



Running SIMPACK Driver-in-the-Loop



The SIMPACK interface for rFactor Pro now offers automotive users of SIMPACK an out-of-the-box solution to driving their vehicle model in a simulator. SIMPACK is particularly strong in the higher frequency domain allowing simulation of handling, ride and secondary ride, impact harshness and even road noise. These strengths combined with rFactor Pro's support for high-bandwidth road modeling and low-latency simulation

allow human drivers to become involved in simulation earlier in the product development process.

There are many reasons organizations have implemented a driver-in-the-loop simulator, such as evaluation of human factors, the human-machine interface, and control-system testing where automated tests are inappropriate. Evaluating vehicle dynamics, ride and secondary ride, however, are far more demanding on the simulation environment and require particular attention to both the latency in the system and the bandwidth available to the tire model from the road surface data.

REAL-TIME, HIGH-BANDWIDTH, LOW-LATENCY DRIVER-IN-THE-LOOP

Vehicle models developed in SIMPACK can take advantage of the product's key strengths to accurately model the higher frequency aspects of vehicle dynamics such as impact harshness and structurally transmissible road noise.

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While handling and ride operate at relatively low frequencies (below 20 Hz), with impact harshness, we are interested in the 20–75 Hz range and structurally transmissible road noise might typically be in the 40–250 Hz range.

In a driver-in-the-loop context, this places significant demands on the simulation environment. In order to achieve simulation in real-time:

1. Accurate simulation of closed-loop maneuvers for handling evaluation re-

quires a lower latency than that typically delivered by traditional driver-in-the-loop simulators. Latency measures the time taken by the simulator to close the loop through the human driver. When we evaluate vehicle dynamics that are affected by the driver's control inputs, we need to minimize latency to levels well below that generally achieved on traditional simulators used for procedural testing.

2. The bandwidth from the road surface model into the vehicle model, for consumption by the tire model, must be sufficiently high to allow modeling of the higher frequency systems while still running real-time.

3. The level of immersion for the driver, in terms of the graphical environment,

audio, motion and control loading, must be good enough that the test driver takes the testing seriously and is providing realistic control inputs proportional to the test activity.

The SIMPACK interface for rFactor Pro addresses these particular requirements in a number of ways:

LOW LATENCY

Careful selection of video and audio hardware is important; however, the largest gains come from implementing custom hardware interfaces for audio and video, in both cases removing buffering from the audio & video pipelines. rFSync is rFactor Pro's implementation of the video interface, which removes buffering from the video pipeline while managing video channel timing to 100 μs accuracy. Similarly, the audio pipeline runs direct to hardware managing all mixing, blending and signal processing in just a 5 ms buffer. In this way,

we are closing the loop through the human driver in the fastest possible way to ensure that the driver is not lagging behind the vehicle model.

HIGH BANDWIDTH

The SIMPACK model needs to incorporate very detailed road surface information in real-time in order to accurately model ride at the higher frequencies, e.g., up to 250 Hz. Existing approaches which are supported, such as OpenCRG and libgr, rely on pre-processing the road data into a data structure that typically supports single-point contact patches running in real-time. By leveraging the power of CUDA (Compute Unified Device Architecture), the SIMPACK interface for rFactor Pro integrates the entire contact patch for all four tyres over a cleaned LiDAR (Light Detection And Ranging) point-cloud survey in real-time. This delivers very high bandwidth in real-time, and avoids the problems associated with running single-point contact patch models. By running over the raw survey data, we avoid the losses due to approximation and filtering associated with conversion to another data format. Running over the LiDAR point-cloud from a survey of your test track or test route allows detailed correlation to be examined between real car testing and simulation. Innovations in integrated LiDAR and IMU (Inertial Measurement Unit) technology that came to market in 2011 have enabled the economical production of sufficiently accurate point-cloud surveys.

IMMERSION

When running in a full simulator, the Image Generators developed for rFactor Pro allow for the projection of High Definition graphics, created by mapping a photographic survey to a 3D model created from the LiDAR survey. For increased levels of immersion, the projection system can be mounted off-platform, which means the radius of the projection screen can go out to 4-6m, allowing the driver's eyes to believe they are looking into infinity while maximizing the dynamic performance of the motion platform by removing mass and inertia. With an off-platform projection system, rFactor Pro re-shapes the projected images in real-time to compensate for the driver's eye-point changing as the motion platform moves and rotates.

rFactor Pro –Wraps around your vehicle model



Fig. 1: The SIMPACK interface for rFactor Pro

Two new motion platforms on the market from McLaren and Ansible, designed specifically for land-based vehicles, provide realistic motion cueing for both handling and ride. Both of these manufacturers offer build options that can take the frequency response of their platforms above 200 Hz. By combining High Definition visuals with a motion platform designed for land-based vehicles, in combination with a high-fidelity control loading system, you are able to offer test drivers a realistic environment within

which they can contribute far earlier in the project's lifecycle, reducing costs and risk.

