Slip Angle is a summary of Claude Rouelle's OptimumG seminars

Application analysis

In this month's article, OptimumG looks at how maths can be used to improve driver braking performance on track

In our previous article, we discussed how braking aggression can be used to understand if a driver is performing at their limit. We discussed how to correlate brake lock-up to brake aggression, and help conclude if the driver needs to change their driving technique, or the engineer needs to make a set-up adjustment.

To expand on what the braking aggression is telling us, we can consider the brake application point for each corner to determine when the driver is braking. In this article, we will discuss how to create a trigger to find the brake application point, how to create a radar plot to track how the relative brake application point is changing in each corner and how to gauge which corners have the greatest effect on the overall vehicle lap time based on brake application point. This analysis can provide the driver and engineer with a tool to help them to improve braking performance during a race weekend.

Having a physical marker to contextualise the brake application point can help your driver be performant and consistent, as well as qualify and quantify the results seen in the data

Table 1: Equations for creating the brake application point

Math channel name	Math channel equation
Total brake pressure	total brake pressure [bar] =^(') brake pressure front^' [bar] +^' brake pressure rear^' [bar]
Brake application point	brake application point=choose('total brake pressure^' [bar]>0,^' lapdistance^' [kilometre],1/0)

Single lap analysis

Before we dive into creating the maths channel, we will define what the brake application point is. It is the distance, inside a defined braking zone, in which a driver starts to brake for a corner.

As described in previous articles, we can define the area to search for the brake application point by using the section tool on the track map to set boundaries to include braking. In addition to having the range within the data to track the application point, it is also good to have a reference for the braking zone so the driver and engineer can visually compare the brake application point to the data driven point.

To create the brake application point math channel shown in **Table 1**, we will create a trigger to record when brake pressure is applied using the 'choose' function available within the MoTeC i2 program. The choose function acts as an 'if' statement that can be found within other programming languages. If there is a non-zero value for the total brake pressure, the distance will be recorded for the sequence. If the brake pressure returns to zero, then there will be nothing returned by using the 1/0 value.

Within each braking zone, we can then define the minimum point at which a driver starts braking using a channel report table. We can then export the data and thereby create a radar plot to compare the capabilities of the two drivers.

In **Figure 1**, each edge of the plot corresponds to a corner on the track where braking is occurring, with the bands representing a percentage later or earlier braking by the second driver relative to the first. We are using a percentage as each corner will have its own unique application point based on the corner radius, the incline leading up to the corner, the camber of the corner and the visual references within the corner. Using the percentage normalises the results and allows us to see the consistency of the driver more clearly in sections that will not have the same distance.

In our example, we can see that the second driver (shown in pink) out-braked his competitor in all but two braking zones on their best lap. This can provide an indication of where to look within the laps afterwards to find differences in driving ability and overall performance that will explain the different brake application points.

In addition, we can find where a driver is inducing a vehicle balance shift in a corner, the wheel locking that comes from a different brake application point and the impact of brake application point on tyre

We can define the area to search for the brake application point by using the section tool on the track map to set boundaries

wear, driver fatigue and fuel usage through an event by using different braking strategy to trail brake or to straight-line brake.

Full session analysis

Knowing the delta between the two drivers during their best laps, we can now go on to look at their consistency across a session. We will look at the average application point in a race situation and compare the overall results to what we see in the one-lap peak. We can then look at the standard deviation of the three situations to see driver consistency and find how much fall off the driver is seeing in an event through, for example, either their own fatigue, loss of focus, or tyre fall off.

The greater the delta between the two values, the more potential fall off is present in that session.

Understand how close they are able to get to their best lap times on average

We can make this inference if we assume lower cornering speeds are required for the driver to get through the corner, therefore warranting an earlier brake application point.

This analysis is one of the tools that can help drive decisions like pit strategy if running a longer event as it can be used to determine the trade-off between more pit stops but a faster average lap vs a longer tyre run but potentially greater tyre fall off. The same data can also be used to coach a certain driving style to conserve or be aggressive with tyres if running a shorter event.

We will now create another radar plot showing the average brake application point across a session with the upper and lower standard deviation for the two drivers.

