MATHEMATICAL MODELS OF VEHICLES USING DATA ACQUISITIONS SYSTEMS

Diogo Rodrigues Pelles, diogopelles@terra.com.br
Alberto Carlos Guimarães Castro Diniz, adiniz@unb.br
Universidade de Brasília, Departamento de Engenharia Mecânica. GDS - Grupo de Dinâmica de Sistemas, Campus Darcy Ribeiro, Brasília, DF. Brasil.
Antônio César Pinho Brasil Júnior, brasiljr@unb.br
Universidade de Brasília, Departamento de Engenharia Mecânica, GREA - Grupo de Estudos Avançados em Energia e Ambiente. Campus Darcy Ribeiro, Brasília, DF. Brasil.

Abstract. *The data acquisition systems usually used in motorsports have limitations set by technical and sportive rules. Such limitations aims to control costs for the teams. The regulations usually define manufacturer`s data acquisition system, the number of channels allowed and the memory specifications to store data, how to transfer the collected data, and even the specification of location and sensor`s specifications. Typically, the regulations require the acquisition of technical data on the car`s powertrain, as measurement data allows for control of engine speed, water temperature, oil and fuel pressure. The rules aims to reduce the number of catastrophic failures in the set, and allowing engineers to check how to use the set by the driver. However, the data acquisition systems go beyond monitoring the powertrain, and can measure another vehicle data, using accelerometers, strain gauges, linear displacement sensors, rotational displacement, pressure, temperature, distance, among others. Such measurements allow engineers to collect data of the damper`s course, the dynamic pressure of the flow around the car, turning the steering system, the throttle displacement, the tyre`s temperatures, the car`s height from the ground, to name a few. This paper aims to present the data acquisition system used by the Brazilian Stock Car V8 series and developments available to the system. We also report the development of an experimental methodology for the optimization of the data collection, obtaining relevant data within the limitations of the system. Finally, the data collected are used to develop the mathematical model of the vehicle that meets in a satisfactory manner, the problem of vehicle dynamics.*
Keywords*: vehicle dynamics, dynamic measurement systems, data acquisition.*

1. INTRODUCTION

The data acquisition, like others technologies, is a broad and complex subject. The present paper is largely about the data analysis - setting up good work habits, interpreting data, and using the knowledge gained effectively. At the begining, a short discussion of hardware focuses mainly on ensuring accuracy and repeatability of data, both of which are essential to confidence in diagnosis.

The essence of using a data acquisition system is in understanding the data it captures. The numbers themselves are fairly simple to understand and mainly convey end results. When the data system reveals that speed on the main straight peaked at 243 km/h or that lateral acceleration in the arbitrary turn reached 1.10 *g* (gravity acceleration, ~ 9.81 m/s^2), it tells to the driver and the engineers what happened, but not reasons why it`s happened.

2. DATA ACQUISITION SYSTEMS

The road racing works require at least six channels - lateral and longitudinal acceleration, speed, RPM (engine`s revolutions per minute) steering angle and throttle position. For chassis development, sensors to record suspension travel are usually the next step. They reveal chassis movement, aerodynamic download, and shock absorber travel or velocity. An accelerometer recording vertical acceleration complements suspension travel sensors. Other useful and popular channels include ride height, suspension load, tyre temperatures, aerodynamic pressures, and separate front and rear accelerometers.

Engine development typically requires RPM, pressures (typically fuel and oil, sometimes coolant fluids), coolant and oil temperatures, flow rates and throttle position. To be useful, the engineer had to establish goals to use data acquisition systems, Whiton, 2007 established testing goals, "state what you plan to accomplish i.e., the purpose of testing at (…) raceway: 1. Develop spring/shock for optimum performance, 2. Monitor critical engine parameters during calibration development-Powertrain, 3. Determine transmission gears for (..) raceway, 4. Establish component operating temps – transmition, engine coolant and engine oil (…)", At least, the engineer suggests to build the car setup for the track, using a vehicle dynamic simulator and the race car's data.

2.1. Sensor range and resolution

The sensor affect accuracy two ways, in their range and in their maximum error. Sensor ranges interacts with data storage precision to define resolution. For example, a ±5 *g*`s accelerometer (total range: 10 *g*`s) used in concert with an 8 bit storage scheme has a resolution equal to 0.0391 *g*, as showed at Eq.1:

Unsmoothed graphs will show data changing in 0.039 *g* steps, with a maximum error of 0.020 *g*. This assumes no inconsistencies in the analog to digital converter, even though they are possible.

