Homework #9 **CE506** **Fall 2003**

GPS pseudorange solution

<u>Introduction</u>

"The GPS satellites are configured, primarily, to provide the user with the capability of determining a position, expressed for example by latitude, longitude, and elevation. This is accomplished by the simple resection process using the distances measured to satellites." [Hofmann-Wellenhof, et. al, 2001]

<u>Purpose</u>

The purpose of the homework is to determine the unknown receiver position and receiver clock offset via least squares. To solve for the unknown receiver position, the position of the satellite in the orbit is considered fixed at a given instant (epoch) in time.

<u>Background</u>

Each GPS receiver contains a cheap quartz clock while each satellite contains two very stable atomic clocks. The receiver can measure the distance or range from a satellite at a given instant (epoch) using the equation dist. = velocity * time. The signal travels at the speed of light and time is the travel time of the signal. The problem is the receiver and satellite clocks are not synchronized. The travel time of the signal is erroneous hence the measured distance or **pseudorange** in erroneous.

<u>Time issues</u>

The government organization in charge of the GPS system maintains "GPS time." GPS time is established by numerous atomic clocks and is the foundation time of the GPS system. The clocks in the satellites maintain time slightly different than GPS time. The cheap GPS receiver clock also maintains a time different from GPS time. In order to use the GPS system for ranging we must account for the time differences in all the clocks.

The difference between the satellite clock and GPS time is the **satellite clock offset**. This offset can be corrected and does not pose a problem. The difference between the receiver clock and GPS time is the **receiver clock offset** and is a significant problem but can be overcome.

For this homework, we will easily remove the **satellite clock offset** and will solve for the **receiver clock offset** and the **receiver position**.

The position solution using **pseudoranges** is good enough for navigation and low level surveying but not good enough for high-accuracy surveying.

Problem Parameters

Xr, Yr, Zr = unknown coordinates of the receiver in the Earth Centered Earth Fixed (ECEF) coordinate system.

dt = receiver clock offset in nano (1e-9) seconds from GPS time

We have 4 unknowns hence we need 4 observations for a unique solution but this does not provide redundancy. So, we need 5 or more observations to provide redundancy. We will be using 7 satellites.

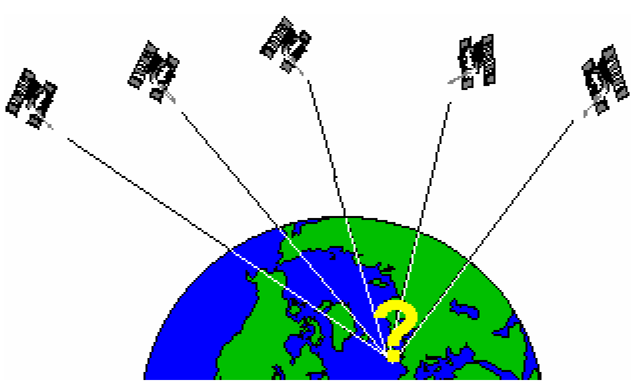
n = 7   no = 4   r =3

Model

R = sqrt[(Xs–Xr)^2 + (Ys-Yr)^2 + (Zs-Zr)^2] + c*dt

R = measured pseudorange
s = fixed satellite position
r = unknown receiver position
c = speed of light
dt = receiver clock offset in nanoseconds (1e-9)

Pictorial representation of homework



Data Example

Example of the "input" matrix within data.mat

Sat. #	time (min)	Satellite Coordinates (KM) ECEF Xs	Ys	Zs	measured pseudorange (m)	sat. clock offset (microsec.) (1e-6)
1.0	0.0	-17104.3	-5228.5	19811.5	23399263.4	292.4
2.0	0.0	-3772.1	-26415.5	117.6	22473250.5	-141.7
16.0	0.0	2600.4	-25804.1	5853.2	21269160.8	42.5
20.0	0.0	-13061.1	-14974.6	17541.7	21606540.7	-214.0
25.0	0.0	8151.9	-13641.5	21624.2	21200953.2	47.0
14.0	0.0	20887.1	-16159.8	3069.0	23681041.7	-20.5
6.0	0.0	22666.0	-2990.0	13842.9	24601072.2	-5.7

Each instant (epoch) in time has 7 satellites to solve for the receiver position. **Each student will be given a different instant (epoch) in time to solve for. See below.**

Suggested solution steps

1. Load the data.mat variable file as provided.
2. Locate the data for your instant (epoch) in the **input** matrix. Each student will have 7 ranges to solve for the receiver position.
3. Correct the satellite clock offset to seconds.
4. Correct the measured pseudorange by **adding** (c (m/s) * sat. clock offset (s)).
5. Correct the satellite coordinates to meters.
6. The initial approximation for dt (receiver clock offset) is 300,000 nanoseconds. In the B matrix and f-vector, multiply c (m/s) by 1e-9 to avoid stability problems during inversion. The variable dt, the receiver clock offset which we are solving for, will have the units of nanoseconds.
7. Solve for dt, Xr, Yr and Zr using least squares.(non-linear problem)
8. Compute the distance between the computed and published position (Xp,Yp,Zp). The published coordinates are in the data.mat file.
9. Use sigma=20m for all refined pseudoranges.
10. Make global test on residuals at significance level alpha=0.05
11. Assume that we **have not** made the above test, compute 99% confidence interval for Z, and 99% confidence region (ellipse) for XY.

Student assigned time

Name	time	Name	time	Name	time
Al-Kheder	0	Johnson	0	Rura	0
Beal	15	Knoy	15	Shutts	15
Boline	30	Kuns	30	Sui	30
Charnas	45	Lenihan	45	Titzer	45
Costello	60	Luo	60	Wang	60
Crouch	0	Nelson	0	Wrathell	0
Galloza	15	Ng	15		
Hanigosky	30	Quansah	30		
Hoy	45	Reed	45		
Jeong	60	Rujikietgumjorn	60		

Do not use any outside sources for variables. Everything you need is in data.mat! Do not manually type in any variables!

Turn in

Below is what you will turn in.

1. The problem design and the statistical evaluations on green engineering paper, other paper acceptable.
2. Email me your program and I will run it. (byentes@purdue.edu)
3. That is all. I will not accept anything else.