Intelligent Vehicles: Exercise 1 - GPS

Yonan Yonan, Jesper Palmér
DT8020, Halmstad University

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1 Ex1a - Stationary GPS receiver

Q1: What is the maximum error? Mark it in the figure.

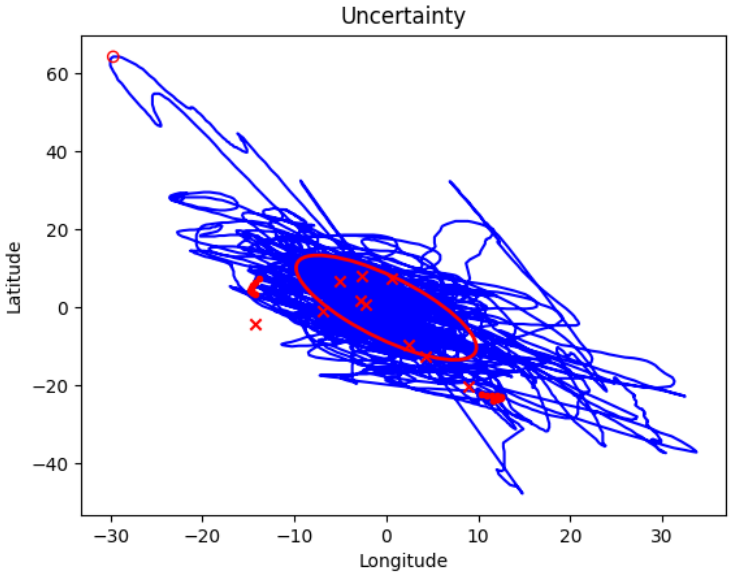

Figure 1: Position error, O marks the max error, X marks randomly generated points

The maximum error is located in the point [-29.69, 64.25] in Figure 1, with value of 70.790

Q2: Can you say something about the GPS errors? What is the difference between the GPS and the randomly generated points?

The difference is that the GPS error is a random walk, while the randomly generated errors generated with the same variance are not following each other, but they are scattered all over the plot.

Q3: Are the errors Gaussian distributed? (To check this, plot, using histogram(...), a histogram over the errors. Use at least 30 bins).

