IA Vehicle Motion Lab

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12 February 2021

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1 Stationary—Q1

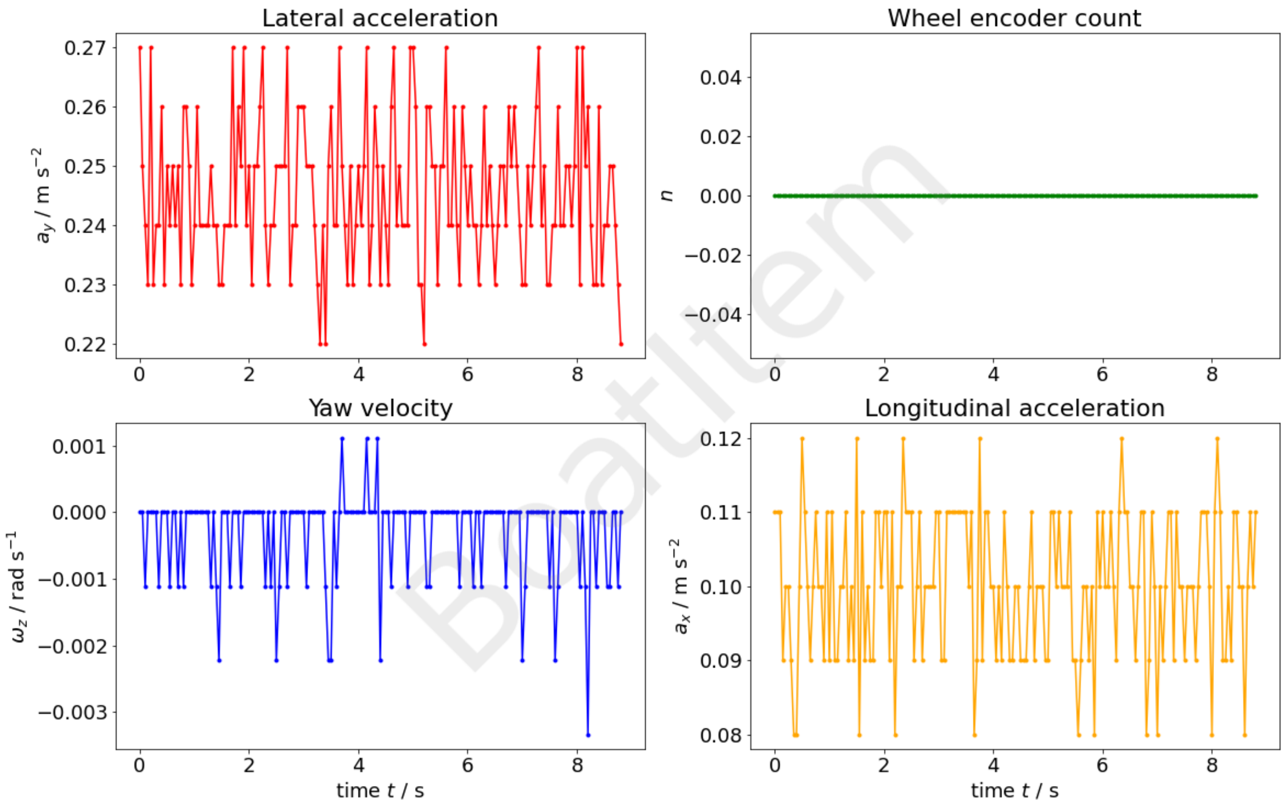

Figure 1: Data of the car when stationary

- To confirm that the sampling rate is $20Hz$, the number of data points between a n second interval should be $20n$, i.e: you should count 40 data points between a 2 second interval

Data	Quantization Step Size	Mean Value	Peak-Peak Value
Lateral Acceleration / ms^{-2}	0.01	0.245	0.05
Wheel Encoder Count	N/A	0	0
Yaw Velocity / $rads^{-1}$	0.001	-0.001	0.004
Longitudinal Acceleration / ms^{-2}	0.01	0.1	0.04

- The approximate mean values and peak-peak values for Yaw Velocity and Wheel Count are ≈ 0, which is expected since it is stationary.
- There was a small $0.1ms^{-2}$ for mean longitudinal acceleration and $0.04ms^{-2}$ peak-peak, which are all insignificant.
- However $0.25ms^{-2}$ lateral acceleration is unexpectedly high, this could be due to calibration errors in the inertial measurement unit. To support this, the peak-peak as very small hence indicating that the value of acceleration does not vary much from $0.25ms^{-2}$ at rest.
- Overall the mean values of each graph did not vary my much which is exactly what we would expect for a stationary car.

