Assignment 1 PMS – Job Meijer – 28 November 2016

In this document are the answers and conclusions included for the PMS assignment. This assignment is about simulating the cornering of a truck and semi-trailer combination. The vehicle is supposed to be able to negotiate an average sized roundabout with a radius between 10 and 15 meters. Also, the optimum values for the lengths are determined to have the smallest possible swept path while having a practical combination. The conclusions are divided over three chapters and are: 'Validating the model', the 'Graphs created by the m file' and the 'Parameter research'.

1. Validating the model

To check if the model is correct, it needs to be validated. This will be done in different ways:

1. Driving backwards: it is expected that by driving backwards the truck and trailer stay in line.
2. Driving a circle: The front axis should be the outer circle, the rear axis the middle and the trailer axis the inner circle during steady state cornering.
3. The distances between all axis at starting position: distance between front axle and rear axle is L, distance between front and trailer axle should be L-L1+L2.

At first, the backwards driving behavior is tested. With a speed of -500 km/h, the trailer is expected to stay in line with the truck. In figure 1 is shown that the simulation does what is expected. The simulation time is 1 second and while driving 500km/h the truck should have a displacement of (-500/3.6=) -138 meters. Looking at figure 1, the vehicle indeed has an displacement of -138 meters.

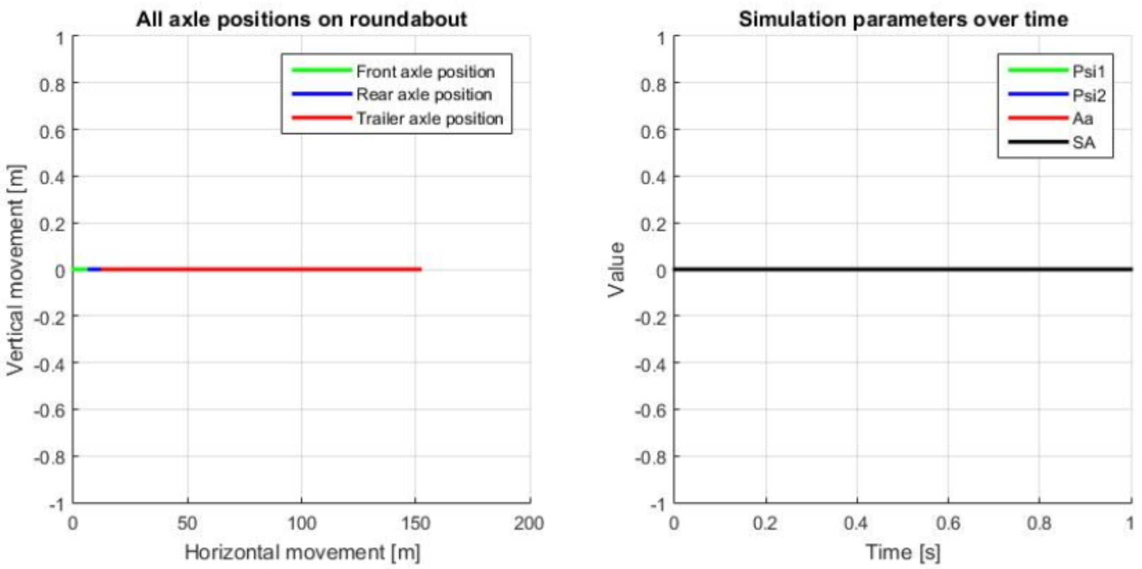

Figure 1 – Driving backwards at 500 km/h for 1 second.

The second test is shown in figure 2. A roundabout is drawn with the two dotted lines and a point in the middle. The truck and trailer start with no initial articulation angle. After a few meters, the trailer reaches a steady state cornering radius which seems reasonable.

