

Driver comparison through data analysis.

by Ashley Edwards

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1. Abstract.

1.1 This report outlines the procedure adopted by many race teams when it comes to driver analysis. This report will outline the test methodology that the group used to gather data, analysis methods as well as the use of additional math channels on the software package to allow for a more in-depth analysis. The reason for the test was to try and improve three drivers lap times by analysing each driver's inputs such as: Throttle position, Brake position, steering input and gear selection, from these inputs each driver will be compared to each other and suggestions were made to aid in improvement.

1.2 One of the drivers was an experienced race car driver who was used as a theoretical model driver to compare the lesser experienced drivers, however as the paper will outline there are points where the experienced driver could improve from the data collected by the other drivers. The data was collected using a motorsport simulator which allowed for controlled testing, as well as being more cost effective. The test plan was to allow each driver to complete 5 laps each, after which they were given instructions to implement during the second 5 lap session to see if the lap times would benefit. The result was that two out of the three drivers benefitted from the suggestions that were made, but one driver did not benefit from the suggestions made, generally, the improvements were 0.5 seconds for those who gained on the existing lap.

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3. Introduction.

3.1 This report has been written to outline the procedure adopted when comparing 3 drivers. In this document there will be analysis of data collected in simulation testing, as well as the methods used to analyse their driving styles and provide guidance to improve on each driver's lap time. The analysis will be undertaken on solely the driver's inputs, with screen captures of the data sets to critically analyse the 3 driver's application of the inputs, and the vehicles response to the inputs. The driver's inputs that will be analysed are: throttle application, steering technique, braking technique and gear selection.

3.2 The data was collected using a Motec data acquisition module and a motorsport simulator, and the test car that was used was an F3 race car. Motec I2 software was used to collect and analyse the data from the simulation package. The test plan that was used in the simulation testing will be outlined, as well as the data that shows the implementation of these changes. The effectiveness of the test plan and the suggestions made to the drivers will be evaluated and improvements outlined.

4. Literature Review.

4.1 To gather data on race drivers and analyse their performance, there are two options available to any race team who wish to investigate either their car or driver. The options are to do live testing with an F3 car on a circuit which not only is very expensive, but the risk of a crash is present. Piola, G 2015 describes a motorsport simulator as the most viable option for many teams where live testing on track may even be banned. Simulators not only allow accurate representation of many racetracks and vehicles but also allows the testing to be undertaken in a controlled and safe manner.

4.2 The test that was undertaken was done on a motorsport simulator as not all the drivers were experienced racing drivers, and therefore the simulator provided a safer and cost-effective mean of getting data. The motorsport simulator was equipped with a data logging package called Motec, which allows Realtime data capturing of the vehicle throughout the

test sessions. The data logging software is required for both live testing and simulation work as it is the only means to record the data from the vehicle and allows quick real-time analysis during the test session or more in-depth analysis once the session is complete.

4.3 The data acquisition that was used was Motec. Motec is a popular and high-end data acquisition package that is often used in motorsport teams as it can manage everything from the engine management to recording live data off the vehicle. The Motec software was used to plot various data points from the vehicle as the tests were run, from this the basic sensor data was analysed and then more advanced maths channels were used to further evaluate the three driver's performance.

5. Methodology.

5.1 The first session that was undertaken as a baseline test was on the 01/11/18, the test car used was a F3 race car, Silverstone GP was used as the test circuit, during this session the primary aim was to allow each driver to get used to the simulator car and the track. The fastest laps from this session were used as a baseline for the test.

5.2 The second session was undertaken on the 22/11/18, where each driver would complete 5 laps of Silverstone and then the other driver would do the same. Once each driver had completed the 5 laps the following notes were made: Driver A had to brake later and turn earlier into turn 14. Driver B had to use 1st gear in turn 16, full throttle through turns 9 and 10, brake later into turn 6 and 16, use 2nd gear into turn 3 and 4. Driver C had to change gear on the indicator light, full throttle through turn 9, and use 1st gear into turn 16.

5.3 Due to the number of notes taken from the first 5 laps, it was impossible for the drivers to implement all the suggestions, so they had to be prioritised. The following suggestions were put forward to the drivers: Driver A had to brake later and turn later into turn 14. Driver B had to use 1st gear into turn 16 and take tighter lines through corners. Driver C must change gear on the indicator light, keep full throttle through turn 9 and use 1st gear into turn 16.

5.4 The following structure was used to organise the team: 2 members were assigned to analysing current data and make real time suggestions, 2 members were giving the driver the suggestions and making sure they were implemented, and the final members were analysing the racing line the drivers were taking and monitoring sector times.

5.5 The analysis will be undertaken to compare driver B and C, to the lap time and driving style of driver A. Driver A was an experienced race car driver and was used as an example to aid in comparison with the other drivers, to ultimately improve not only driver B and C but to improve driver A as there will be sections within the race where each driver may be faster than the other drivers.

5.6 Existing text documents, books and online documents on the topic will be used to support any analysis undertaken, as well as to aid in the use of maths channels on the Motec to allow more in-depth critical analysis, instead of the basic sensor data being captured. The addition of maths channels allows a wider picture to be made of what is going on with the vehicle, that the raw data cannot allow the race engineer to see.