2 Straight Line Motion—Wheel Encoder—Q2

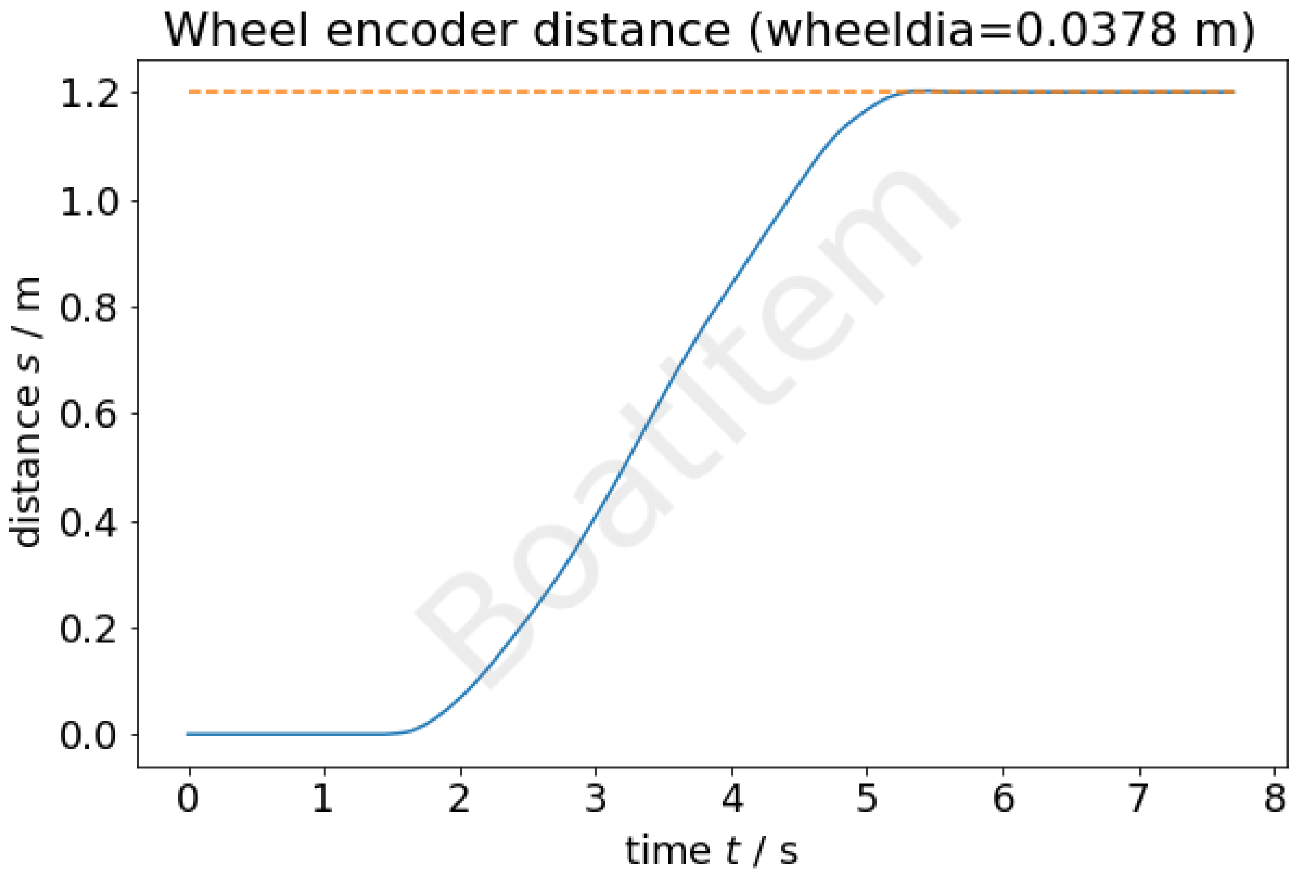

Figure 2: Wheel encoder distance under straight line motion

- The wheel encoder data is used to calculate the distance d travelled by multiplying the number of turns completed n by the circumference of the wheel of wheel diameter D, giving us $d(t) = 0.25\pi D^2 n(t)$
- To ensure that the final distance was equal to the measured distance ($1.2m$), the wheel diameter value was changed to $D = 0.037m$. In reality, using a tape measure, it was found that the $D_{reality} = 0.037m$, which represents a +2.2% error

