Physical Modelling in Transport Automation

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Abstract

The transport automation has its specific challenges in modelling and simulation. The virtual integration of ego vehicles in an environment with dynamic agents, physical infrastructure, perception, autonomous driver, and cloud services has a long chain of supporting tools and server infrastructure. The technical domains all have their respective development tools solving their specifics.
The federate nature of the virtual integration and systems validation sets new requirements on modelling and simulation tools, including their business models.
Keywords: Modelica, FMI, federated simulation, business model

1 Introduction

Volvo Autonomous Solutions AB, VAS, is a recently established business within Volvo Group to drive the development of transport automation. It sells transport rather than vehicles and therefore works with development of new business models.

The transport automation at VAS is built on the use of vehicles within the Volvo Group, a globally operating and manufacturing business in commercial vehicles and machines. VAS uses trucks from Volvo Trucks as well as machines from Volvo Construction Equipment.

Mining and quarries are prime VAS customers. VAS develops the automation stack and interfacing hardware, between the Volvo vehicle's- and machine's hardware and the logistics solutions at customers' sites. The automation stack includes production planning, route planning, tactical motion planning and actual vehicle and machine motion control.

The entire stack needs a simulation environment to efficiently develop, verify, and validate the software modules (domains). For physically sound and dynamic agents, VAS has opted for the use of Modelica and FMI.

2 Virtual Verification

The scale of our verification challenge calls for Software in the Loop (SIL) solutions. SIL allows running faster than real-time and running multiple instances simultaneously in one scenario. The verification solution space can only be scaled efficiently if it is entirely virtual. Multiple simulation alternatives are available for setting up a simulation environment for terrain and infrastructure, provided these solutions support the import of physical sound dynamic simulation models, the entire vehicle or machine.

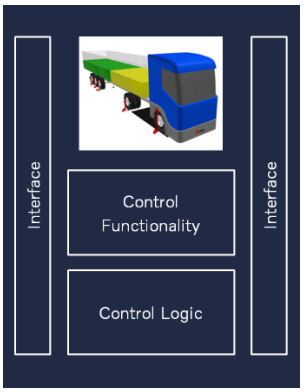

Figure 1 Schematic of a dynamic simulation model

The dynamic simulation models must thus include all the relevant physics at purposeful fidelity level, control functionality and control logic. The latter two parts will have to be integrated with portable code from the ECU's and other onboard computers.

3 Multi-domain

The vehicles and machines are mechanical structures that bear systems and subsystems for multiple purposes. Internal combustion engines, electric motors, hydraulic suspension, pneumatic brakes, etc. All these systems have a different dominant physical domain to be modelled. Dedicated modelling and simulation tools could be used, and are used in different development departments, for every specific physical domain. But that would require physically sound co-simulations within the single deliverable of a dynamic simulation model. Apart from the fact that this is a technically non-trivial task (Drenth, 2017; Drenth 2019), there are usually (technically for the task at hand) inhibitive license models attached to the export of co-simulation models.
Beyond that, many of the commercial model integration solutions require licensed platforms that do not lend

themselves to export a single executable deliverable as envisioned.
VAS rather takes the all-in Modelica route for its single executable deliverable. The underlying Modelica models can be validated with similar technologies as shown by Takkoush (Takkoush, 2022)

4 Modelica

To support the multi-domain aspects of the simulation problem, Modelica is chosen because it has a great modelling paradigm. Its object-oriented capabilities allow the support of purpose driven model fidelity in a configuration managed manor. The use of a modelling language, over purely graphical modelling paradigms, is the support of traceability of model evolutions. Traceability is key in quality assurance and safety aspects. The acausal aspects of the paradigm also lead to re-useability of models and solutions and hence increasing the model "mileage". Mileage does matter! (Drenth, 2015)
Secondly, multiple commercial and non-commercial domain libraries are available. There is a wealth of academic expertise conveyed through these libraries. The use of libraries further increases the model mileage.

5 FMI

Standard API's help the proliferation of simulation models as VAS needs to spread these models to multiple domains. From a technical standpoint free distributable executable leverages the use of simulation models to virtually verify multiple facets of the AD-stack. In some environments multiple simulation models run "against" each other as multiple so-called ego-vehicles. For example, on a production site where multiple autonomous machines may constitute a discretized conveyor belt.
The nature of the FMU's, an executable in accordance with FMI standard, allows for federate simulations. Federation of simulations allow VAS to distribute required computational power across its servers. The simulation models are physically weakly coupled through the simulated infrastructure for communication and sensor interference in the scenario they have in common.

6 The market

Modelica and FMI have fantastic technical prerequisites for the modelling and simulation problem at hand. Acausal multi-domain modelling support and standardised API in accordance with the open FMI standard. The standard is in whole or partial supported by a wealth of vendors.
But the market for libraries is extremely fragmented. There are multiple vendors for both libraries and compilers. On the face of it, that sounds like music in the ears of prospects. But Modelica libraries are more often than not tied to specific Modelica compilers. This makes it hard from a customer perspective to choose the libraries that best fit the customer needs.
Secondly, Modelica libraries supported by multiple (or all) available Modelica compilers would greatly benefit the proliferation of Modelica and library quality; mileage does matter! Beyond library quality, also compiler quality would benefit cross compiler support of libraries. Multiple design teams have developed a compiler along a specification, basically a required recipe for high integrity systems development. This is not a hypothetical statement; library porting experience (by author) have indeed confirmed the aspects mentioned. Two compilers and one Modelica library increased quality and performance significantly during the porting project.

7 Proliferation

Technically the FMU has unbound proliferation possibilities. However, many vendors restrict proliferation contractual or physical by means of license checking mechanisms. License checking mechanisms are impossible for the VAS use case. It will inhibit the unification of multiple model sources in one (1) FMU as discussed in chapter 3.
The contractual restriction also puts difficulties on the proliferation because the administrative burden and/or measuring mechanisms are possibly ambiguous. Contractual ambiguity is a recipe for future pains.

8 Simscape

From a business model perspective, Simulink/Simscape is the competition for the use of Modelica not the Modelica library and/or compiler vendors amongst them. The Simulink embedded solutions come with renown and well supported code export capabilities. The proliferation of exported products is commercially unlimited. The tools have also a large footprint at many R&D sites, because it is frequently used in algorithm development for embedded systems. So does Volvo, with success.
The proliferation and accessibility of Simscape makes it a serious contender, despite technical advantages Modelica has to offer. Simscape is widely used and has domain specific libraries too on offer. Considering the Simulink/Simscape footprint, this comes with significant and all-important mileage too.

9 FMU factory

VAS develops an FMU factory for its needs of federated simulations. Good business is a win-win, and it takes two to tango.
Is the Modelica marketplace offering an alternative or alternatives to VAS ambitions and needs or the entire vehicle automation industry as a whole? A superior technical solution may not be enough, success requires having sound business models too.

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