# Exercise 1 – Global Positioning Systems (GPS)

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## 1 Introduction

This exercise is about one of the most important sensors for outdoor applications, i.e. the Global Positioning Systems (GPS) sensor. This sensor is seen in more applications each day and is used for navigating e.g. cars, ships and airplanes. This exercise consists of two set of data, the first set 'gps_ex1_window2012.txt', which is a series of GPS positions taken in the same location, i.e. the GPS doesn't move (static receiver). The other data set 'gps_ex1_morningdrive2012.txt' consists of data collected during a regular drive by car within Halmstad. A map of Halmstad is also included as the image file 'halmstad_drive_area.gif'.

Use the papers (that dealt with GPS data) handed out in the lectures.

## 2 Matlab – quick help

Almost all the commands in Matlab contain help on how the commands should be called, how they work and what they returns. To get help, simply write help followed by the command, e.g. to get help on plotting write: `help plot`. To search for specific topics, i.e. in case you don't know the command name exactly, write lookfor followed by what to look for, e.g. looking for plotting commands could be done by writing: `lookfor plot`.

If you not familiar with Matlab it's recommended that you do a Tutorial found on Matlab home page.

## 3 Stationary GPS receiver

Use the data set 'gps_ex1_window2012.txt' (simply write `DATA = load('gps_ex1_window2012.txt')` in Matlab), which consists of time stamps and status flags together with values for longitudes and latitudes (given in NMEA-0183), i.e. the data file looks like:

```
Status(1) Timestamp(1) Latitude(1) Longitude(1)
Status(2) Timestamp(2) Latitude(2) Longitude(2)
...
Status(N) Timestamp(N) Latitude(N) Longitude(N)
```

To extract the Latitude and Longitude data from the variable DATA you can simply write:

```
Longitude = DATA(:,4);
Latitude  = DATA(:,3);
```

The "`:`" means that all rows in the given column (i.e. 3 or 4) are put in the new variable. Note that `Longitude` and `Latitude` are vectors and that in Matlab you can do operations on vectors!

### 3.1 Write a function that transform your longitude and latitude angles from NMEA-0183 into meters

This transformation includes two steps:

1) Write a function that transform your longitude and latitude angles from NMEA-0183 into degrees (use the first Equation in the second page in the compendium, i.e. http://adamchukpa.mcgill.ca/web_ssm/web_GPS.html). Note: Square brackets mean integer of a value inside. In Matlab you can use the `floor` function to take the integer part of the value, i.e. truncation. Your code can look something like this:

```
LongDeg = floor(Longitude/100) + (Longitude - floor(Longitude/100)*100)/60;
```

   `LongDeg` is a vector containing the angles in degrees only. To look at the 10 first values of `LongDeg` write `LongDeg(1:10)` and the 10 last values write `LongDeg(end-10:end)`

2) Then from degrees into meters (use the conversion tables given in the end of the compendium, http://adamchukpa.mcgill.ca/web_ssm/web_GPS_tb.html. Assume height zero and latitude of 56 degrees.) in a co-ordinate system that has the x-axis on the Equator and the y-axis passes Greenwich. Your code can look something like this:

```
X = F_lon * LongDeg;
```

Don't forget to plot your results using: `plot(X,Y,'.');` To plot in a new figure use: `figure, plot(X,Y,'.');`

### 3.2 Estimate the mean and variance of the position (in x and y)

Plot the position errors (mark each error with an 'x') in a 2D plot – can you say something about the errors? Test to plot different fractions of the signal, e.g. `plot(X(1:10),Y(1:10))`or `plot(X(101:110),Y(101:110))`. Are the errors Gaussian distributed? (To check this, plot, using `hist(…)`, a histogram over the errors. Use at least 30 bins). What is the maximum error?
Calculate the co-variance matrix of the errors in the x and y position data, i.e. in Matlab simply write `COV([X Y])` if you have your have the errors stored in X and Y as [N x 1] vectors. Plot the co-variance matrix in the same 2D plot in which you plotted the errors, but use a different color, e.g. red (you have to edit the plot_uncertainty.m Matlab script). Use the function plot_uncertainty(…), called by e.g.: `plot_uncertainty([0 0]', cov([X Y]), 1, 2)`, which then plots the co-variance matrix centred around (0, 0).

### 3.3 Plot, with respect to time, the errors and the auto-correlation in x and y separately.

Plot, with respect to time, the errors in x and y separately – (use Matlab's function of creating subplots, i.e. write `subplot(4,1,1); plot(X), subplot(4,1,2); plot(Y);` etc.) do you find any interesting with the errors? Also plot the auto-correlation of the errors in x and y respectively. Call the function `xcorr(…)` and calculate the auto-correlations according to the following: `cx = xcorr(X – mean(X), 'coeff');` and `cy = xcorr(Y – mean(Y), 'coeff');` Plot the auto-correlations (`cx` and `cy`) in subplots 3 and 4. Also, generate a random signal using following: `R = randn(1,length(X))`, that generates a random signal of the same length as `X`. Do the auto-correlation on this signal and plot it in subplots 3 and 4 using the `hold` command, i.e. `cn = xcorr(R – mean(R), 'coeff'); subplot(4,1,3); hold; plot(cn,'r');` Compare the random (Gaussian) signal with the GPS-error. What is the difference? Are the GPS error correlated or not? How does this affect your position measurements? Compare when you plot parts of the GPS-error signal in section 3.2, i.e. what does it means that the peak in the correlation plot is wider compare to the random signal?

## 4 Mobile GPS receiver

Use the data set 'gps_ex1_morningdrive2012.txt', which is collected during a drive on the eastern side of Halmstad. Also see the map of Halmstad and see if you can locate where in Halmstad the drive took place.

1) Plot the position data (x and y) in the same plot, which should give you the path taken by the car (this path is the same path I showed you in the lectures).
2) Calculate the maximum speed taken by the driver. (I actually looked at the speedometer and saw that I had a maximum speed of approximately 70 km/h.) Did I ever break the speed limits? How come the estimate in speed is so accurate, while the estimate in position is not? This is **very** important! Recall what you did in section 3.3.
   (Note: In Matlab you can do element vise operations, e.g multiplication, like `x.*x` instead of vector operation `x*x`)
3) Calculate the headings (and plot them with respect to time) along the path (see compendium http://adamchukpa.mcgill.ca/web_ssm/web_GPS.html). Can you calculate the error in headings? If you only consider the headings along the straight line path (along Laholmsvägen or Vrangelsleden) – can you then estimate the variance in the heading?

## 5 Others

The reports (which are individual, although you are more than welcome to solve the exercises in smaller groups, e.g. by groups of two students) should contain all necessary equations with all assumptions motivated. You should also interpretive your results, i.e. handing in a plot without any explanations is not enough.