5.7 In addition to the basic sensor data provided by the Motec data acquisition system, more advanced maths channels can be used to explore avenues of data that the raw sensors alone cannot show. Textbooks such as “analysis techniques for race car data acquisition” by Jorge Segers and “Race car vehicle dynamics” by William, F. Milliken were used for the following maths channels. Brake pedal speed = Derivative (Brake pedal position (%)), throttle pedal speed = Derivative (throttle position (%)), Negative yaw rate (Deg/s) = -yaw rate (Deg/s), Inverse corner radius = choose [“Corrected speed”(Km/h)>30. “G force lateral” (M/s/s)/ (“Corrected speed” (M/s)^2). 0.0].

6. Results/Analysis.

6.1 From the first session the following lap times were achieved: Driver A, B and C had lap times of: 1:37.844, 1:38.907 and 1:43.943 respectively. Once the suggestions were made Driver A, B and C had lap times of 1:37.380, 1:38.374 and 1:44.228 respectively.

6.2 The following analysis of data will be undertaken on each driver fastest laps from both sessions, the analysis will begin with Driver C being compared to both other drivers. From looking at figure 1, it can be observed that driver C throughout the lap comes off the throttle before both other drivers, while also being the last driver to reach 100% throttle application. Driver C also takes longer than both other drivers to reach full throttle. This is supported by figure 7, which is a maths channel created to observe pedal speed. This maths channel allows the observation of the time the driver is no at 100% pedal application, whether that is the brake or throttle pedal. Looking at figure 7, Driver C should have the majority of the histogram bars should be as close to 0 as possible, meaning the pedal is released and re-applied a quickly as possible. Comparatively, figure 8 shows driver A’s pedal speeds and has a good example of what driver C’s pedal speed graph should look like, with the majority of driver A’s histogram bars closest to 0.

6.3 The brake pedal position (%) data shows that driver C is the earliest on the brakes compared to the other two drivers. Driver C is considerably earlier on the brakes into turn 5, which is reflected in the “G force long” data set where the driver C achieves peak longitudinal G force sooner than the other two drivers. Driver C also uses greater brake inputs into turn 10 which unlike driver B that uses less brake input, and driver A does not use any brake input into turn 10. Driver C however has good pedal speed through the both sessions laps as shown in figure 7, meaning driver A does not “Ride” the pedal. This shows driver C does not spend time using partial brake input, and instead is utilising maximum brake input and releasing the pedal as quickly as possible to return to throttle application.

6.4 Driver C applies the steering angle in two stages in turn 1, unlike the other two drivers which apply the steering earlier and use less steering angle throughout the corner. Through turn 6 driver C applies less steering angle in comparison to the other two drivers, which results in a gain over the other two drivers as supported by the variance. Segers, J 2008 describes the ideal corner line as being at the greatest radius possible which allows speed to be maintained. Driver C enters turn 7 at a lower speed than the other two drivers, which in turn is why the steering angle is greater than the other two drivers and that the driver reaches peak steering angle later in the corner than the other two drivers. Segers, j 2008 describes achieving peak steering angle later in the corner as hitting an early apex through the corner and trying to prevent the wider exit.

6.5 Figure 2 shows Driver B's points of analysis throughout the different data sets. Looking at driver B's throttle application throughout the lap, the first point to highlight is leaving turns 4 and 10 driver B is later returning to full throttle. Looking at the brake pedal position (%) data, it can be concluded that into turn 5 driver B loses time against driver A because driver B uses more brake input than driver A and therefore loses more speed into the corner, then has to re-apply the brake due to the amount of throttle applied during the small stretch between the corner which in turn causes a loss over driver A. Looking at figure 9, driver B has a throttle pedal speed similar to that of driver A, which means that driver B spends minimal time at partial throttle and instead is either applying the throttle as quickly as possible, or is releasing the throttle input as quickly as possible to then apply the brakes.

6.6 Finally, driver B's steering input through turns 11, 12 and 13 driver B is greater than the other 2 drivers and used more steering input later in the corner than the other 2 drivers. Driver B also didn't change to 6th gear through turn 1, as shown by his engine speed of 9500 RPM, therefore if driver B had changed to 6th gear then driver B could have gained time on Driver A. Figure 10 shows a "G-G" diagram that was created to observe the G forces each driver was able to generate laterally and longitudinally. According to Milliken, W, F. et al 1995 the "G-G" diagram can be used to see how hard the driver is working the car. However, in the application of this test the "G-G" diagram was used to compare how hard each driver was working the car in comparison to each other, from the diagram it can be observed that the red and black traces that shows lateral force which are driver B and C, are closer to the outer boundaries of the graph, this shows that driver A and B are utilising more of the vehicles lateral cornering potential than driver C. Looking at the longitudinal force, driver A and B are still utilising more of the vehicles longitudinal potential than driver C, meaning that driver A and B are generating more longitudinal force under braking and are able to generate more force under acceleration as shown at the bottom of the graph.

6.7 Driver A had minimal mistakes in comparison to the other two drivers, however figure 3 shows driver A is later applying the throttle than driver B coming out of turn 11. Driver A also brakes entering turn 9, instead of turn 10 like both driver B and C which allows driver B and C to gain time over driver A. Figure 8 shows the brake and throttle pedal speed of driver A, driver A has reasonable throttle pedal speed, however there is still an area either side of 0 which is populated. This means that driver A is smoothly applying and releasing the throttle pedal which could be an area to improve upon. Looking at the brake pedal speed graph it is similar to that of the throttle graph, however the braking graph has a small area in the negative area of the graph as it shows that the driver is bleeding off the brakes as the speed reduces into the corner, similar to that of driver B. Figure 4 shows Driver A's fastest laps of the first and second session after the suggestions were made as stated in paragraph 5.2 and 5.3, the red trace was the fastest lap before the suggestion was made and the black was once the driver implemented the changes.

