Connecting MATLAB to the SMP2 Standard

Harmonizing new and traditional approaches for automatic model transfer

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Presentation overview

MOSAIC 10 activity (ESTEC/NLR/MathWorks collaboration)

● Traditional MOSAIC approach
  ● Latest developments
  ● New release of transfer tool: MOSAIC 10

● Studying a new approach
  ● Based on Target Language Compiler technology
  ● Direct configuration of code generator
  ● Feasibility study
  ● Prototype developed

● Integration/harmonization of approaches: future plans

● Conclusions
Introduction: automatic model transfer

- **Purpose**
  - Re-use of models during a complete project life-cycle to reduce cost, time, effort

- **Approach**
  - Automate model transfer between COTS tools and model standards

- **Product**
  - MOSAIC

*Model-Oriented Software Automatic Interface Converter*

**Modelling tools:**
- MATLAB
- EcosimPro
- 20-sim
- Modelica
- ..
MOSAIC usage

- Usage principles
  - Model adaptation in originating environment
  - MOSAIC treats model as black box
  - Analyses the source code’s API and adds interfacing code to it
  - End-to-end support

- Free-of-charge license in ESA member states

- Used in European space industry
  - For more than 15 years
  - In a large number of projects

- Latest version: MOSAIC 10 (March. 2015)
Example use case, traditional MOSAIC approach

Develop spacecraft system models

Simulink

Export

Simulink Coder

Automatic conversion

MOSAIC

Compiled SMP2 model

SMP2 compliant simulator (C, C++, catalogue, etc.)

Visual Studio

Spacecraft simulation

SimVis Designer

(Re)connect models

SIMSAT

SMP2 compliant simulator with integrated models

NLR - Dedicated to innovation in aerospace
MOSAIC 10 tool upgrade: key requirements

- Upgrade MOSAIC 9 to latest MATLAB version (R2014a at start of project)
- Maintain backward compatibility with MOSAIC 9 (e.g. EcosimPro and 20-sim support)

[Diagram showing the transfer of model to Simulink R2014a, EcosimPro 4.8, and 20-sim 4.1, resulting in exported C code and ready-to-use code.]

SMP2 Standard:
- SimVis2.2/SIMSAT2
- SimVis3.1/SIMSAT4.3
- Basiles
- EuroSim Mk5.2
MOSAIC 10 results: Transfer combinations

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet
MOSAIC 10 results: Transfer combinations (Simulink input)

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet (■ = validated)
MOSAIC 10 results: Transfer combinations (EcosimPro input, MOSAIC 9 compatibility)

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet (■ = validated, → = not validated, □ = not yet supported)
MOSAIC 10 results: Transfer combinations (20-sim input, MOSAIC 9 compatibility)

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet (● = validated, ➡ = not validated, □ = not yet supported)
MOSAIC 10 validation

- Validated transfer combinations based on ESTEC use cases
- Other transfer combinations possible as well (at own ‘risk’)
- Tested with MOSAIC internal test suite and ESTEC acceptance models
- SMP2 Conformance suite, for compliance verification of MOSAIC 10 output SMP2 files
MOSAIC 10: specific user requests addressed

- Parsing of Simulink parameters with multiple comment lines in the generated code.
- The SMP2 input attribute for parameter fields has been adapted.
- SMP2 Universally Unique Identifier (UUID) issue (see paper)
  - Problem analysed and solution proposed.
  - Algorithm to be implemented in future version
Introduction to Simulink

*Code Generation*

- Automatic code generation from model
- Suitable for any embedded application
- Early and continuous verification
Studying New Approach

What? Why? How?

Simulink
Studying New Approach

What? Why? How?

Simulink

- Direct code generation
- R2010b, R2014a and +
Studying New Approach

What? Why? How?

Simulink

- STF: Custom System Target File
- TLC: Target Language Compiler File
Embedded Coder
Generate custom C/C++ code with TLC

**Simulink Coder**

TLC program:
- System target file
- Block target files
- Inlined S-function target files
- Target Language Compiler function library

Run-time interface support files

- Simulink model
  - `model.slx`
- Simulink Coder Build
  - `model.rtw`
- Target Language Compiler
  - `model.c`
- Make
  - `model.mk`
- `model.exe`

**Model.rtw = Intermediate Representation**

- SMP Compliant model
  - C/C++
  - XML artefacts

SMP.TLC
Validation of the SMP.tlc prototype
Validation of the SMP.tlc prototype

- Tested with ESA Gyroscope Simulink model

- Validation:
  - Inspection of the generated SMP artefacts and source code, comparison with MOSAIC generated output
  - Check with SMP2 Conformance Suite
  - Successful load in EuroSim Mk5 on a 32-bits Linux platform
Study Results

- STF supporting main features of modeling and Embedded Coder options

- Mapping doc between Simulink and SMP

- Identification of new features or evolutions
Integrating SMP.tlc with MOSAIC

- **Future work:** Further harmonize new and traditional model transfer approaches

- **Ensure efficient maintainability**

- **Avoid duplication of functionality**

- **Several options:**
  - Stand-alone STF from end-to-end (target environment support to be added)
  - STF connects to MOSAIC modular architecture
Traditional MOSAIC architecture

- Generated model source code
  - MATLAB Module: GRT, ERT, GRT malloc
- C source code
- API + source code (C++)
  - EcosimPro Module
- XML file + source code (C++)
  - 20-sim Module

Modeling platform support

- Tool independent model specification
  - Standard support
  - Simulation platform support
  - Basiles Module
  - SIMSAT4 Module
  - SimVis / SIMSAT2 Module
  - EuroSim Native Module
  - EuroSim Mk4 Module
Possible MOSAIC architecture with STF

- **STF**
- **API + source code (C++)**
- **XML file + source code (C++)**

**Modeling platform support**
- STF Integration Module
- EcosimPro Module
- 20-sim Module

**Tool independent model specification**
- Model description Module

**Standard support**
- SMP2 Module
- EuroSim Native Module
- Basiles Module
- SIMSAT4 Module
- SimVis / SIMSAT2 Module
- EuroSim Mk4 Module
Conclusions

- **MOSAIC 10**
  - Free-of-charge in ESA member states (license request: mosaic@nlr.nl)
  - Supports recent updates to corresponding simulation environments

- **System Target File**
  - Effective collaboration between NLR/ESA/MathWorks
  - Complementary approach
    - Meta data of Simulink model accessed directly
    - Less development effort expected

- **Integration of approaches**
  - New and traditional transfer approach fit well together
  - Integration activity planned -> MOSAIC 11
  - Contribute to high-level objective
    - Cost reduction of space system development
    - Efficient harmonization of System Modelling & Simulation (SM&S)
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