# Toolbox for attitude determination with a multiple-antenna system using GPS

*User Manual*

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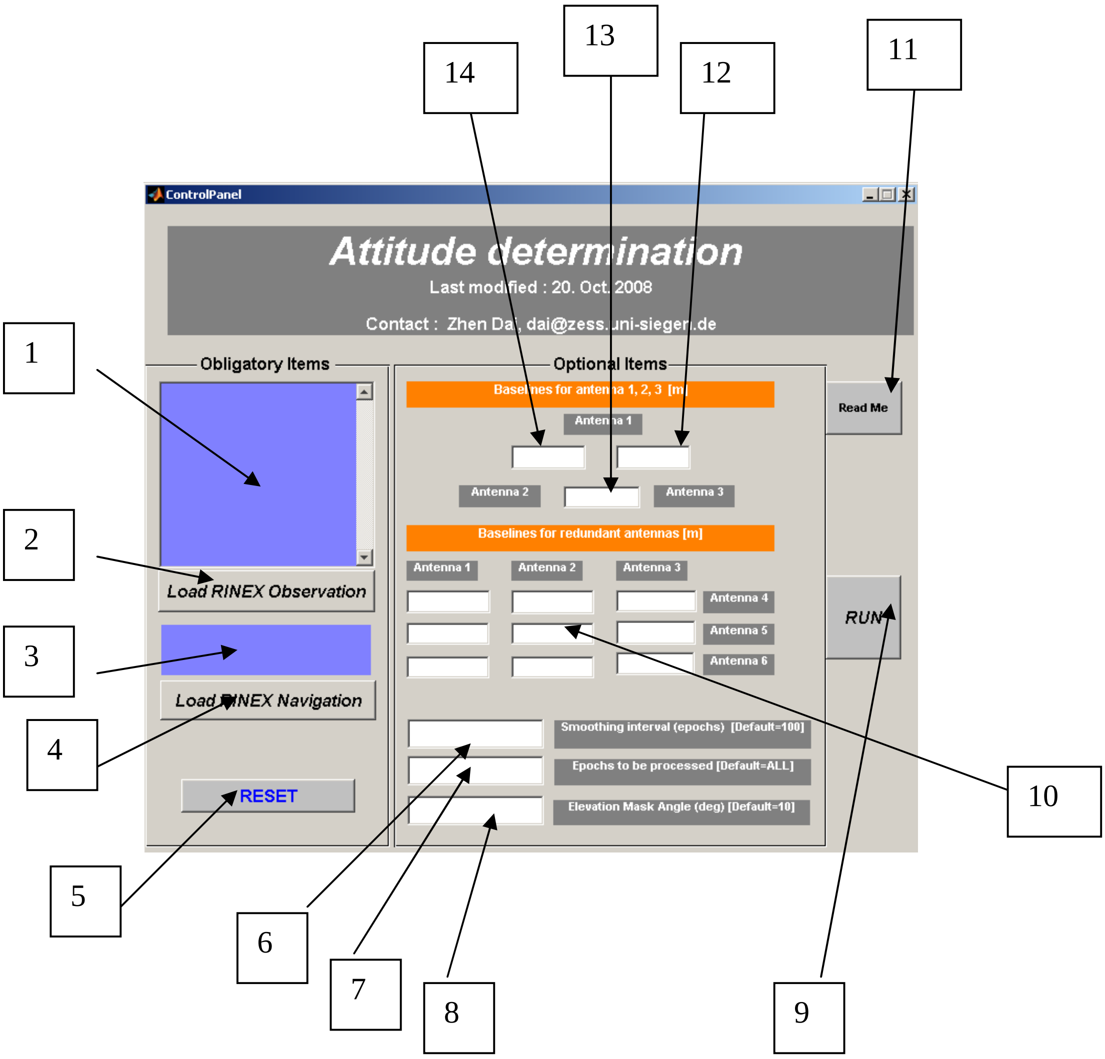
# 1. Installation of the program package

- Download the ZIP file from the internet.
- Extract all files into a directory.
- Make sure that you have MATLAB installed on your computer.