From the full race results shown in **Figure 2**, we can see from the average brake application point that the two drivers are significantly more split in brake application point than would appear in the one-lap result.

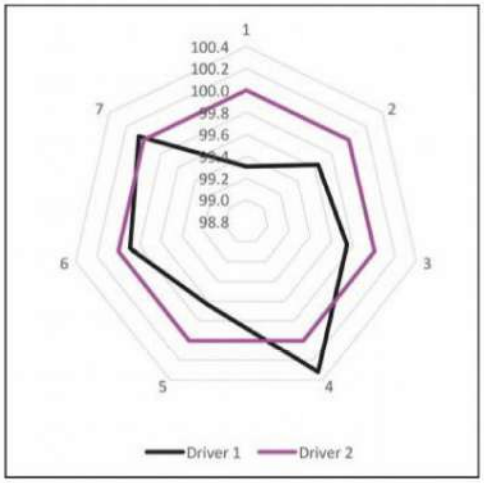

Figure 1: Relative brake application point radar plot

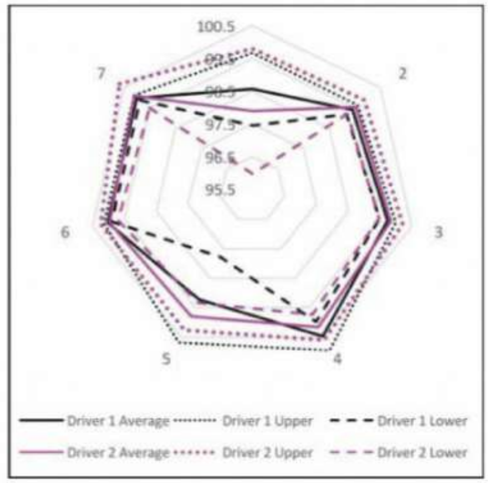

Figure 2: Brake application point across a full race session with upper and lower bounds for each corner