6.8 Driver A implemented the suggestions made in paragraph 5.3 on the fourth lap and gained 0.464 seconds over the previous run. Looking at the brake pedal position data on figure 4, through turn 14 driver A brakes later and generates more longitudinal force, this allowed the driver to gain time on the previous session, Driver A also brakes later in the last two braking zones which allowed driver A to gain time. Driver A however, lost time through the lap over the previous session by not using as much throttle input between turn 6 and 7,

this could be due to the higher entry speed into the corner which is shown in the lateral G force trace as the driver reaches peak lateral G sooner in the corner and holds it throughout the corner.

6.9 Driver A also used incorrect gears in turns 4, as shown in the engine RPM trace at turn 4 driver A is at 5600RPM in 2nd gear when the throttle is applied to exit the corner, whereas on the previous session driver A used 1st gear and was at 7000RPM when full throttle was applied, causing driver A to lose time over the previous session.

6.10 Figure 5 shows driver B's fastest laps before and after the suggestions were made, driver B gained 0.533 seconds over the previous session. The suggestions made in paragraph 5.3 were implemented by lap 3 which was the fastest lap driver B completed, looking at the steering wheel input driver B turns later into turn 7 and 15 than previous which proved to be beneficial as shown in the gain in the lap time. Through turn 12 driver B uses more steering input than previous, this however had a negative impact on the lap as shown in the variance channel. This is also reflected in the lateral G force trace to the right labelled figure 5a occurs. This error would be a new suggestion had the test continued for longer. Driver B also gained on the previous session entering turn 6 as the driver applied the brakes later, and achieved a higher longitudinal force entering the corner.



Figure 5a

6.11 Driver C's fastest laps before and after the suggestions were made are shown in figure 6, the suggestions made to driver C had a negative impact on the overall lap time. Driver C completed a 1:43.943 in the first suggestion, and once the suggestions were made the driver completed their fastest lap in 1:44.228. This shows a loss of 0.285 seconds once the suggestion was made. The loss of time was found to be a lack of structure and organisation within the group. Looking at the data in figure 6, driver C was significantly later applying the brakes than previous into turn 3. Driver C also implemented the instruction of maintaining full throttle through turn 9 which could have resulted in a gain on the previous time. Driver C was later applying the brakes throughout all the corners, however was slower in re-applying the throttle on the exit from the corners. This would be a further suggestion in a future test session.

6.12 Figure 11 shows the negative yaw rate against steering angle for driver A, the graph shows the correlation between the steering input and the cars response which is its yaw rate. The graph shows that driver A has an even application of steering angle input and maintains a steady yaw rate through the corner, indicating stability through the corner. Comparatively, figure 12 shows driver B's trace whereby the steering is greater than the yaw rate. This shows that driver B is using excessive steering angle to achieve the same yaw as driver A, this is a sign that driver B is taking different racing lines to driver A as supported by Segers, J 2008. Some areas of the trace show the yaw rate exceeding the steering angle input, this is due to higher cornering speeds affecting how much steering input was required to achieve the yaw rate needed for the corner.

6.13 Figure 13 shows that driver C also uses greater steering input through corners 1, 3 and 9 than driver A and B. However, from corner 10 onward to the end of the lap driver C is more like driver A than driver B. Therefore, driver B could develop their lap time by taking different racing lines more like that of driver A and C through turn 10 onwards. This is reinforced by figure 14, and 14a to the right which shows the inverse corner radius graph, looking turn 16 on the graph all three drivers are taking different lines through the corner.

Figure 14a shows all three drivers achieving peak corner radius at different points, driver C reaches peak corner radius first meaning a later apex was achieved, whereas driver A achieved peak corner radius slightly later than driver C, meaning a mid-corner apex was achieved, and driver B achieves peak corner radius last meaning driver B hit the apex early as dictated by Segers, J. 2008.

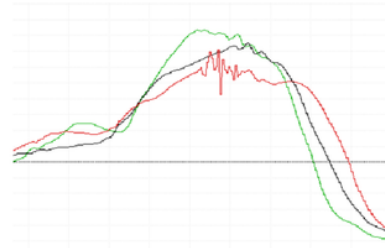


Figure 14a

6.14 Figure 15 was created using a maths channel as discussed in section 5, the channel shows pedal "off-time". Pedal "off-time" shows the percentage that each driver is not providing any pedal inputs. As shown in figure 15, driver A spends less than 1% with no pedal inputs in comparison to both other drivers. Driver B spends 2% without any pedal input, whereas driver C spends 4% without any pedal input. This shows that driver A is spending as much time on one pedal or the other without effectively wasting time not applying pedal inputs, unlike the less experienced drivers B and C.

7. Conclusion/Evaluation

7.1 From the data that was analysed above in section 6, it can be concluded that driver A showed a more consistent driving style through the laps and was ultimately the fastest driver. Driver B was the second fastest managing to be 0.994 seconds slower than driver A, despite a more aggressive corner style than both other drivers and taking different racing lines than both drivers. Finally, driver C finished last 6.848 seconds behind driver A, despite having a steering style similar to driver A, driver A was not able to carry enough speed through corners and lost 0.285 seconds after the instructions given in the second session. Comparatively both drivers A and B gained from the instructions given, driver A gained 0.464 seconds and driver B gained 0.533 seconds over their session 1 lap times.

