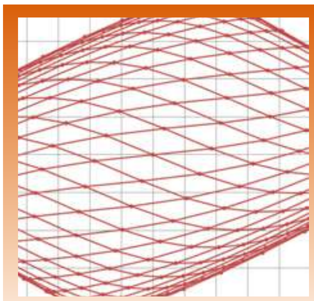

Slip Angle provides a summary of OptimumG's seminars

Characterising tracks for set-up solutions

OptimumG's Claude Rouelle explains why, and where, you might want to make use of an asymmetric set-up on your racecar

Having difficulties convincing someone to use more camber on the right-hand side than on the left for a counter-clockwise circuit; running higher tyre pressure on one side than the other; using different damper settings?

Looking at the number of left and right corners already gives you a good indication of the need to run an asymmetric set-up or not, but this is only part of the answer and more accurate track characterisation will help you to understand how much left to right set-up bias is required for a particular race track.

Track characterisation can be a very powerful tool. For any given circuit, evaluating the time that the car spends under acceleration, braking, lateral acceleration, or any combination of those can help you understand the characteristics of the circuit. This type of characterisation, together with the use of tyre metrics, helps decide the set-up.

There are many ways of characterising a race circuit. In this feature we will be explaining one particular method of doing so. This is making use of the GG diagram. We will be looking at vehicle accelerations and lap time to evaluate the track asymmetry.

This type of track characterisation, together with the use of tyre metrics, helps decide the set-up

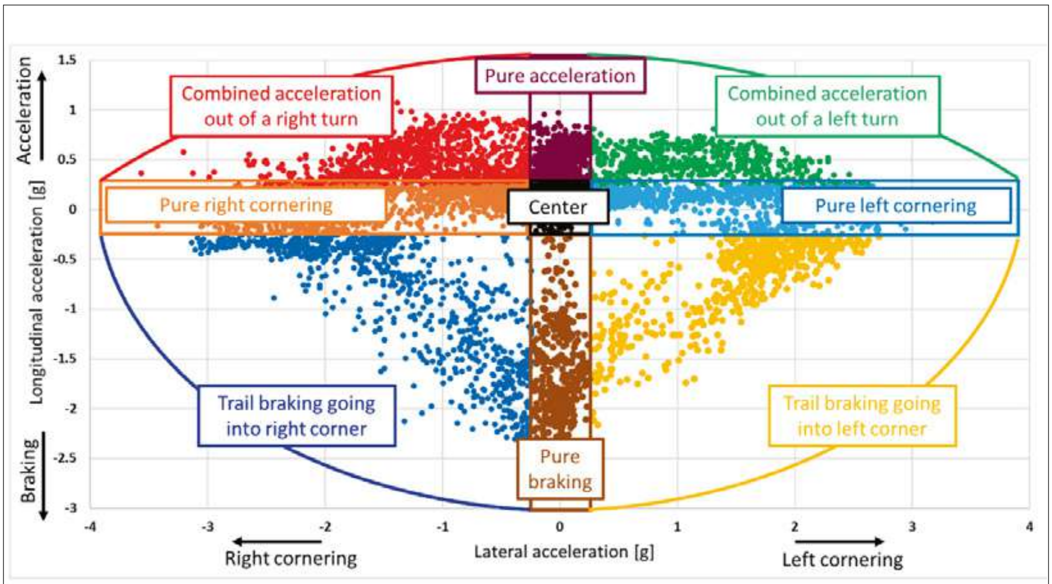

Figure 1: A GG diagram that's divided into the different car conditions is a fantastic way to characterise a race circuit

Table 1: The logic to create the different areas in the GG diagram ('Long G' is longitudinal acceleration, 'Lat G' is lateral acceleration)