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To improve resolution, choose sensors that bracket the car`s operating limits as closely as possible. In the preceding example, if the car only corners at 1.5 g, a ±2 *g*`s accelerometer provides resolution of 0.0156 *g*. With a 16 bit storage system, this improves to 0.00006104 *g*.

$$\frac{sensor\ total\ range}{2^{storage\ system\ bits}} = \frac{10}{2^8} = sensor\ resolution \quad (1)$$

For a sample 0.10 meter travel sensor rated for a maximum error of 0.2% of full scale, this would be 0.002 meters. For a 0.05 meter sensor, the same 0.2% error becomes 0.0001 meters. This error occurs before any additional errors in analog to digital conversion.

Either type of sensor error grows larger as the range of the sensor increases. To minimize both, choose sensors with as little excess range as possible.

2.2. Noise

The sensors, cables, connectors, any circuits leading to the analog-to-digital converter will add some noise to the basic sensor signal. This noise can affect the values stored by the system if it exceeds the resolution of the analog-to-digital converter. For example, a 8 bit system has a noise calculated by:

$$\frac{sensor\ tension\ range}{2^{storage\ system\ bits}} = system\ noise \quad (2)$$

For a 0-5 volt sensor, this is 0.01953 volts. Any noise that exceeds this voltage will be recorded by the system as if it came from the sensor.

"The data analysis software provide tools to noise filtering (Archer, 2008)". They allow the record data can be treated so that there is reduction or even, elimination of unwanted signals. This tool not only for the signal's processing from noise, but also to facilitate the interpretation of results.

For example, the fuel pressure signal: It is recommended to be observed if the pump responsible for maintaining the desired pressure in the fuel circuit is getting to meet this objective, and rapid and low amplitude fluctuations can be ignored.

2.3. Total error

Finding the total error possible in any system is not the objective of this paper. Typically, the technical specifications for electronic equipment may reflect a worst case scenario, with the real performance often exceeding the specifications.

The most important consideration is the accuracy required to run a race car. Measuring cornering to the nearest 0.001 g is not necessary. But, if wheel speed is only precise to ± 0.15 m/s (± 0.54 km/h), the effects of some improvements to the car may be lost to system error. The Tab. 1 shows recommended maximum error level for racing purposes.

Table 1. The acceptable error levels for each typically channels used in race car data acquisition systems (Fey, 1993).

Channel	Minimum	Desired
Lateral Acceleration (g)	± 0.030 *g*	± 0.015 *g*
Longitudinal Acceleration (g)	± 0.030 *g*	± 0.015 *g*
Speed (km/h)	± 0.50 km/h	± 0.25 km/h
RPM	± 50	± 25
Throttle position(1)	± 1.00 %	± 0.50 %
Steering angle(2)	± 1.00 %	± 0.50 %

(1): Is % of full potentiometer travel. (2): Steering angle error is % of travel in one direction of rotation.

2.4. Brazilian Stock Car V8 Series Systems

The Brazilian Stock Car V8 Series uses a version of Pi Delta Lite data acquisition system, called Pi Stock Car Brasil. The system was developed by Pi Research, a company of Cosworth Eletronics.

Typically, the system hardware needs a clear, dry and safe location. This location is typically inside the cockpit`s racing car. The system contains the LCU (logging control unit), Fig. 1.

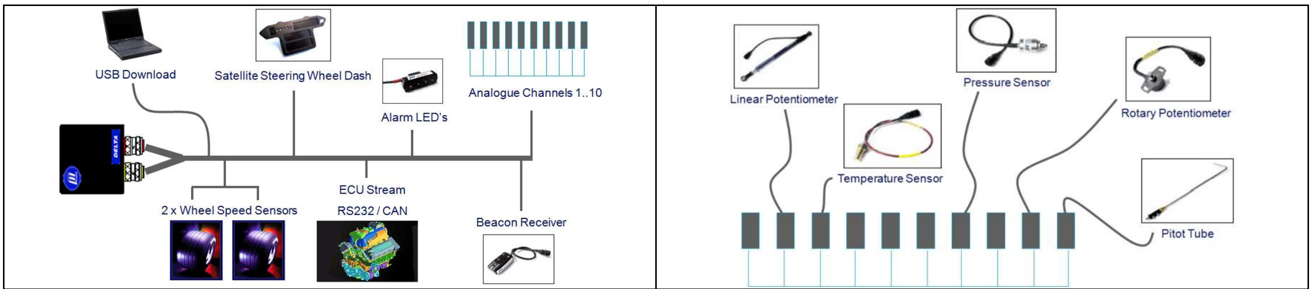
The LCU primary function is to record data from sensors installed on the car and the ECU (engine control unit). It`s contains the logging memory, main processor and communication electronics for PC, dash (display), radios, etc. The data acquisition system needs analogue and digital sensors connected to the LCU.

The system capabilities are showed at Tab. 2, and the Fig. 2(a) and (b) showed the system`s diagram.

Figure 1 - The Pi Delta Lite Logger Control Unit (LCU).

Table 2 - The Pi Delta Lite system specifications (Mackoski, 2003).