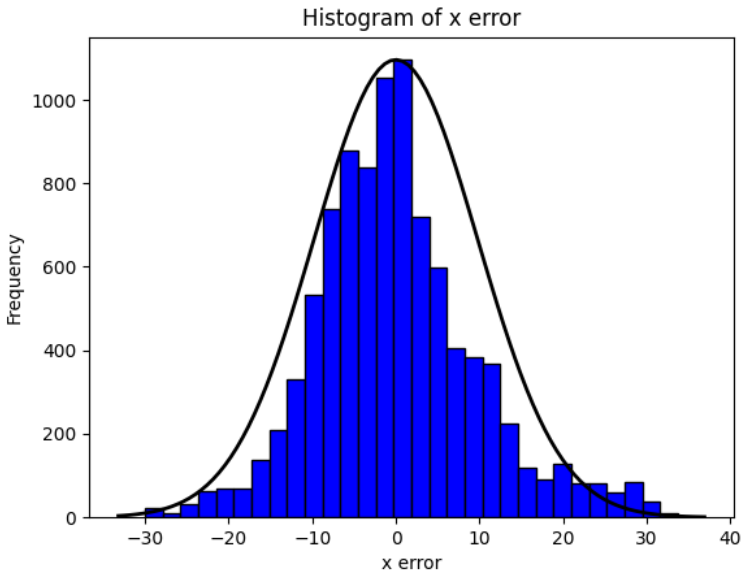

Figure 2: Bins for the X errors

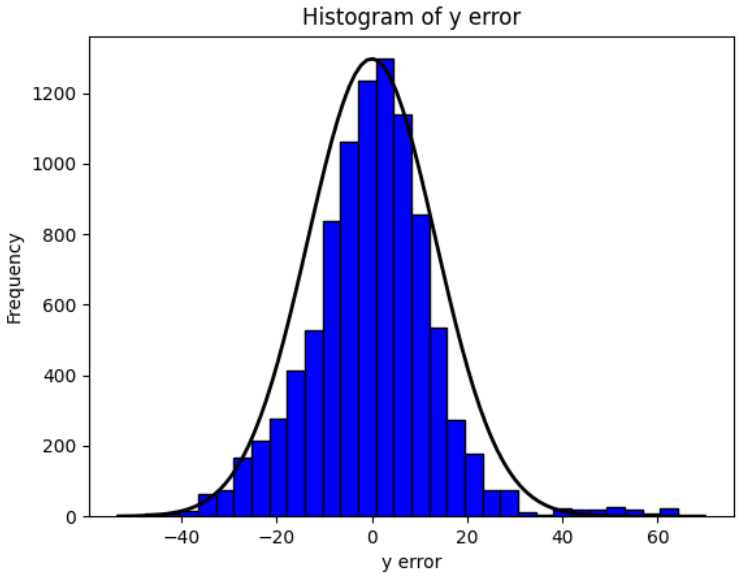

Figure 3: Bins for the Y errors

The errors in the X-dimension are shown in figure 2 and the Y-dimension in figure 3. While they do look imilar to a bell-cruve, we don't think they line-up with the actual gaussian distribution very well. Let's compare them to an actual random-generated signal of the same length shown in figure 4 and figure 5.

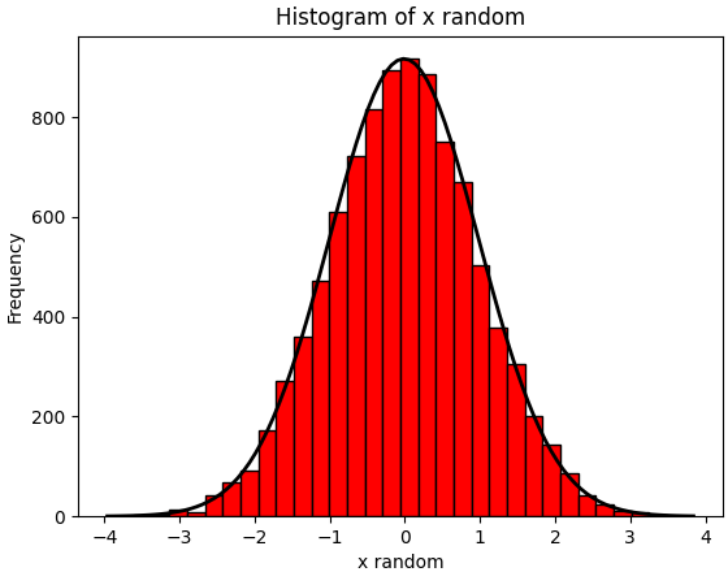

Figure 4: Bins for the X random errors

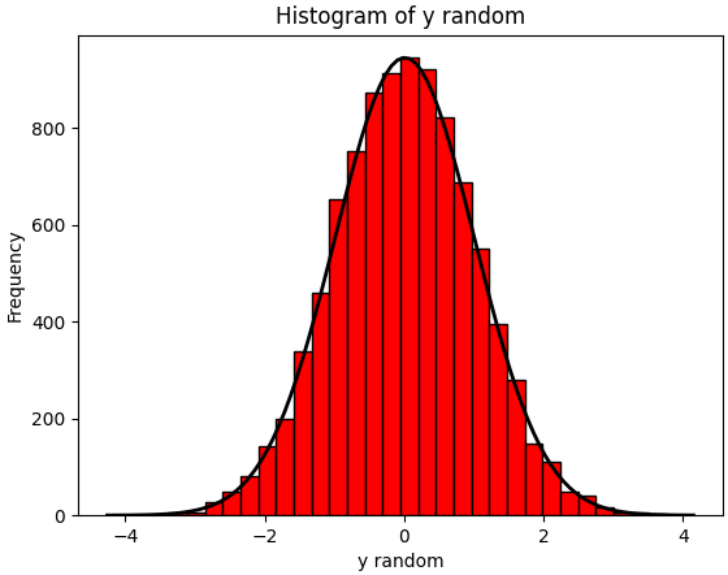

Figure 5: Bins for the Y random errors

As we can see, the random generated signal resembles the Gaussian distribution very well. The GPS error looks like it's undershooting too much to be normally distributed, especially in the positive direction (The right side of both graphs).

Q4: Do you find anything interesting with the errors (Subplot 1 and 2)?

