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Application of Description Models Based on the International Standard Language VHDL-AMS to Digital Validation

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The introduction of MBD into automotive system development helps improve development efficiency and virtual testing (VT), which uses simulations in a digital space. For example, in Europe, there is a movement to gradually replace various real testing (RT) with VT, such as the activities of EGVI in the HORIZON 2020 and subsequent projects. This is mainly because, in the digital space, simulations can freely combine various usage environments, including the target vehicle's temperature and load conditions.

For example, in efforts to achieve carbon neutrality, RT can be used to estimate the mileage per charge and the fuel efficiency of EVs. We have already reported that the results of this simulation-based calculation of electricity consumption were in good agreement with the actual measured values. Furthermore, we have confirmed that the simulation results agree with the measured results when the load conditions are changed, i.e., when the mileage, air conditioning, ambient temperature, and sunlight conditions are varied.

The advantage of VT is that it can easily simulate ideal conditions in the digital space, combining various usage environments, including the target vehicle's temperature and load conditions. In contrast, as seen across multiple fields, the experiment itself often becomes more complicated as the target becomes more complex. For example, in RT, testing a vehicle under a given temperature takes time, money, and effort; even then, it can be challenging to set the target temperature. Achieving a collision under the assumed conditions in a crash test may be difficult. Therefore, due to the limitations of RT, the necessity and importance of VT via simulation are becoming increasingly evident.

To enable testing and validation in the digital twn space, it is necessary to perform appropriate numerical processing based on a valid, distributable model. In particular, the models that form the basis of the evaluation must be supplied and distributed in a format that guarantees compatibility, and the simulation results, etc., must be stored as evidence to ensure transparency. These requirements can be addressed by circulating compatible models written in an international standard language (VHDL-AMS). Under this background and with these requirements, the Model-Based Development (MBD) Committee, which develops models using global standards, was established to implement model-based development technology in the automotive field, and has been working to create and distribute models that comply with international standards that can be used as a common platform by participating organizations and companies.

The purpose of this presentation is to explain the requirements for the simulation setup, specifically from a numerical computation perspective. In other words, this presentation summarizes the principles previously explained in the committee's OS presentations, symposia, forums, textbooks, and an explanatory article.

A crucial point in solving system equations is to handle division operations that arise during numerical computation in a way that maximizes numerical stability. Specifically, the system equations are differential-algebraic equations that implicitly involve differential operations, and the system is solved by solving the equations directly. This allows for appropriate handling of division operations based on the selection of pivot elements when solving the final system of equations. In other words, this allows us to suppress the amplification of errors caused by selecting small pivot elements. It is not always possible to convert from an implicit system of equations to an explicit state equation. That is, the implicit system representation is more general.

Furthermore, even if the equations are equivalent, if the factors involved in the differential operations are small, there is a possibility that errors will amplify, as when the selection of pivot elements fails. This can be inferred, for example, from the fact that $y = ax + b$ and $cx + dy + e = 0$ are not equivalent, and the latter is more general; to express the latter in terms of the former, d must be non-zero and, numerically, a relatively large value. Expressing system relationships as a flow diagram may also harbor similar problems. Specifically, when determining the coefficients between inputs and outputs, whether the division involves zero or relatively small values can significantly affect the numerical calculation results. These concerns can be resolved at the level of the original model formulation by solving the system equations implicitly.

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