7.2 Overall, the test session was successful as 2 out of 3 drivers benefitted from the instructions given, however in future testing a more defined group structure would be beneficial as it would make or a more efficient test session. Moving forward, the following suggestions would be made to each driver: Driver A could apply the throttle sooner exiting turn 11, and to not brake into turn 11 but brake into turn 13. Driver B could benefit from taking less wide racing lines throughout the lap, and to apply the throttle earlier leaving turns 4 and 10. Driver C would need to maintain full throttle through turn 9 and generally carry more speed through corners and be faster in re-applying the throttle on the exit. Now the simulation sessions are complete, the next step would be to validate the findings by carrying out the test in real life and comparing the data, due to the limitations with the simulator. The simulators limitations are as follows: no tyre degradation data, ideal driving conditions were used i.e. dry, clear conditions, no actual G-force being exerted on the driver. All these factors are beneficial as it allows a more controlled test to be undertaken, however

in a real racing situation the conditions are never ideal or controllable.

8. References.

8.1 Segers, J. (2008) *Analysis techniques for race car data acquisition* 2008 ed. Warrendale: SAE International.

8.2 Milliken, W. Milliken, D. (1995) *Race Car Vehicle Dynamics*. 1st ed. Warrendale, PA: SAE International.

8.3 Vaduri, S. and Law, E. (2000), *Development of an Expert System for the Analysis of Track Test Data*, SAE international, 2000, accessed: <https://doi-org.ezproxy.uwtsd.ac.uk/10.4271/2000-01-1628>.

8.4 Piola, G. (2015) *Inside story: How Red Bull's F1 simulator really works*. Available at: <https://www.motorsport.com/f1/news/inside-story-how-red-bull-s-f1-simulator-really-works/639880/?nrt=54>. (Accessed: 10th December 2018)

9. Bibliography.

9.1 Mitchell, W. (1998), *A Method for Data Alignment*, Warrendale, PA: SAE international, 1998, accessed: <https://doi-org.ezproxy.uwtsd.ac.uk/10.4271/983087>.

9.2 Searle, J. (1999) *Equations for Speed, Time and Distance for Vehicles Under Maximum Acceleration*. SAE international, 1999, accessed: <https://doi-org.ezproxy.uwtsd.ac.uk/10.4271/1999-01-0078>.

9.3 Vaduri, S. and Law, E. (2000) *Development of an Expert System for the Analysis of Track Test Data*, Warrendale, PA: SAE international, 2000, accessed: <https://doi-org.ezproxy.uwtsd.ac.uk/10.4271/2000-01-1628>.

9.4 Colunga, I.F. and Bradley, A. (2014) *Modelling of transient cornering and suspension dynamics, and investigation into the control strategies for an ideal driver in a lap simulator*. Proceedings of the institutional mechanical engineers, Part D: Journal of automobile engineering.

9.5 Gadola, M., Vetturi, D., Cambiaghi, D., and Manzo, L. (1996) *A Tool for Lap Time Simulation*, Warrendale, PA: SAE international 1996, <https://doi-org.ezproxy.uwtsd.ac.uk/10.4271/962529>.

10. Appendices.

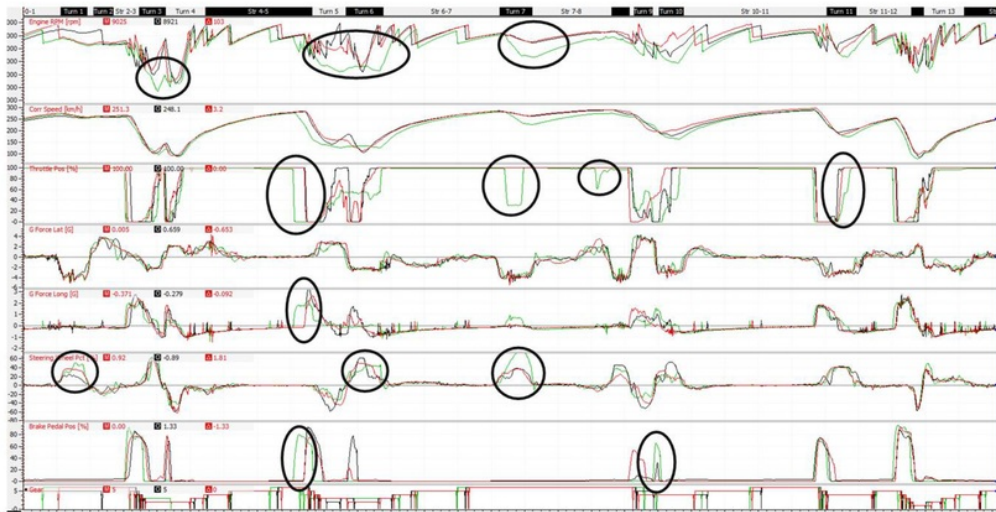


Figure 1.