Characteristics	**Technical Specification**
Logging memory	8 mb
Logs data rate	500 Hz
Analogue channels	10 (expandable to 34 channels)
Digital channels	06 (4 wheel speed, RPM and Beacon)
Internal channels	04 (Lateral and Longitudinal Acceleration, LCU temperature, LCU voltage)
Data download	USB



(a) (b)

Figure 2(a) - The Pi Delta Lite system expanded. 2(b) - The 10 analogue channels (Mackoski, 2003).

3. DATA ANALYSIS

Once recorded, the data are available for interpretation. This chapter shows the format of the main types of graphics displayed by the software Pi Toolbox.

3.1 Charts: Time and distance

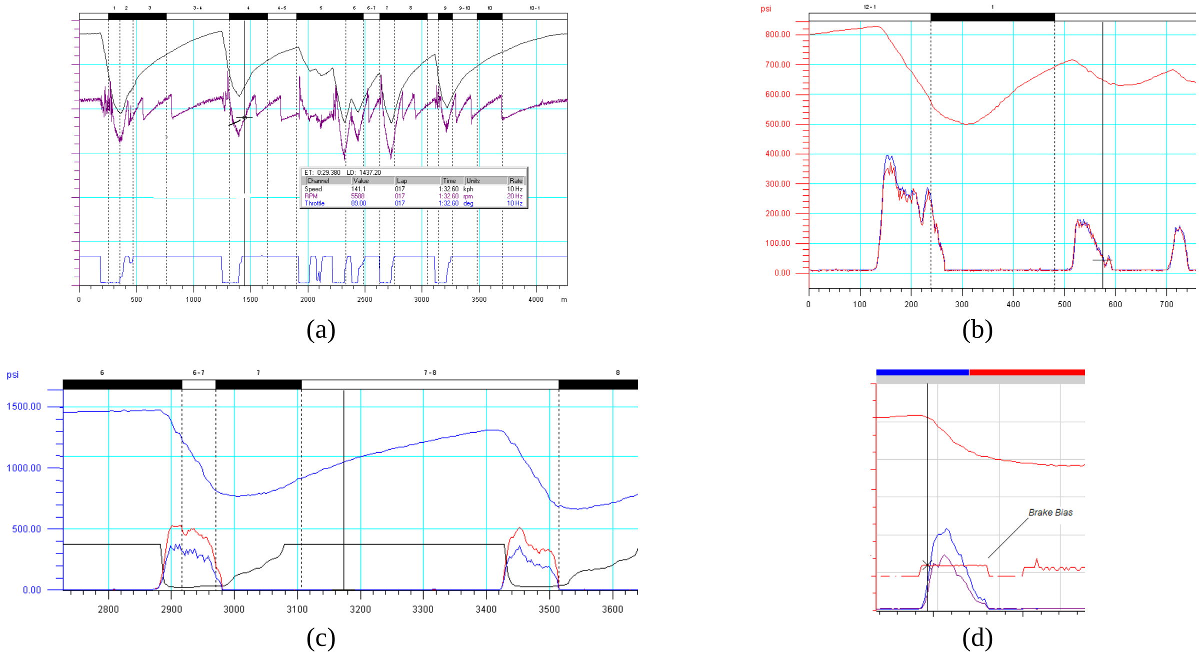
Each system has a standard format to present the charts above. The standard format consists of speed (Km/h or MPH) on the vertical axis by distance or time on the horizontal axis. A very useful feature in the analysis software is the possibility of displaying a table (cursor) showing the values of the channels on display in the chart, as shown in the Fig. 3(a).

3.2 Brake analysis

There are two options to monitoring the brakes operation. The first one is by brake's pedal displacement and the second is by measurement of the hydraulic brake line pressure. Due to its limitation of only measuring the point of application, the first option is less used.

The second is that pressure sensors, usually mounted on the front of the car, next to the brake's cylinder. The brake's data analysis has at least, four important functions. Starting with monitoring of the pressure applied on the brake pedal by the driver during approaches to the curve. Another useful function is the verification of balance between the front and rear brakes. The third was the analysis of the location of the application, ie, at which point the curve near the brake was activated (very useful when two different drivers are compared), and monitoring the overall functioning of the system, such as fault detection

The Fig. 3(b) shows a situation in which the brake balance was made to balance the pressure between the front and rear lines, while the next graph shows a situation where the balance was made in order to have more brake on the front line.



(a) (b) (c) (d)

Figure 3(a) – Time and distance chart. 3(b) – Brake balance equals front and rear wheels. 3(c) – Increasing the front brake pressure. 3(d) – Brake bias.

Another way to measure this difference is through a channel called mathematical Brake Bias, defined as follows:

$$BrakeBias = (FrontBrake\ Pressure / RearBrake\ Pressure) \times 100\% \quad (3)$$

This equation will provide the percentage of front brake compared with the rear brake.