# 2. Introduction to GUI



| No. | Type | Function | Remarks |
|---|---|---|---|
| 1 | Listbox | Show the selected observation files | To run the program, at least 3 observation files are required. |
| 2 | Button | Load the RINEX observation files. | |
| 3 | Static textbox | Show the RINEX navigation file | Only one navigation file is needed. Since the multiple antennas are closely distributed, they probably share a common RINEX navigation file. |
| 4 | Button | Load the RINEX navigation file | |
| 5 | Button | Reset the RINEX files | All the selected RINEX files will be erased and then the user should re-input all files. |
| 6 | Textbox | Carrier phase smoothing interval | In the unit of epochs. Can also be 0, implying that there is actually no smoothing applied. |
| 7 | Textbox | Epochs to be processed | If a positive number is given, say n, the program accounts for the measurement at the first n epochs of each RINEX observation file.<br>In other cases, the program will process all the data embedded in the files. |
| 8 | Textbox | Elevation mask angle | Scaled to degrees. This is only used for the master antenna to cancel some low elevation satellites due to their large atmospheric error and multipath error. |
| 9 | Button | Run the program | Click it after the parameters are identified. |
| 10 | Group of textboxes | Baselines of the redundant antennas | All baselines are magnitude in meters<br>Row Column Baseline of<br>1 1 Antenna 1 and 4<br>1 2 Antenna 2 and 4<br>1 3 Antenna 3 and 4<br>2 1 Antenna 1 and 5<br>2 2 Antenna 2 and 5<br>2 3 Antenna 3 and 5<br>3 1 Antenna 1 and 6<br>3 2 Antenna 2 and 6<br>3 3 Antenna 3 and 6 |
| 11 | Button | Load the ReadMe file | |
| 12 | Textbox | Baseline between antenna 1 and 3 | Magnitude, in meters. |
| 13 | Textbox | Baseline between antenna 2 and 3 | Magnitude, in meters. |
| 14 | Textbox | Baseline between antenna 1 and 2 | Magnitude, in meters. |

# 3. Run the demo program

### *Step 1*

Run the file “ControlPanel.m” in MATLAB, a GUI is shown in the middle of the screen.

### *Step 2*

Click Button 2 (Load RINEX Observation) to identify the RINEX observation files. The files are saved in the subdirectory “TestData” under the same main directory of the toolbox. To do this, please select the four files in the following order:

Master.06O
Slave_1.06O
Slave_2.06O
Slave_3.06O

Do not confuse the order of these files, otherwise it will provide unexpected results. The selected files are displayed in the listbox 1.

### *Step 3*

Click Button 4 (Load RINEX Navigation) to identify the RINEX navigation file named “Navigation.06N”. This file is saved in the same subdirectory as the observation files. It will be displayed in the listbox 3 after being selected.

### *Step 4*

If you made mistakes when selecting files, please click the button 5 to reset the input.

### *Step 5*

Now input the magnitudes of baselines between the first three antennas.

| | | |
|---|---|---|
| Textbox 12 | : | 16.192 |
| Textbox 13 | : | 21.733 |
| Textbox 14 | : | 23.140 |

### *Step 6*

Input the baselines between additional antennas
Now input 9.910, 15.219 and 18.103 from left to right in the first row, respectively.

### *Step 7*

Input 100 in the textbox 6.

### *Step 8*

Input 400 in the textbox 7.

### *Step 9*

Input 10 in the textbox 8.

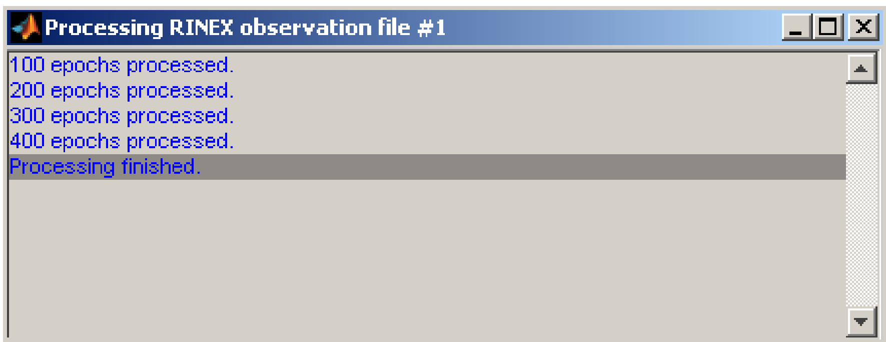
### *Step 10*

All the inputs are accomplished.
Click button 9 (Run) to start the data processing.