3 Straight Line Motion—IMU Unit—Q3

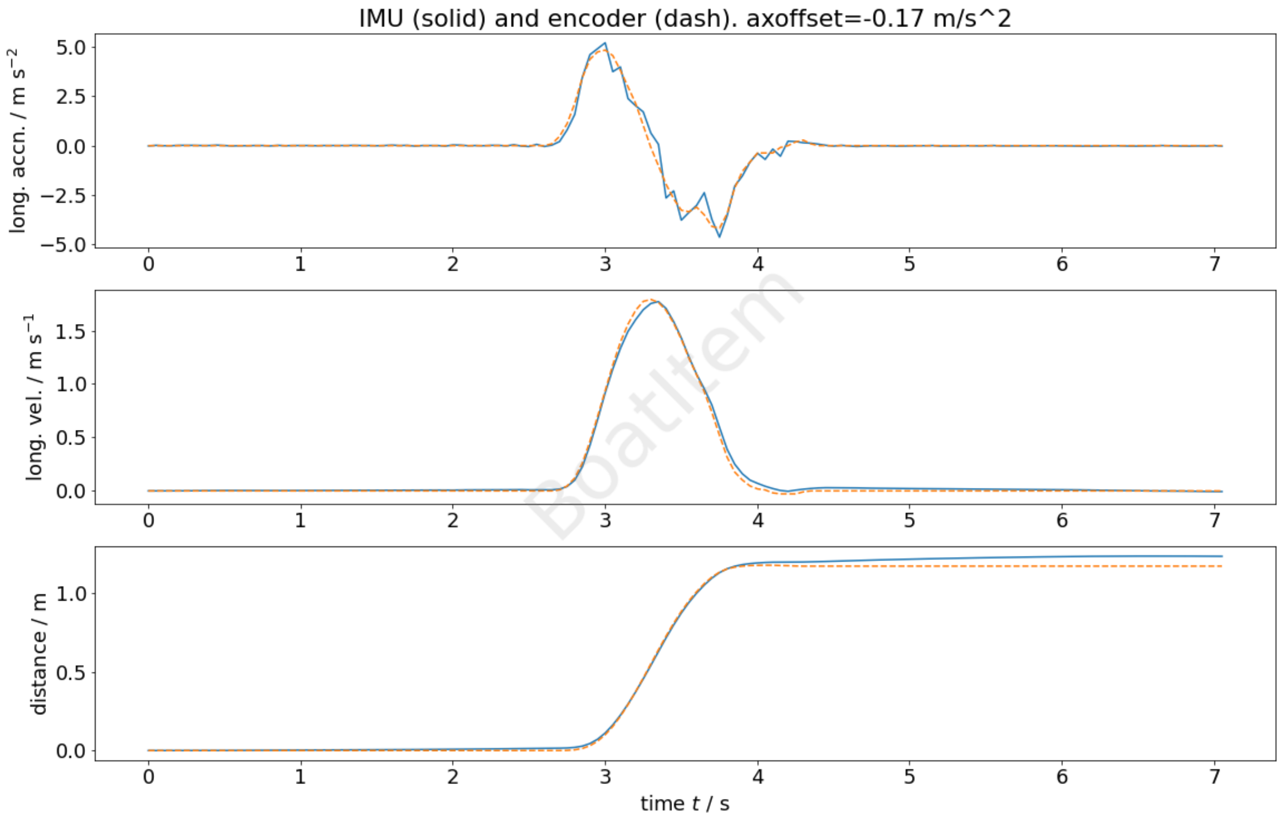

Figure 3: Graphs of longitudinal acceleration,velocity and distance

- The distance graph was achieved by numerically integrating the longitudinal acceleration twice to achieve the distance
- Without the necessary boundary conditions, it was found that the graph of distance was way off the encoder graph. This happens since the longitudinal velocity at rest is not zero as shown in Section 1, as when this is integrated twice it caused a quadratic increase in the displacement near the end of the motion.
- Applying the boundary condition that the velocity at the end should be zero, (by setting `axoffest=-0.175`), gave us graphs which are very similar, Figure 3. We found that the $d = 1.234m$, which represents a $+2.83\%$ error from the measured value.
- Overall, the change in `axoffest`, gave us results with no significant discrepancies between the two sets of data.