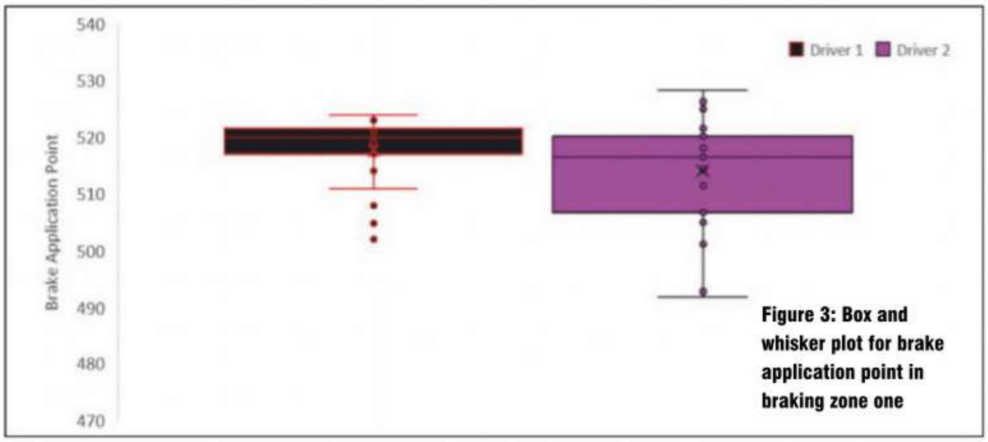

Figure 3: Box and whisker plot for brake application point in braking zone one

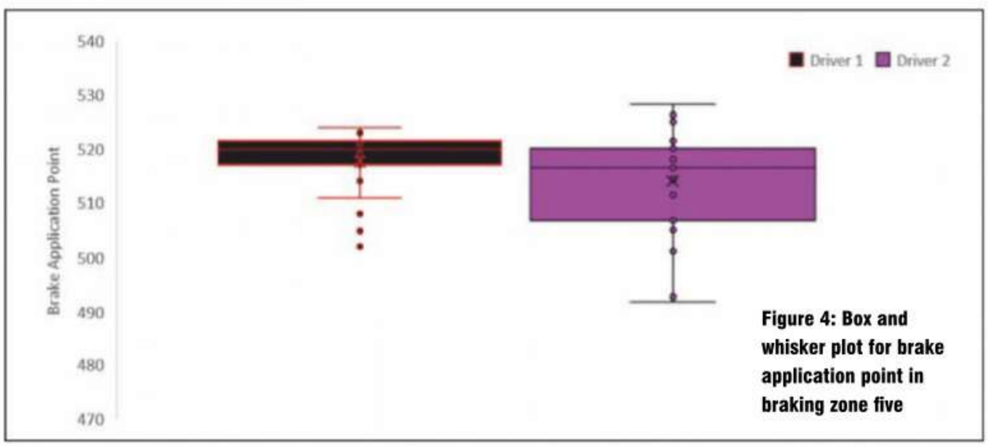

Figure 4: Box and whisker plot for brake application point in braking zone five

For instance, while the first driver was braking earlier on their best lap in braking zone one, they are braking much later in the full race pace compared to the second driver. We can also see that the large variation we saw in braking zones two, three and six is not as exaggerated as we would have expected.

From this, we can begin to understand the sustainability of the brake application points seen in the fastest laps and understand how close they are able to get to their best lap times on average.

Looking beyond the average, we can look at the upper and lower bounds to see how the application point is developing throughout the race. In this example, we can begin to predict that the second driver is using more of their tyres as they had a much larger variation in braking zones two, three, six and seven. This data can be misleading, though, as it does not consider events such as overtakes, which can cause great variance in the data depending on the location of the overtake. To see if this is the case, or if there is inherently an inconsistency in that braking zone, we can create a box and whisker plot. The plots for braking zones one and five are shown in **Figures 3** and **4**.

To read the plot, the quartile boxes correspond to the range in which the driver was most often braking, with the centre line being

When looking at the same plot for the first braking zone, we see the later the driver was able to brake, the faster their lap was

the median brake application point. The whiskers off the box correspond to the upper and lower 25 per cent of the range of the data in relation to the median. The smaller the plot area, the more consistent the driver was in that range. In this case, we see that for both braking zones where drivers were inconsistent, the inconsistency was beyond just a few outlier laps (maybe attempting to overtake, or defend position). In both instances, we see that lower bound of application had the larger variation for both drivers.

This does not tell us the cause of the variation in brake application point, and the effects that using the different point had on the overall performance of the vehicle. But at least we have identified a problem, the causes of which can be analysed with other data and / or during debriefing conversations.

