Integration of Real-time Systems into the entire Vehicle Simulation

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Keywords: real-time system, co-simulation, coupling, entire vehicle system simulation, HiL simulation

Abstract:

(please use Times New Roman, 12 pt., max. 400 words)

The co-simulation approach allows development departments (typically different domains) to use their most suitable simulation tools for subsystem modeling of an overall mechatronic product e.g. the entire vehicle. Applying this approach a flexible and efficient vehicle development process considering different departments respectively domains is possible. This approach addresses the left branch of the well-known V-model. To extend the co-simulation approach to the right branch of the V-model a so called real-time co-simulation problem has to be solved. The right branch, which represents the advanced product development stage, is characterized by the integration of real-hardware in form of control units, HiL test systems or whole test beds. This incorporation of real-time systems is directly connected with new coupling challenges as real communication media and sensors are present: the coupling of the involved systems has to be time correct; round-trip-times must be kept as small as possible in order to ensure the stability of existing control loops; noisy sensor signals must be taken into account; coupling data losses has to be handled adequately. So offline simulation models, typically with a high level of detail, test scenarios or environment simulations can be used with the real test equipment without the necessity of model conversion and/or code generation. In conclusion the real-time co-simulation concept enables the application of the classical co-simulation techniques during the whole product development process (V-model).

To demonstrate the application of the (real-time) co-simulation approach during the whole development process an entire vehicle simulation is presented. The entire vehicle consists of three different subsystems, which are linked via AVL Model connect: the drivetrain modeled in AVL Cruise or MSC Adams, an ABS control unit modeled in Matlab/Simulink or AMESim and the rest of the vehicle modeled. To address also the right branch of the V-model the ABS control unit is also integrated in form of a real-time system (dSpace MicroAutoBox) via the real-time co-simulation approach. Beside the presentation of the real-time co-simulation approach also a flexible subsystem exchange (variability) is addressed via this example.

Tractor & Implement optimization by combined vehicle and powertrain consideration

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Company/ University, Department: AVL, Driveability & Simulation Department

Keywords:

Tractor, implement, soft soil, Model.Connect, VSM, Cruise, Maneuver designer

Abstract:

The agriculture behavior have changed dramatically since the last few years and it is an ongoing process. The manufactures of vehicles and implements achieved great progress in optimization of workflow in transportation, cultivation and harvesting – keyword “Precision Farming”.

The upcoming aggravation of emission and fuel economy limits by international legislation standards will force agricultural industry to take the complex interaction between vehicle, implement and soft soil more and more into consideration. To overcome the problem that in most of the cases vehicle and implement manufactures are located in different companies as well as prototypes for investigations and innovative development are very expensive, simulation work is the state of the art solution approach.

AVL offers here a powerful solution including the tool VSM for precise vehicle, soft soil implemented modelling as well as Cruise for detailed powertrain representation. This combination enables tractor and implement manufactures to optimize the entire system regarding fuel efficiency and productivity targets already in the concept phase.

A Short Cut from the Office to the Test Bed – An Integrated and Open Environment for Simulation

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Company/ University, Department: AVL List GmbH

Keywords:

Office, Simulation, Test Bed, Integration, Simulation Environment

Abstract:

In the vehicle development process a lot of simulation is performed in the office for the different development tasks. Simulation results from the office need to be validated on the test bed having real unit-under-tests and also additional test bed testing is required. To get consistent and comparable results simulation models from the office have to be re-used on the test bed. Furthermore, to decrease development time on the test bed and enable high dynamic simulation, models need to be integrated in a common simulation environment which can already be used in the office.

In this paper, an environment for the integration of real-time simulation models on the test bed is presented. Simulation models from different simulation tools can be integrated on different test bed types. To reduce development time the simulation environment running on a dedicated hardware can be prepared in the office. The different simulation components can already be connected in the office using a graphical user interface and different simulation model variants can easily be exchanged for testing. The results show the openness for different simulation tools and the flexibility for the integration of different vehicle model components. The high real-time performance on the test bed enables accurate simulation.