For purposes of calculation, the percentage value only take effect after the time when the brake pedal is pressed, because when the pedal is released, will always be a pressure in the brake line (about 0.2 psi) which is insufficient to cause any effect on the brakes, but who but is captured by the sensor will be part of the calculation shown above, which may result in errors.

In the chart above. Is showed the blue and purple lines in the two pressures (front and rear respectively) and the channel mathematical Brake Bias in red.

3.3 Throttle analysis

The Throttle Position Sensor (TPS) depending on where the sensor is mounted can show the variation of the pedal position (mounted on the chassis), the opening angle of the throttle (engine mounted) or percentage accelerator. Once calibrated the figures reported by the sensor will not be so relevant, except in specific cases where the full stroke of the pedal does not correspond to fully open the throttle. The important thing to note in this sign are the forms submitted by the graphics.

Full Throttle: The range of application of accelerator pedal by the driver for a situation of full throttle part usually corresponds to a problem with the car or driver: incorrect balance of the car, lack of traction or lack of confidence in the driver around a given section with the throttle pedal. It can also happen that the driver be anticipating too much acceleration in output curve, forcing him to take his foot out to prevent a very sharp front.

Gear changes: In systems where there must be a need to take their foot off the throttle to change gears, it is clear the time lost for this purpose. Comparisons between different drivers can help find the minimum time required for exchange.

The figure below shows the typical shape of the behavior of the RPM signal during gear changes. Histograms: A histogram showing the total time of full throttle during the turn and gives an idea of the RPM of the engine as well as assists in the staging of marches to be used in addition to providing a feature of the track is average, low or high speed.

The histogram below represents the percentage amount of time that the engine (RPM represented in the graph above) was in a certain range of spins.

3.4 Steering wheel analysis

For the generation of the chart wheel sensor, as explained in section 3.3.2 is used a pot to be fed, generates a signal of 0 to 5 volts. The representation of this signal in a graph of time or distance corresponds to a line that changes its values as the steering wheel is turned left or right as pictured below. When the car is straight the value of the signal tends to remain near the average value of the course of the sensor. As the sensitivity of the sensor is too large, one can notice some variations between the average value - more or less - since it can also capture the vibration of the car or small changes in direction made by the driver.

When the car approaches a curve, the shape of the graph tends to become a "belly", indicating that the wheel is being turned to one side and stop their localization returning home. Any strange in the original form of this signal indicates that the pilot had to fix a front or rear output and behavior of this curve will be the object of study in later chapters.

3.5 Lateral Acceleration analysis

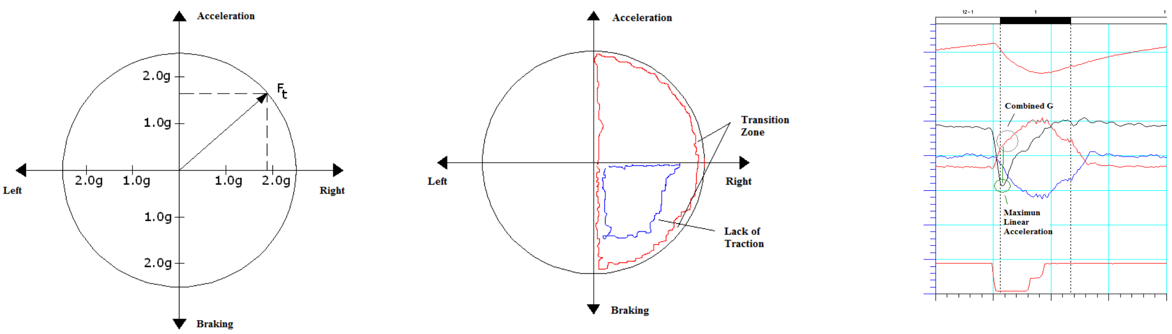
The graph shows the result of lateral acceleration of the reading of accelerometer and its typical format for distance (or time) is shown below.

In the straight, the value of lateral acceleration should be near zero, as can be seen in the chart. However the vibrations of the car, small steering movements, ripples on the track among other factors, can disturb the order of 0.2 g. Because the acquisition system records the movement of the car, subject to all these variables, these "imperfections" will always be a part of the data.

In curves the values change as the grip of the car varies, reaching a peak in the curves. These values can be positive or negative direction corresponding to the curve (right or left).

3.6 'Combined G' analysis

The understand the G Combined channel must build on the principle that all the potential that a car has to work around a curve is the maximum force of grip a tire that develops in both acceleration and braking and cornering. If we plot the maximum forces that a tire is capable of developing in each direction, the graph will look similar to the 4(a), commonly called the Circle of Traction.



(a) (b) ©

Figure 4 (a) – Polar chart of Combined G. Figure 4 (b) – Transitions zones and the lack of traction at G Combined polar chart. Figure 4 (c) - G Combined plot at Pi Toolbox.