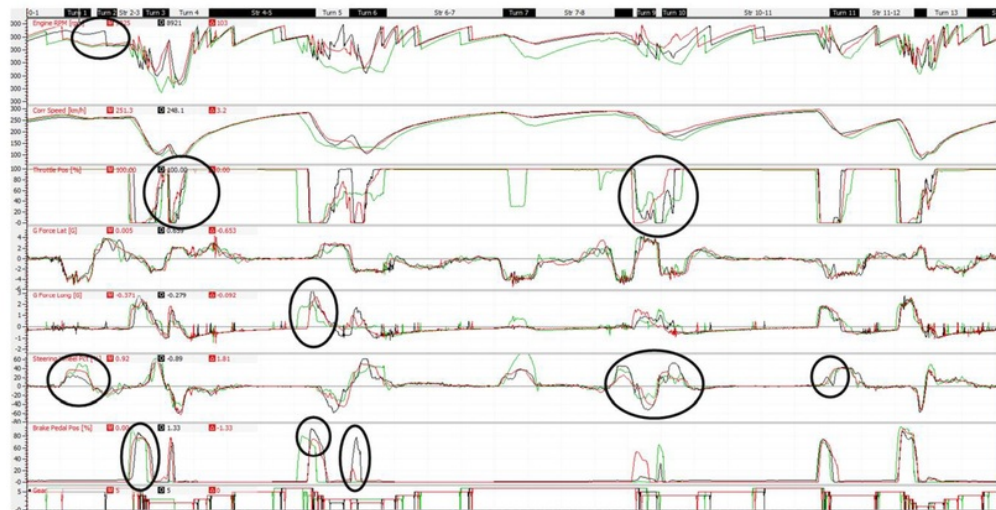


Figure 2.

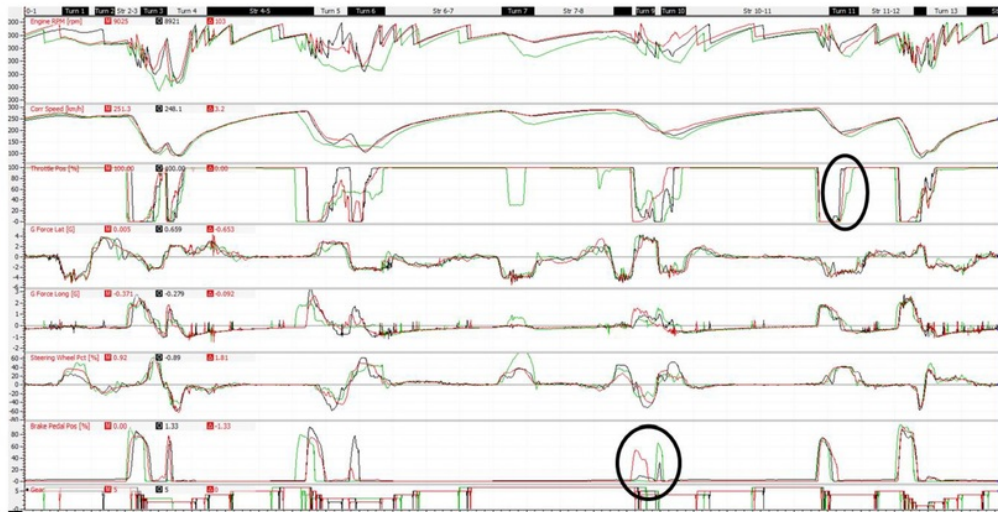


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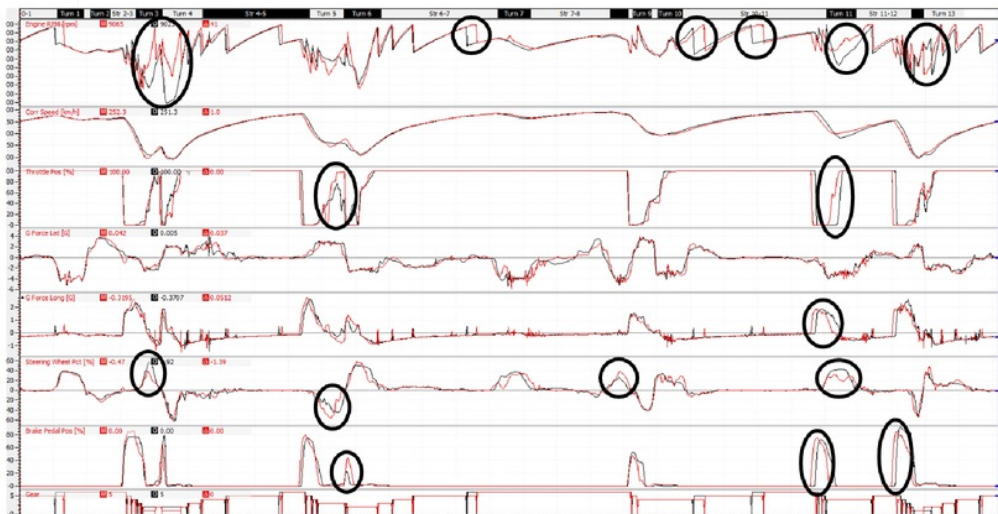


