ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.7

MATLAB Software for GNSS Mission Planning

Sermet Ogutcu
Necmettin Erbakan University
Meram, Konya, Turkey

Abstract:
This paper introduces the software for Global Navigation Satellite System (GNSS) mission planning. The software was written in MATLAB programming language. It consists source codes (m files) and Graphical User Interface (GUI). The software supports American Global Positioning System (GPS), Russian Globalnaya Navigatsionnaya Sputnikovaya (GLONASS), Europe's GALILEO and Chinese BEIDOU GNSS constellation. Input parameters of the software are latitude, longitude, ellipsoidal height and cut-off angle of the related point on the earth, time interval and GNSS selection. The software provide Dilution of Precision (DOP) values for horizontal, vertical, time and the number of observed satellites with respect to the time interval. The users can also obtain the earth centered earth fixed coordinates (ECEF) of GNSS satellites chosen for the planning. The software check for several issues before the processing. One of the most important one is the satellite health issues in almanac files. The unhealthy satellites are reported and automatically removed from the processing. The lack of satellites in almanac files are also reported. The users can modify the source codes as the necessity of their studies. Besides the most online GNSS mission planning software, this software can be used offline using the downloaded GNSS almanac files. The source codes can also be used for educational purposes for anyone who is interested in the computation of the relevant parameters.

Keywords: BEIDOU, GALILEO, GLONASS, GPS, GNSS, MATLAB, MISSION PLANING

I. INTRODUCTION

With the latest development of Global Navigation Satellite System (GNSS), the importance of GNSS mission planning is getting increased. For particular studies involved accuracy evaluation of stand-alone GNSS constellations (Afifi and El-Rabbany, 2017; Afifi and El-Rabban, 2016), location of the GNSS constellations with respect to the receiver's location should be known before the processing. In this way, users can choose the optimal GNSS availability with regard to the observing time. Most of the available GNSS mission planning software are based on online and users cannot obtain each data they need. They cannot be run offline and users cannot modify the software in according to their wishes. The users also cannot obtain the source codes. For these reasons, GNSS mission planning software was written in Matlab programming language. Graphical Users Interface was written for the convenience of the users.
The software support American Global Navigation Satellite System (GPS), Russian Globalnaya Navigatsionnaya Sputnikovaya (GLONASS), Europe's GALILEO and Chinese BEIDOU GNSS constellations (Li et al, 2015;Cai et al, 2015). The mission planning requires the computation of dilution of precision (DOP) values of horizontal, vertical and time parameters (Langley, 1999). The users can choose the most optimum observing sessions with respect to DOP values. In order to compute DOP values of associated GNSS satellites, almanac files (Ma and Zhou, 2014) of the related GNSS satellites are required. Almanac files of GPS and GLONASS satellites are broadcasting daily whereas the almanac files of GALILEO and BEIDOU GNSS satellites are broadcasting with latency. For GALILEO, latency generally does not exceed three-four days but latency for BEIDOU would be several months.
Almanac parameters include reduced version of broadcast parameters namely, reference epochs in seconds, square root of semi-major axis, eccentricity, mean anomaly at reference epoch, argument of perigee, inclination angle at reference epoch and longitude of ascending node at reference epoch. Computation of satellite coordinates from almanac parameters are similar for GPS, GALILEO and BEIDOU but computation for GLONASS is significantly different and requires much more computational steps compared to other GNSS constellations
(https://www.unavco.org/help/glossary/docs/ICD_GLONASS_4.0_(1998)_en.pdf).
The users can obtain every information they need like the Earth Centered Earth Fixed coordinates (ECEF) of the GNSS satellites using the software. Computing satellite coordinates with respect to the determined time interval is necessary for accuracy evaluation of almanac parameters. The coordinates obtained from almanac parameters can be compared to coordinates obtained from final and rapid orbit products (Dow et al., 2005). The users can modify or develop the source codes as the requirement of theirs study. Section 2 explains the some useful properties of the software and conclusion is given in section 3.

