Modeling for Smart Cyber-Physical Systems
Application to Farming Systems

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Complex Software-Intensive Systems

- Multi-engineering approach
- Some forms of domain-specific modeling
- Software as integration layer
- Openness and dynamicity
Multiple concerns, stakeholders, tools and methods

- Aerodynamics
- Avionics
- Mechanical Structure
- Airlines
- Human-Machine Interaction
- Environmental Impact
- Safety Regulations
- Propulsion System
- Communications
- Navigation
- Authorities
Heterogeneous Modeling
Model-Driven Engineering (MDE)

Distribution

Fault tolerance

Security

Functional behavior

Use case

Platform Model

Change one Aspect and Automatically Re-Weave: From Software Product Lines... to Dynamically Adaptive Systems

Code Model

Design Model

"Perhaps surprisingly, the majority of MDE examples in our study followed domain-specific modeling paradigms"

• software design models for functional and non-functional properties
To Cyber-Physical Systems

• multi-engineering design models for global system properties

• runtime models (i.e., included into the control loop) for dynamic adaptations
To **Smart Cyber-Physical Systems**

- **analysis models** (incl. large-scale simulation, constraint solver) of the surrounding context related to global phenomena (e.g. physical laws)

- **probabilistic models** (predictive techniques from AI, machine learning, SBSE)

- **user models** (incl., general public/community preferences) and **regulations** (incl., economic/social/political laws)

Not a solution to an isolated problem as Doug said
To Smart Cyber-Physical Systems

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An MDE-Based Approach for **Data Integration** and **Socio-Technical Coordination** in Smart CPS Development
A MDE-based approach to develop Smart CPS

• Convergence of engineering and scientific models

• A modeling framework to support the integration of data from sensors, open data, laws/regulation, scientific models, engineering models and preferences.

• Domain-specific languages for socio-technical coordination
  • to engage engineers, scientist, decision makers, communities and general public
  • to integrate analysis/probabilistic/user models into the control loop of smart CPS

Using MDE in Smart-CPS Development

• Cyber-Physical Systems
Using MDE in Smart-CPS Development

- Based on informed decisions
  - with environmental, social and economic laws
  - with open data
Using MDE in Smart-CPS Development

- Providing a **broader engagement**
  - with "what-if" scenarios for general public and policy makers
Using MDE in Smart-CPS Development

- Supporting **automatic adaptation**
- for dynamically adaptable systems
Using MDE in Smart-CPS Development

- Application to health, farming system, smart grid…

![Diagram showing the relationship between System Models, Simulation Tool, and Sustainability System.]

- MEEs ("what-if" scenarios)
- Heuristics-Laws
- Open Data
- Energy Production/Consumption System
- Context
- Software
- Simulation Tool (incl. constraint solver, prediction tool, etc.)

- Policy Makers
- Engineers
- General Public
- Scientists

- Physical Laws (economic, environmental, social)

- Sustainability System (e.g., smart grid)

- Simulation Tool

Farming System Modeling

Farming System Modeling

Farming System Modeling


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**Heuristics**

- Laws
- Scientists
- Open Data
- Engineers
- General Public
- Policy Makers

**MEEs**

- "what-if" scenarios

**System Models**

- Physical Laws
- Simulation Tool (incl. constraint solver, prediction tool, etc.)

**Sustainability System**

- e.g., smart grid

**Context**

- sensors
- actuators

**Energy Production/Consumption System**

**Software**

- in collaboration with INRA

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**Irrigation System**

- water to be irrigated

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**Farmers**

Agronomist in collaboration with climate series

Vegetal and animal lifecycle

farm definition

activity description

hydric stress

biomass growth, water consumption, and activity schedule

water to be irrigated

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Farming System Modeling

- Heterogeneous modeling and simulation
- Graphical animation and debugging (incl. breakpoints, timeline, step forward/backward, stimuli management, etc.)
- Multi-dimensional and efficient trace management
- Concurrency simulation and formal analysis

https://github.com/gemoc/farmingmodeling
Globalization of Modeling Languages

Challenge:

- DSMLs are developed in an independent manner to meet the specific needs of domain experts,
- DSMLs should also have an associated framework that regulates interactions needed to support collaboration and work coordination across different system domains.

Globalization of Modeling Languages

Supporting *coordinated use of modeling languages* leads to what we call the *globalization of modeling languages*, that is, the use of multiple modeling languages to support the *socio-technical coordination* required in systems and software engineering.

Globalization of Modeling Language

- Context: new emerging DSML in open world
  ⇒ impossible \textit{a priori} unification
  ⇒ require \textit{a posteriori} globalization

- Objective: socio-technical coordination to support interactions across different system aspects
  ⇒ Language-based support for technical integration of multiples domains
  ⇒ Language-based support for social translucence

Open Challenges (just of few!)

- Diversity/complexity of DSL relationships
  - far beyond structural and behavioral alignment, refinement, decomposition
  - Separation of concerns vs. Zoom-in/Zoom-out

- Live and collaborative modeling
  - minimize the round trip between the DSL specification, the model, and its application (interpretation/compilation), and support personalization (views, properties...)
  - *Model experiencing environnements*

- Integration of analysis and probabilistic models into DSL semantics
"If you believe that language design can significantly affect the quality of software systems, then it should follow that language design can also affect the quality of energy systems. And if the quality of such energy systems will, in turn, affect the livability of our planet, then it’s critical that the language development community give modeling languages the attention they deserve."

– Bret Victor (Nov., 2015), [http://worrydream.com/ClimateChange](http://worrydream.com/ClimateChange)