## 4. Execution of demo program

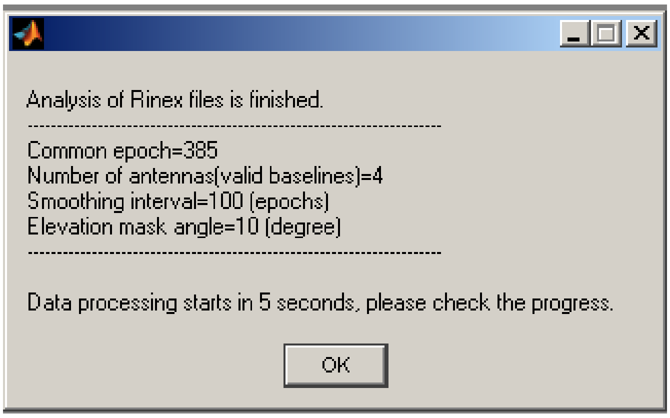
### *Step 1*

Read and analyze the RINEX files



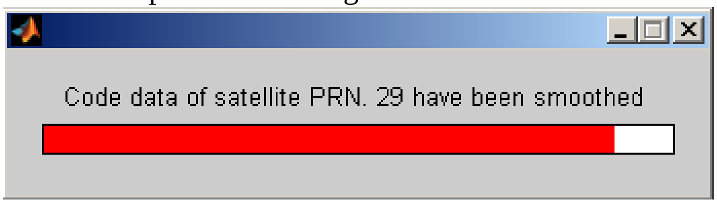

### *Step 2*

After the 4 RINEX observation files and the RINEX navigation file are completely analysed, a short summary is shown.



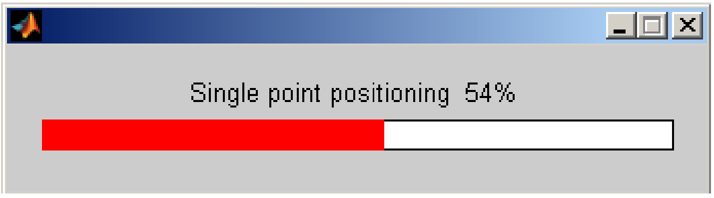

### Step 3

The carrier phase smoothing is carried out.



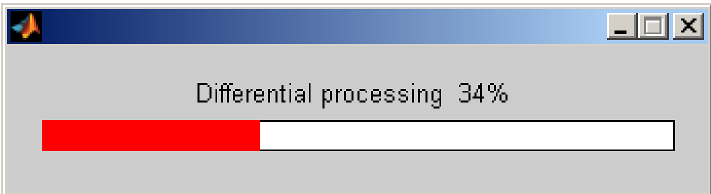

### Step 4

Then the single point positioning is applied for the master antenna.