Observing the chart, two things become clear:

• At the point marked acceleration hit a tire is able to produce 1.8g of lateral and longitudinal acceleration (acceleration and braking), but is not able to generate both simultaneously, as the vector Ft Due to the geometry of the circle of traction and the result of the sum of the vectors, a tire is capable of generating both forces in two directions, which when combined result in a force greater than that developed in either direction.

• To use the full capacity of around curves using the maximum performance available from the tire has to offer, it is necessary to make the tire is working close to the maximum of this combination of forces during the full time.

This combination of forces, called G combined, is nothing more than the sum of the vectors Lateral Acceleration and Linear Acceleration, as shown in the equation below, which can be enabled as a math channel.

What to look for - and forcing the driver to do - is to curb the entry phase of the curve while it is already turning the wheel. At this stage, while the tire is developing its potential to bypass the curve he is at the same time (even decreasing) contributing to their potential braking. That way the tire will always be close to their maximum potential use.

It can be observed by the graphs 4(b) presented that the ideal would be that the driver "walk down" the vector Ft all the time, or at least was close to that value throughout the curve, which represent the red line in the chart above. That transition should occur when you reach the point of maximum stopping potential if this potential "turn" potential curve, so that the calculation result of vector Ft is always the maximum possible value of the two simultaneous accelerations.

Figure $(c) showed that any fall in value would then represent the potential lost during braking and approximation, shown in blue line. This can also be observed by time and distance charts, analyzing the combined channel G.

In the red line is shown in G combined while the traces in blue and black in the middle of the graph represent the lateral acceleration and linear respectively.

It can be observed that the black line to reach the point of maximum braking that potential is transformed into potential curve without falling, or vouchers, as it is known. From this point we can observe the growth of lateral acceleration showing that the car is now benefiting from their ability to make turns.

3.7 Gear calculation

The gear used by the driver may, at any time, be calculated. This calculation is independent of sensors positioned in gearbox for such purpose and is based on the principle that the relationship between RPM and speed is constant, ie, if the driver is driving at the correct rhythm, there is only one way (for turning) to that particular spin and speed. This calculation is given by the following equation:

$$\text{Gear} = \frac{\text{Speed}}{\left(\text{RPM}/_{1000}\right)} \tag{4}$$

The result of this calculation may or may not provide a rounded value, mainly due to noise present in the signal RPM. Subsequently, a filter can be applied to software where the values can be rounded (or filtered) into the right gear, or if the result of a calculation was 4.9 the right gear will be the 5th gear.

3.8 Compare time

This graph represents the time difference in the distances traveled by cars. Also known as Time Difference or Compare Time, this channel can be detected when two distinct loops overlap, where there is time difference in a particular sector or the whole round. Starting from point zero (zero seconds) graph "up" or "down" as there is now a time difference in the sites covered, whether curved or straight. Figure 5 a shows a graphic example of this.

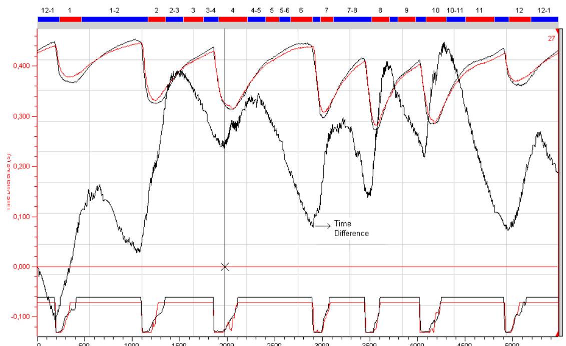


Figure 5 – Plot of mathematical channel compare time.

To view this graphic, it is mandatory that two separate rounds are selected, whether from the same output or different outputs. For both of the rounds need to be selected as a back reference (commonly called Datum).