Development of a Python based tool allowing the interaction of alternative I/O with the AVL CRUISE simulation tool

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Keywords: AVL CRUISE, Python, Sensitivity Analysis, Design of Experiment, Optimization

Abstract:

The present paper describes the development of a Python based tool, allowing the use of alternative Input/Output (I/O) platforms for the interaction with the AVL CRUISE simulation software. The main motivation for this exercise is the facilitation of Sensitivity Analysis (SA) studies and the execution of simulation runs in batch, with the aim to define the WLTP introduction effect on the European light-duty vehicles CO_2 emissions target.

AVL CRUISE offers various alternatives for batch calculations: matrix calculation, component variation, DOE plan and batch calculation. Additionally, available components allow the definition of more complex functions and/or strategies: MATLAB DLL / SIMULINK and MATLAB API components, and Map / Function components. However, possibilities for interaction with more complicated dynamically defined input systems, necessary for optimization purposes, and interaction with variable and flexible input data, such as data produced directly from measurements, are limited.

Initially, Python programming language, along with the XLWINGS library, is chosen to facilitate the I/O handling using the widely adopted MS Excel as the main Graphical User Interface (GUI). Subsequently, a baseline template model in AVL CRUISE is developed and analyzed in terms of its files structure and files' interactions. The main parameters for scalar and table values, properties and connections, which need to be altered are located in the relative files and replaced with variables. The Python based script reads the input from MS Excel and assign values to the variables, creating a new model. Using MS Windows Console, CRUISE is called and runs the model. The output is read from pre-defined templates and stored to MS Excel for easy handling and visualization.

Additional modules of the tool include an in-house developed gearbox calculation tool, developed in collaboration with AUDI, and a WLTP cycle calculation tool, developed under the framework of the WLTP Development Group.

The tool is mainly used to provide the following capabilities: (i) sensitivity analysis calculations, (ii) simulation runs in batch, (iii) optimization of unknown / calibration parameters. A first demonstration of each of the previous is done via an extensive experiment, using a BMW X1 model as the baseline for the estimation of the WLTP introduction effect on the CO_2 emissions for its segment.

Online Parameters Identification and SOC Estimation for Healthy and Aged Electric Vehicle Batteries Based on Equivalent Circuit Models

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Keywords: Battery Management Systems, Battery Modeling, State-of-Charge Estimation, State-of-Health Estimation, Battery Aging

Abstract:

Recently, extensive research has been conducted in the field of Hybrid (HEVs) and Battery Electric Vehicles (BEVs) since they represent a more sustainable alternative compared to conventional, fossil fuel-based vehicles. The battery pack is one of the most expensive and important elements of the electric vehicle powertrain. It requires accurate, real-time monitoring and control. Parameters such as battery State-of-Charge (SOC) and State-of-Health (SOH) have to be accurately monitored in real-time to ensure battery safety and reliability and avoid overcharge or under-discharge conditions. These conditions can cause irreversible capacity degradation and power fade. For battery condition monitoring, an accurate battery model is needed in conjunction with a robust estimation strategy for extracting battery health information from a limited set of measurements. In this reserch, online battery model parameters identification and state of charge estimation at various states of life has been implemented. An extensive aging test has been conducted over a period of 12 months using real-world driving scenarios. This paper provides the following contributions: (1) tracking changes in the battery OCV-R-RC model parameters as battery ages, (2) online estimation of the battery model parameters using square-root recursive least square (SR-RLS) with forgetting factor methodology, (3) estimation of the battery state of charge using regressed-voltage-based estimation strategy at various states of life, (4) model validation using a series of real-world driving cycles. The limitations and benefits of the proposed strategies are discussed.