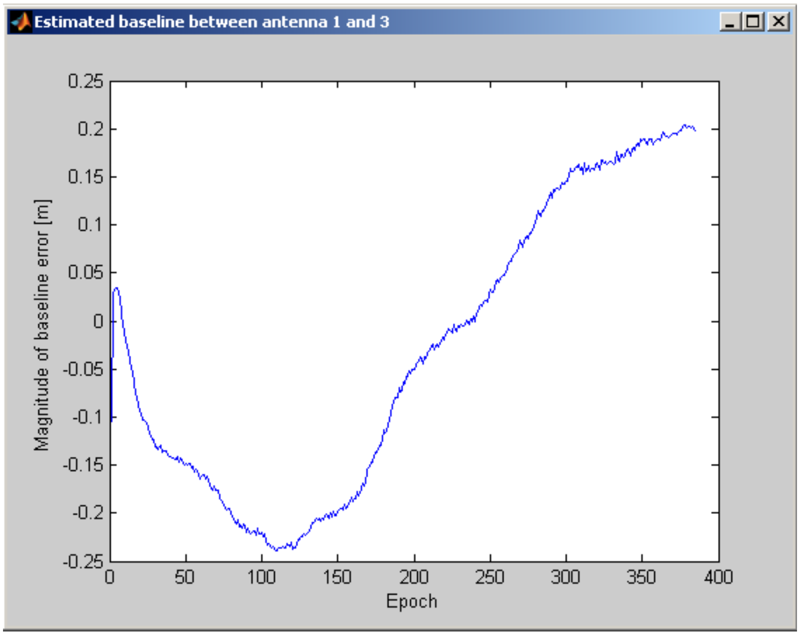

### Step 5

After the single point positioning, differential positioning is performed to construct the baselines between the master antenna and the slave antennas.



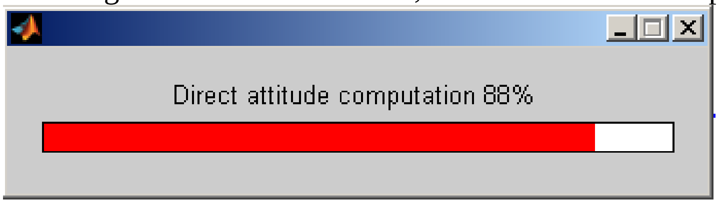

### Step 6

Obtained the estimated baselines, the magnitudes of three-dimensional baseline errors are depicted, for example, for the baseline between antenna 1 and 3:



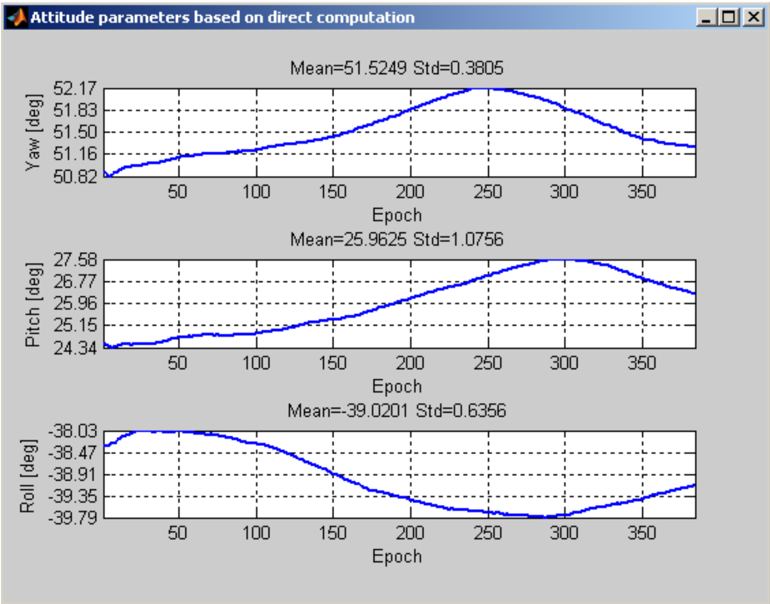

## *Step 7*

Knowing the estimated baselines, the direct attitude computation will be invoked first.



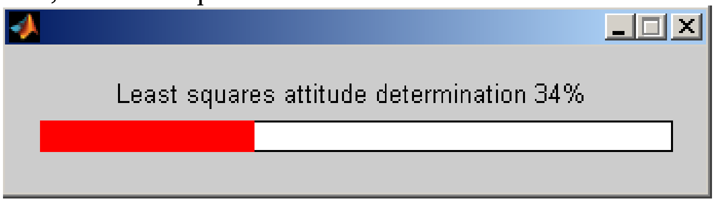

## *Step 8*

The attitude parameters obtained from direct attitude computation are illustrated:



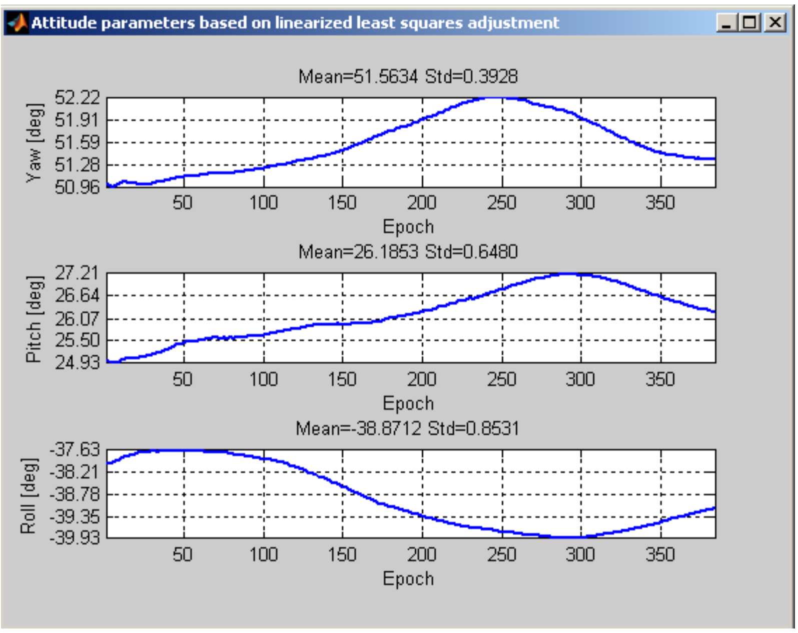

## *Step 9*

The next step is to identify the antenna body frame from the given true baselines. After that, the least squares attitude estimation is then invoked.




## *Step 10*

The results from least squares attitude determination approach are also shown.




## *Step 11*

Finally, the results from direct attitude computation and from least square estimation are saved into a data file named "Results.txt". This file is also displayed on the screen:

27-Aug-2008 16:51: 6
Observation data of #1 antenna : C:\AttDet\TestData\Master.06O
Observation data of #2 antenna : C:\AttDet\TestData\Slave_1.06O
Observation data of #3 antenna : C:\AttDet\TestData\Slave_2.06O
Observation data of #4 antenna : C:\AttDet\TestData\Slave_3.06O
Ephemerides data : C:\AttDet\TestData\Navigation.06N
Common epoch=385
Number of antennas(valid baselines)=4
Smoothing interval=100 (epochs)
Elevation mask angle=10 (degree)

Result from direct attitude determination using CODE

At Epoch 2006.10.29 01:44:30.00 -> YAW=50.875 ROLL=24.440 PITCH=-38.319
At Epoch 2006.10.29 01:44:31.00 -> YAW=50.886 ROLL=24.484 PITCH=-38.332
At Epoch 2006.10.29 01:44:32.00 -> YAW=50.862 ROLL=24.437 PITCH=-38.339
At Epoch 2006.10.29 01:44:33.00 -> YAW=50.841 ROLL=24.415 PITCH=-38.338
At Epoch 2006.10.29 01:44:34.00 -> YAW=50.823 ROLL=24.375 PITCH=-38.325
At Epoch 2006.10.29 01:44:35.00 -> YAW=50.830 ROLL=24.382 PITCH=-38.297
At Epoch 2006.10.29 01:44:36.00 -> YAW=50.838 ROLL=24.340 PITCH=-38.290
At Epoch 2006.10.29 01:44:37.00 -> YAW=50.872 ROLL=24.365 PITCH=-38.280
At Epoch 2006.10.29 01:44:38.00 -> YAW=50.879 ROLL=24.381 PITCH=-38.251
At Epoch 2006.10.29 01:44:39.00 -> YAW=50.892 ROLL=24.397 PITCH=-38.220
At Epoch 2006.10.29 01:44:40.00 -> YAW=50.918 ROLL=24.434 PITCH=-38.200
At Epoch 2006.10.29 01:44:41.00 -> YAW=50.925 ROLL=24.429 PITCH=-38.182
At Epoch 2006.10.29 01:44:42.00 -> YAW=50.937 ROLL=24.447 PITCH=-38.166
……

# 5. Execution of demo program based on carrier phase

A demo program processing carrier phase data is also provided in the toolbox. It has the following variations compared to the above-mentioned program employing only the code data:

(1) The main program to be invoked is called “mainpro_ph.m”. The short extension of “_ph” reveals that the program is carrier phase oriented.

(2) A matrix file named “ambiguity.mat” is needed which contains the ambiguities in cycles. Since the visible satellites do not change during the observation session, only one ambiguity set for each antenna is saved.