4. CAR SETUP

4.1 Understeer

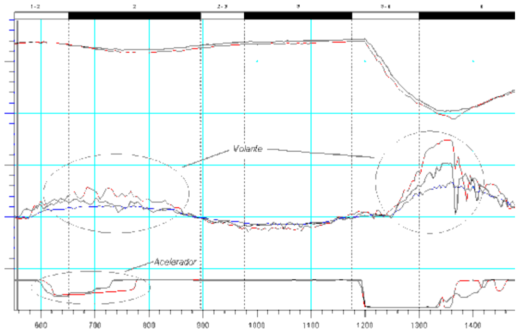


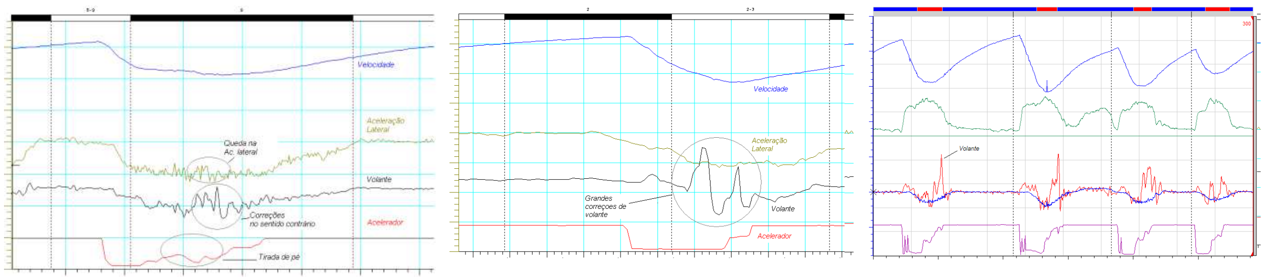
Figure 6 – Car unbalanced: understeer.

When the car has any imbalance caused by an inadequate setup, be it tyre with the wrong calibration or faulty workmanship problems, big difference in weight between the wheels, etc., a symptom that can be caused is the output from the front the inputs of the curve. The Figure 6 illustrates this situation.

This situation is exemplified in the case that the same driver faces two distinct situations with the same car and same accuracy. In the chart wheel can observe how the pilot had to turn over the wheel to enter the curve and how much speed is lost with this maneuver. Is also evident from the delayed of full throttle, since the unbalanced with the car driver needs to put the car at the ideal track to be able to accelerate again.

4.2 Oversteer

Oversteers are characterized by an abrupt change in the steering angle of the steering wheel to avoid the car spin. This reduction could be until the wheel is straight with the axis of the car or going beyond this point, or turning the wheel in the opposite direction of the curve. This scenario may also observe a drop in the value of lateral acceleration, indicating that the car is losing grip on the bow. The chart below illustrates a situation out of the back of medium intensity.



(a) (b) (c)

Figure 7(a) – When the car was oversteer, was common the driver loose the throttle pedal. Figure 7(b) - The in intense oversteer situation. Figure 7(c) - Pi Delta Lite Logger Control Unit (LCU).

Depending on the intensity of the output back, the driver may or may not take their foot off the accelerator or even anticipate the acceleration in an attempt to compensate for the lack of rear grip with acceleration (Figure 7(a)).

The Figure 7(b) illustrates a situation with a intense oversteer. In this case, the driver, being accustomed to this type of problem, did not have to make the walk but can not apply full throttle at the exit of curve, having to wait for the car "accommodate" in order to accelerate.

In an extreme condition of oversteer, Figure 7(c), the car tends to be unstable to the point of the pilot having to counter steer the wheel at all times in order to offset the imbalance of the car. It can be seen from the chart below that when approaching the curve (brake) and entering the curve (right) keeps the driver turned the wheel left until the end of the curve.

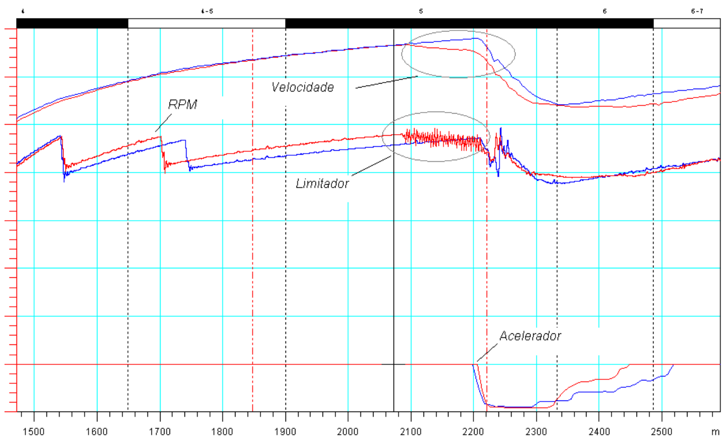


Figure 8 – Maximum engine revolution per minute allowed by electronic injection.

4.3 Selection gears errors

When this type of error happens, it is common that the engine reaches its maximum revolution allowed by electronic injection unit (stop) before the end of the line, as shown in the chart below.

It may be noted that when the car hit the limiter is exposed to all the drag caused by wind and aerodynamics, causing him to lose speed. With the right schedule, the car may finally reach its maximum speed.

