objective

You will determine the locations and orbit of one or more GNSS satellites using pseudorange data recorded by ground stations with known locations.

2 Data

The CORS site has data from GNSS receiver stations, most located in the United States or US territories. The CORS map shows the exact locations. Each group will need to choose the following

- One day in 2019 between January and October and one twelve hour segment within that day.
- Two GNSS satellites (identified by PRN) that were broadcasting signals on that day.
- At least three ground stations for each satellite that consistently received and recorded signals on that day. Pick locations that are spread far apart in order to get good trilateration solutions, but close enough that all sites receive satellites from the chosen satellite simultaneously. The two satellites need not have the same set of stations.

There are several ways to download the data; see Data Products on the CORS site. The "User Friendly CORS" (UFCORS) may be the easiest way. Download 12 hour segments and keep the sampling rate "As is". Select the "IGS Orbits in SP3c format" once for the day (it is the same for all ground sites).

The data will be in RINEX observation format, which is explained in section 10.1.2 of the book. You will need the pseudoranges from the satellites (PRNs) you have selected at the times you have selected. If there are several pseudorange signals available, pick any one.

Copy the spreadsheet template to your own files and record the data you use in it. For the first satellite, do the following.

1. Select a time t_1 near the beginning of the time range, and a time t_2 near the end.

2. Find three ground stations that are spread as far apart as possible and have recorded pseudoranges at t_1 for the particular GNSS satellite.

3. Find three ground stations that are spread as far apart as possible and have recorded pseudoranges at t_2 for the particular GNSS satellite. They need not be the same as those selected for t_1.

4. Record the information in the spreadsheet under "satellite 1".

Then repeat for satellite 2.

At the top (header) of each observation file, find the phrase "APPROX POSITION XYZ" starting in column 61. To the left will be three numbers giving the ECEF coordinates in meters of that station. Record these in the second tab with the four-character station code.

The OBS RINEX format consists of a file header that ends with `END OF HEADER` starting in column 61, followed by time blocks of observations. Each time block has its own block header, usually one or two lines, followed by PRN blocks. The time block header has the date and time and list of the satellites observed (as PRN numbers). The following example shows a time block for October 31, 2019 at 06:00:00. There were 10 satellites observed, all GPS "G", with PRNs 20, 11, 17, etc.

```
 19 10 31  6  0  0.0000000  0 10G20G11G17G07G08G30G13G28G05G15
 130506643.275 5 101693497.29942  24834582.641    24834587.703
        33.500          14.800


 124103104.059 7  96703747.17444  23616037.508    23616041.027
        42.900          25.600
```

The first two observation blocks follow. The meaning of the data is explained in the file header with the lines `# / TYPES OF OBSERV` starting in column 61. For this file, it says

```
    20    L1    L2    C1    P2    P1    S1    S2    C2    L5# / TYPES OF OBSERV
          C5    S5    L6    C6    S6    L7    C7    S7    L8# / TYPES OF OBSERV
          C8    S8                                            # / TYPES OF OBSERV
```

Note the blanks in the data mean there was no data recorded of that type. The pseudoranges will be labelled "C" and "P", in this case, for example, C1, P1, and P2, are the third, fourth, and fifth data fields. Each field contains three numbers, one floating point number with 14 characters, followed by

two one-digit numbers (which you can ignore and may be blank), for a total of 16 characters. Each line has five fields, for a total of 80 characters. If the field of 16 characters is blank, that data is missing. In this example, for GPS PRN 20 (first PRN block), the pseudorange C1 is 24 834 582.641 m, P2 is 24 834 587.703 m. The rest are missing. For GPS PRN 11 (first PRN block), the pseudorange C1 is 23 616 037.508 m and P2 is 23 616 041.027 m.

3 Analysis

Once the data has been collected, you can determine the location of each satellite at each of the two times, and from that, using a Lambert solver, the orbit. For each satellite do the following.

1. For t_1, t_2 pick three pseudoranges and use the trilateration computation of section 7.2.4 of the book using the pseudoranges as ranges to determine the ECEF position vectors $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$ at the two times.

2. The actual position of each satellite may be determined from the `.sp3` that is in the downloaded zip file from UFCORS. Starting at line 24, there are blocks of data by time with the location of each satellite in ECEF coordinates; the top of each block of data has the date and time for that block, and each line gives the GNSS satellite number, followed by ECEF coordinates. For details, see the description of the SP3c format.

3. Compute the IJK position vectors from these vectors (see book section 5.4).

4. Solve the orbit using a solution to the Lambert problem (see book section 7.3.3).

5. Find which PRN belong to which satellites in space-track.org

   (a) First select "Recent TLEs", then "Navigation three line". This is a list of two-line elements for all NAVSTAR (GPS) satellites but for the latest data set.

   (b) Make a list of the five-digit SDC numbers for all the NAVSTAR satellites TLE description.

   (c) Select TLE Search in space-track.org, and under "Entries", make a comma-delimited list of all these numbers. Then select "EPOCH Date Range" and the date of interest.

(d) From the resultant orbital elements, find the satellite corresponding to your chosen PRN.

(e) Make a table showing the actual Kepler orbital elements derived from the TLE, and what you have computed.

4 Format

Write a report that includes the following:

1. A brief statement and summary of the problem: what you set out to do and what you found.

2. For each of the parts described in the previous section, show the procedures and calculations used, referencing the data in the spreadsheet.

3. Conclusion, summarizing your results and an explanation on the sources of errors and limitations of your analysis.

You should place the following files in a folder designated by your instructor for your group:

1. The report as a PDF or Google Document.

2. The filled-out data spreadsheet.

3. Any software files used in the computation. Indicate their function and origin (who wrote it and where you got it from).

4. A brief statement from *each member* of the group giving your name and what you did on the project. If you shared responsibility for some part of the project with another member of the group, indicate who that was.

If you find that you need to make a correction after you've turned in the document, please remove the old document(s) so there is no confusion about which is the latest version.

Your whole group should collaborate on one report. Please coordinate within your group to make sure you are all in agreement when the report is finished and should be submitted, and agree on one person who will submit the finished report.