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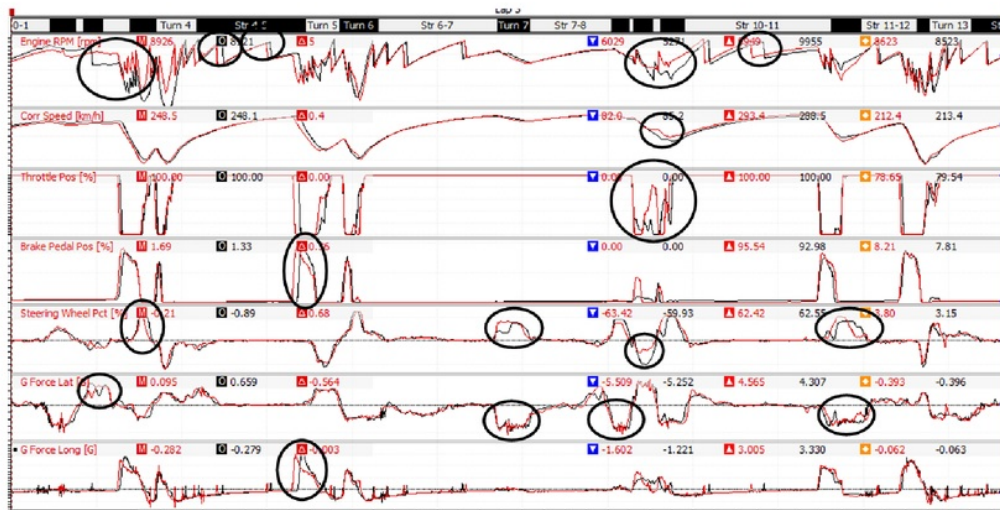


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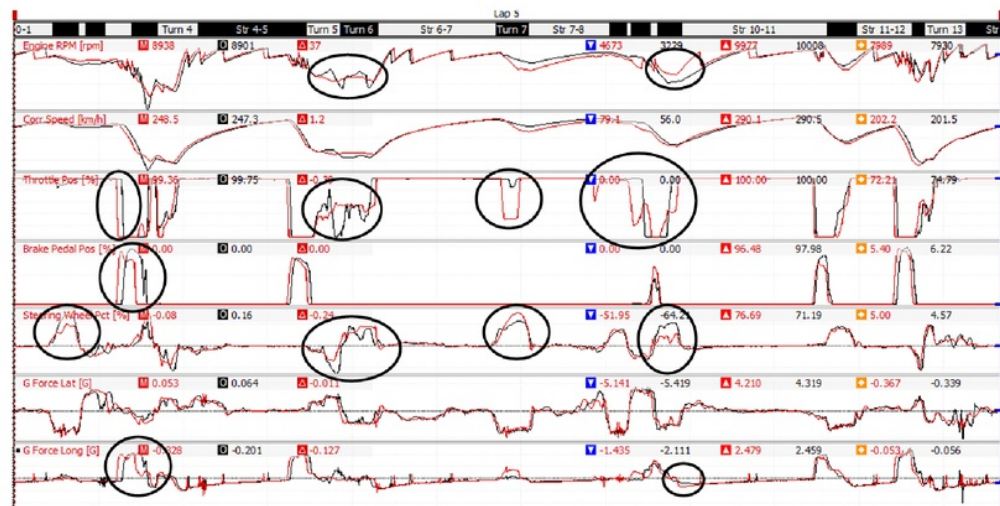


Figure 6.

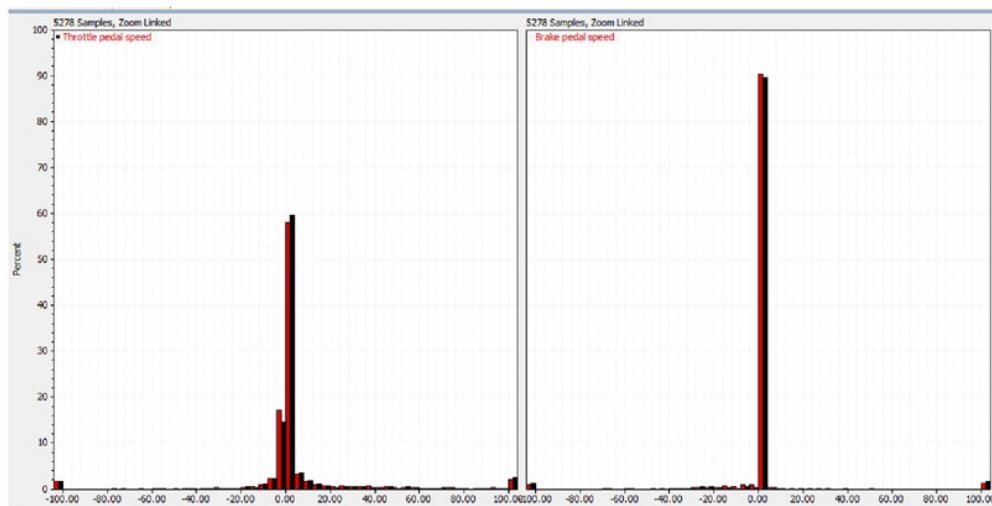


Figure 7.

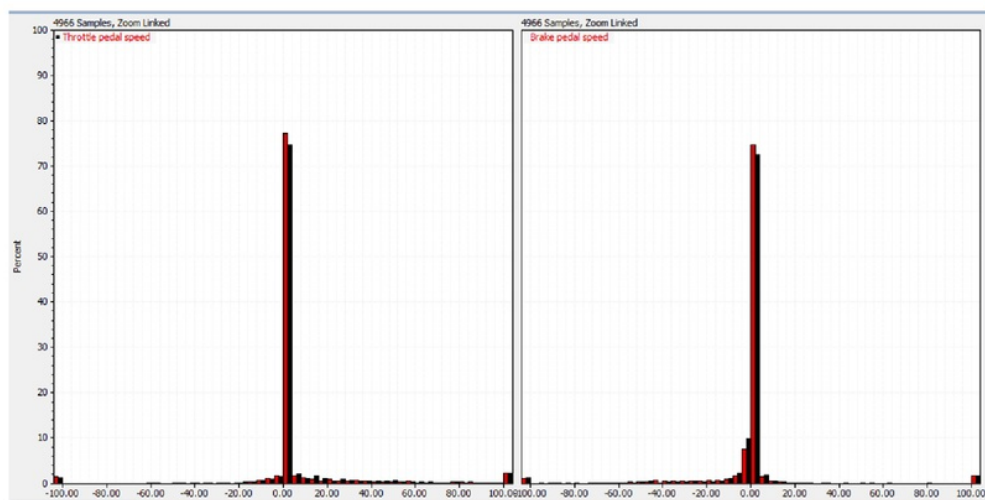


Figure 8.