4 Circular Motion—Q4

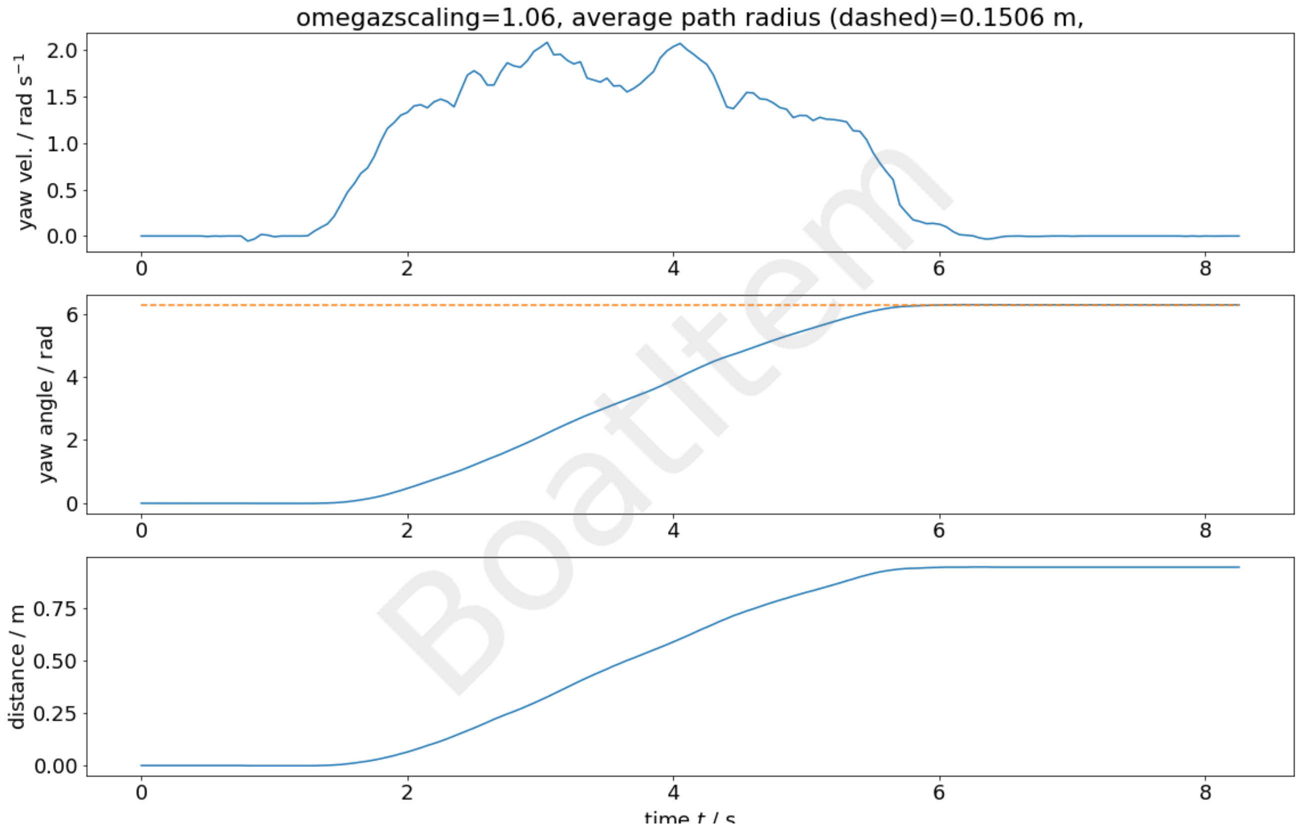

Figure 4: Graph of yaw velocity and angle and the radius of path

- Integrating the yaw velocity data gave us the yaw angle. For 1 complete turn, setting `omegazscaling=1.06` ensured that the measured yaw angle (in blue) and the expected yaw angle, 2π rad (in orange) are the same.
- The average radius r_{avg}, was calculated by dividng the distance travelled by the yaw angle at the end. We found that $r_{avg} = 0.1506m$. From the practical it was found that $r = \frac{30.5cm}{2} = 0.1525m$, which means our measured value has an error of -1.25%
- The estimate is quite consistent with the average value. Hence this method of calcualting raduis of the path is accurate.