Pure acceleration	Long G > 0.25G AND -0.25G < Lat G < 0.25G
Combined acceleration out of a left turn	Long G > 0.25G AND Lat G > 0.25G
Pure left cornering	Lat G > 0.25G AND -0.25G < Long G < 0.25G
Trail braking into left corner	Lat G > 0.25G AND Long G < -0.25G
Pure braking	Long G is < -0.25G AND -0.25G < Lat G < 0.25G
Trail braking going into right corner	Long G < -0.25G AND Lat G < -0.25G
Pure right cornering	Lat G is < -0.25G AND -0.25G < Long G < 0.25G
Combined acceleration out of a right turn	Long G > 0.25G AND Lat G < -0.25G
Centre	-0.25G < Long G < 0.25G AND -0.25G < Lat G < 0.25G

The GG diagram

To display a GG diagram, on the y-axis, we plot the longitudinal acceleration where a positive value means forward acceleration and a negative value means braking. On the x-axis, we plot the lateral acceleration where a negative value means a right-hand corner and a positive value means a left-hand corner. The GG diagram can be divided in many different ways, but we have chosen to divide it into nine areas for our example: pure acceleration; combined acceleration out of a right turn; pure right cornering; trail braking going into a right corner; pure braking; trail braking going into a left corner; pure left cornering; combined acceleration out of a left turn; centre of the GG diagram.

To split the GG diagram, first we need to create acceleration thresholds. To create the 'pure acceleration' boundaries shown in **Figure 1**, this is defined as when the longitudinal acceleration is greater than 0.25*g* and the lateral acceleration is between -0.25*g* and 0.25*g*. The math channel should return 1 or 'True' when the conditions are satisfied. The threshold value of 0.25*g* was chosen based on experience. Depending on the type of vehicle that we are analysing, the threshold will be different.

Table 1 summarises all of the necessary logic to create the remaining areas shown in **Figure 1**.

For each condition in **Table 1** a math channel is created in which we integrate the vehicle's speed only when the logic for this condition is satisfied. As a result, since we are integrating the speed, we obtain the total distance travelled along the lap under each condition individually.

An example of a MoTeC math channel to calculate the distance travelled under pure acceleration is as follows: *'integrate('Speed'[m/s], 'Pure acceleration'=1, range_change('Outings:Laps'))'.*

The same logic should be applied to obtain the distance travelled under all the other defined conditions by substituting 'pure acceleration' by the name used for the other logic channels (defining a condition/area) as shown in **Table 1**.

This same analysis can be done using time instead of distance. **Figure 2** shows the percentage of lap distance travelled in each area of the GG diagram around Le Mans.

By summing all the pure, combined, and trail braking in right cornering conditions, we can see that 30.83 per cent of the lap distance is right corners, while 16.58 per cent is left corners.

Lap distance histogram

With all the integrated sections, we can create percentages for each section. **Figure 3** shows a histogram at five different circuits: Silverstone, Spa, Le Mans, Imola, and Paul Ricard. The y-axis represents the percentage of the total distance that the vehicle travelled for that particular area. Each colour corresponds to the areas previously defined in **Table 1** and shown in **Figure 1** and **Figure 2**.

Based on the histogram, a few observations can be made: Imola has the highest percentage of pure acceleration as well as combined acceleration out of a left turn. Spa has the most distance travelled in pure left cornering. All have more distance in pure left cornering than in pure right cornering.

Figure 4 shows a histogram for the same five different circuits. The 'Left turn' is composed by combined acceleration out of a left turn, pure lateral acceleration, and trail braking into a left corner. 'Right turn' is the sum of the combined acceleration out of the right turn, trail braking into right corner acceleration, and pure right cornering. The y-axis represents the percentage of the total distance that the vehicle travelled for that particular area.