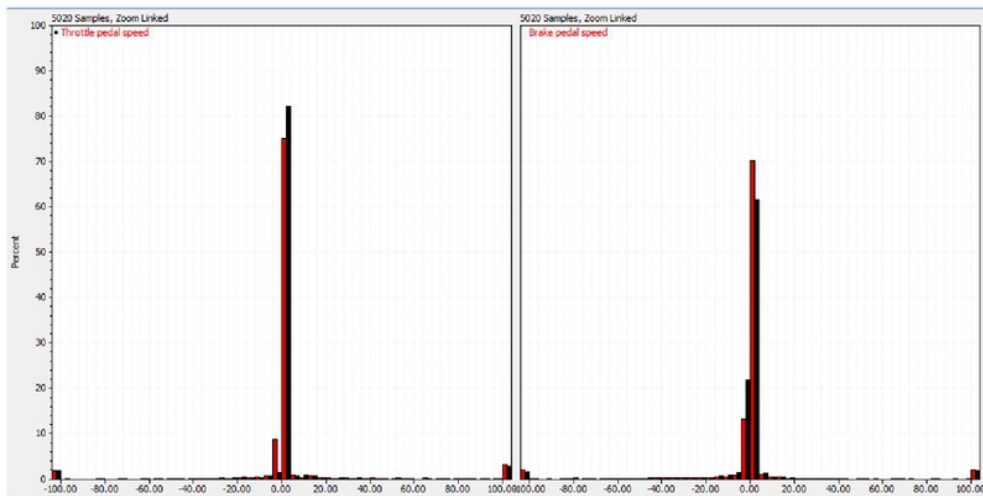


Figure 9.

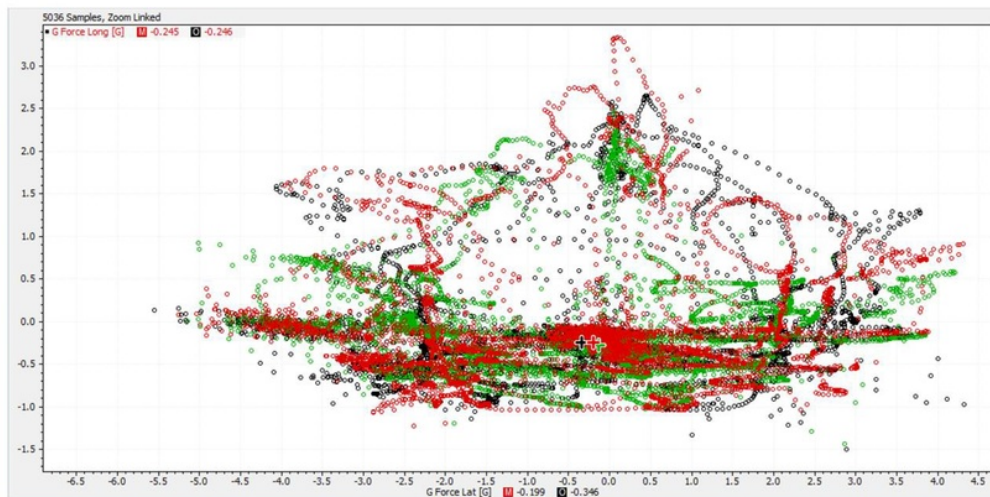


Figure 10.

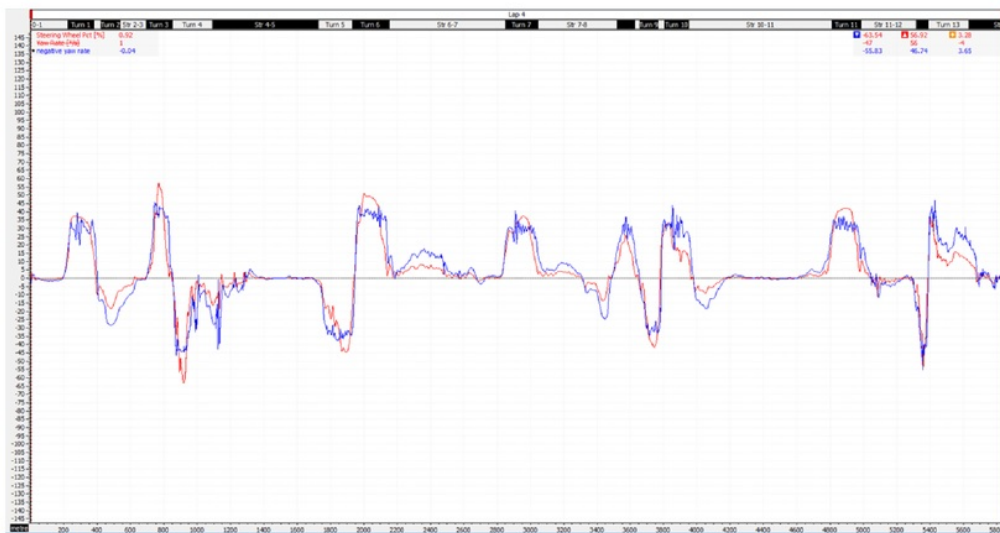


Figure 11.

