MBSE et Jumeau numérique

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CEA List
MBSE AND DIGITAL TWIN: R&D CHALLENGES FROM THE PERSPECTIVE OF SOFTWARE TOOLS AND METHODS

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Hub Day "Digital Engineering" - JUMEAU NUMERIQUE
DIGITAL TWIN (REMEMBER)

- **Digital twin** = Digital counterpart of the real system
  - Gather information from the real system (to construct)
  - Experiment and evaluate scenarios in the digital twin
  - Apply decisions on the real system

**Digital twin**

- Gather information
- Apply decisions
- Evaluate options and scenarios

**Real system**
DIGITAL TWIN (REMINDER)

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- Not one single view or model
- But a set of (hopefully) consistent views on the real system
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=> MBSE can help!
• MULTIPLE DIMENSIONS OF THE DIGITAL TWIN (AT LEAST 5...)

- Factory
- Ship
MULTIPLE DIMENSIONS OF THE DIGITAL TWIN (AT LEAST 5...)
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- Organic views
  - Components
  - Machines
  - Assembly Lines
  - Factory
  - ... Decks

- Operational views
  - Assembly Processes
  - Sub-Processes
  - Manufacturing
  - Logistics
  - ...
MULTIPLE DIMENSIONS OF THE DIGITAL TWIN (AT LEAST 5...)

- Organic views:
  - Components
  - Machines
  - Assembly Lines
  - Propeller
  - Factory
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- Operational views:
  - ... Sub-Processes
  - Assembly Processes
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- Operational views
  - Deck
  - Sub-Processes
  - Assembly Processes
  - Manufacturing
  - Logistics
  - ... (Continued)

- View points

- Level of details

- Concerns
  - Normative Concern
  - Ecological Concern
  - Economical Concern

- Life cycle

- Development Evolution « Design time »
  - Production Maintenance « Run time »

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- ... (Continued)
MULTIPLE DIMENSIONS OF THE DIGITAL TWIN (AT LEAST 5…)

Level of abstraction

View points

Level of details

Organic views

Operational views

Components

Machines

Assembly Lines

Propeller

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Deck

Sub-Processes

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MULTIPLE DIMENSIONS OF THE DIGITAL TWIN (AT LEAST 5...)

- Level of abstraction
- View points

**Organic views**

**Operational views**

**Need for:**
- Flexibility
  - Easily add new domain specific views
- Software interoperability
  - Integrate new/legacy tools and models
- Consistency
  - Help in keeping « digital continuity »

**Concerns**
- Life cycle
- Development Evolution « Design time »
- Production Maintenance « Run time »
- Development Evolution « Design time »
- Production Maintenance « Run time »

**Systematic**
PAPYRUS IN A NUTSHELL

• Open source Eclipse project:
  • Eclipse Public Licence (EPL)
  • ~40 active developers
  • 15 years of R&D

• Open and flexible modeling platform
  • Based on general purpose modeling languages (UML / SysML)
    • Can be used to model anything (at a high abstraction level)
  • Can be easily customized to fit in specific application domains
    • Graphical representations, vocabulary, methodologies, ...
    • To ease adoption by domain experts (who are not necessarily UML / SysML experts)
  • Highly modular tool architecture
    • Software modules can be easily plugged in (simulation, optimization, visualization, code and doc generation, ...)
    • Can be adapted to fit in (tool) ecosystems of our partners

• R&D focused on Flexibility, Software Interoperability, Executable Modeling

https://www.eclipse.org/papyrus/
A FEW USE CASES (2016/2019)
• **Optimization of manufacturing processes**
  • Process modeling and characterization (cycle times, size of storage zones, etc.)
  • Optimization brick for identification of possible configurations
  • Evaluation / selection of configurations with an external simulation tool (PhiSim)
  • Approach validated on a use case from PSA

• **Similar use case for the naval domain**

• **Solution currently extended to deal with co-activity constraints (assembly lines, naval construction sites)**
ENERGY PRODUCTION GRID OPTIMIZATION THROUGH SYSTEM MODELING & SIMULATION

- Grid system architecture modeling
- Interface with equipment models and simulator
- Global simulation orchestration

Collaboration LIST / LITEN

Cosimulate the heterogeneous models

Model of the energy system

Simulation results
R&D CHALLENGES FOR MBSE APPLIED TO DIGITAL TWINS

- **Software interoperability: Integrate new/legacy tools and models**
  - Standards can help (e.g. BIM)
    - Does not deal with legacy models / tools
    - Needs commitment from tool vendors
  - Investigate on “Interoperability standards” (OSLC, ontologies, etc.)
  - Specific interoperability issues for simulators (co-simulation standards exist, but have limitations)

- **Flexibility: Easily add new domain specific views**
  - Model-driven approaches and tools are getting mature, but...
    - How to make tools actually usable by end users?
    - How to deal with multiple abstraction levels (generic solution for abstraction / refinement issues)?
  - Useful information from the real system is often “unstructured”
    - Could AI techniques assist in digitalization?

- **Consistency:**
  - Ensuring consistency needs to handle software interoperability and flexibility issues...
  - An interesting tool/conceptual framework: the CAESAR project (initiated at JPL, CEA getting involved)
    - Relies on modeling and semantic web standards and techniques
    - Multi tool / multi users (infrastructure for consistency management)
    - But does not deal with heterogeneous level of abstractions
    - Only deals with « design time » data and models
PAPYRUS FOR THE FUNCTIONAL DIGITAL TWIN

- Predictive maintenance
- Continuous certification
- Requirement engineering and validation
- Logistics / Supply chain
- Process modeling, simulation and optimization
- Digitalization of factory equipments
- Flexibility
- Interoperability
- Consistency
- Current use cases
- Ongoing / Future use cases
### TOOLS BASED ON PAPYRUS

- SCADE 2012
- Safety analysis 2016
- System engineering 2017

### SYSTEMS IMPLEMENTED WITH PAPYRUS

- Telecom network archi.
- Instr. & control design in fuel tank
- Defense & avionics engineering
- Robot safety analysis
- Onboard control SW
- Robot control design
- Satelite control SW

https://www.eclipse.org/papyrus/testimonials.html