The first thing that we can observe is that Imola is the track in

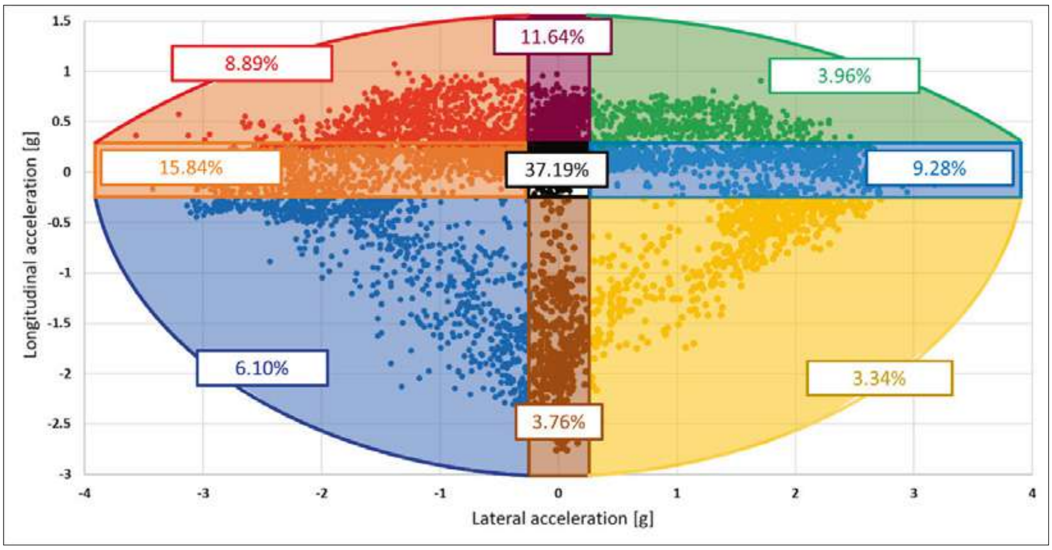

Figure 2: This shows the percentage of distance spent in each area of the GG diagram around the full Le Mans circuit

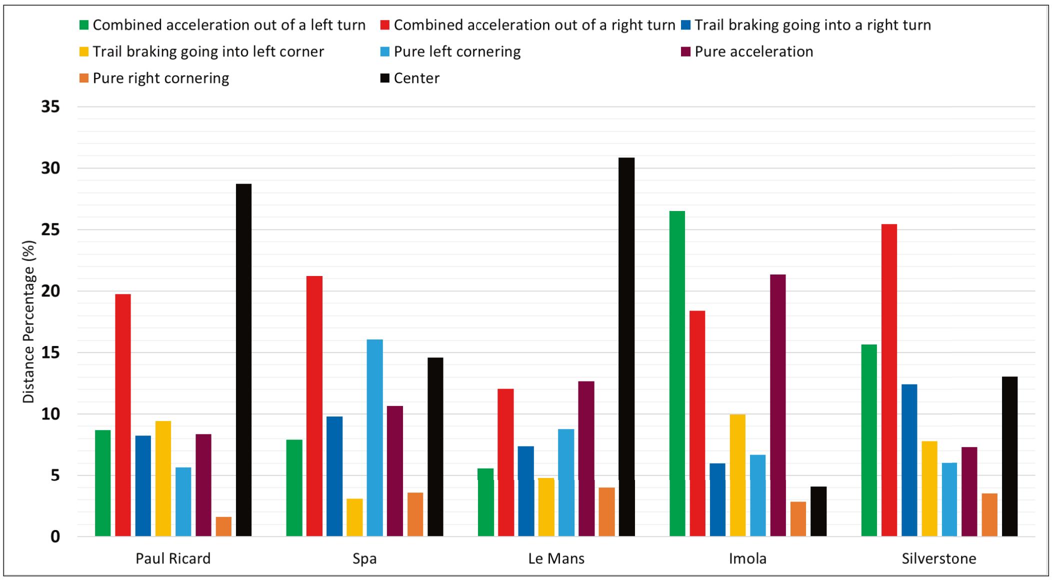

Figure 3: This histogram shows the percentage of distance spent in each condition at a variety of international tracks