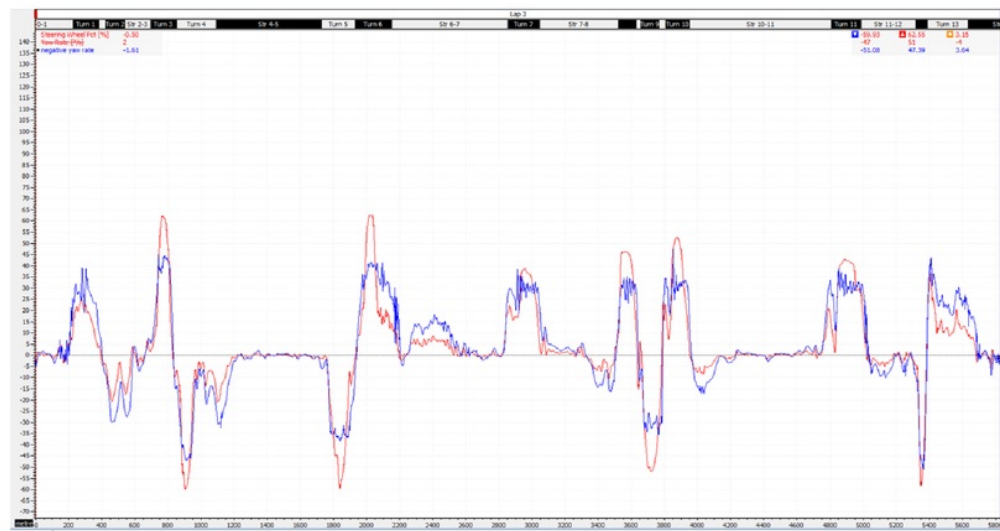


Figure 12.

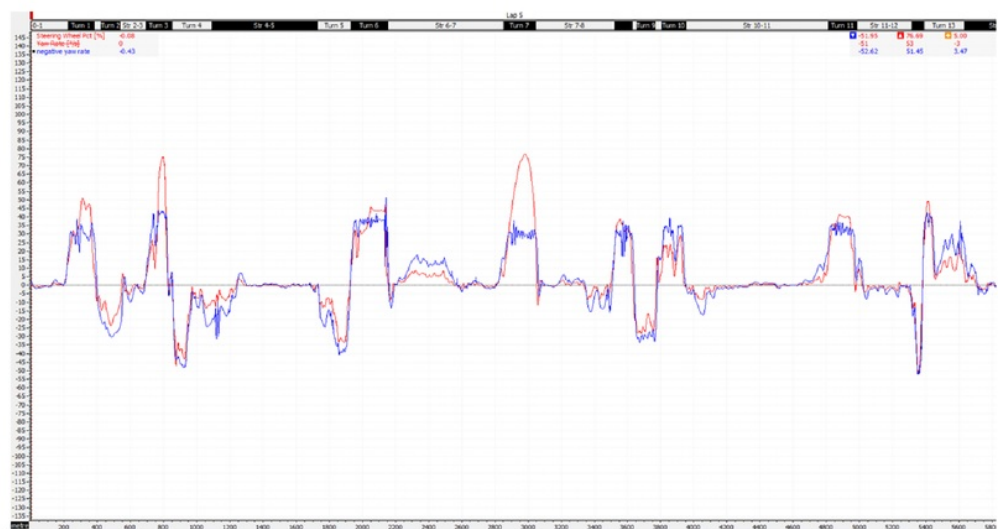


Figure 13.



Figure 14.

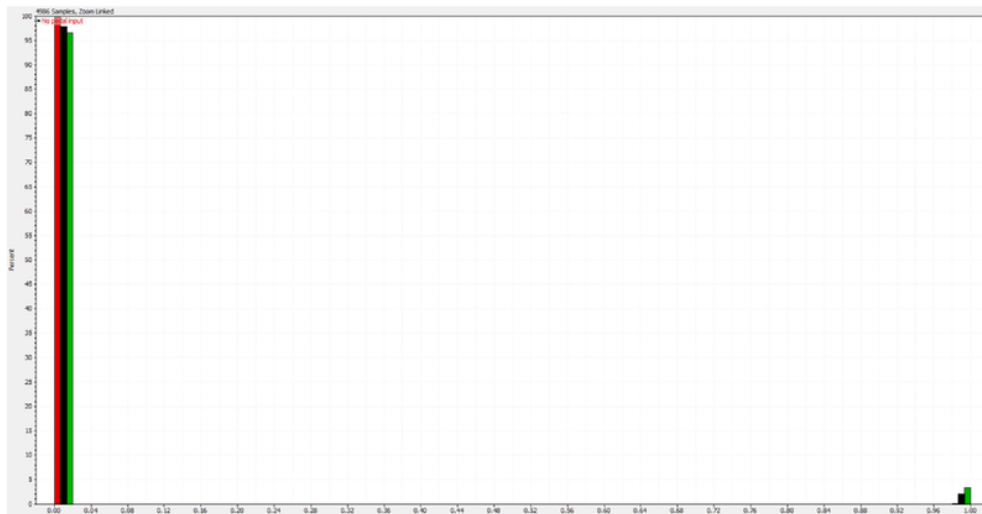


Figure 15.