The 3rd International Workshop on Simulation at the System Level for Industrial Applications

Jointly organized by ENPC, ENS-Cachan, Inria and Eurobios

Ecole Normale Supérieure de Cachan, France

October 14th–16th, 2015

Program and abstract book

Program

The workshop will take place at Ecole Normale Supérieure de Cachan

	Wednesday 14th	Thursday 15th	Friday 16th
9h30		Using the OPC Classic Modelica library for Model Predictive Control	SIMULIM, a Platform for the Modeling and Simulation at System Level
10h10		Multicore Acceleration of System-level Simulation	A Methodology for Best Pathway Identification of Waste Recovery
10h50		Coffee Break	Coffee Break
11h10	Arrival of participants	Deployment of Standalone Modelica Models to the Raspberry Pi+Arduino	Modeling Cyber-Physical Systems with 3D Animated Scenarios : a Railway Simulation Case Study
11h50		Integrated Optimization in System Models	Method for Evaluation of Technology Impact on Subsea System Lifetime Costs and Risks
12h30	Lunch	Lunch	Lunch
14h15	Welcome Address		
14h30	An FMI Extension Enabling Structured Physical Modelling	The Benefits and Challenges of Massive Behavioural Simulation for Cyber-Physical Systems Engineering	Departure of participants
15h10	Quantized State System Simulation in Scicos	Modeling for Designing - An Essential Stage	
15h50	Coffee Break	Coffee Break	
16h10	SCADE Hybrid : an Extension of SCADE with ODEs	Simport : A Simulink Model Importer for Scicos	
16h50	High Dimensional Switched Systems : Control and Observation	Panel Discussion	
17h30			

An exhibition space is located at the ground floor of Laplace building, where Maplesoft and Dassault Systèmes present their simulation software products.

Session chairmen:

- Wednesday afternoon: Pierre Weis
- Thursday morning: Jean-Philippe Chancelier
- Thursday afternoon: Sébastien Furic
- Panel Session: Florian De Vuyst, Jean-Michel Ghidaglia
- Friday morning: Dirk Reusch

Summary

An FMI Extension Enabling Structured Physical Modelling

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A Functional Mock-up Interface extension proposal for higher-level physical modelling will be presented.

Functional Mock-up Interface (FMI, see https://fmi-standard.org/) is an emerging standard which enables conforming tools to exchange and co-simulate system-level submodels. Thanks to FMI users can pack heterogeneous simulation code into connectable entities called FMUs, whose connection eventually creates complete simulation models. But while users of physical models often expect a high level of model description—typically in terms of energy flows—, the current level of description of FMUs is rather low: FMUs are quite similar to I/O blocks with some additional event handling capabilities.

We propose to enhance this situation by extending the FMI standard with a new layer which allows energy flows to be described by means of linear graphs. Moreover, this additional layer enables models to be checked for the absence of structural singularities for which other proposals based on lower level representations provide limited verification capabilities.

This proposal is a candidate for inclusion into the FMI standard.

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Quantized State System Simulation in Scicos

Dirk Reusch*

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A proof-of-concept implementation of some basic blocks for Quantized State System (QSS) simulations within SCICOS will be presented.

QSS numerical integration methods lead to discrete event approximations of continuous systems. In contrast to traditional ODE solvers there is no discretization of time, but rather a quantization of the states of a system. It is known, that QSS methods are especially efficient in simulating continuous systems with frequent discontinuities and thus are well-suited for many industrial applications.

We have implemented two (first and second order) QSS integrator blocks suitable for non-stiff system simulations accompanied by some low-level blocks, which resemble a small framework for future implementation of higher order or linear implicit QSS methods (LIQSS; suitable for stiff systems).

The usage of the implemented blocks is shown by examples, corresponding simulation results and their peculiarities are discussed, and compared with results from a reference implementation (PowerDEVS).