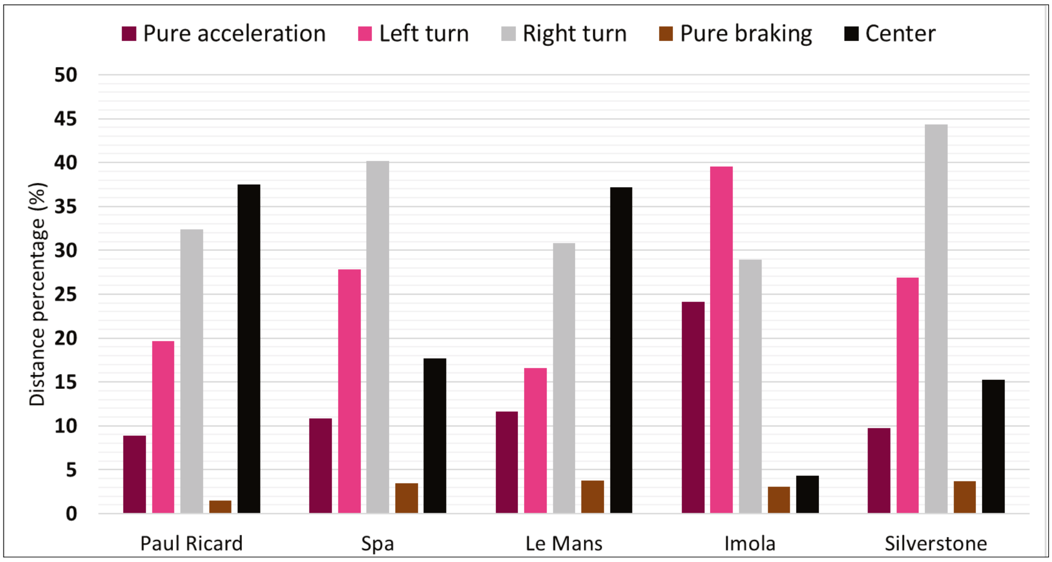

Figure 4: This shows the percentage of distance spent in each of the racecar conditions shown at the top of the chart

We can see that 30.83 per cent of the lap is right corners, while 16.58 per cent is left corners