II. INTRODUCTION OF THE SOFTWARE

The program is developed in MATLAB. The Graphical User Interface (GUI) was developed in order to simplify the operation. All necessary input parameters can be configured in the GUI. Figure 1 shows the GUI of the software.
The input parameters of the software are geodetic latitude, longitude, ellipsoidal height and cut-off angle (Button 1) of the related location on the earth or space, time interval, resolution for the DOP values (Button 2-3) and the almanac files (Button 4-7) for GNSS satellites. The software check several steps before the processing. The input parameters should be inputted sequentially. For example if users input the start time (Button 2) before inputting the coordinates, warning message appears and the process stops. If the format of the input almanac files is not proper as they are defined in the software, users will be informed by the warning messages. The unhealthy and any lack of satellites in almanac files are also informed by the software.

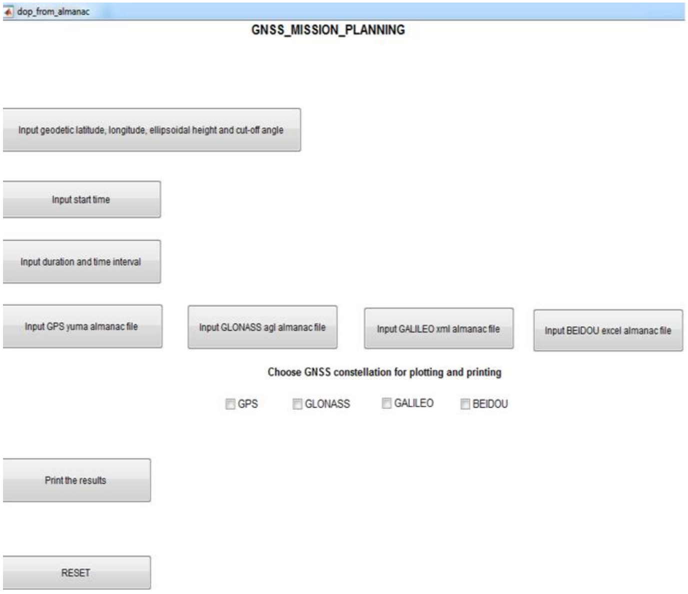

Figure 1. GUI of the software

The supported format of the GPS, GLONASS and GALILEO almanac file are Yuma format (https://celestrak.com/GPS/almanac/Yuma/), agl format (ftp://ftp.glonass-iac.ru/MCC/ALMANAC/) and xml format (https://www.gsc-europa.eu/system-status/almanac-data), respectively. Since BEIDOU almanac parameters are given in the web site as tabulated values (https://www.glonass-iac.ru/en/BEIDOU/ephemeris.php) without a specified format, users need to create excel file for BEIDOU almanac parameters. Copying the whole parameters with their headers in the web site into the excel file is needed to read properly from the software. Figure 2 shows the excel file format of BEIDOU almanac parameters for DOY 201 in 2018.