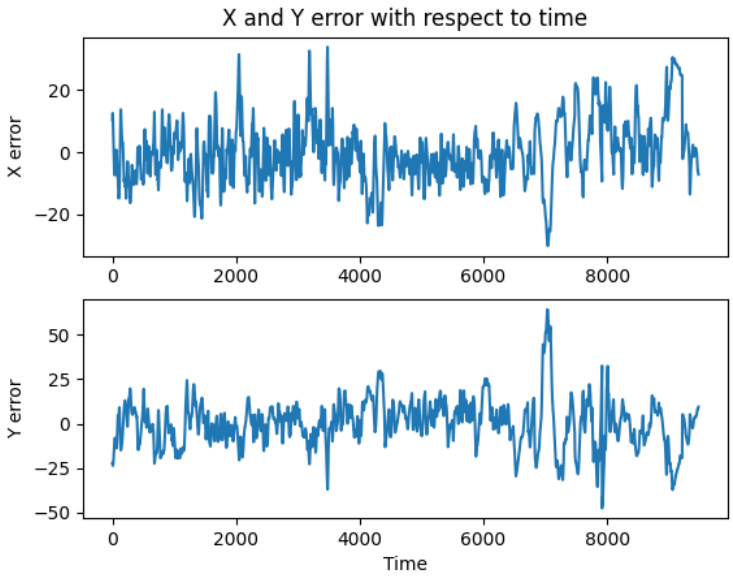

Figure 6: Error over time (subplot 1 and 2)

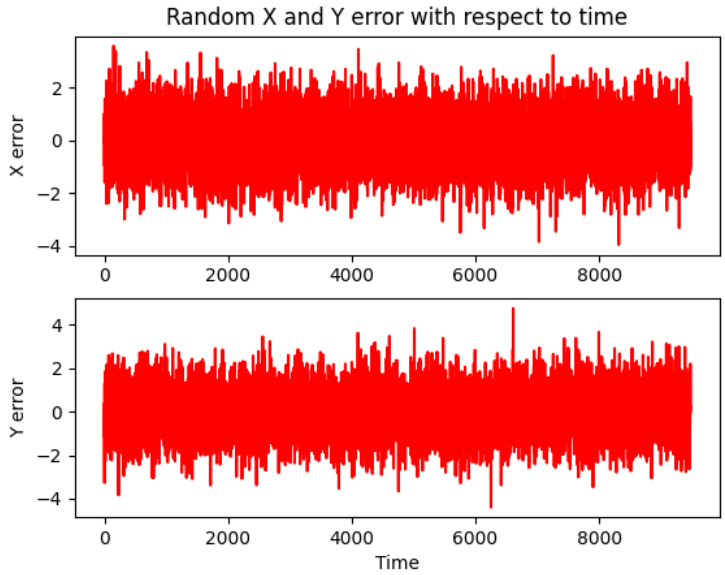

Figure 7: Random Error over time

We compare the real errors in figure 6 with the random errors in figure 7. The errors seem to be "following each other" in a random walk, just like it has been shown in Q1. The signal also looks periodic a little.

Q5: Compare the random (Gaussian) signal with the GPS-error. What is the difference?

The difference is that the random generated error signal is jumping all over the place while the GPS error seem to be following the previous point.

Q6: Are the GPS error correlated in time or not? See the result of the auto-correlation?

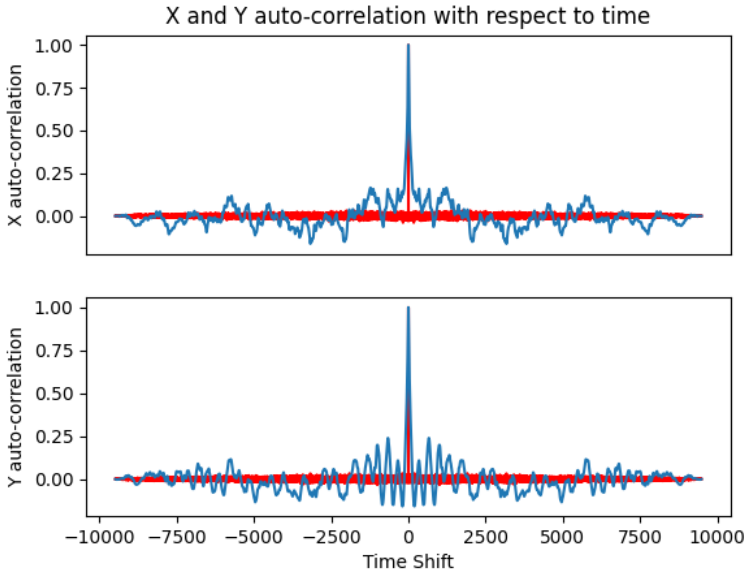

Figure 8: Auto-correlation

The autocorrelation is shown in figure 8. Compared to the truly random signal, yes, they are time correlated as the peak of the GPS-error around 0 is too wide. A truly random error would have the same peak at time shift 0 but at all other values would look like random noise. These results show clear peaks and valleys that change as you move closer to time shift 0, similar to some type of sinus wave.