(3) The function performing differential positioning based on carrier phase has a slight difference with that based on code data. That is, the ambiguities appear as the input parameters of the functions.

Note that the ambiguities are just resolved for this demo program with all parameters exactly identified as described in section 4. To employ the carrier phase of users’ data sets, the ambiguities have to be resolved by the users first, saved into another matrix file and incorporated into the function of differential positioning.

The user can check the source code of “mainpro_ph.m” to figure out how to incorporate the ambiguities and carrier phase data.

### *Step 1*

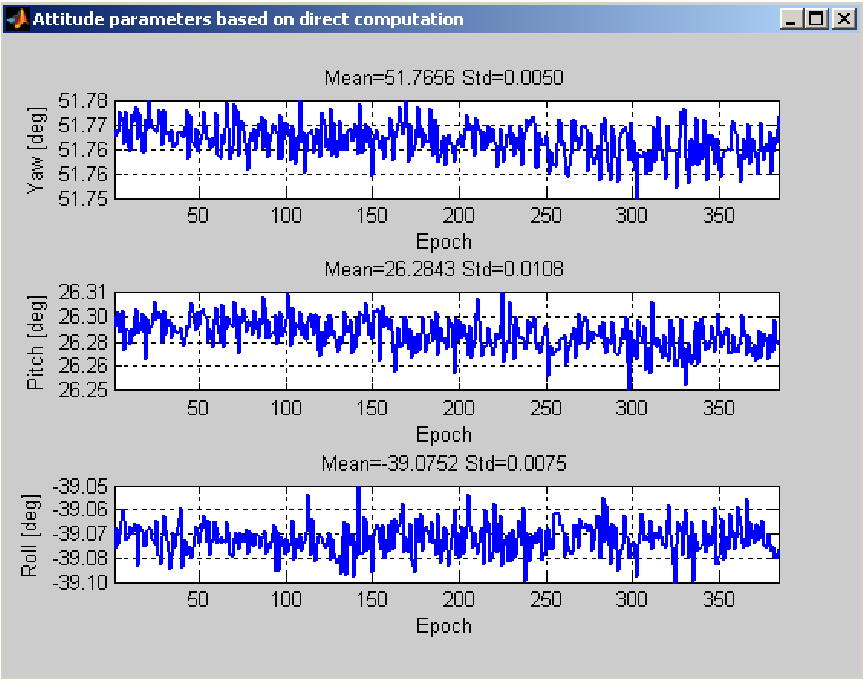
Make sure that you have run the demo program to process the C/A code data by going through all the steps in section 4.

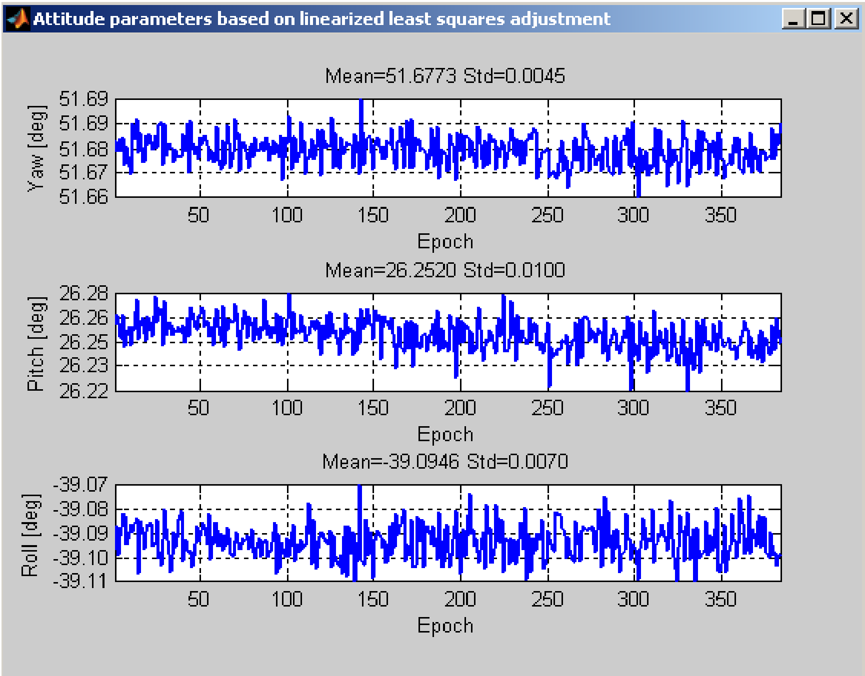
### *Step 2*

Open the file “mainpro_ph.m” in MATLAB and run it.