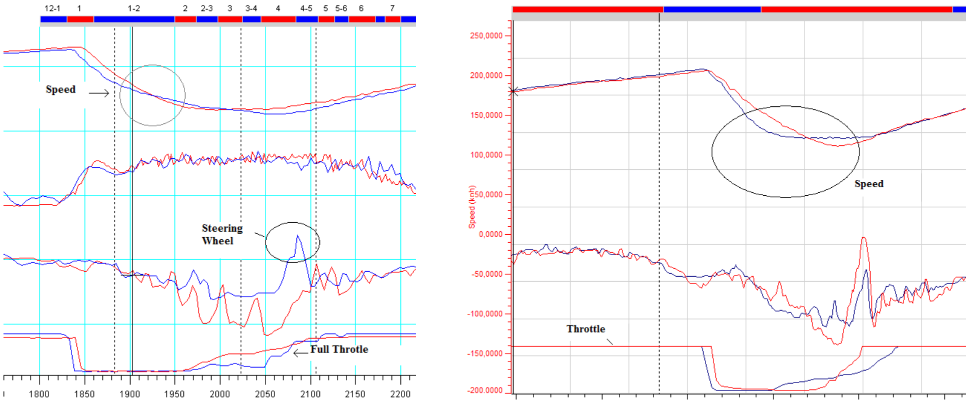
Because sometimes not be possible to hear the engine noise when it hits the limiter, you can confuse the speed drop with a drop in engine performance.

This is a mistake to be corrected as soon as possible, since it is an issue that also bothers the pilot, causing him to lose the references to speed and braking to the point of entry at the bow.

5. DRIVER`S PERFORMANCE DEVELOPMENT

5.1 Analysis approach and braking

The Figure 9(a) shows a common error in the approximations of the corner, where the driver, noting that began braking too early or too strongly, take your foot off the brake and let the car slip at the entrance of the corner, `putting` a lot of speed to the middle of the corner. This speed in excess and cause an imbalance in the car (the car does not generally accept around the corner with such speed) causes a delay at the point where the driver's foot on the throttle, damaging the corner exit.



(a) (b)

Figure 9(a) – Driver’s mistake at the corner apex. Figure 9(b) – Low speed at the middle of low speed corner.

In the Figure 9(b), there is another type of error by the driver, this time in a low-speed curve. In this type of curve, with minimum speed spinning around 100 km/h, the diver in red is a better approach, braking later and with more intensity, but with a speed of medium below the corner of the driver in blue. The latter makes the mistake of trying to get around the corner with plenty of speed, especially at the point of minimum. To try to make this the driver has to brake sooner, spending too much time for this maneuver. To try to catch up, he applies the throttle earlier, which may not always be accepted by car, causing a orversterr, as seen in Figure.

5.2 Understeer

Another common mistake and little noticed by the driver is the anticipation of braking and acceleration. In this case the stop in advance (and note that lost too much time inside the curve) the driver tends to also anticipate the acceleration.

Thus the trend is the car gain speed when the driver is still returning the wheel to the normal position. As the curve has a limited range, it is common that the car wants to go through the curve with the largest possible radius, forcing the driver to easy the throttle pedal to keep the car leaves the track. The Figure 10 below illustrates this situation.

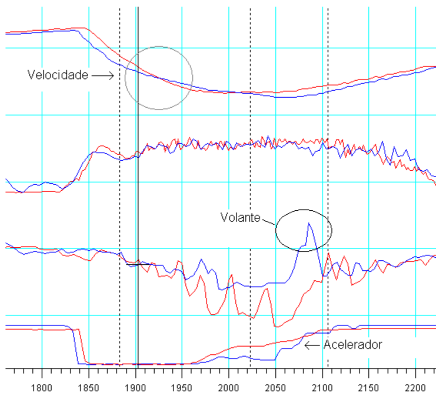


Figure 10 – Driver understeer mistake: Anticipation of braking and acceleration.

5.3 Oversteer

By analyzing the RPM drop for a gear reduction is possible to diagnose a oversteer of the corner apex. In the Figure 11, one can visualize two gear reductions performed by two different drivers. The driver in red can make the exchange more quickly, avoiding any kind of "stride" given by the motor to try to equalize the engine speed with the shifter. In the driver in red, there is a drop in turnover for a very long time. When reverse gear is lower, and time consuming to do this, the driver of the engine causes a jolt that is eventually transferred to the tyres. This transfer of torque causes a very abrupt oversteer at the turn apex, which unbalances the car. This fact can also be caused by an imbalance in the distribution of brake. With much brake ago, this torque may ultimately become more pronounced and also cause this "noise."

5.4 Power On Oversteer

Channels of speed, rpm, throttle and steering is possible to detect a rear exit when the driver tries to resume the speed of the output curve. In this particular case the driver correctly rounded the curve (apex and middle) but is anticipated in the re-acceleration than do it abruptly, because the grip of the tyre could not soothe. It may be noted in the Figure 12 (red trace) that caused an imbalance in the car, causing him to lose traction (and therefore time). This imbalance is accompanied by a oversteer (counter steer the wheel). In the graph of RPM also note a decrease in the rate at which the engine accelerates, indicating that the rear tires (rear-traction car) are "slipping".