The starting position of the front axle is (0, 0), the rear axle is (7, 0) and the trailer axle is (13, 0). This is all according to expectation. This simulation is done with the values L = 7, L1 = -1 and L2 = 7. The front axle has a starting position of x =0 and y = 0. The rear axle starting position is the same as length L for x and 0 for y. The trailer's axle starting position is L-L1+L2 for x and 0 for y.

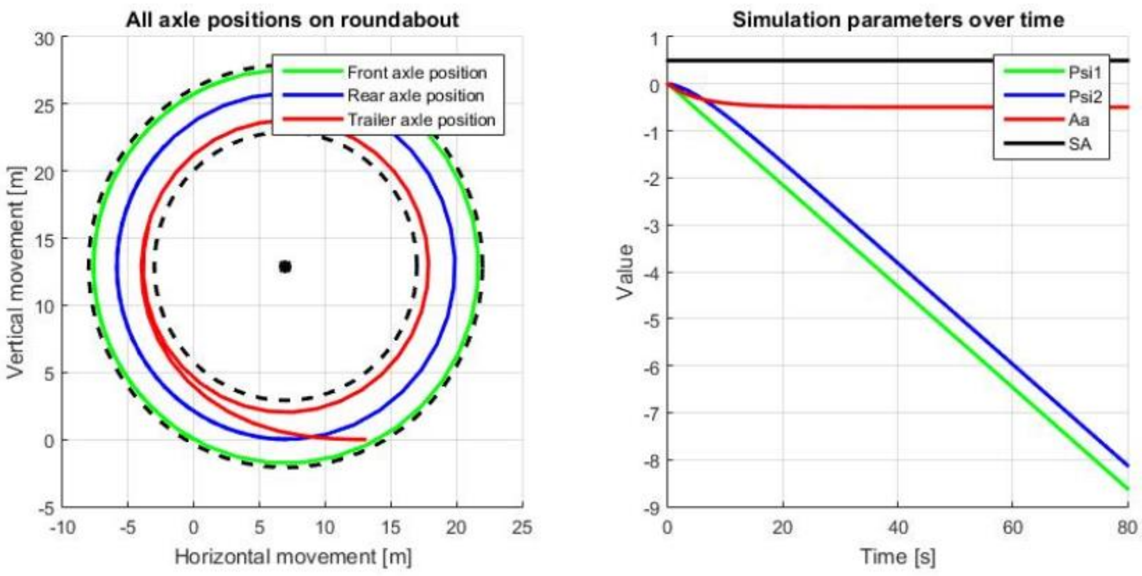

Figure 2 – Undertaking a roundabout with L = 7, L1 = 1, L2 = 7 and SA = 28.5 degrees.

While creating the model, the starting position of the trailer axle seemed wrong. After some research it became clear that L1 needed to be multiplied with -1. After changing this, the model reacts as expected. This comes from the X2 formula, shown in figure 3.

$$X_2 = \int \left\{ \left(\dot{\psi}_1 \cdot L_1 \cdot sin(\gamma) \right) + \left(-v_1 \cdot cos(\gamma) \right) \right\} \cdot cos(\psi_2) dt + \left(L + L_1 + L_2 \cdot cos(\gamma_0) \right)$$

Figure 3 – Formula for x-position trailer axle.

When L1 is not 0, the -v1*cos(gamma) starts subtracting from the positive value on the left of the integral. This value should be negative when starting, otherwise the x position of the trailer axle is wrong. The second fault is in the right part of the formula, after the integral. Here it says L+L1+L2 for the total length of the vehicle, where it should be L-L1+L2. Changing only this did not solve the problem, because there was also the fault in the integral. This is why L1 needs to be multiplied with a value of -1.

2. Graphs created by m file

There are four graphs created by the m file. Two of those are shown in figure 2, the other two graphs are for the parameter research. All four graphs are shown in figure 4.

The lower left graph shows all possible combinations of lengths with their steering angle. The lower right graph shows the filtered values. Those values are filtered on the total vehicle length being 16 meter or larger and length L1 between -1 and 1. More about this in the chapter ‘Parameter research’.