### *Step 3*

The attitude parameters are shown on the screen and saved at the end of the data file “Results.txt”.




At Epoch 2006.10.29 01:50:49.00 -> YAW=51.756 ROLL=26.281 PITCH=-39.081
At Epoch 2006.10.29 01:50:50.00 -> YAW=51.762 ROLL=26.273 PITCH=-39.079
At Epoch 2006.10.29 01:50:51.00 -> YAW=51.766 ROLL=26.294 PITCH=-39.084
At Epoch 2006.10.29 01:50:52.00 -> YAW=51.765 ROLL=26.280 PITCH=-39.084
At Epoch 2006.10.29 01:50:53.00 -> YAW=51.773 ROLL=26.278 PITCH=-39.080

Result from least squares estimation using carrier phase

At Epoch 2006.10.29 01:44:30.00 -> YAW=51.680 ROLL=26.258 PITCH=-39.098
At Epoch 2006.10.29 01:44:31.00 -> YAW=51.677 ROLL=26.264 PITCH=-39.089

At Epoch 2006.10.29  01:44:32.00 -> YAW=51.677  ROLL=26.260  PITCH=-39.100
At Epoch 2006.10.29  01:44:33.00 -> YAW=51.681  ROLL=26.251  PITCH=-39.093
At Epoch 2006.10.29  01:44:34.00 -> YAW=51.677  ROLL=26.249  PITCH=-39.089
At Epoch 2006.10.29  01:44:35.00 -> YAW=51.681  ROLL=26.265  PITCH=-39.084
At Epoch 2006.10.29  01:44:36.00 -> YAW=51.673  ROLL=26.244  PITCH=-39.084

……

……

# 6. Troubleshooting

(1) Baselines do not need to be specified. In this case, please assign 0 to all baseline items and then the direct attitude computation will be applied. If you want to use the least squares attitude estimation, you have to identify all the baselines.

(2) The program terminates when an interruption occurred in the RINEX observation file. Here "interruption" implies that the GPS measurements of some epochs are completely missing.

(3) Make sure that the selected RINEX observation files have a proper common data rate.

(4) It is recommended to identify the total epochs to be processed; otherwise the program implements no initialization of the matrix recording the observation data. In this case, if the total number of the observation data is too large, the processing then becomes very slow.

(5) Since the carrier phase smoothing will be performed, a preprocessing is therefore proposed to check the cycle-slips.

(6) Some special configurations of antennas may yield unexpected result. For example, singularity problem when some values of the antenna body frame tend toward to 0.

(7) For the least squares attitude estimation, the initial guess of yaw, roll and pitch can be obtained from the direct attitude computation, yielding an improved efficiency.

(8) As is known, the RINEX observation files provided by different GPS receiver manufactures have slight variations in the format and also in the content. The function used for the RINEX file analysis may not work properly when reading some RINEX observation files, as we can not taken all possible examples into account.

(9) The time span of the RINEX navigation file cannot override 1 day.

(10) The following internal files will be overwritten by each execution of the toolbox:

| File name | Remarks |
|---|---|
| DataGUI.mat | This file contains the parameters inputted from GUI |
| DataSatRecordx.mat | "x" is a number ranging from 1 to n, implying the n antennas.<br>Each file contains the GPS measurement and satellite visibility of a specific antenna. |
| RinexNav.mat | Ephemerides parameters of GPS satellites. |
| Results.txt | Calculated attitude parameters resulted from the multiple-antenna data. |

(11) The source codes are developed based on MATLAB® Version 7.4.0.287 (R2007a) under Windows® XP. It may not work properly when running on the lower version MATLAB or under other operation systems.

# 7. Support

Any suggestions, corrections, and comments about this toolbox are sincerely welcomed and could be sent to:

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| | |
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