5 Circular Motion—Q5

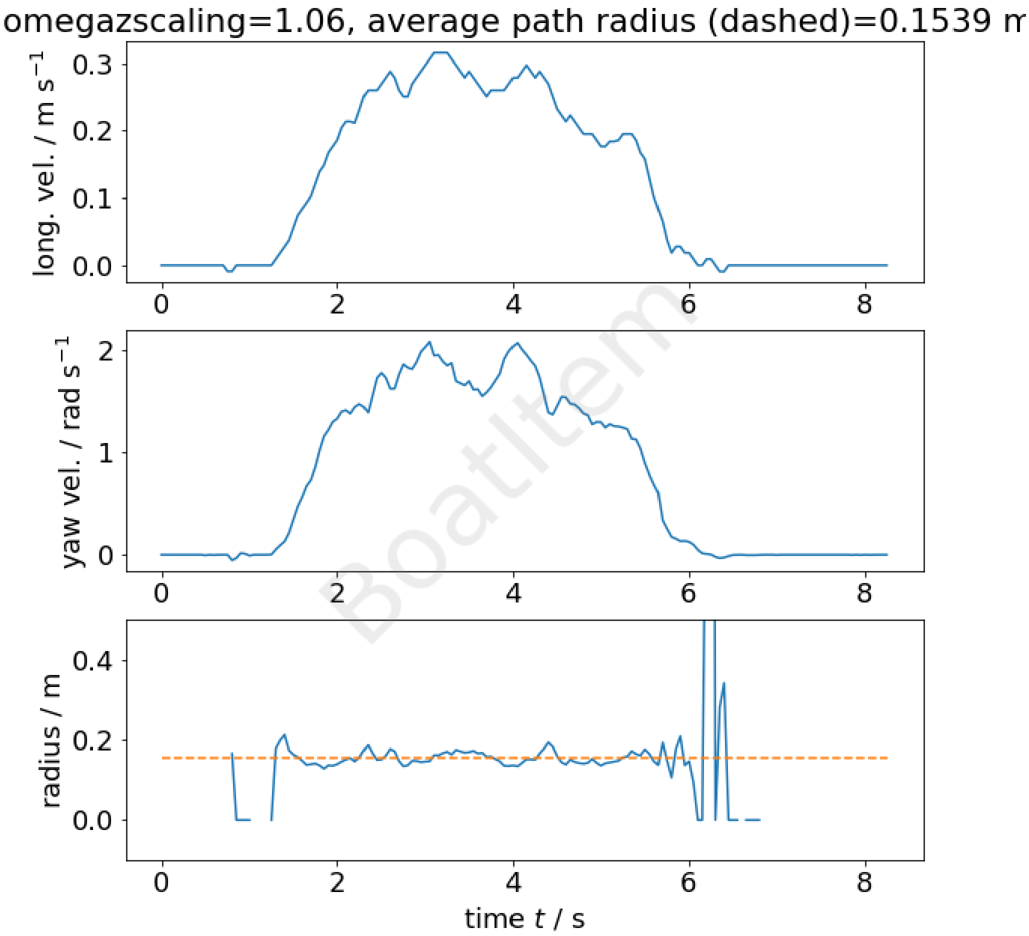

Figure 5: Graph of longitudinal, yaw velocity and radius of path

- This section we use the formula $v_\perp = \omega_z r$, to calculate the radius of a path. So we get

$$\text{Radius of Path} = \frac{\text{Longitudinal Velocity}}{\text{Yaw Velocity}}$$

- The average value of the radius found with this method is comparable to the radius found with the method in Section 4
- However the initial and final values are quite wrong, this occurs because it is when the car is stationary so the value for yaw velocity is low, leading to very high radius

6 Circular Motion—Q6

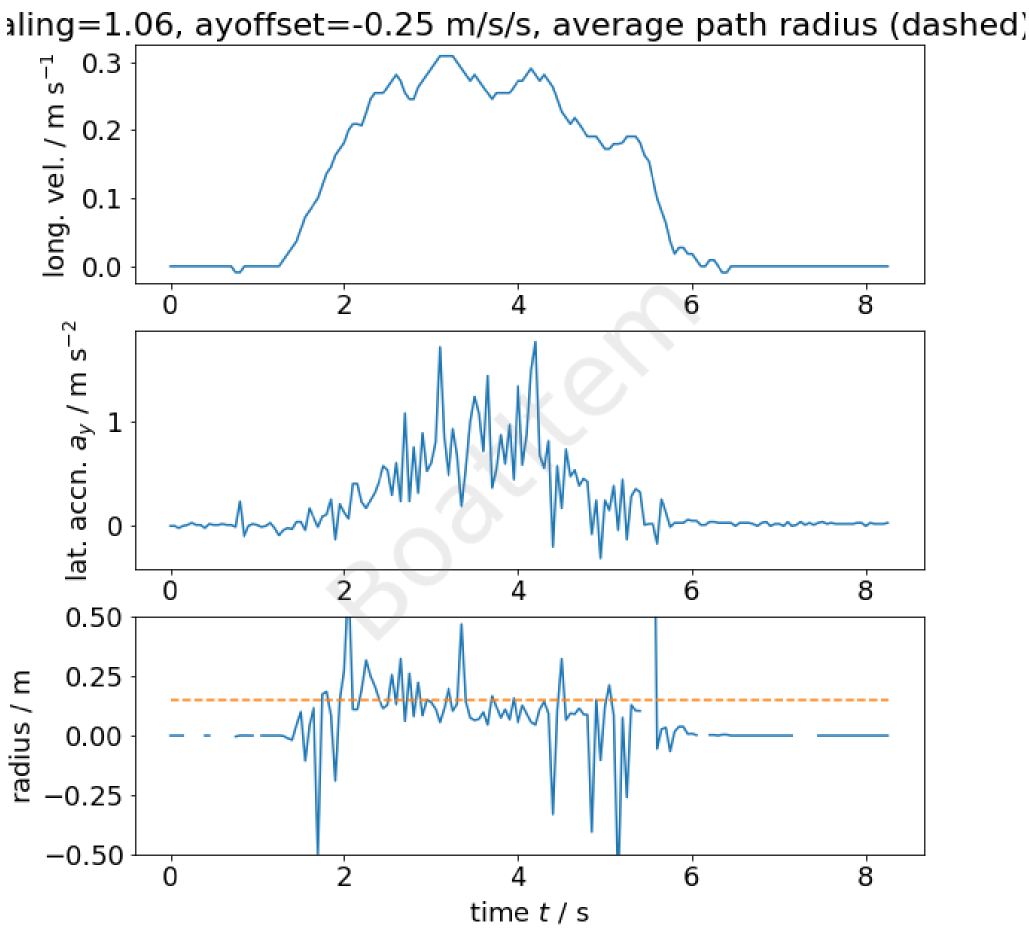

Figure 6: Graph of longitudinal velocity, lateral acceleration and radius of path