1	ID	H	e	t	δ_i	Ω	A	Ω_0	ω	m	af_0	af_1	week
2	C08	0	0.0032444	81920	0.07570435	-2.54E-09	6493.7715	2.37503556	-2.75843152	2.12840433	0.000439644	1.82E-11	654
3	C01	0	0.00042295	81920	0.02594585	1.29E-09	6493.4893	1.26215759	2.60127077	-1.72807804	0.000344276	4.73E-11	654
4	C06	0	0.00681925	81920	0.00190549	-1.81E-09	6493.7314	-1.8000905	-2.2256331	-0.52103365	0.000102043	2.18E-11	654
5	C03	0	0.0006175	81920	0.02411825	1.47E-09	6493.4585	1.53482156	-0.22296388	0.30901436	-0.000245094	8.73E-11	654
6	C17	0	0.00009155	81920	0.01342233	1.20E-09	6493.4556	1.07797654	-1.76013922	2.89607184	0.000519753	4.00E-11	654
7	C05	0	0.00029182	81920	0.02620351	1.34E-09	6493.3486	2.2828589	-0.89433102	-0.67308351	0.000299454	-2.55E-11	654
8	C10	0	0.00562954	81920	-0.02282396	-2.37E-09	6493.0737	0.23321077	-2.70910557	-2.4680897	-0.000389099	-2.91E-11	654
9	C15	1	0.00300646	552960	0.02063084	-2.39E-09	6493.1558	1.11734659	3.00032898	0.17234664	0	0	615
10	C13	0	0.00316095	81920	0.03628823	-2.66E-09	6493.3804	2.36211545	-3.09443473	2.12904399	-0.000179291	-1.82E-11	654
11	C02	0	0.00011253	81920	0.03387341	1.29E-09	6493.4624	2.58694512	1.57601733	-3.00551964	-3.33786E-05	-2.55E-11	654
12	C11	0	0.00208998	69632	0.04297543	-6.83E-09	5282.5601	1.88863445	-2.34750555	-0.69717292	-0.000593185	-1.46E-11	654
13	C07	0	0.00660086	81920	-0.02410028	-2.38E-09	6493.4487	0.24179485	-2.78889242	-1.95151905	6.58035E-05	-1.46E-11	654
14	C04	0	0.00018883	81920	0.01670002	1.26E-09	6493.4165	2.13843963	-2.53604138	2.88031633	-0.000266075	1.09E-11	654
15	C12	0	0.00233603	36864	0.04181895	-6.90E-09	5282.5645	1.87857407	-2.45149717	2.07665346	0.000516892	1.46E-11	654
16	C14	0	0.00206709	53248	0.0154956	-6.69E-09	5282.5659	-2.31750716	-2.04917438	1.05391446	0.000239372	6.18E-11	654
17	C09	0	0.00550747	81920	0.00715458	-1.81E-09	6493.3335	-1.75805359	-2.42114225	-0.7360887	5.34058E-05	3.27E-11	654

Figure 2. Excel file of BEIDOU almanac parameters

Input of leap second is needed when using GALILEO almanac file. GALILEO system time considers the leap second (Hahn and Powers, 2005) contrary to the other GNSS system time thus users need to know the true leap second in the associated time otherwise coordinates of GALILEO satellites cannot be computed correctly.

Figure 3 shows the plot of DOP values and GNSS satellites numbers for DOY 201 in 2018 using the all GNSS satellites associated almanac files of DOY 200. Latitude, longitude, ellipsoidal height of the location and cut-off angle were selected as 39.93222, 32.8555 degrees, 1000 meter and 10 degree, respectively (location is Ankara province in Turkey). The associated almanac files for GPS, GLONASS, GALILEO and BEIDOU as follows, respectively; almanac.yuma.week0986.405504.alm, MCCJ_180719.agl, 2018-07-17.xml and excel file with the necessary BEIDOU parameters.

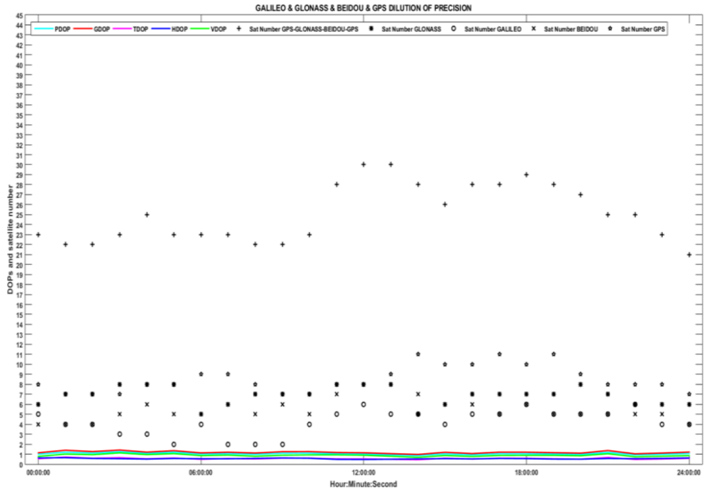

Figure 3. Visualization of the results

Figure 4 shows the text file of the result with respect to each time interval after pushing the "print the results" button.

