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SHOW ISSUE

Vehicle Dynamics Expo 2010
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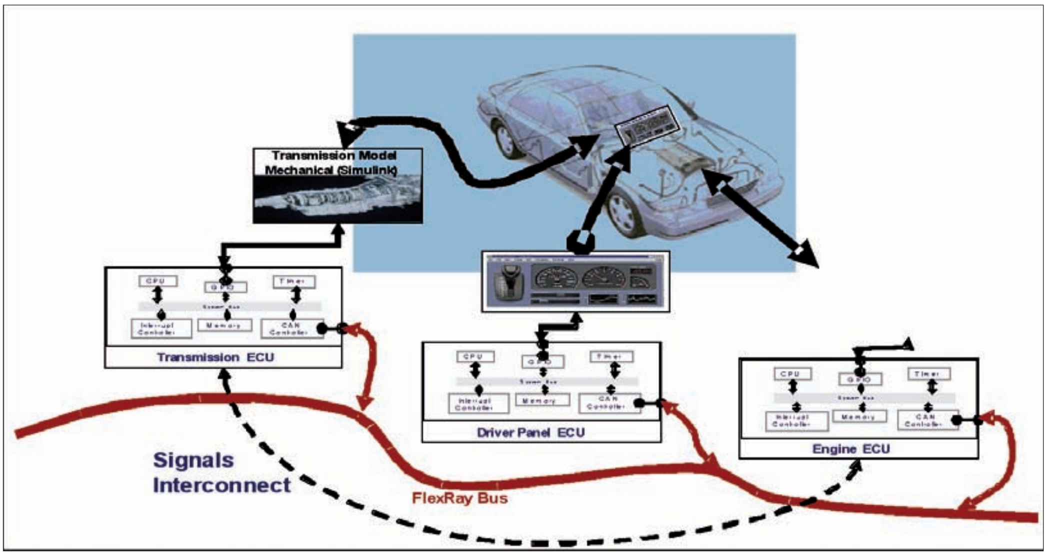

FIGURE 1 (BELOW): **CARSIM VEHICLE MODEL, INCORPORATING VEHICLE DYNAMICS MODELS AUGMENTED WITH HIGH-FIDELITY CONTROL AND PLANT MODELS FOR ENGINE, TRANSMISSION, AND INSTRUMENTATION PANEL**

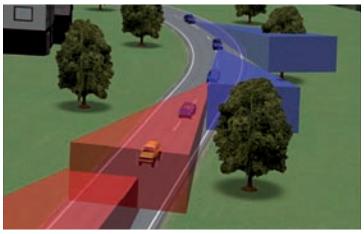

FIGURE 2 (FAR RIGHT): **ESSE MODELING AND SIMULATION OF A SMALL NUMBER OF AUGMENTED CARSIM (AUTONOMOUS) MODELS FOLLOWING THEIR LEAD CAR IN TRAFFIC**

In automotive transport, two vehicle models that provide an excellent foundation for specifying and empirically determining optimum control system architectures are Mechanical Simulation Corp's CarSim and TruckSim models.

These models are calibrated, widely used, and have several hundred parameters for specifying and tweaking the underlying high-integrity suspension, chassis, tire, and other constituent models (equation subsets). A number of vehicle subsystems, such as engine, transmission, torque converter, braking, and steering are available as abstract tables, which CarSim and TruckSim allow to be replaced by models having higher integrity functionality and timing (Figure 1).

One of Embedded Systems Technology's (EST) OEM customers has integrated their internal model of a hybrid powertrain and regenerative braking system with the suspension, chassis, and tire models of a CarSim vehicle model that is parameterized to closely match the physical vehicle in question. This model's simulated behavior correlates highly with the behavior of the physical vehicle.

A vehicle-use case that demands the good functional and timing accuracy of all models embedded in a competent vehicle model is one where a vehicle loses traction on a wet and icy road, over-corrects and rotates 180° with a lateral and (now) backwards momentum. Such use cases should be in the standard testing repertoire, and vehicle control systems should be able to detect the aberrant behavior early, initiate timely corrective action with appropriate intensity, and/or ensure that a vehicle and its occupants survive with damage minimized.