- In this section we use the longitudinal velocity v_x, the lateral acceleration a, to calculate the radius of the path r, using $r = \frac{v_x^2}{a}$
- Firstly, we need to ensure that the initial and final values of a are zero, this can be achieved by setting `ayoffest=-0.25`
- From Figure 6 we can see that the average value of radius is not very accurate with the previous calculations.
- We should note that the IMU is located in the center of the car, whilst the encoder is located on the left, this means that the average value of radius calculated using this method should be greater than the previous calculations by $\frac{\text{car width}}{2}$.
- The graph is very 'spiky', this is mainly due to the noisy lateral acceleration data. For this very reason I would deem it to be an unsuitable method to calculate radius, as the graph is just too chaotic, making it impossible to get a reasonable value for the radius.

7 Circular Motion—Q7

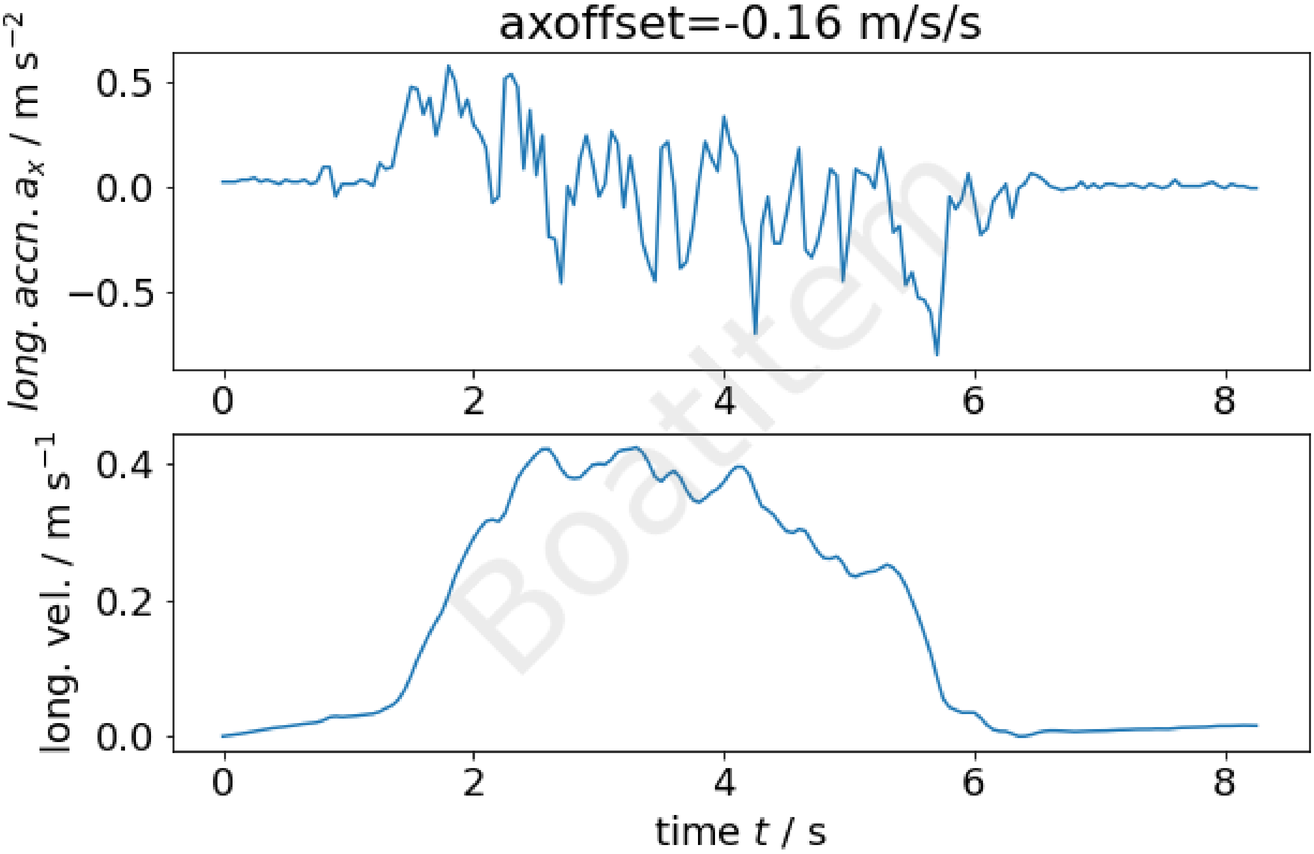

Figure 7: Graph of longitudinal velocity and acceleration

- In this section we get the longitudinal velocity by integrating longitudinal acceleration.
- To ensure that the initial and final longitudinal velocity were zero, we used an `axoffset=-0.15625`.
- This value is slightly different from the value we used in Section 3, this is because the data set used in this section is not the same as the one used in Section 3, so they won't be exactly the same.