Q7: How does this affect your position measurements?

Since the errors are a random walk, it will cause the true position to deviate over time since all the errors will be accumulated. As the errors accumulate over time, the reported position becomes increasingly uncertain and less accurate.
In our case, since we are not moving, the accumulated error will be a bias from the true position.

Q8: Compare when you plot parts of the GPS-error signal above, i.e. what does it mean that the peak in the auto-correlation plot is wider than the random signal?

It means that the GPS error is correlated in time. Or in other words, the current error is influenced by the previous one. The random signal, however, is scattered all over the plot and so does not have this effect. The peak is much thinner because the random signal is only correlated when the shift is 0, or with itself unshifted.

2 Ex1b - Mobile GPS receiver

Q9: Calculate the maximum speed taken by the driver. In the speed plot, mark the where the maximum speed occurs.

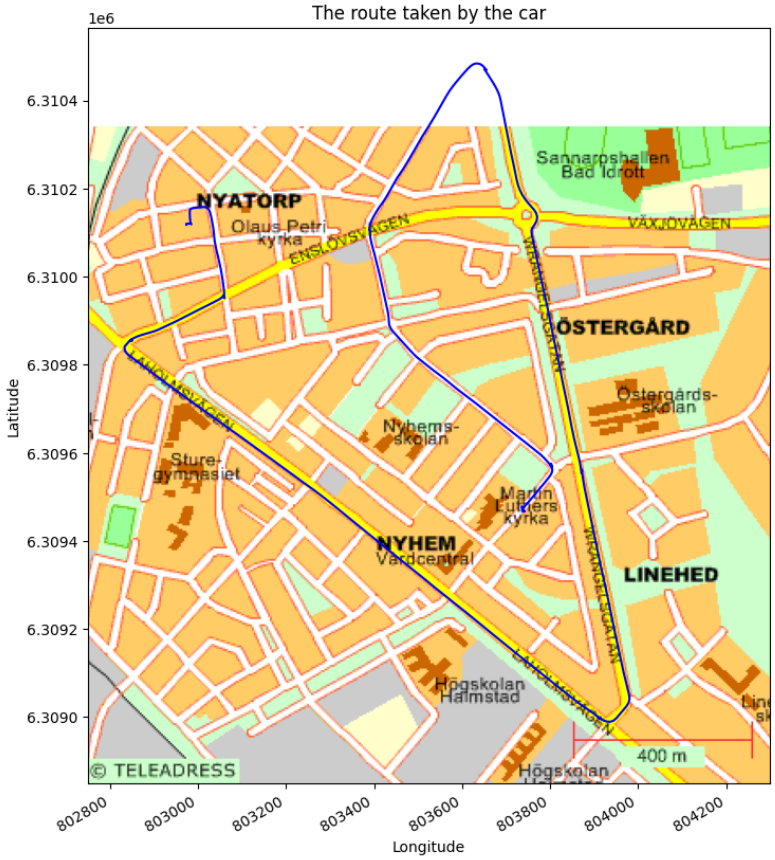

Figure 9: The route taken by the car over the map

The path taken is plotted on a map of Halmstad in figure 9. Figure 10 presents the speed during the trip in km/h, not plotted on a map for the sake of clarity. The top speed acheived was 70.6 km/h. The top speed is marked with a red circle, which when compared to the map is located on Laholmsvägen.

Q10: Did I ever break the speed limits, i.e. 70 km/h?

Yes, but only by less than 1 km/h and only for a couple of seconds. Figure 11 shows the location where the speed was above the speed limit.