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SCADE Hybrid: an Extension of SCADE with ODEs

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Modeling languages for hybrid systems are cornerstones of embedded systems development in which software interacts with a physical environment. Sequential code generation from such languages is important for simulation efficiency and for producing code for embedded targets. Despite being routinely used in industrial compilers, code generation is rarely, if ever, described in full detail, much less formalized. Yet formalization is an essential step in building trustable compilers for critical embedded software development.

In this talk, I will present a novel approach for generating code from a hybrid systems modeling language. By building on top of an existing synchronous language and compiler, it reuses almost all the existing infrastructure with only a few modifications. Starting from an existing synchronous data-flow language conservatively extended with Ordinary Differential Equations (ODEs), this work details the sequence of source-to-source transformations that ultimately yield sequential code. A generic intermediate language is introduced to represent transition functions.

The versatility of this approach is exhibited by treating two classical simulation targets: code that complies with the FMI standard and code directly linked with an off-the-shelf numerical solver (Sundials CVODE).

The presented material has been implemented in two compilers, the academic Zélus compiler and the industrial KCG code generator of SCADE 6 used for implementing critical software. This is a joint work with Timothy Bourke (INRIA Paris-Rocquencourt), Jean-Louis Colaco, Cedric Pasteur and Bruno Pagano (Esterel-Technologies/ANSYS).

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High Dimensional Switched Systems: Control and Observation

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We are focusing here on high dimensional switched control systems, mostly obtained from discretized Partial Differential Equations (PDE). This class of hybrid systems, recently used with success in various domains such as automotive industry and power electronics, is still an important field of research with many practical and theoretical issues. We investigate two of these issues: control and observation.

Several strategies have been developed to design control laws for such systems; we use here the invariance analysis [1]. The associated algorithms are very expensive and require a limited state space dimension; we thus use a model order reduction in order to synthesize a controller at the reduced-order level. Two methods are proposed to apply the controller to the full-order system. Off-line and on-line controls are enabled, and the computation of upper bounds of the error induced by the reduction allowed to guarantee the effectiveness of the controller [2].

During an on-line use, one is only supposed to know the output of the system. If just this partial information of the state is known, we cannot directly apply our state-dependent controller synthesis method. An intermediate step must be introduced: the reconstruction of the state, made with the help of an observer: it provides an estimate of the state of the system from the measurements of the output and the input. While theoretical results of convergence of the observer to the state of the system have been obtained under some limited hypotheses [3], we managed to design an observer based control synthesis algorithm, permitting to take an initial reconstruction error into account. The efficiency of the coupling with model order reduction techniques has not been proved yet, but numerical results are encouraging.

The proposed methods are tested on various examples of the literature, including distillation systems, heat control applications, vibration control applications.

References:

[1] L. Fribourg, R. Soulat, Control of Switching Systems by Invariance Analysis: Application to Power Electronics,Wiley-ISTE, 2013

[2] A. Le Coënt, F. de Vusyt, L. Chamoin, C. Rey, L. Fribourg, Guaranteed Control of Switched Control Systems Using Model Order Reduction and State-Space Bisection, Open Access Series in Informatics, 2015

[3] U. Serres, J.-C. Vivalda, P. Riedinger, On the Convergence of Linear Switched Systems, IEEE Transactions on Automatic Control, 2011

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Using the OPC Classic Modelica Library for Model Predictive Control