A single vehicle losing control may cause a rapidly escalating wave of collisions of increasing severity. The intentional modeling of such situations imposes a paradigm of progression unlikely to correlate well with the physical analog since it is extremely difficult to predict the effects of the primary collisions.

This may be a relatively infrequent example of traffic, but it is in these circumstances that safety-prioritized design is extremely important. The requirement on the vehicle designers must still be that each vehicle's control system should be able to correct in such a way as to avoid a collision and/or ensure that each vehicle and its occupants survive with minimized damage.

This traffic use case is impossible to apply to a set of physical mule vehicles due to the very high likelihood of test drivers being killed and expensive mule vehicles being wrecked. This is not a contrived example – there are many similar cases where it is more than useful to determine the likely outcome and to gather insight into what controls can be efficaciously applied to avoid collisions and/or minimize damage to occupants and vehicles.

Rigorous testing of corner cases in physical systems will be destructive – including for the driver, which is unacceptable. The practical and feasible approach to building and verifying vehicle and traffic control systems is via functional and timing-accurate simulatable models. For large systems, high-performance simulation is necessary.

In order to simulate a complex traffic-use case, the number of intra-vehicle physics and geometric collision and near-miss calculations to be performed at the same time as the usual inter-vehicle control system computations (probably each millisecond or so) rapidly becomes exponentially overwhelming.

However, with an appropriate competent modeling and simulation system, each vehicle model will be expected to compute the effects of impacts on itself and combine this with the responses of its internal control system, instant by instant. This requires each vehicle model to contain detailed models of its vehicle dynamics, detailed models of its relevant control and plant elements, and accurate models of the topography and road surface.

The combined information from all vehicle models reveals an accurate picture of the entire mounting disaster or resolving traffic perturbation. This modeling and simulation paradigm only requires each vehicle to keep track of what is happening to it and to make this information available to its neighbors, thereby avoiding overwhelming computations that will grind the simulation to a halt.