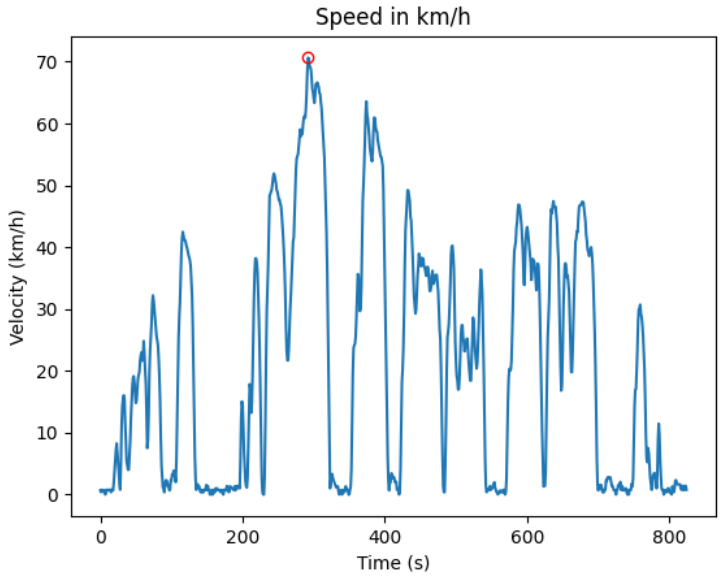

Figure 10: Speed over time

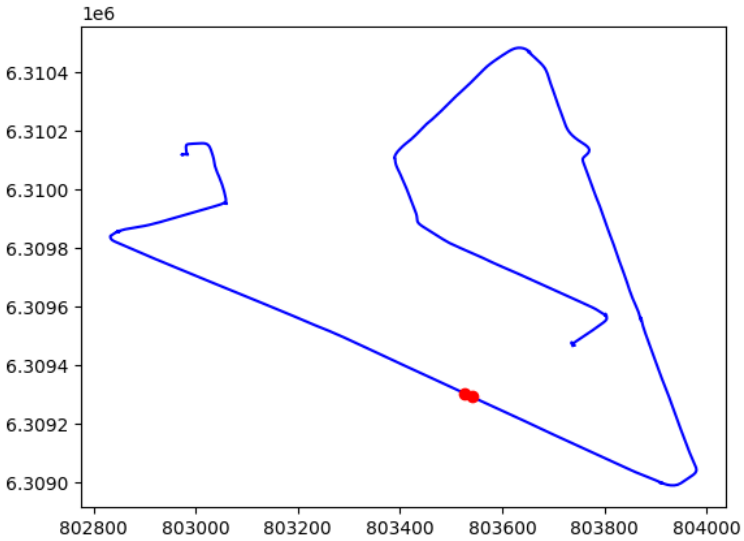

Figure 11: Map featuring markings where speed > 70 km/h

Q11: How come the estimate in speed is so accurate while the estimate in position is not?

As explained before, when trying to estimate position with a random walk error, the accumulated error can grow large over time, making it difficult to determine the true position with a high level of accuracy. But, when estimating speed, the random walk errors do not accumulate over time in the same way. This is due to the speed being, by definition, the change in position over time. This means that even if our position drifted by a light-year due to accumulated errors, our change

in position over time will still be somewhat the same.

This can be shown mathematically too, say the position at any given time t is $x(t) = x(0) + \sum_{i=1}^{t} E_i$ where $x(0)$ is the true position, assuming we are stationary, if we were moving, this would be a function of time, and $\sum E$ is all the accumulated errors over time.
The equation for speed will be, by definition, the derivative, $\frac{dx}{dt}(x(t)) = 0 + E$
where E is the current error only.
As we can see, the speed is 0 + the current error only, and not the accumulated error, therefore it's a small number. Since all the accumulated errors over time are just a sum of constants from all the individual measurements, they vanish when taking the derivative.

Q12: Can you calculate the error in headings? Tips! If you only consider the headings along the straight-line path (along Laholmsvägen or Vrangelsleden) – can you then estimate the variance in the heading?