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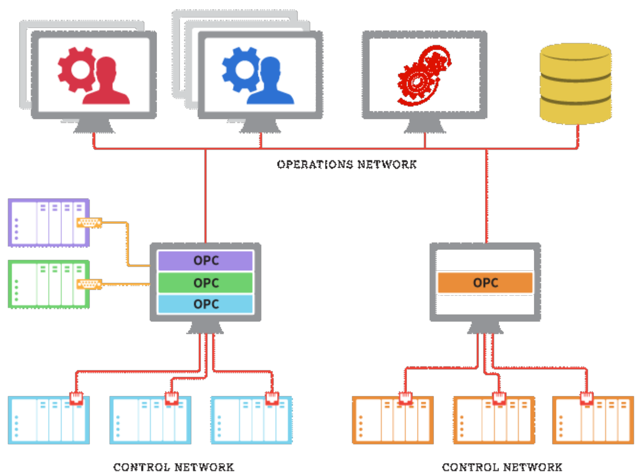
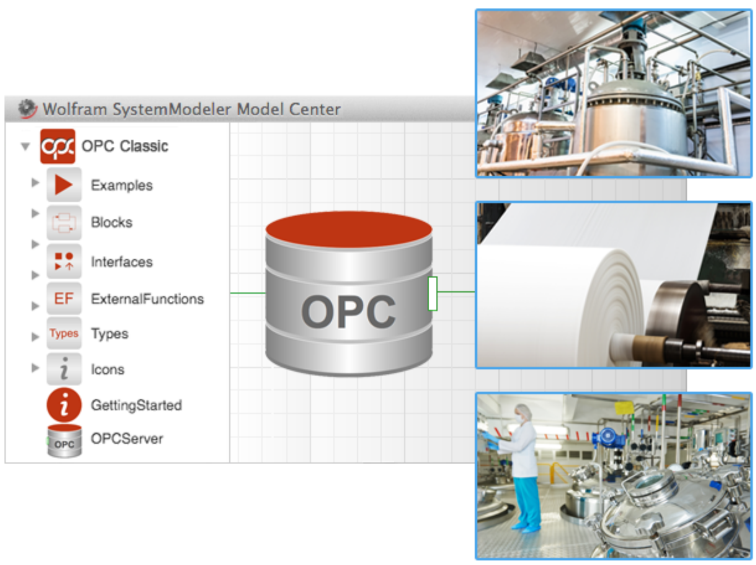
[1]Wolfram Core

The OPC Classic library is a new Modelica library developed by Wolfram Research. The library contains a full set of components for connecting to physical systems using the OPC (Open Platform Communications) Classic standard. OPC is a set of data transfer standards for multi-vendor, multi-platform, secure and reliable interoperability in industrial automation[1], as illustrated in the image below.



The library makes it possible to connect to an OPC server, or in fact as many as you need, in order to connect to your real world process in a variety of industries such as oil and gas, industrial energy, and life sciences.



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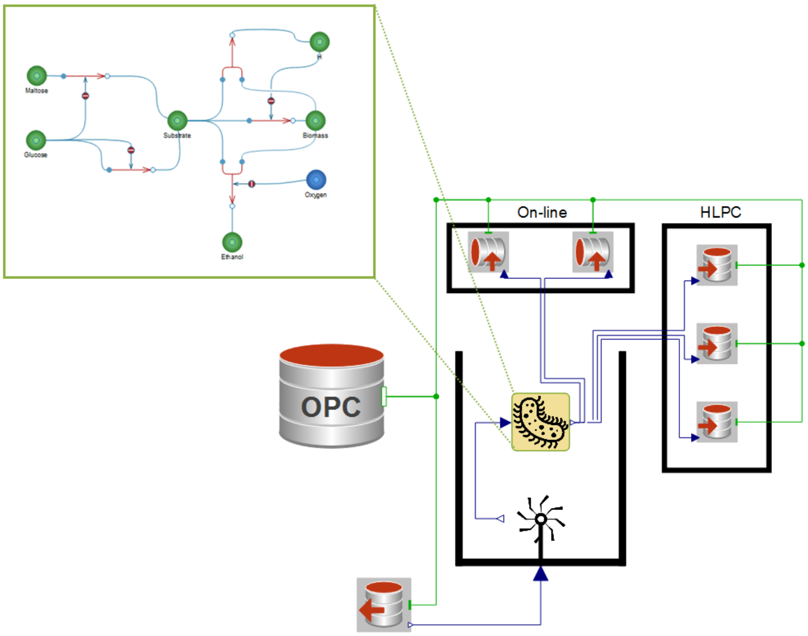
In this presentation we will exemplify the usage of the OPC Classic library by showing how it can be used to optimize the production in a bio ethanol process using model predictive control (MPC). The controller is tested in a simulated environment, where the bio process is modeled with the BioChem library[2], as shown below:



The MPC controller (bottom left) is implemented in the Wolfram Language[3] and controls the amount of oxygen in the batch by adjusting the stirrer speed, while the on-line and HPLC parts communicates with measurement equipment (in this case measurements made in the model). The biochemical model is finally replaced with the real world system.

[1] OPC Foundation, What is OPC? [ONLINE]
Available at: https://opcfoundation.org/about/what-is-opc/ [Accessed 02 October 15].

[2] Wolfram MathCore, BioChem Library. [ONLINE]
Available at: http://www.wolfram.com/system-modeler/libraries/biochem/ [Accessed 02 October 15].

[3] Wolfram Research, Wolfram Language. [ONLINE]
Available at:https://www.wolfram.com/language/ [Accessed 02 October 15].

Multicore Acceleration of System-level Simulation

Salah Eddine SAIDI[1*] Abir BEN KHALED[1] Yves SOREL[2]
Nicolas PERNET[1] Mongi BEN GAID[1]

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In the early stages of complex systems design, engineers integrate different numerical models, often from different modeling platforms, in order to simulate the whole system and estimate its global performances. For such system level-simulation, simulation time becomes more and more a bound, leading to trade-off between model-complexity and accuracy of the system performance estimation. However, most of the time, the different cores of the machine which runs the simulation remains sub-employed.

Moreover, when some parts of the system become available, it is possible to connect these real components to the simulation in a Hardware-in-the-Loop (HiL) approach. In this case, the simulation has to be performed in real-time where models execution consists in periodically reacting to input from the real components and provide numerical output updates. The increase of requirements on the simulation accuracy and its validity domain requires models more complex, leading to forbid to reach real-time execution without using multiprocessor architectures.

The Functional Mock-up Interface (FMI), increasingly common standard, offers new opportunities for distribution of numerical models, by enabling intra model parallelization.

In this talk, we will present our work on multicore acceleration of system simulation, using algorithm to express both granularity and parallelism of a multi model simulation, and heuristics to fit these small-grain operations onto multicore architecture. We will also describe how real-time constraints of an HiL configuration are propagated onto the multi-model simulation in order to run efficient real-time simulation.

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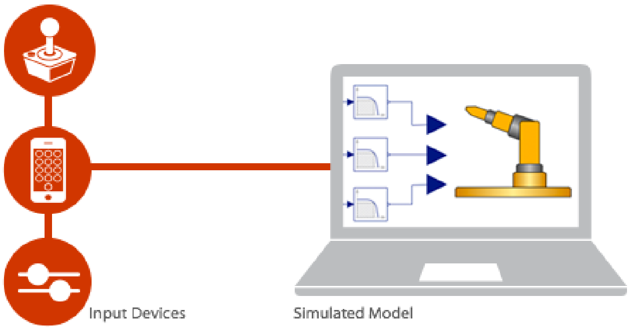
Deployment of Standalone Modelica Models to the Raspberry Pi+Arduino

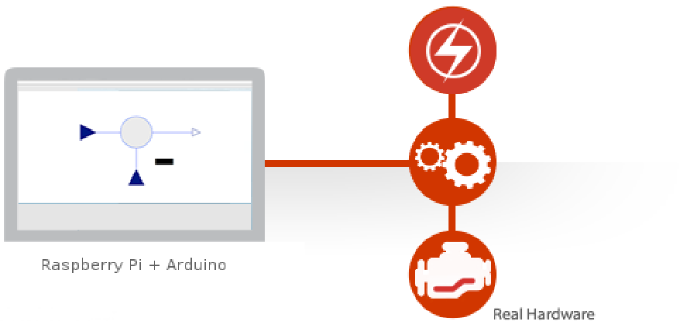
Leonardo LAGUNA RUIZ[1*] Henrik TIDEFELD[1]