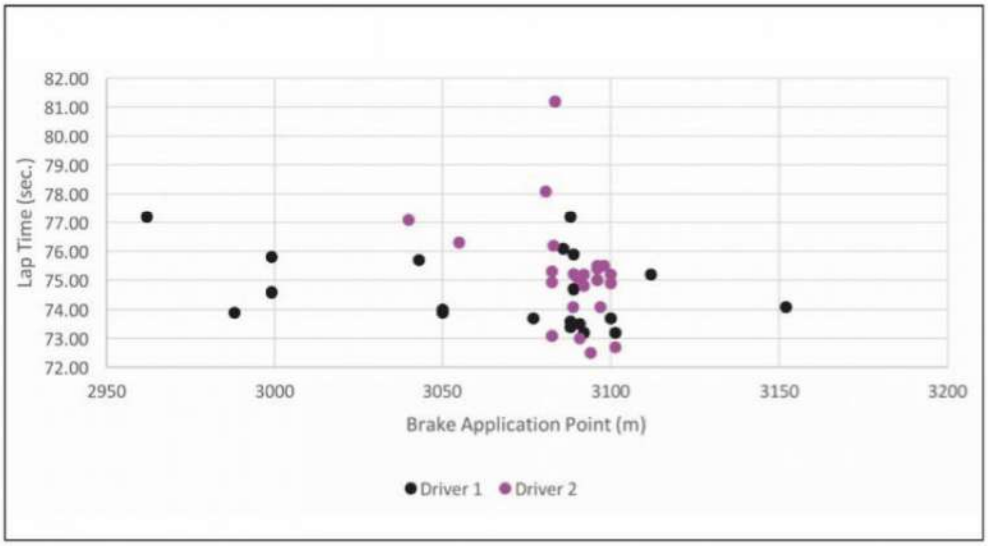

Figure 5: Comparison of brake application point in braking zone five to lap time

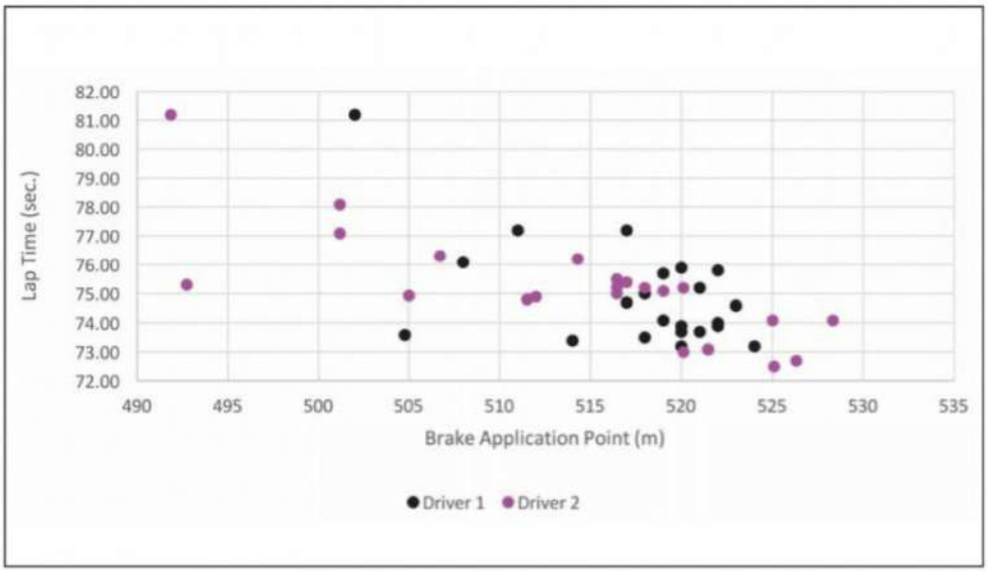

Figure 6: Comparison of brake application point in braking zone one to lap time

Critical corners

To look at the effects of the brake application point on the lap time, we can compare the lap time of the car to the brake application point to determine if there is a correlation. This will show how much the inconsistency is affecting overall performance during the race, and how much the drivers will need to change their style for future runs. This can also help the driver and engineers determine which corners can be compromised to emphasise fuel, tyre saving, or overtaking, and which ones should not be compromised as they will cause a more significant fall in performance.

When looking at the correlation between the time and brake application point, we see that for braking zone five (**Figure 5**) there is very little correlation between a faster lap time and a later, or earlier, brake point with driver two. We can therefore determine this is a corner that would leave more ability to compromise as driver one appears to have done.

To see the more far reaching effects of the driver one approach, we could look at the braking stability and turn-in point to see how they are approaching the corner, the line being taken and the balance of the car as the turn in is induced. In contrast to braking zone five, if we look across the course at the first braking zone (**Figure 6**), we can see there is a much larger correlation to lap time. When looking at the same plot for the first braking zone, we see the later the driver was able to brake, the faster their lap was, especially for driver two. This suggests to the driver and the race engineer that this is then not a corner to compromise their application point for as it can have a significant effect on how much the driver can gain on a competitor, or how quickly they can be caught by a chasing competitor.

In supplementing our brake aggression KPI, we can now understand not only how a driver is braking, but also when the driver is braking, and the effects of that application point on the overall performance of the vehicle, be it over a short or a longer stint. We can see which corners are the most important to be consistent within and which ones can be used for race craft or vehicle conservation.

This now adds another useful tool within the engineer's arsenal to find an advantage and provide context to how the racecar is behaving on course.

OptimumG offers a complete solution for testing, simulating, and improving the dynamic performance of your vehicle. All consulting services can be sub-contracted or we can simply guide your race team through our methodology.

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