Engineering support for the design-operation continuum

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Efficient design and operation

- continuously evolving which softens the traditional separation between the engineering/design phases and the operational stages
- high degree of heterogeneity and partial autonomy requires new, fully integrated approaches for their design, validation, and operation
- highly flexible and thus subject to frequent, dynamic reconfiguration, which must be supported by design support tools
- failures, abnormal states, unexpected/emerging behaviours are the norm
- socio-technical systems: machines and humans interact closely

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Old-Classic</th>
<th>New-SoS</th>
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</thead>
<tbody>
<tr>
<td>Scope of System</td>
<td>Fixed (known)</td>
<td>Not known</td>
</tr>
<tr>
<td>Specification</td>
<td>Fixed</td>
<td>Changing</td>
</tr>
<tr>
<td>Control</td>
<td>Central</td>
<td>Distributed</td>
</tr>
<tr>
<td>Evolution</td>
<td>Version controlled</td>
<td>Uncoordinated</td>
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<tr>
<td>Testing</td>
<td>Test phases</td>
<td>Continuous</td>
</tr>
<tr>
<td>Technology</td>
<td>Given and fixed</td>
<td>Uncertain</td>
</tr>
<tr>
<td>System development</td>
<td>Process model</td>
<td>?????</td>
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Research topics

1. Integrated engineering of CPSoS over their full life-cycle

2. Modelling, simulation, and optimization of CPSoS

3. Establishing system-wide and key properties of CPSoS
Challenges:

- separation between design phases and operational stage is disappearing
- asynchronous lifecycles of constituent parts
- components are developed independently / insufficient information
1. Research and innovation needs

- engineering frameworks for specification, adaptation, evolution, and maintenance of requirements, structural and behavioural models, and realizations not only during design, but over their complete life cycle

- engineering frameworks supporting integrated cross-layer design

- model-based analysis to detect design errors and for risk management
1. Research and innovation needs

- collaborative engineering and runtime environments
- open, easy-to-test interfaces and platforms for integration
- semantic integration
- tools to demonstrate industrial business cases
Challenges:

- high cost for building and maintaining models
- modelling of human users and operators
- simulation and analysis of stochastic behaviour
- models for validation and verification purposes
2. Research and innovation needs

- software tools for model management and for the integration of models from different domains
- efficient simulation algorithms for system-wide simulation of large heterogeneous CPSoS, including dynamic on-the-fly reconfiguration
- high-level modelling and simulation for performance and risk analysis
- collaborative environments for competing companies
- integration of legacy system simulations as well as open approaches for tight and efficient integration and consolidation of data, models, and engineering tools
Challenge:

- establishment, validation, and verification of key properties of CPSoS
3. Research and innovation needs

- new approaches for dynamic requirements management during the continuous evolution of a CPSoS, ensuring correctness by design during its evolution, and for verification especially on the SoS level
- new algorithms and tools to enable the automatic analysis of complete, large-scale, dynamically varying and evolving CPSoS
- formal languages and verification techniques for heterogeneous distributed hybrid systems including communication systems
- theory for successive refinement and abstraction of continuous and discrete systems so that validation and verification at different levels of abstraction are correlated
- joint use of assume-guarantee reasoning and simulation-based (Monte Carlo) and exhaustive (model checking) verification techniques