[1]Wolfram MathCore

The simulations produced by SystemModeler[1] are executable files that can be run on any compatible platform. This feature allows executing simulations in embedded platforms running a Linux operating system. In combination with the ModelPlug[2] library and Arduino[3] it is possible to make the simulations interact with the real world. For example, reading and writing analog inputs and outputs.



The ModelPlug library allows rapid prototyping of controllers without the need of writing a single line of code, thereby enabling interaction with complex simulation models and easy creation of realistic test scenarios.



This presentation will show how to create simulation models that can be deployed to a Raspberry Pi[4] that uses Arduino as an interface. These models can be used as standalone controllers for Hardware-in-the-loop or Model-in-the-loop simulations.

Links

[1] http://www.wolfram.com/system-modeler

[2] http://www.wolfram.com/system-modeler/libraries/model-plug/

[3] https://www.arduino.cc/

[4] https://www.raspberrypi.org/

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Integrated Optimization in System Models

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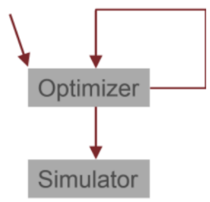
Optimization is required at some point in many or most system applications. Optimization is used for example for parameter identification, feedback control design, open-loop control and filter parameter tuning, in particular for applications in diagnosis and failure detection.

The standard approach to implement such optimization problems uses a master-slave configuration where the optimizer is the master and the simulator is the slave:

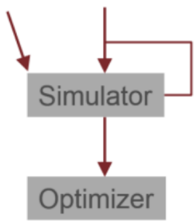


In system modeling tools with supporting scripting environments such as NSP/Scicos (Scilab language), VisSim SIMULATE (HyperMath language) and Matlab/Simulink, the optimizer is usually developed as a script and the function evaluating the cost calls the simulator in batch mode.

In this presentation, we propose an alternative formulation of the optimization problem where the optimization criterion is integrated within the simulation model thus running the simulation alone would perform optimization. With that respect, the model is self-contained. Similar integrated formulations have been considered for Modelica and implementations have been proposed, see for example Optimica. But these implementations require the extensions of the Modelica language and their methodology cannot directly be applied to other modeling and simulation environments.

In our approach, the formulation of the optimization criterion can be done using a regular block. One such block is provided in VisSim SIMULATE block libraries but users may develop their own optimization blocks.

The development of the methodology proposed here uses reverse communication optimization. Reverse communication optimization, well known in the optimization community, is also based on a master-slave configuration but in this case the optimizer is the slave and the simulator is the master:



Thanks to reverse communication, the optimization is integrated within the simulation environment. The implementation details and examples will be presented.

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The Benefits and Challenges of Massive Behavioural Simulation for Cyber-Physical Systems Engineering

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The complexity of large industrial or infrastructure systems such as railways transportation systems, smart electric power grids or commercial aircrafts, and the importance of their societal impacts, call for rigorous engineering approaches. In most cases, such systems combine physical, logical and human aspects, and are said to be "cyber-physical systems".

The proposed presentation first highlights the many activities in the engineering and operation of such systems that could benefit from massive behavioural simulation. They include the elicitation and validation of behavioural requirements, design evaluation and optimisation (e.g., assessment of multiple design variants, use of genetic algorithms), dysfunctional analyses (such as failure modes effects and criticality analyses - FMECA, or system theoretical process analyses - STPA), testing (such as testing against coverage criteria, model-in-the-loop testing, software-in-the-loop testing, hardware-in-the-loop testing, statistical testing), probabilistic analyses (e.g., using Monte Carlo approaches), training, diagnostics, what-if operational aids, etc.