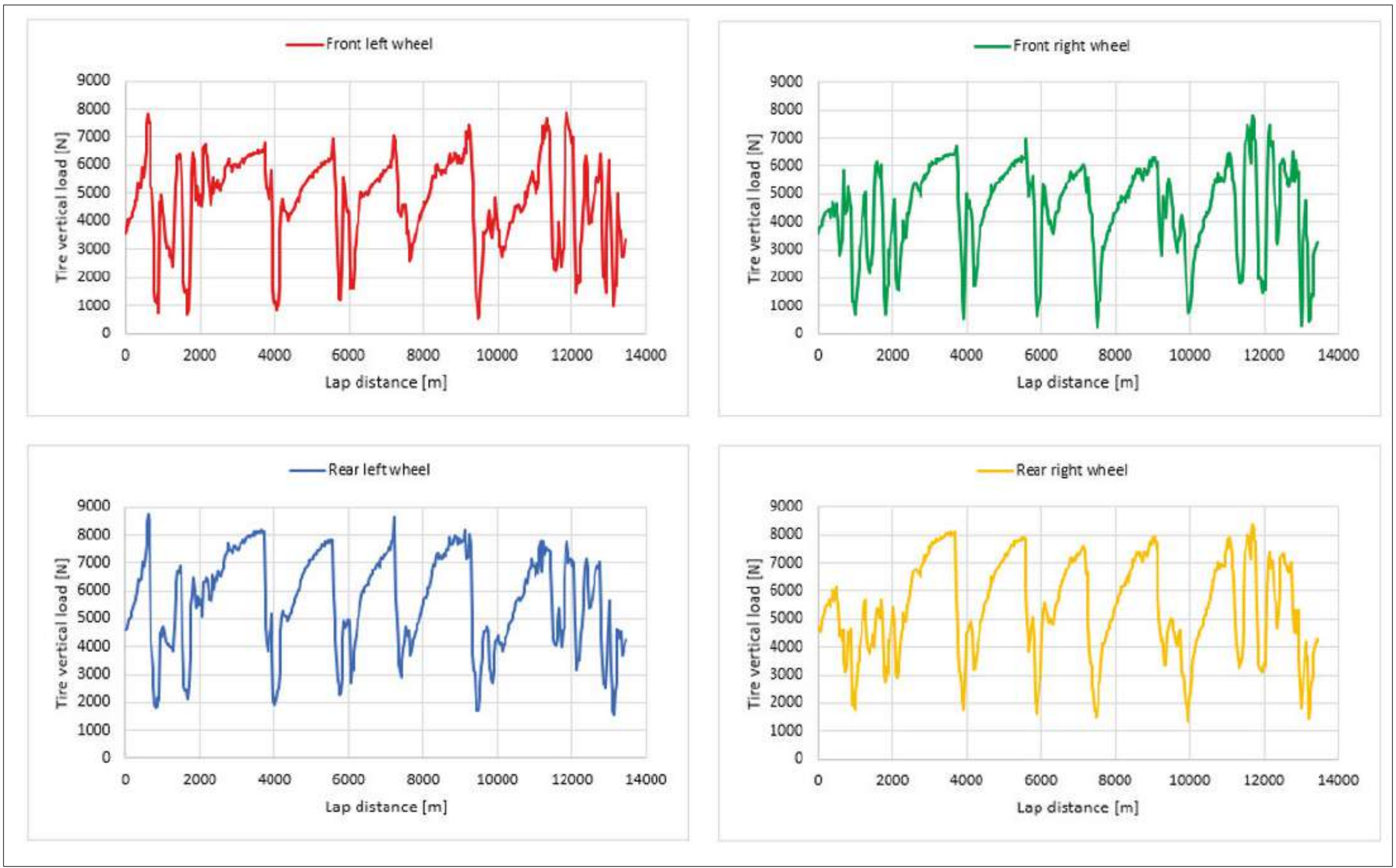

Figure 5: The tyre vertical load applied in each wheel along the track at Le Mans. This has been complied using the OptimumDynamics track replay feature

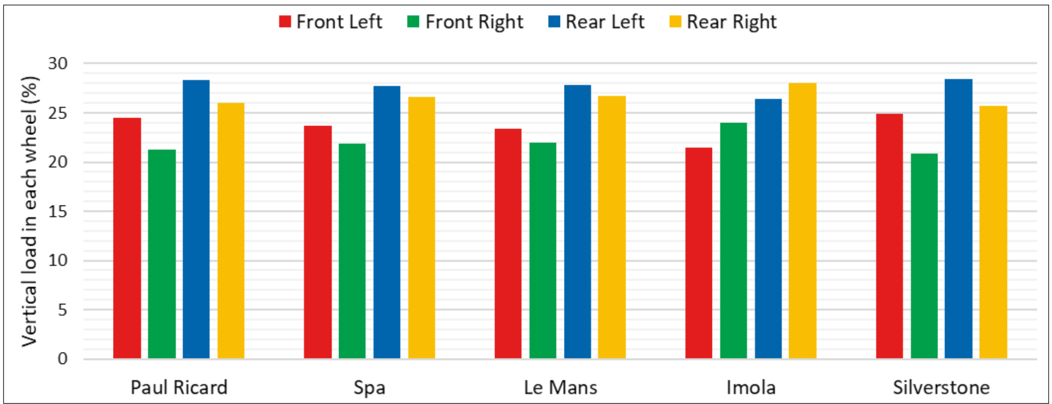

Figure 6: The percentage of tyre vertical load acting on each of the car's wheels through a lap of our example tracks

which more distance is covered in left-handed turns. We can observe that all circuits, except Imola, are more asymmetric to the right, because the racecar covers more distance in cornering to the right than it does to the left.