Model-based Control-System Development and Pre-Calibration of Injection System for Locomotive Application

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Keywords:

Model-based development, physics-based real time injection system & engine model, control-system development, HiL (hardware-in-the-loop)

Abstract:

Best controller performance is indispensable in order to achieve optimum engine performance, clean mobility and high reliability. Hence, the control-system development as well as the pre-parametrization of the injection-system control of a 2-stage turbocharged common rail Diesel engine for locomotive application was performed using physics-based real time engine & injection-system plant models. This advantageous approach facilitates significant reduction of development time and cost. In addition, quality assurance by means of virtual validation is made possible.

The first step of the model-based control-system development process is the control-algorithm development and control-system concept-definition by means of “Model-in-the-Loop” (MiL) using an innovative AVL CRUISE M real-time engine plant model in closed loop operation with a simulation model of the control system. In the second step, once the engine-control system-hardware is available, the developers can use the HiL environment (“Hardware-in-the-Loop”): The same CRUISE M engine model (continuous application of plant model) runs on AVL’s XIL.STATION™ in closed loop operation with the ECS hardware for further optimization and the pre-calibration of control-system parameters. The purpose is to have a robust and pre-calibrated engine-control system already available when the engine is started for the first time, so that the subsequent engine tests can concentrate on performance & emission development.

The AVL CRUISE M model is a physics-based real-time engine model. The applied innovative modelling approach consists of crank-angle resolved simulation of the cylinders as well as consideration of 0D gas dynamics in the gas path. Hence, pulsations of the torque of the engine and pulsations of mass flow, pressure and temperature in the gas path are simulated in real time. Additionally, a crank-angle based hydraulic model (describing injection pump, volume-control valve, rail, pressure-relief valve and injectors) is implemented to the engine model: With the simulation of the injector nozzle’s needle motion and the pressure waves in the rail the rate-of-injection for multiple injections can also be calculated in real time. The physics-based crank-angle resolved engine model allows the description of the discontinuous gas exchange, EGR induced by pressure pulsation, cylinder-individual approach (e.g. variance of injector behavior)

and specific engine configurations (e.g. variance of performance of cylinders and cylinder groups due to asymmetric charging or EGR systems).

Consequently, the major advantages of physics-based plant models with high model depth can be used for control-system development and calibration on HiL test benches reducing the overall development time and costs as well as opening up new perspectives.

An advanced real-time capable mixture controlled combustion model

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Keywords: System level simulations, Internal combustion engine, Combustion model, Spray model

Abstract:

High level of predictability is of utmost importance when using system level models in early development stages and when modifying system and control parameters in the late calibration and validation phases. Due to their mechanistic basis and thus inherent higher level of predictability crank-angle based internal combustion engine (ICE) models gain on importance compared to the data driven models. Combustion models are one of the main areas where predictability of the system level ICE model should be enhanced. This presentation therefore focuses on a contribution towards enhancing prediction capability of a mixture controlled based combustion model of a Diesel engine.

The basis for achieving high level of predictability and short computational times arises from the innovative 0D spray model that is based on a transient momentum equation. The spray model thus enables: a) predicting the amount of fuel between arbitrary pre-prescribed lambda limits, b) modeling spray detachment from the nozzle after end of injection and c) evaluation of the mass or share of the fuel that has reached the walls. The spray model is integrated into the mixture controlled modeling framework that predicts the rate-of-heat-release (ROHR) based on contributions of premixed and diffusion combustion. The diffusion combustion further considers contributions from different lambda regions under consideration of oxygen availability in particular region and allows for rate reduction due to wall wetting.

This combustion modeling framework is implemented in a 2-zone cylinder modeling framework, which thermodynamically balances the burned and unburned zone, while the spray zone is treated as a quasi-additional zone for balancing masses. The modeling framework is laid out generically enabling injection or arbitrary number of sprays to support modeling of modern Diesel engines.

The entire modeling framework is validated with the comparison to the experimental data, where emphasis was put on the comparisons of the ROHR curves. Presented results confirm high level of predictability of the proposed advanced combustion model being based on an innovative spray model.