8 Circular Motion—Q8

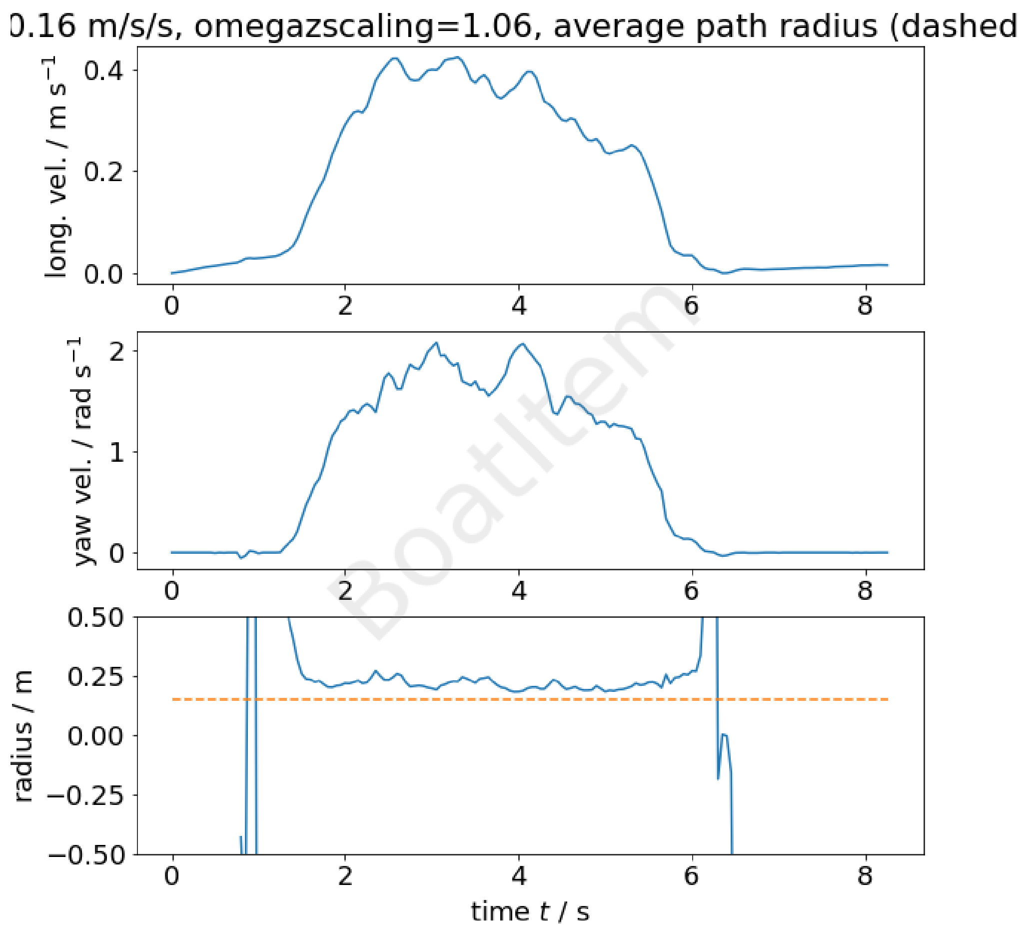

Figure 8: Graphs in Section 8, plus a graph of radius of path

- Now using the same method in Section 5 calculate the radius of the path.

$$\text{Radius of Path} = \frac{\text{Longitudinal Velocity}}{\text{Yaw Velocity}}$$

- From the graph we get $r \approx 0.23m$, which is $0.23 - 0.1506 \approx 0.08m$ greater than the radius calculated in Section 5.
- This difference in radius is due to the reason that was mentioned in Section 6, that the IMU is located in the center of the car, whilst the encoder is located on the left, this means that the average value of radius calculated using this method should be greater than the previous calculations by $\frac{\text{car width}}{2}$
- Once again, like in Section 6, the values of initial and final values of radius on the graph are very high due to the fact that the initial an final Yaw velocities were very low, since the car was stationary.
- Generally speaking this method works quite well for determining the radius, if we ignore the 'errors' in the beginning and end of the graph.

