car towards circuits that are as-yet unfinished, or which have not been raced at before for which only track edge data exists. Secondly it allows the re-generation of a racing line for changes in setup or regulations which significantly effect the grip/power balance of the car. In our experience the change in racing line precipitated by a change in mechanical grip, or aero regulations for example, is a significant factor in determining the lap-time sensitivity of the car to such a change. Thus the ability to run Generate Racing Line enables you to see second-order effects that your competitors may well miss.

Limitations

Care should be taken when defining the track edges so that an appropriate amount of curb can be taken by the car. The car front wheel centre isn't allowed to pass over the track edge. Where the car is allowed to cut the corner more you may like to move the track edge out slightly. This simulation has been largely superseded by Dynamic Lap which can automatically generate its own optimal racing line without having to run Generate Racing Line first. If you plan to run a Dynamic Lap, then it is better to let Dynamic Lap automatically pick the racing line, as it will do a better job than Generate Racing Line. The main use for Generate Racing Line is if you want to run a Quasi-Static Lap, as Generate Racing Line has been designed to produce racing lines for this simulation (although Dynamic Lap does a great job of producing racing lines which also work with Quasi-Static Lap).

Virtual 4-Post Rig

Assessing the direct effect of changes to damping and other ride variables on lap-time is fiendishly difficult. Formula 1 teams have spent years trying to reflect ride dynamics in lap-time simulation, all to no avail. The solution which has been arrived at after these years of ride analysis and tool development is to use a Virtual 4-Post Rig simulation. Unlike the simulations above, Virtual 4-Post Rig runs the car fully dynamically. The car is run over a defined road profile by feeding the road heights into the four corners (wheels) of the car in continuous time. The results show the dynamic response of the car to the given road profile, enabling analysis of contact patch load variation and (through the Canopy Platform's infrastructure) exploration of how changes in damping and compliance will affect ride characteristics.

Results

Time series data reflecting the states of the car as they react dynamically to the applied bump profile. In addition, scalar ride metrics are returned allowing for rapid optimisation of ride performance by leveraging the Canopy Platform's huge capacity for running many simulations.

Strengths

Years of R&D by top Formula 1 teams have arrived at this solution as being the best way to tune ride dynamics in offline simulations. Far more accurate and reliable than a forward-marching dynamic lap simulation with a driver model.

Limitations

Whilst the true dynamics of the car are fully modelled in the Canopy Vehicle Model, and thus reflected in Virtual 4-Post Rig, your driver's preferences for curb riding are not. It is expected that the setup arrived at with Virtual 4-Post Rig will require some fine-tuning trackside.

Dynamic Lap

The holy grail of lap simulation. A fully dynamic simulation with no driver model, achieving the maximum performance of the car, including all of its dynamics, without any assumptions about how it is driven. Even the racing line is computed as part and parcel of this simulation. Dynamic Lap solves *every state* of the car model at every point on the track *simultaneously* to give a dynamically consistent state trajectory which traverses the lap in minimum time subject to any number of algebraic or integral constraints on it's behaviour. For example, Dynamic Lap can minimise lap time subject to constraints on both energy consumption and tyre usage simultaneously. Dynamic Lap can also solve for minimum time including slow dynamics such as high-rebound damping, banked corners, and bumps such as those which characterise tunnel-turns in NASCAR. As if that weren't enough, Dynamic Lap can also optimise one or more parameters of the car for minimum lap-time whilst it's simulating the lap, examples include stiffness of suspension components, size of battery, ride heights etc. etc...

Results

As for other lap simulations but including transient dynamics and full state-consistency and lap-time sensitivity

Strengths

Fully dynamic simulation of your car; ability to include numerous otherwise neglected dynamic effects such as rebound damping, bumps, battery thermal dynamics, tyre thermal dynamics, aeroelasticity, wake catch-up etc. etc.; automatic re-optimisation of racing line; optimisation of car parameters.

Limitations

Tendency to expose the limitations of your drivers! For the solver to function special care must be taken with the vehicle model. Lookup tables must be nice and smooth (this is one reason why we prefer parametric functions). The car must have dampers in. Dynamic lap may have some difficulties following a racing line generated from telemetry as there may be a mismatch in car dynamics. The order of precedence for racing line use is: i) use track edges and optimise racing line as part of the simulation, ii) if track edges are not available use saved centre line and optimise racing line, iii) if centre line not available used fixed racing line. Dynamic lap can follow sLap and cLap generated from a Dynamic lap run on a similar car if for some reason you wish to restrict all cars in a study to the same racing line. Conversely Quasi-Static Lap will only follow the fixed racing line (run generate racing line first, if only track edges are available).

Dynamic Lap (SLS)