Causes of Complexity in Cyber-Physical Systems

Foundations for Industry 4.0

Hans Vangheluwe and Joachim Denil
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Universiteit Antwerpen
Industry 4.0

IoT
Additive Manufacturing
Big Data
CPS
Cyber-Physical Systems (CPS) are engineered systems where functionality and salient characteristics emerge from the networked interaction of computational and physical components. 

Term coined around 2006 and tended by “instigators”: Gill, Kumar, Lee, Midkiff, Mok, Rajkumar, Sastry, Sha, Shin, Stankovic, Sztipanovits.
Based on the recognition that convergence in engineered systems is deeper than an interdisciplinary approach would enable.
CPS is engineering (but foundations of), not science: medicine, biology, physics, ...

Beyond:
- embedded systems
- mechatronics
- control theory
- networks
- systems of systems

potential:
- deal with complexity
- radically new designs (DSE)
Example CPS: Networked car
CONFERENCES

The CPSWeek brings together four leading conferences - HSCC, ICCPS, IPSN, RTAS - as well as several workshops and tutorials on various aspects on the research and development of cyber-physical systems: Embedded Systems, Hybrid Systems, Real-Time and Sensor Networks. All CPSWeek workshops are scheduled on April 13th, 2015.

HSCC - 18th ACM International Conference on Hybrid Systems: Computation and Control
ICCPS - 6th ACM/IEEE International Conference on Cyber-Physical Systems
IPSN - 14th ACM/IEEE International Conference on Information Processing in Sensor Networks
RTAS - 21th IEEE Real-Time and Embedded Technology and Applications Symposium

WORKSHOPS

1. Big Data Analytics in CPS: Enabling The Move from IoT to Real-Time Control
2. Second International Workshop on the Swarm at the Edge of the Cloud
3. Second International Workshop on Robotic Sensor Networks
4. 6th Workshop on Medical Cyber-Physical Systems (MedicalCPS)
5. 10th International Workshop on Feedback Computing
6. IEEE workshop on Modeling and Simulation of Cyber-Physical Energy Systems
7. 7th Workshop on AdaPlive and Reconfigurable Embedded Systems
8. 1st Workshop on Cyber-Physical Systems for Smart Water Networks (CySWater)
9. 8th International Workshop on Numerical Software Verification (NSV-VIII)
10. 2nd International Workshop on Applied veRification for Continuous and Hybrid Systems (ARCH)
CAUSES OF COMPLEXITY
Heterogeneity

Boeing 747 Cutaway (source: flightglobal.com)
Universiteit Antwerpen

VATSIM air traffic control simulation (source: wikipedia.org)
Emergent Behavior

Vijay Kumar, Robots that fly and cooperates (source: ted.com)
SOME SOLUTIONS...
Dealing with Complexity

Model Everything Explicitly...

For Design and Analysis

Using the Most Appropriate Formalism(s)

At the Most Appropriate Level(s) of Abstraction

=> Minimize Accidental Complexity, Only Essential Complexity Remains...

Model Everything Explicitly for...

Documentation and Communication

Memorization

Inference and Reasoning

Formal Verification  Model Checking  Simulation

Synthesis
Reduce Cognitive Gap...


Rule-Based Model Transformation

Tool Support…

For Debugging…

And Verification…


Process Modelling

What does this mean?

Languages need semantics!

Composition also needs semantics!

Bart Meyers, Joachim Denil, Frédéric Boulanger, Cécile Hardebolle, Christophe Jacquet, Hans Vangheluwe: A DSL for Explicit Semantic Adaptation. MPM@MoDELS 2013: 47-56

<table>
<thead>
<tr>
<th>Our Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Validation, Verification, Testing and Accreditation</strong></td>
</tr>
<tr>
<td>Analysis and Verification of Model Transformations, Debugging, Instrumentation, Tracing, etc.</td>
</tr>
<tr>
<td><strong>Language Engineering</strong></td>
</tr>
<tr>
<td>Domain-Specific Languages, Model Transformation, (web-based) Visual and Textual Modelling Environments, etc.</td>
</tr>
<tr>
<td><strong>Simulation &amp; Reasoning</strong></td>
</tr>
<tr>
<td>Co-Simulation, Discrete-event, DEVS, continuous time, acausal, Modelica, etc.</td>
</tr>
<tr>
<td><strong>Deployment &amp; Resource-optimized Execution</strong></td>
</tr>
<tr>
<td>Platforms (e.g. AUTOSAR, CAN, etc.), Design-Space Exploration, Virtualization, Models@run-time, Efficient execution of model transformations, etc.</td>
</tr>
<tr>
<td><strong>Model Management &amp; Process</strong></td>
</tr>
<tr>
<td>FTG+PM, Safety (ISO 26262, Railway, etc.), Agile Modelling, Consistency management, Experimental frames, etc.</td>
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