For example, let's consider a very small system made up of 40 components. The components have an average of 10 different failure modes. The FMECA of that system needs to consider the possible failure modes of each component, in different scenarios (system operational conditions, when the failure occurs,...). This could easily result in 10 000 + cases to be analysed. A manual work would be costly, difficult to verify and update, and impossible to reapply to different design alternatives.

The presentation will then list the main stumbling blocks that need to be overcome for massive physical simulation to become practical. This includes:

- The economy of models: we should be able, as far as reasonably achievable, to re-use the same models for different activities.
- Models verification and validation: we should be able to verify that the models we use do represent what we intend.
- Test case generation: we should be able to automatically generate as many test cases as we need, based on a few scenario models.
- Satisfaction of coverage objectives: we should be able to guide the automatic test case generation in order to satisfy the specified coverage objectives.
- Results assessment: we should be able to automatically verify that the outcome of a simulation run is complies with specified requirements.

Lastly, the presentation will propose the practical solutions that have been investigated and developed in the framework of the ITEA2 project MODRIO. They are based on:

- The formal specification of requirements in FORM-L (FOrmal Requirements Modeling Language), a constraints language that allows the specification of WHAT is to be achieved, WHEN in time, WHERE in the system, and HOW WELL (fault tolerance, failure probabilities) this must be acheived. The language also allows the modeling of the assumptions made regarding

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system environment (including human actions), the specification of test scenarios and coverage requirements, and the high-level modeling of designs (where not all design decisions have been taken yet).

- Deterministic, multiphysics or logical modeling, with languages such as MODELICA or SCADE. Multi-mode modelling facilitates the representation of different behaviours for the same system or component (including failure modes).
- A random generator of test cases consistent with the specified assumptions and scenarios (StimuLus, from ArgoSim).

References:

Engineering a Safer World - System Thinking Applied to Safety (Nancy G. Leveson, The MIT Press)

Principles of Object-Oriented Modeling and Simulation with MODELICA (Peter Fritzon, Wiley Inter Science)

MODRIO D2.1.1 - FORM-L, a FOrmal Requirements Modelling Language extending MODELICA for properties modelling (Thuy NGUYEN, EDF R&D)

MODRIO D8.1.1 - The Backup Power Supply (BPS) Case Study (Thuy NGUYEN, EDF R&D)

Modeling for Designing – An Essential Stage

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Designing new technological engineering systems is a more and more complex task. Main difficulties are linked to the system itself (multi physics, multi energy, mixing power and information) and to the constraints to be taken in consideration (energy consumption, safety and reliability, quality, costs, time, industrial strategy...).

Modeling is an essential stage, because it allows the designer to study firstly in the virtual world the new device properties. In the context of virtual prototyping desk, a wide offer of dedicated simulation tools allows the covering of most of the need for domain specialists, but lower is the offer for multi-domain, multi-scale simulation for system engineers.

After analyzing the engineer and researcher needs from the technical point of view, it will be shown the interest of using the bond graph methodology providing the user with models with real physical insight, for all physical domains, with an energetic approach, allowing structural analysis and dynamic study. Several industrial applications will be presented to illustrate the presentation.

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Simport: A Simulink Model Importer for Scicos

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Simport is a comprehensive Simulink import assistant for the Scicos system modeler: it reads a textual representation of a Simulink model (MDL or SLX file format) and generates the corresponding equivalent Scicos model.

Automating the translation of Simulink models, Simport alleviates the migration process from Simulink to Scicos. Furthermore, Simport allows easy embedding of existing Simulink models or part of models into a Scicos development.

Simport supports a large subset of Simulink basic blocks, but exotic blocks from specific Simulink libraries have no Scicos equivalent; in such a case, Simport generates an empty Scicos super block to incorporate the mandatory hand written Simulink block translation.

