Challenges and Countermeasures in Using FMUs to Perform Scenario-Based Testing in a Cloud Environment

Takashi Yamada[1]   Kensuke Araki[1]   Katsuya Tsuzuki[1]

1) dSPACE Japan K.K 4-7-35 Kita-Shinagawa, Shinagawa, Tokyo 140-0001 Japan

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Model-based development (MBD) is a methodology of programming that use "models" to describe a behavior. MATLAB/Simulink is often used to describe a model. As Japan Automotive Model-Based Engineering center (JAMBE) was established in 2021, MBD is getting more popular and popular here in Japan. Tool vendors provide also models, an essential element of MBD, to the market. One of current challenges in MBD how we integrate multiple model components provided from multiple tool vendors to prepare a validation environment in a short time period. Functional Mock-up Interface (FMI) and Functional Mock-up Unit (FMU), proposed by Modelica Association, are going to solve it. Nowadays most of MBD tools are FMI-compliant.

Now the automotive industry is facing a couple of new trends. One is electrification and the other is automation. In particular, trends of automation has shifted from development and integration of advanced driving assistance systems (ADAS), such as development of automatic emergency brake system, to development of autonomous driving (AD) systems. There are a variety of public-private joint activities to cope with this transformation.

There is a strong market demand to apply MBD for efficient development and validation of AD systems. In Germany, the PEGUSUS project discussed validation methods for AD systems through public-private partnerships, and the project proposed a new test method called scenario-based testing. Similar discussions are also taking place in Japan under the SAKURA project.

However, it is estimated that an AD system validation environment should be much larger than real-time control systems such as control system for internal combustion engines. In addition, workload for the validation should be also large. Use of a cloud computing environment is expected to be one of solutions to this requirement. A cloud computing environment allows us to execute enormous amounts of simulations in parallel with flexibly increasing or decreasing computing resources required for testing. However, there are still few empirical examples where tools that have been frequently used for validation in an on-premise environment with actual hardware to a cloud environment.

This study attempts to implement a prototype of validation environment for AD algorithms using FMUs in a cloud environment, and to identify challenges that may get apparent during the implementation. Furthermore, we will examine solutions to the challenges identified during the implementation. Fig. 1 shows a prototype environment that was built in this study.

The challenges that emerged during the implementation can be broadly categorized into those arising from transition of the operating systems and those arising from use of a FMUs.

It can be considered that the issues arising from transition of the operating systems come from the fact that most MBD environments have been built on-premise in Windows. In contrast, simulation environments in a cloud are often built on Linux-based operating systems. We have found challenges during the transition from the former to the latter. Especially, some of them are caused by Linux-specific software libraries, and others are caused by Windows-specific file path descriptions that result in errors when accessing files in a Linux/cloud environment. Another challenge is that measurement and calibration software used with Windows does not support Linux. If you have a validation environment that you are considering migrating to a cloud environment, it would be a good idea to check operating system dependencies of the environment before starting the migration.

As for challenges arising from use of FMUs, we identified a challenge that FMU termination time configuration is contained within a FMU, and another challenge that a struct or buses cannot be used to describe interface FMU. These are challenges that can occur independently of environments, and are applicable to the challenges and countermeasures that have already been discussed in the FMI utilization working group in the Society of Automotive Engineers of Japan. It would be advisable to consider countermeasures in prior to actual environment establishment while referring to these existing documents.

One of the most important preliminary measures to address the challenge is to build models for simulation which are free from limitations caused by operating systems, assuming future simulation environment migration. It is said that a huge amount of testing is required to bring AD algorithms to the market, and the market is developing a scalable testing environment using a cloud computing environment. We wish we can facilitate the smooth transition of those who have built MBD environments on-premise to an environment where scenario-based testing is performed in a cloud environment by taking countermeasures against the challenges identified in this study.
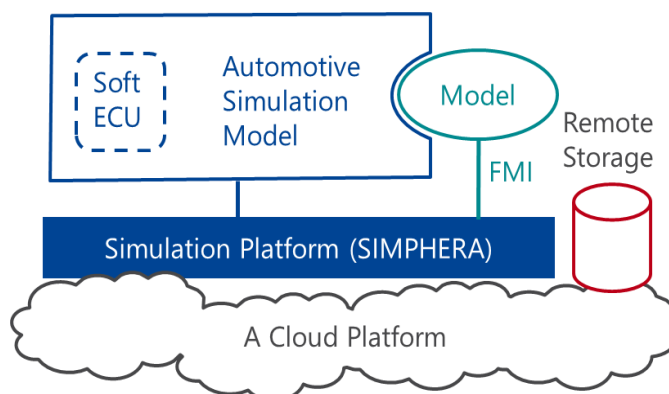

Fig.1 An overview of simulation configuration on a cloud