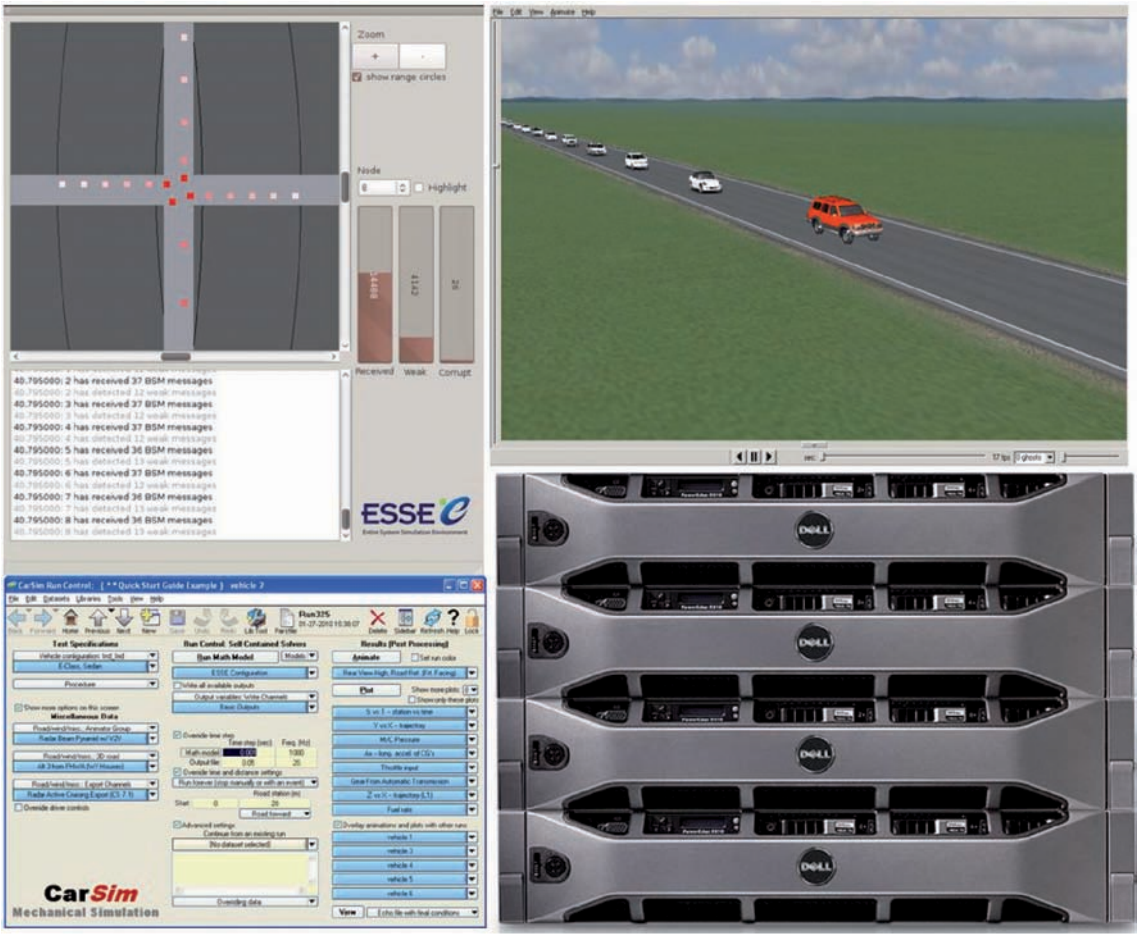

FIGURE 3 (LEFT):
[UPPER-LEFT] **THE ESSE SYSTEM DISPLAYING THE PROGRESS OF FOUR LINES OF TRAFFIC ENTERING AND EXITING A TRAFFIC-LIGHT-CONTROLLED, FOUR-WAY INTERSECTION. 50 AUTONOMOUS VEHICLES ARE COMMUNICATING WITH THEIR OWN DSRC RADIOS**

[UPPER-RIGHT] **ESSE SIMULATION OF 24 CARSIM VEHICLES IN A CONVOYING PROCEDURE, DISPLAYED USING THE ANIMATOR**

[LOWER-LEFT] **THE CARSIM GUI USED TO CONFIGURE THE VEHICLES**

[LOWER-RIGHT] **A MULTICORE, MULTINODE COMPUTER USED IN VERY HIGH-PERFORMANCE ESSE SIMULATIONS**

The EST Specification and Simulation Engineering (ESSE) system provides precisely the distributed modeling and simulation capabilities needed to build the complex vehicle, traffic, and infrastructure models that mean the distributed simulation can be performed, often faster than in real time. The ESSE distributed simulator coordinates the activity of many independent simulations – such as ESSE CarSim vehicle models, Simulink plant models, and SystemC ECU models – and supports intercommunication between simulations via high-performance, accurate models of networks, such as CAN, and FlexRay, 802.11p radio. Currently, the ESSE distributed simulation system is the highest performing, accuracy-preserving distributed simulator in the world.

In Figure 2, each vehicle is following its lead using a partial but relatively sophisticated Gipps following-driver model. In the ESSE simulation, each vehicle is a separate CarSim model running on its own core in a multicore host, multicore computer system. When the vehicle model is a CarSim model augmented with high-fidelity models of the engine, transmission, perhaps connected via a CANbus, the single vehicle model may be spread over several cores in order to preserve the highest possible simulation performance. The simulation depicted in Figure 2 executes six times faster than a wall clock (real) time, even though there are six full CarSim models being independently and concurrently simulated – in both simulation and real time – using the same infrastructure model.

Since each vehicle model is completely autonomous, but the driver model can see the other vehicles in its visual range, each vehicle-driver model can make decisions that are independent of any other vehicle-driver model. This exactly mimics reality.

Another of EST's customers, together with EST, is currently using the ESSE system to systematically identify the dominant factors controlling the minimization of fuel consumption and particulate emissions when maximizing safety in urban traffic. Up to 50 CarSim vehicle models, augmented with accurate engine models, are being simulated stopping and starting through models of the maze of downtown intersections, complete with traffic light and vehicle sensor models.

The advent of competent large-scale modeling and multicore, distributed simulation capabilities, coupled with detailed models of vehicle dynamics and control and plant systems in vehicles, is enabling extraordinarily complex, never before attempted, large-scale problems to be examined and solved.

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