Based on compilation techniques, Simport is a fast and reliable translator from Simulink models to Scicos or Simulate models.

Simport is distributed with NSP Scicos http://scicos.org/. Simport based professional migration services are available by Sciworks Technologies, see http://sciworkstech.com/.

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SIMULIM, a Platform for the Modeling and Simulation at System Level

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SIMULIM (Simulation, Integration, Modeling at the University of Limoges) is a federating tool that combines the R&D carried out by XLIM researchers. To achieve this, a software forge is aimed at project teams. This tool thus developed will focus on capitalization of the acquired know-how to share it on the widest scale possible.

An integration activity is also proposed through SCERNE project (Simulation de Chaînes d'Emission/Réception Nouvelle gEnération). Scerne is a generalist programmable environment which aims to enable the use of models into multi-domain and heterogeneous system simulators. It provides multi-physics simulations (covering electrical, electromagnetic, thermal and mechanical domains). Through its API, Scerne is open to high level system tools allowing for example the modeling and the optimization of a full telecommunication or Radar RF front-end.

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A Methodology for Best Pathway Identification of Waste Recovery

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Industry has always looked for maximizing on-site synergies using energy and mass integration methods, rather independently. Many studies were conducted to assess the economical feasibility of heating networks based on industrial heat recovery and similarly for water reuse and recycling.

However, considering the component valorization in its original form, corollary implies missing the reuse opportunities of the component in another form. The conversion brings the possibility of turning the non-usable waste into another usable energy or material through chemical processes, and allows its reinsertion in the system. Hence the inclusion of these processes enables exploring new paths for the recovery of waste streams and bridging the gap between the two integration methods.

We introduce a methodology which couples Energy and Mass integration techniques through conversion processes, in the aim of finding the best valorization pathway of waste streams in a local context. In this methodology, the valorization pathways are driven by the local demand leading to the synergies maximization. Indeed modeling the local demand profile will indicate the feasible pathways through identifying the needs. The best pathway will hence be determined through detailed economic evaluation.

The proposed methodology is demonstrated on a case study considering a large industrial site where waste wood valorization is assessed. Since waste wood has multiple valorization pathways by its conversion to energy or to another high added value material, the proposed methodology will serve as a tool for the identification of the best economic valorization solution. Each of these conversion pathways is modeled using Modelica meta language and validated with literature results. In this case study, waste wood valorization through heat and power generation, hydrogen or methane generation is challenged in a multi-objectives optimization. For each possible waste wood conversion system, the obtained superstructure is analyzed through Energy and Mass integration methods for each set of the objectives.

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Modeling Cyber-Physical Systems with 3D Animated Scenarios: a Railway Simulation Case Study

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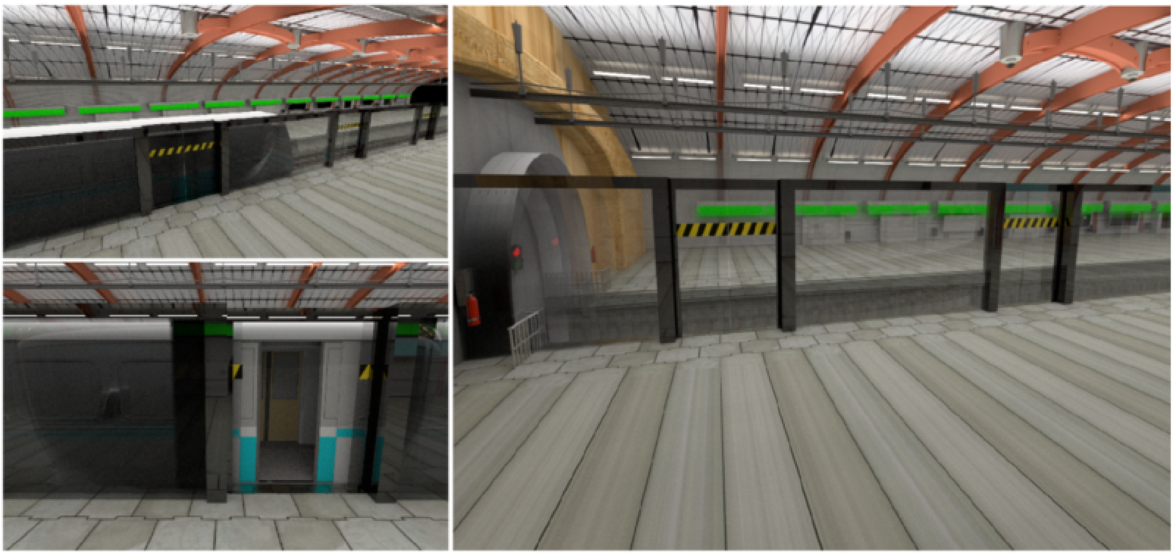
[1]CEA LIST, CEA Saclay - F91191 Gif-sur-Yvette Cedex, France