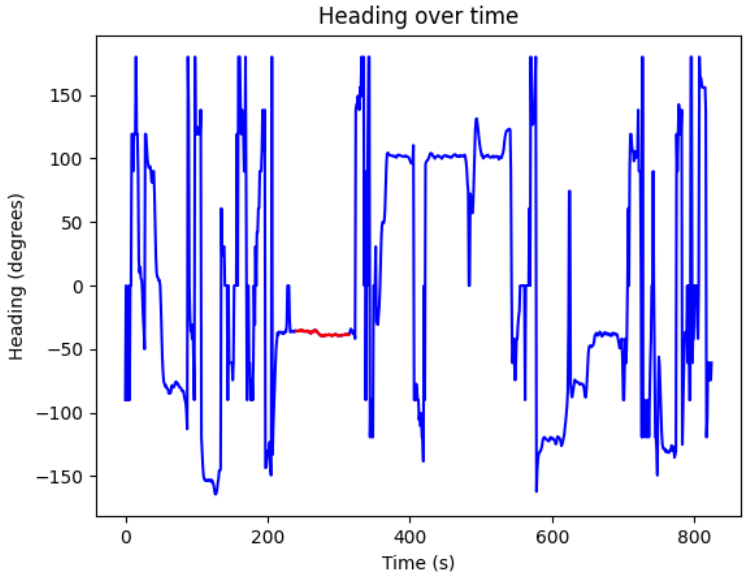

Figure 12: The headings over time, red mark is used to calculate the variance

The headings are plotted as degrees over time in figure 12. The straight path used for calculating the heading error is marked with red. Plotting this same path as longitude and latitude in figure 13 shows that this path is along Laholmsvägen.
When the error of the headings in this segment are plotted against time in figure 14 we can see that it does not look very straight at all. Variance in heading along the straight-line path is 2.387.

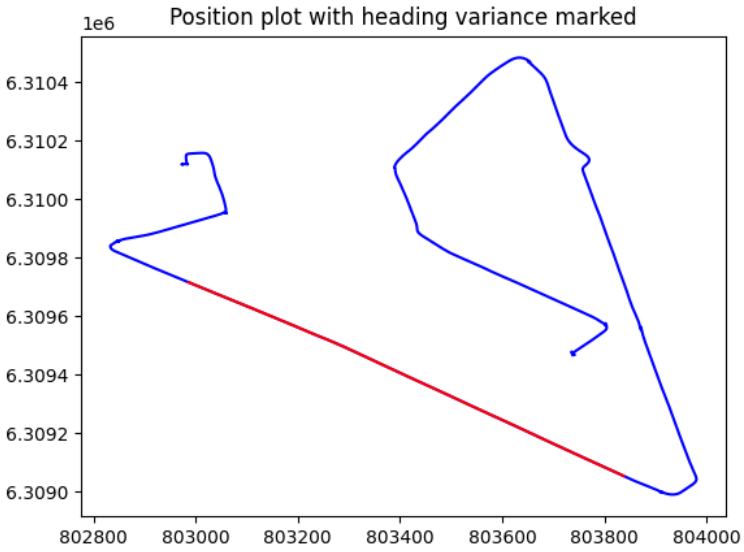

Figure 13: The points that was used to calculate the error and variance in headings

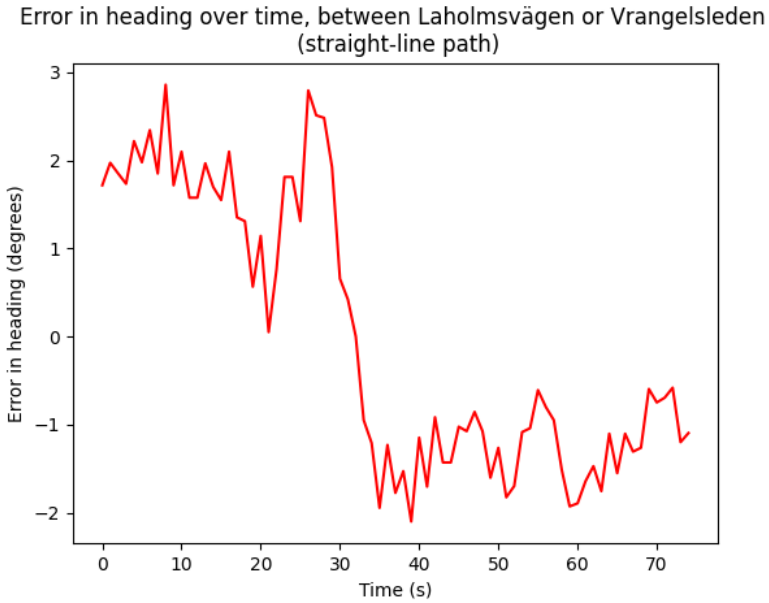

Figure 14: The error in our headings (this is supposed to be a straight line)