Report: Comparison of AF3 and INTO-CPS Technologies

Description of Work and Outcomes

Initial Purpose of the Visit

INTO-CPS is a tool chain for CPS development based around multi-modelling being developed in an H2020 project of the same name. AutoFOCUS3 (AF3) is an in-house tool produced by fortiss capable of co-simulation. Both technologies aim to support multi-model based development from requirements analysis through to platform deployment. The aims of this STSM are:

- To compare the features of the two technologies;
- To identify and compare the domains in which the technologies have been used successfully;
- To identify patterns of use between the two tools that might form part of best practice; and
- To plan for further collaboration.

The two technologies will be assessed in the following areas: licensing, standards, dependencies and extensibility; requirements handling and traceability; types of modelling enabled (CT, DE, other); underlying formal semantics; analysis techniques enabled (e.g. test automation, design space exploration); hardware- and software-in-the-loop (HiL / SiL) simulation support; and code generation support.

Description of Work Carried Out

The following activities were undertaken during the visit:

- Received a demonstration of AF3;
- Completed the AF3 tutorials;
- Gave a talk and demonstration of INTO-CPS technology to the AF3 team;
- Gave a talk on INTO-CPS during the regular "BreznTalk" slot;
- Discussed difficulty of co-simulating tightly-coupled elements such as bond graphs;
- Discussed automatic systhenthis of master algorithms for customisable co-simulation;
- Received a demonstration of a production planning software platform and discussed the AF3 Eclipse stack;
- Received a demonstration of fortiss future factory and discussed current work in the area; and
- Received a demonstration of fortiss' domain specific user interfaces for robotic planning.

Futher Collaboration and Foreseen Publications

Collaboration on co-simulation and master algorithm semantics is ongoing since the STSM. A paper on automatic synthesis of master algorithms for customisable co-simulation will be submitted during 2017.

Comparison of AF3 and INTO-CPS Technologies

AutoFocus 3 (AF3) is a based development tool for designing distributed, embedded software. **INTO-CPS** is an emerging tool chain for model-based design of CPS, based around co-simulation of heterogeneous component models. Both technologies aim to support CPS development from requirements analysis through to platform deployment.

AF3 is a more mature product than INTO-CPS, having been developed for longer, and is also more tightly coupled, with all steps in the design workflow offered within a single tool with a consistent interface. INTO-CPS is a more loosely-coupled chain of tools, which permits more flexibility, but at the expense of less automation in workflow steps and more complexity in user interface (for example by requiring users to learn the interfaces of different tools).

There is also a different focus. AF3 aims mainly at software development using discrete-event (DE) models, while INTO-CPS aims to allow for more complete system models including physical behaviours modelled in continuous-time (CT) tools. In this sense, AF3 is more like Overture (which used the VDM or Vienna Development Method notation), one of the tools in the INTO-CPS tool chain which is used to model controllers in a CPS. As such, the new FMU export feature of AF3 will allow AF3 to work with the INTO-CPS tool chain, for example by taking the role of Overture, allowing AF3 controller models to be co-simulated against high-fidelity models of the physical system.

In the remainder of this section, a more detailed comparison is given based on various aspects of model-based CPS design.

Licensing AF3 is open source, based on the Eclipse platform. INTO-CPS has an open-source front end, and the Overture, Modelio and OpenModelica baseline tools are also open source. The co-simulation orchestration engine (COE) is free-to-use, but closed source. 20-sim is closed-source, but significantly cheaper than its competitors.

Dependencies and extensibility Both tools require Java dependencies. As a more mature and integrated tool, AF3 has no other dependencies. As a less mature "chain" of tools, some of the INTO-CPS features have dependencies (for example git and Neo4J for traceability support). As an open source tool, AF3 can be extended, however it is not specifically design for this.

As INTO-CPS adopts the FMI co-simulation standard, models from other tools the export FMUs can be incorporated easily— this has happened with 4diac from fortiss, and AF3 itself now has a new FMU export feature. Most links in the INTO-CPS tool chain use a simple interface based on simple JSON notation (Java Script Object Notation), so tools can be replaced if they accept and produce compliant JSON files, however this has not been tested yet.

Requirements handling and traceability AF3 integrates requirements handling, including use cases, glossary and source-document support. Requirements can be linked to architecture, then architecture to code, so requirements can be traced along the development.

Traceability support in INTO-CPS is currently in development, with a traceability database being developed that can be triggered by tools in the chain when traceability data is to be recorded.

At the time of writing, INTO-CPS primarily handles requirements by giving guidance on how use existing practice (Excel, IBN DOORS, SysML) to develop architectural models. Traceability links must be recorded manually here, but from this point forward in the chain links can be created automatically.

Types of modelling enabled Both tools allow for architectural modelling. Where AF3 covers software architecture and deployment, architectural modelling in INTO-CPS refers primarily to the architecture of the system in terms of division in to components that will be realised in DE (discrete-event) and CT (continuous-time) models.

AF3 is a DE modelling tool, primarily focused on modelling and code generating software components, including modal and target platform behaviours. Within INTO-CPS, Overture and the VDM notation perform this role, however Overture is less mature on deployment and code generation (see below). As a co-simulation tool, INTO-CPS permits a wider range of models to be incorporated, including DE with Overture and CT with 20-sim and Open Modelica.

Analysis techniques enabled Both tools allow simulation of behaviours and both tools offer Design Space Exploration (DSE) support. AF3 focuses on traditional DSE in terms of assessing deployment schemes for software components, while INTO-CPS considers a more broad (but less detailed) category of DSE at the system level, where parameters of DE and CT model can be varied to choose different designs.

Hardware- and software-in-the-loop and code generation support AF3 has fully integrated code generation support for components and deployment. Code generation is being developed for the modelling tools within the INTO-CPS tool chain, to be deployed with 20-sim 4C (a deployment-specifc extension to 20-sim), but this is currently experimental. 20-sim 4C also enables HiL and SiL simulation.