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Co-Simulation of Automation Systems in the Internet-of-Things

State-of-the-Art and Approaches

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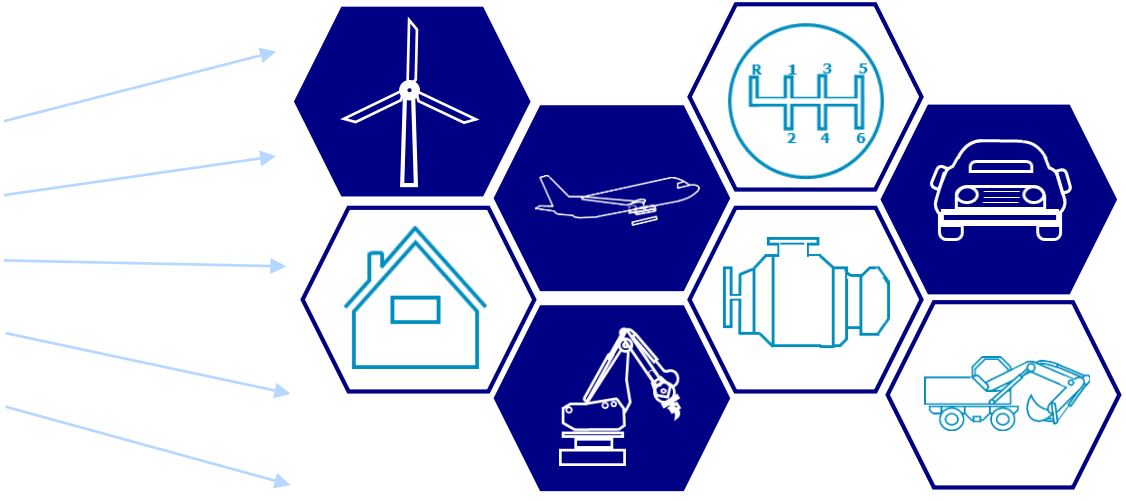
Contents

- Vision and Potential of Co-Simulation
- State-of-the-Art and our Research approach
- Hurdles and future Challenges

Simulation: Bringing a connected Reality into the Digital Space

Digital technologies are revolutionizing value chains, organizational structures and creating new technical Features in almost all industries.

[1] Source: Siemens AG, Pictures of the Future



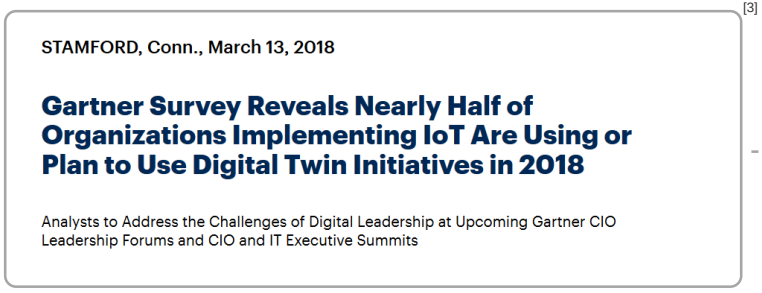
Co-Simulation in the Internet-of-Things change the way how systems work

Digital Twins are a virtual representation of the physical system which can be scattered

[2]

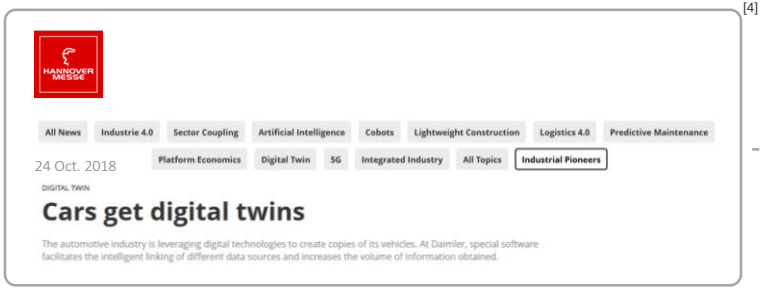
*"**High efficiency and zero defect quality control** in automated manufacturing"*

[3]



*Gardner Prognosis: „In 2020 about 2/3 of the companies with IoT-projects are going to have a **Digital Twin in operation**"*

[4]



*"Daimler is working on a **'Data Layer'** project with the goal of creating digital twins **of every delivered vehicle**"*