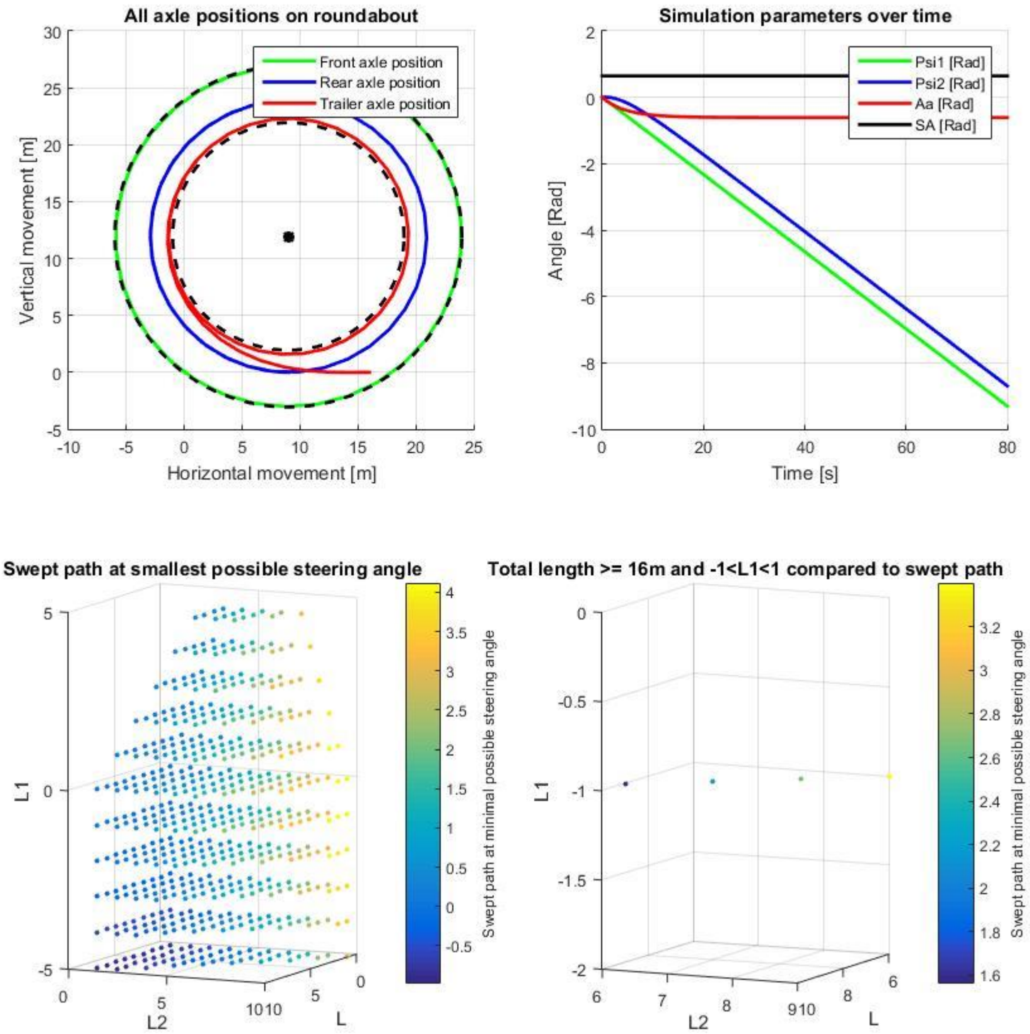

Figure 4 – All graphs generated by the m file.

3. Parameter research

To find the optimum lengths for the smallest swept path, a few for loops have been used. First, all logical combinations are created. Then, those combinations are simulated to find a possible steering angle to take the roundabout. When a possible steering angle is found, the combination is saved in a matrix. The different lengths that are used are:

- L between 1 and 10 with steps of 1
- L1 between -5 and 5 with steps of 1
- L2 between 1 and 10 with steps of 1

This matrix is used later to create a plot with all possible combinations and the swept path of those combinations. The swept path is calculated using the smallest possible steering angle, because at the smallest possible steering angle the swept path is also the smallest.