9 Arbitrary Path—Q9

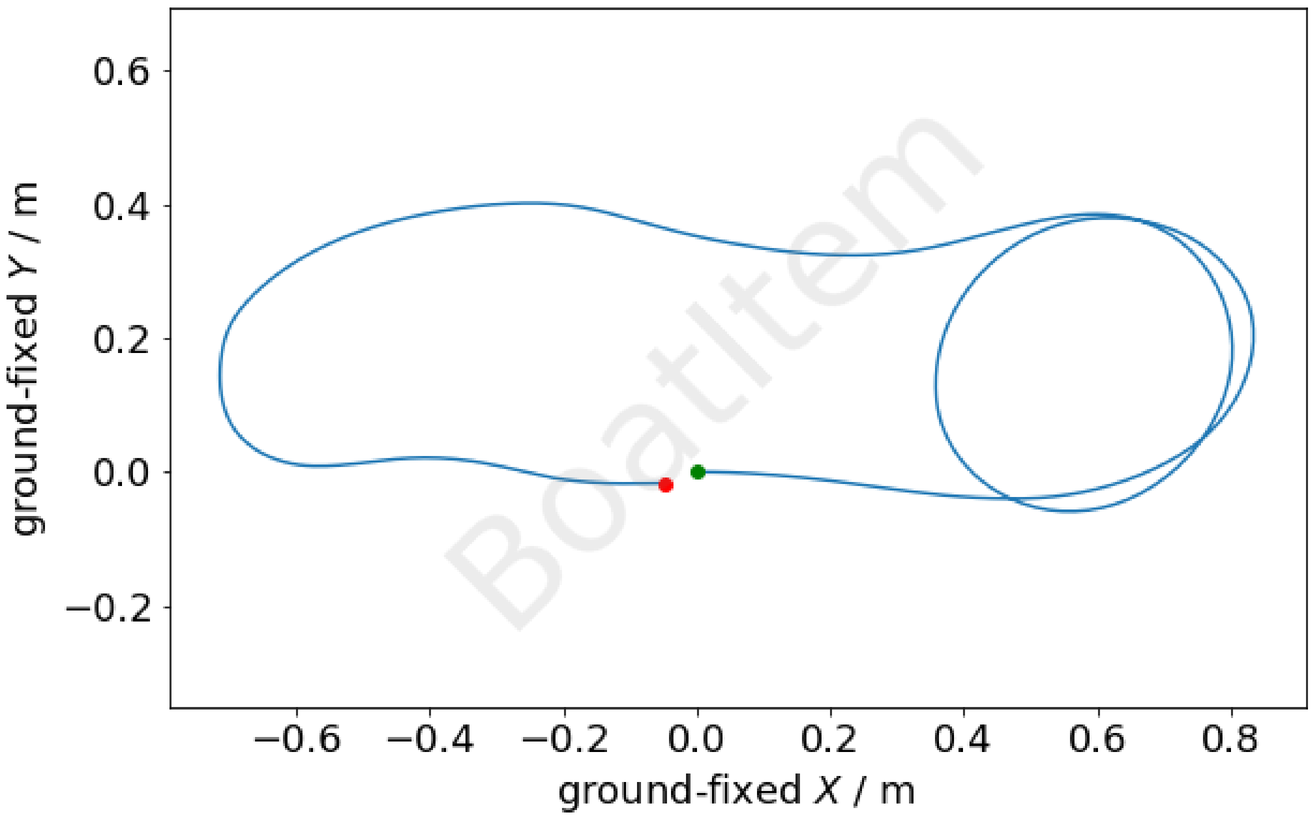

Figure 9: Graph representing arbitrary motion of the car in the XY plane

- Figure 9 is exactly what we would expect the motion to look like in the XY plane.
- The only discrepancy I could notice is that the starting point is not aligned with the ending point, this could be due the fact that the car did get slightly shifted during its motion and did not perfectly return to its original point, or it could be due to errors in the sensors.

Alternative methods to get XY motion

- Longitudinal and lateral acceleration provides us with enough information to plot 2D motion, a major disadvantage of this is that the data for accelerations are quite noisy and thus the 2D motion plot will not be that accurate.
- Longitudinal acceleration and Yaw Angle will also be enough information to plot 2D motion, but for the very same reason as the other alternative method, the resulting plot will be inaccurate and noisy.

10 Conclusion

In conclusion, we have explored the different ways in which we can use

- Lateral Acceleration
- Longitudinal Acceleration
- Yaw Velocity
- Wheel encoder count

data from a IMU and a rotary encoder to analyse the motion of a vehicle.We considered the possible benefits and disadvantages of using certain measurements in analysis and used the best method to plot the cars motion in 2D in Section 9.