IMPLEMENTING THE SIMPACK INTERFACE FOR RFACTOR PRO

The process starts by the SIMPACK user creating a SIMPACK model in the SIMPACK GUI using standard library elements. The user can test the model using both the standard SIMPACK variable-time step solver, as well as the SIMPACK real-time fixed time-step solver. The ability to run the same model



Fig. 2: Mobile LiDAR ensures precise correlation with your test routes and tracks



Fig. 3: Test with high levels of immersion with consistent and controlled conditions

with both solvers creates a convenient environment to test the accuracy of the model as well as the stability of the model when running in real-time. As all the suspension components are modeled fully, we do not require any look-up tables for suspension kinematics and compliances, so errors due to interpolation of such tables, which inevitably occur during conditions such as combined braking and cornering, are avoided. The same applies for elements such as springs, dampers, anti-roll-bars and bump-stops which are all modeled individually and are connected to the suspension in exactly the same way as in real-life. So again, errors due to interpolation are avoided and non-linear coupled effects are captured accurately. The model is then exported to Simulink® as an s-function where it is combined with other elements of the SIMPACK interface for RFactor Pro. Compiling the entire Simulink model using MATLAB® Real-Time Workshop completes the process.

The SIMPACK interface for rFactor Pro can be implemented at the desktop, on a workstation with USB attached driving controls, to allow engineers to test and develop the model without the need for a full simulator. Alternatively, it can be implemented as a full-scale driving simulator. This allows a phased approach but, also enables multiple departments to share the same simulator facility, each connecting their own workstation and model when running with a test driver.

The SIMPACK model may be run in combination with other models, either SiL (Software-in-the-Loop) or HiL (Hardware-in-the-Loop). This allows you to operate your model in conjunction with control strategies or ECUs that affect the handling and ride characteristics of the car, e.g., stability control, active damping.

When running SiL, the SIMPACK interface implements an execution framework that may run multiple models concurrently in soft-real-time at 1–12 kHz with <25 µs of jitter. Running SiL means you can take advantage of the price / performance available from commodity multi-core PCs running at over 4 GHz, allowing increased model complexity, or more models to be run, while remaining real-time.

LEVERAGING YOUR INVESTMENT IN SIMPACK

By running your SIMPACK models Driver-in-the-Loop, your organization benefits from real human feedback earlier in projects, reducing costs and risk, while your models benefit from the feedback of your test drivers. The use of simulators also allows the creation of a very low-carbon test facility compared with manufacturing and operating mules and test fleets.

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The SIMPACK interface to rFactor Pro provides engineers and vehicle dynamicists with a new tool from which the essential contribution and feedback of a human driver can influence the handling and ride characteristics of vehicles yet to be built. Automated testing with a driver-model ensures that systems are safe, but DiL (Driver-in-the-Loop) testing ensures that engineering and systems feel right and perform correctly when a real human is in control. rFactor Pro and SIMPACK now play a central role in providing a highly realistic immersive experience, under consistent and controlled conditions, for drivers to contribute to engineering development in a way that previously has never been possible.

INFORMATION AND CONTACTS

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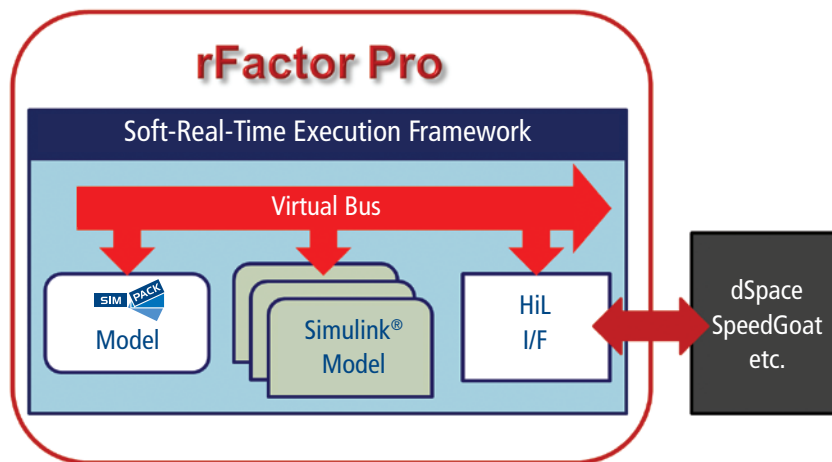


Fig. 4: Run SIMPACK HiL or SiL