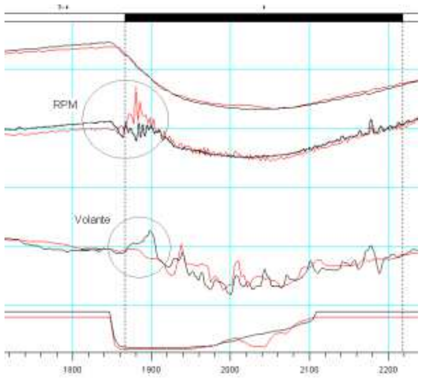


Figure 11 - Oversteer. The channels showed are speed, throttle, engine revolutions and steering wheel.

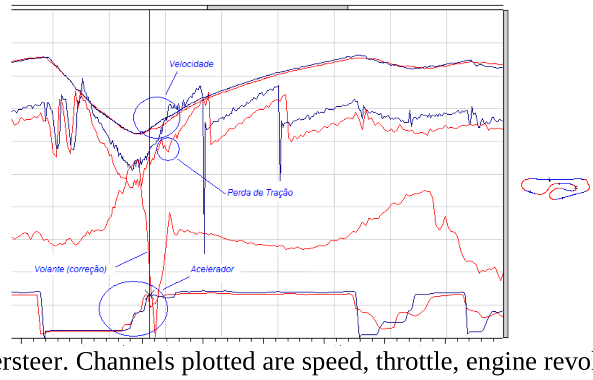


Figure 12 – Power on oversteer. Channels plotted are speed, throttle, engine revolutions and steering wheel.

5.5 Locked wheel under braking

The locked wheel under braking occur for several reasons: poor distribution of brake, braking late, lack of grip on the track among other factors and can be observed as a sharp drop in the speed signal and a return of this signal as the driver pulls the brake.

At this point, it is worth commenting on the advantages of using two speed sensors (One in each front wheel). As the distance charts are constructed based on counting the pulses of the triggers for the speed sensor, a locked wheel will make this count is reduced, which will result in a shorter distance. Once the graphics are overlaid - and one due to a smaller distance - the presentation of them will be with a gap distance, which hinder their analysis since there will be so clear whether the differences in the brake will be a result of displacement chart or a better performance of the driver.

If the two speed sensors are being used within the same axle, the gearbox will automatically compute the acquisition of higher speeds, bypassing the blocked end to count the pulses. In the chart below we can see the blue dash speed signal left and red on the left with a locked wheel. The line in black shows then the end result - the highest speeds - ignoring the locked wheel (the scale were modified to provide this analysis)

5.6 Error in gear shift

This type of error is characterized by a decrease in throttle rate and also the speed of linear acceleration. When analyzing the signs of RPM and throttle can be noted that first reaches a maximum value (usually the cutoff point of the engine) and the second shows a discontinuity signal to full throttle, indicating that the driver had to take his foot in order to engage the gear again.

5.7 Engine over revolutions

It is quite common for driver when effecting an approximation to a corner, not to modulate braking with the right time to reduce speed. When this synchronization is done wrongly can happen that the driver is above the limit tolerated by the rotating engine, damaging it and then reducing its useful life. This over-revolution can also happen when the driver gives a touch of the throttle at the same time that it reduces the gears, called `punta taco`.

6. TRACK: ENVIROMENT INFLUENCES

6.1 Wind

The intensity and wind direction affect mainly the final speed of the car, straight and well, with less intensity, the balance of the car, in some cases accentuating the understeer.

The most common way to diagnose this problem is a drop in speed on stretches of medium and high speed. Generally it can be confused with engine problems such as loss of power. However, due to even have a specific direction, a drop in speed on a stretch may be accompanied by a speed gain on another section.

Because the engineers and mechanics often get the following training and racing in the pits, this is a factor often overlooked since it is difficult to detect these variations.

6.2 Track grip

The grip between the tyre varies continuously throughout the day and time of year. When large periods of drought at a given circuit and this track is used for a long period of time the grip tends to increase. However, it may decrease with a simple rain that by removing the rubber track also brings a lot of dirt.

Despite being a subjective criterion for judging the problem of grip can be realized by analyzing the data, and the trial of the rider himself.

7. CONCLUSIONS

When showed at the present paper, the data acquisition system is a useful electronic tool that helped track engineers to setup the car, optimize the driver style and understand the enviroment influences at the race car. But, if the sensors was installed without some care, the data collected will be measurement errors, and all the channel data will be wrong.

When the team uses more than one car, is important to install the sensors at the same location in every car. When the track engineer had a metodology to install the sensors , the data acquired by the loggers will be useful to compare more than one car.

The last point, some teams uses the data to compare and validate the numerical codes developed to simulate the car dynamics.

8. ACKNOWLEDGEMENTS

Our sincerely thanks to ANR and Cosworth Eletronics for the technical support to use the PI Research System.

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