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================GALILEO && GLONASS && BEIDOU && GPS ================

/Hour/Minute/Second  PDOP  GDOP  TDOP  HDOP  VDOP GALILEO-GLONASS-BEIDOU_NUMBER GALILEO_NUMBER GLONASS_NUMBER BEIDOU_NUMBER GPS_NUMBER

 00:00:00        0.997 1.137 0.546 0.626 0.777    23.0          5          6          4          8
 01:00:00        1.197 1.390 0.706 0.645 1.009    22.0          4          7          4          7
 02:00:00        1.108 1.257 0.592 0.575 0.948    22.0          4          7          4          7
 03:00:00        1.249 1.408 0.649 0.546 1.123    23.0          3          8          5          7
 04:00:00        1.078 1.202 0.532 0.505 0.953    25.0          3          8          6          8
 05:00:00        1.200 1.347 0.612 0.572 1.054    23.0          2          8          5          8
 06:00:00        1.013 1.125 0.490 0.543 0.855    23.0          4          5          5          9
 07:00:00        1.054 1.195 0.563 0.542 0.904    23.0          2          6          6          9
 08:00:00        0.978 1.109 0.523 0.578 0.789    22.0          2          7          5          8
 09:00:00        1.090 1.247 0.606 0.623 0.895    22.0          2          7          6          7
 10:00:00        1.100 1.254 0.604 0.591 0.927    23.0          4          7          5          7
 11:00:00        1.042 1.166 0.524 0.478 0.926    28.0          5          8          7          8
 12:00:00        1.008 1.134 0.520 0.465 0.894    30.0          6          8          8          8
 13:00:00        0.930 1.049 0.484 0.494 0.789    30.0          5          8          8          9
 14:00:00        0.861 0.969 0.444 0.521 0.685    28.0          5          5          7         11
 15:00:00        1.028 1.186 0.592 0.556 0.865    26.0          4          6          6         10
 16:00:00        0.924 1.056 0.512 0.521 0.763    28.0          5          7          6         10
 17:00:00        1.044 1.200 0.592 0.575 0.872    28.0          5          7          5         11
 18:00:00        1.044 1.197 0.585 0.555 0.884    29.0          6          7          6         10
 19:00:00        1.019 1.148 0.529 0.508 0.883    28.0          5          7          5         11
 20:00:00        0.977 1.095 0.496 0.500 0.839    27.0          5          8          5          9
 21:00:00        1.185 1.362 0.670 0.568 1.040    25.0          5          7          5          8
 22:00:00        0.919 1.033 0.473 0.546 0.739    25.0          6          6          5          8
 23:00:00        0.981 1.107 0.514 0.576 0.794    23.0          4          6          5          8
 24:00:00        1.058 1.209 0.585 0.623 0.856    21.0          4          6          4          7

Mean Satellite Visibility: 25.08
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Figure 4. Results of the processing

As it is seen from Figure 4, position dilution of precision (PDOP), geometric dilution of precision (GDOP), time dilution of precision (TDOP), horizontal dilution of precision (HDOP), vertical dilution of precision (VDOP), number of satellite visibility with respect to each GNSS satellites and average number of satellite visibility are recorded in the results.

III. CONCLUSIONS

This software packages implements GNSS satellites coordinate computation using the almanac files for mission planning purposes. The report text file includes DOP values and number of satellite visibility for chosen GNSS satellites. Plot and text file can be saved for the evaluation. Users can easily use the software with GUI. Users can modify the source codes according to focused studies. The software can be downloaded in https://tinyurl.com/ycv9l97a. The author would like to have any comments, suggestions, and critiques sent to the author's e-mail address. If this software is used for any scientific purpose, please cite to this article.

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