This gave a lot of data points, so it is needed to filter those for finding an optimum. Most of the data points are combinations that are not useful in practice or logical. For example, the combination that leads to the smallest swept path has an L2 of 1, an L1 of -5 and an L of 10. A 1 meter long trailer will not be very useful in practice.

To find a more useful solution, the data is filtered. This is done by filtering for a total length as large as possible and the L1 length that is as close to 0 as possible. In this manner, the most useful combination should come out because this gives the largest usable lengths. To do this, all combinations for a total length of 16 or greater and an L1 value between -1 and 1 are filtered. After filtering, the combination with the minimal swept path is taken for the optimal values.

This gave the following optimum lengths: L = 9, L1 = -1 and L2 = 6. In figure 4 is shown that this is indeed the set of logical combinations that leads to the smallest swept path, around 1.6 meters.

To determine if there is a more precise optimum, the simulation will be done again but with the following lengths:

- L between 8 and 10 with steps of 0.1
- L1 between -1.5 and 0.5 with steps of 0.1
- L2 between 5 and 7 with steps of 0.1

This gave the following results, shown in figure 5.

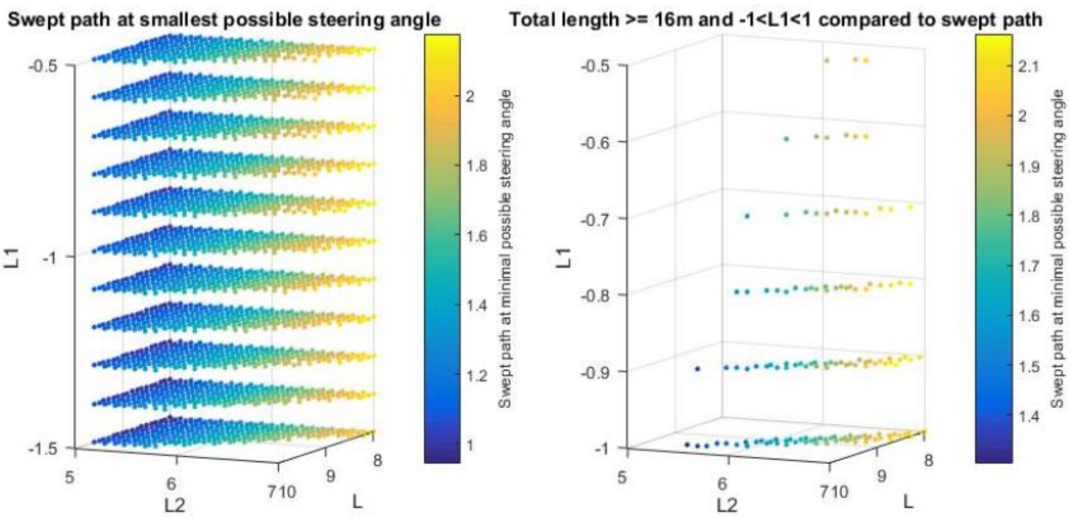

Figure 5 – Precise simulation for finding optimal values.

After this simulation, the points from the right graph of figure 5 are filtered. This is done by finding the combination with the smallest swept path, because there is not much difference in total vehicle lengths. This gives the following results for the optimum parameters:

- L = 9.6
- L1 = -1
- L2 = 5.4

This combination has also a total length of 16 meters compared to the first simulation and a swept path of 1.3 meters. This is an improvement of 0.3 meters over the last simulation.

If needed, it is possible to simulate again to find more precise values for the optimum lengths. The optimum values also depend on what is wanted from the vehicle. If a larger total vehicle length is wanted, the optimum values will change. Those optimum parameters are usable for the smallest swept path while still having a reasonable (and usable, so small L1) length.