Systems are becoming more and more complex, modeling all the possible interactions between their heterogeneous components is a challenge that engineers face every day. Improper management of emerging behaviors can lead to catastrophic failures and unexpected conducts. This is the case for Cyber Physical Systems (CPS) which combines computing aspects with a physical aspect which involves electrical and mechanical processes [1].

Contract-based approaches are considered as a promising means to deal with CPS. The contracts, which are specifications on both physical and computational components, help us identify precisely the conditions for a correct interaction.

In this talk, we introduce the bridging between 3D animated scenarios and the contract-based approach to deal with heterogeneous components. We discuss the results by adopting a railway simulation case study. This later is based on 3D animated scenario of the Communication Based Train Control system (CBTC). The high level architecture of the CBTC system contains the Automatic Train Protection (ATP) and Automatic Train Operation (ATO) sub-systems. Over the constructed 3D model we implement a method to verify timing properties specified via contracts expressed in linear temporal logic (LTL). Industrial feedback on the preliminary results is positive and very encouraging.

[1] Benveniste, B. Caillaud, D. N. R. Passerone, J.-B. Raclet, P. R. A. Sangiovanni-Vincentelli, W. D. T. Henzinger, and K. Larsen. Contracts for Systems Design. Research Report, (8147), November 2012.



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Method for Evaluation of Technology Impact on Subsea System Lifetime Costs and Risks

Keld Lund Nielsen[1*] David Benoit[2] Joris Costes[2] Jean-Philippe Saut[2]
Nicolas Vayatis[3] Jean-Michel Ghidaglia[3]

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Subsea systems engineering has come to a situation where costs, time and risks are of major concern. It is proposed to move beyond classical *document-based engineering* and to assess a *model-based engineering* approach. It is inspired by *Lean and Six-Sigma* methodologies.

The *Lean* aspect concerns the overall systems view. It must enable global evaluation of several phases of the subsea plant life, such as: construction and installation, operation and maintenance, scenario analysis for resilience assessment etc.

The *Six Sigma* aspect relates to risk and uncertainty. The idea has been adapted by deploying a Markov-Chain-Monte-Carlo method (MCMC). It permits to assess operational scenarios of test cases.

Our work demonstrates that economics and risks can be explicitly connected to the technical design. It has been obtained by a multi-physics approach. Mainly the Modelica modeling language is deployed.

A case with a FPSO and 40 km tieback is proposed. Two different designs are compared, one with active heating layout and one with hybrid loop design.

The active heating approach is technically very innovative, i.e. risks and uncertainties are relatively high. Conversely, there are interesting features in terms of handling during shut-in cases. The hybrid loop is more conventional. The shut-in simulation shows longer time to recovery of production due to the replacement with diesel, i.e. system characteristics are radically different. The two test-cases are compared in terms of costs and risks.

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