Combined lab report for L1 and L2

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1 Assignment 1 – Conversion of coordinates, computation of satellite's azimuth and elevation

To convert from Cartesian to ellipsoidal coordinates, the results are great, although latitude above 90 degrees is not reasonable, the code will still work because of the symmetry property of the trigonometric function. However, when it comes to the inverting coordinate converting process. The following equations are the equation that will encountered some errors when in particular points. Those points are the north pole and south pole. When in the pole, X, Y, p and $cos(\varphi)$ are all 0, which will make the code failed. We can analyzed it with the equation list below.

$$
\begin{aligned}
h &= \frac{p}{cos(\varphi)} - N \\
tan(\varphi) &= \frac{Z}{p} * \left(1 - e^2 * \frac{N}{N+h}\right)^{-1} \\
tan(\lambda) &= \frac{Y}{X}
\end{aligned}
$$

Since we cannot divide anything with zero, the code will encounter some problems when the calculation comes to those three equations. This needs to be considered when inputting data into the script, if not it can led to numerical problems.

We also test the code by convert the position than do the reverse convert to check if the answer are the same. For most cases, we get the results what we expected, which is our input and output are about the same. This implies that our converting process and reversed converting processing are doing the same thing but in inverse direction.

However, if we do some special test case, such as if we enter the latitude larger than 90 degree, which is not a real case, than the code will give us a result that is not the same with our expectation. It will be better if we add some restriction when entering the data. For instance, if the value exceed some point, than asked the user to input a reasonable number to do the converting.

Finally the next table contains the coordinate lists containing (X, Y, Z) in ITRS, (e,n,u) in the local system, and elevation, azimuth, and distance to the visible GPS satellites.

PRN	X (m)	Y (m)	Z (m)	e (m)	n (m)	u (m)	elevation	azimuth	distance (m)
1	20168.351485	16031.499732	6738.889838	8985239.568576	-17318582.122134	11744657.969739	31.046239	152.578779	22772896.338673
3	24273.678267	11044.106703	-1764.647745	2970471.312817	-23680442.481762	5630147.013635	13.273755	172.850171	24521125.817292
7	-10223.345281	-18084.472469	17056.624880	-14021599.719540	21901122.052055	496964.944377	1.094806	-32.628302	26009832.371431
9	-14334.822123	5786.630033	21041.443466	9947465.164707	20925507.874032	5707018.801781	13.837371	25.425250	23862083.031309
11	15283.168838	-6864.297868	20551.059410	-11266132.007638	-172307.675695	17639215.409438	57.430670	-90.876231	20930774.964372
14	10970.084031	17831.945509	16426.350996	13549911.496422	-5337420.548155	15905447.602531	47.522351	111.499885	21565514.672866
19	23960.296160	5523.981720	10166.246448	-2180206.599153	-15868834.322199	14869493.279800	42.870694	-172.177154	21855778.045140
20	22851.628387	-13287.334354	2439.791807	-19719897.710797	-13881452.095913	4710634.801555	11.052667	-125.142911	24571511.110411
22	-2798.634442	17719.894476	19744.555718	17714022.928089	7645059.700067	12069299.926930	32.028768	66.655825	22757450.358962
28	4721.788658	-18461.064822	18607.922741	-19015143.443736	10569334.962690	9015209.936415	22.508839	-60.933041	23549108.941466
31	-764.509501	-16615.402115	20301.220467	-15558824.213595	15427139.382392	8104831.385698	20.299680	-45.243495	23361548.155546

Table 1: Calculated attributes of the visible GPS satellites

Our results collected in the table are reasonable, all the calculated distances are between 20930.774 km (for 57.43° elevation) and 26009.832 km (for 1.09° elevation). We can cross reference these numbers with the values found in literature. We can see that this range is acceptable for GPS satellite orbits.

2 Assignment 2 – Compute satellite position from broadcast ephemerids

The following table contains the satellite coordinates and their corresponding clock errors for the system transmit time. The given results of the table were extracted from the attached RINEX format files. These were calculated using the attached MATLAB script.

PRN	X	Y	Z	dts_Li
24	23421962.768253	-12587454.896122	999742.383390	0.000001
13	7552201.472331	22602195.697607	11771817.079905	-0.000031
8	19783013.601423	3244987.165424	17378752.707202	0.000374
21	-11894221.979181	-10766055.410957	21172792.763545	0.000072
29	11084173.931864	-17544464.832653	16816648.852921	0.000219
26	8280837.254754	-21834335.527924	11796581.029459	0.000438
10	16224624.833054	-6015374.987310	20186079.081770	0.000039
17	16522601.792030	-16233813.575696	12453407.323159	0.000158
2	-13921125.994947	10520857.438908	20752899.943494	-0.000268
28	23778312.648123	11792189.993946	-2950541.777395	0.000018
3	-12326720.731331	15206586.330821	17758732.273850	0.000083
27	9544662.436440	12516483.254512	21878717.204534	0.000904

Table 2: Satellite coordinates and their corresponding clock errors

Comparing the data with the content of the "SatPosResult-2.pdf" file provided for the verification, we found that our results are reasonably close.

Next we compared the calculated results with the data provided to us from the *.sp3* file. Our comparison is visible in the following table.

PRN	X (m)	X_sp3 (m)	X_error (m)	Y (m)	Y_sp3 (m)	Y_error (m)	Z (m)	Z_sp3 (m)	Z_error (m)
2	-13921125.99	-13921312.6	186.601053	10520857.44	10520761.48	95.962908	20752899.94	20752821.24	78.700494
3	-12326720.73	-12326751.32	30.589669	15206586.33	15206397.99	188.338821	17758732.27	17758875.35	143.07915
8	19783013.6	19782854.27	159.327423	3244987.165	3245082.489	95.323576	17378752.71	17378913.54	160.830798
10	16224624.83	16224803.88	179.048946	-6015374.987	-6015262.066	112.92131	20186079.08	20185971.41	107.66977
13	7552201.472	7552188.114	13.358331	22602195.7	22602321.03	125.335393	11771817.08	11771590.05	227.033905
17	16522601.79	16522731.43	129.63897	-16233813.58	-16233846.55	32.977304	12453407.32	12453184.03	223.290159
21	-11894221.98	-11894023.02	198.957181	-10766055.41	-10766162.2	106.790043	21172792.76	21172848.85	56.082455
24	23421962.77	23421977.86	15.090747	-12587454.9	-12587441.51	13.391122	999742.3834	999472.31	270.07339
26	8280837.255	8280855.184	17.929246	-21834335.53	-21834204.35	131.177924	11796581.03	11796812.57	231.540541
27	9544662.436	9544474.137	188.29944	12516483.25	12516604.25	120.999488	21878717.2	21878727.4	10.191466
28	23778312.65	23778331.47	18.820877	11792189.99	11792225.25	35.256054	-2950541.777	-2950281.325	260.452395
29	11084173.93	11084189.97	16.041136	-17544464.83	-17544287.6	177.235653	16816648.85	16816826.25	177.398079

Table 3: BRDC v.s SP3

The data we are calculating is from the broadcast ephemerids, it is using the UTC system and converts the coordinates by using Keplerian elements. All the information is included in the navigation message and broadcast to all the users. It has acceptable errors for most use cases but still contains more errors than the sp3 file. The sp3 file is using the GPS time as the timing system, it is more precise because all the ephemeris parameters and clock parameters are from the GPS control segment. In our assignment case, we have calculated the difference between the broadcast result and the sp3 result, and all of the differences are smaller than 260 meters.