Besides looking at lateral asymmetry, we can also look at longitudinal asymmetry, the distance travelled in braking or acceleration. From the histogram, it's clear that the vehicle travelled more distance in pure acceleration than pure braking. Imola is the track that has the most percentage of distance travelled in the pure acceleration area.

Based on this conclusion, we can expect that for Paul Ricard, Spa, Le Mans, and Silverstone the left side will have the highest vertical loaded tyres. At Imola it will be the right.

Simulation

Using logged accelerations, speed, and steering wheel angle from the vehicle, we can run a simulation, where we reproduce a lap at the same track to analyse the vertical load for each tyre. **Figure 5** shows the vertical load, from simulation, in each of the tyres at Le Mans.

If we sum the vertical load from the simulation shown in **Figure 5**, along the lap, we can analyse the vertical load distribution between all tyres. The results, in percentage for each tyre, are shown in **Figure 6**.

As we have concluded above, **Figure 4** indicates that the car spends a higher lap distance under lateral acceleration to the right, except for Imola. Therefore, we expect that the left side of the car would be more loaded during the lap. This is confirmed by the simulation results displayed in **Figure 6**, where it is shown that the sum of the vertical load along the lap is higher for the left side, both front and rear, and in the case of Imola for the right side.

Corner weights

Looking at the dynamic cross weight also gives an indication of whether we should run with an asymmetrical static cross weight on the set-up pad to compensate for the dynamic cross weight for the circuit.

The cross weight is defined as the sum of the vertical front right and rear left wheel divided by the total sum of all vertical loads. From the vertical loads obtained from **Figure 5**, we can calculate the cross weight. By applying an average, we obtain the average dynamic cross weight for a lap **(Equation 1).**

On a given circuit we will put a little bit more cross weight on the

Besides the lateral asymmetry, we can also look at the longitudinal asymmetry, the distance travelled in braking or acceleration

Equation 1

$$cross\ weight = \frac{Fz_{FR} + Fz_{RL}}{Fz_{FL} + Fz_{FR} + Fz_{RL} + Fz_{RR}}$$

Where:

Fz_{FR} – front right, Fz_{FL} – front left, Fz_{RL} – rear left, Fz_{RR} – rear right

Table 2: Average cross weight along the tracks

Track	Cross weight (%)
Paul Ricard	49.53
Spa	49.45
Le Mans	49.82
Imola	50.56
Silverstone	49.35

diagonal that is less loaded along the race track (see **Table 2**). That would then help to preserve the tyres by avoiding putting an unnecessary load on them.

Conclusion

Splitting the GG diagram into eight areas can be useful to understand the amount of distance that a vehicle is spending in a particular area of the diagram. If we then integrate with respect to the distance of each of the areas that we previously defined, we can then quantify the percentage of distance that the vehicle spends in that area of the GG diagram.

This presents us with a way to understand the effort going through each tyre for different tracks. If we then sum the braking, acceleration and cornering for the left/right side we can have a quantifiable way of measuring the asymmetry of the track. The same can be done for pure acceleration and braking.

Using simulation we can then further understand how the asymmetry of the track affects the vehicle, for instance studying how the total vertical load distribution in each tyre changes from track to track, as shown.

These metrics can be generated from one or multiple laps, from qualifying or race laps. Depending on the data that is being used the results can differ slightly, but the most important thing is to use the same type of data for all race tracks to get a good reading of the delta between the circuits.

In this article we showed how to characterise a track, and why the set-up should be asymmetrical. This type of track characterisation and simulations are taught more in depth in OptimumG's data-driven seminars. In these we teach step by step how to process the data, interpret it, and draw conclusions. Based on these conclusions you can then choose the amount of camber, spring stiffness, damper set-ups, tyre pressures, etc. that you should be running on your car for a particular race track.

To find out much more about the OptimumG seminars' content and their dates, please visit the website at optimumg.com

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