Value Add of Co-Simulation based on Digital Twins

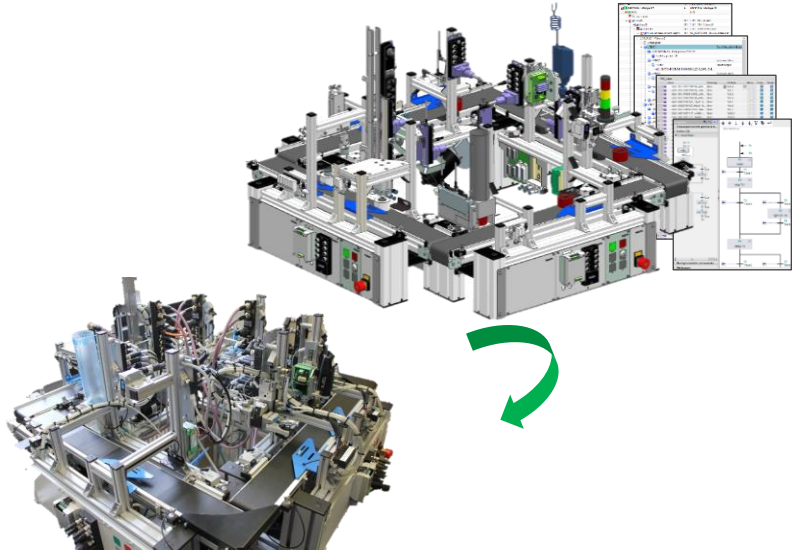
In future, various simulations will utilize In Design time and run in parallel to a real system in operation

During Engineering and Design:

- prevent design errors and serious defects
- improves safety and usability
- speeds up market launch

During Operation:

- prevent down times
- Gain productivity by optimization
- Quality control



Digital Twins: *co-simulated models to cover various aspects*

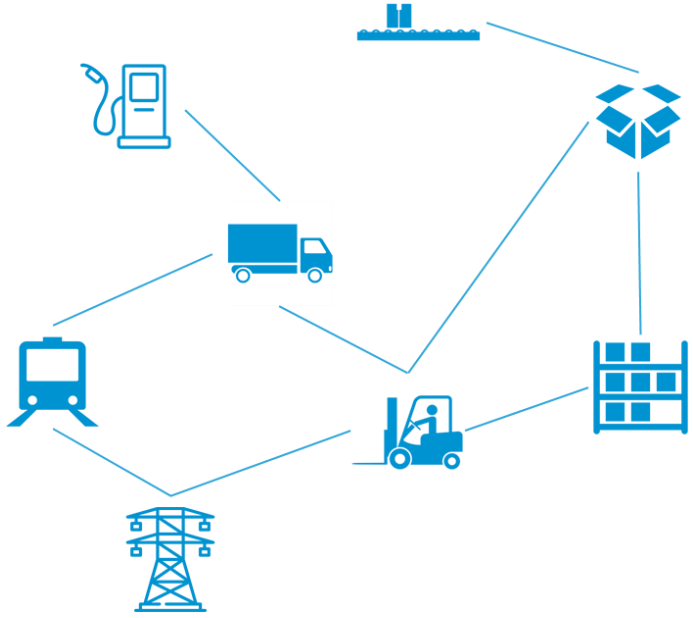
For Instance: a Logistics Network with connected Subsystems

Co-Simulation aggregates all networked data and thus enables analysis of the entire system during operation

- A joint simulation of all individual subsystems is useful for prognosis
- Companies need to deploy various simulation tools to cover them all

A joint (co-)simulation, needs to cope with systems which are

- in a ***different location*** (special distributed / decentral) and
- from ***different vendors*** (heterogynous IT)



Internet-of-things systems are organized in a decentralized way, consisting of components such as transport systems, loading facilities and warehouses

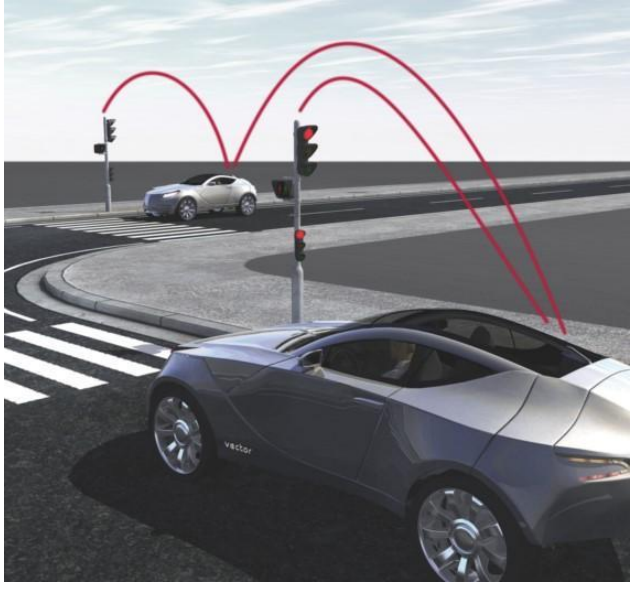
For Instance: Automated Driving of Connected Cars

Co-simulation support decision making of Autonomous Systems which act in a dynamic (i.e. changing) environment.

- More and more artificial intelligence is used to enable autonomous behavior
- 5G enable seamless connections during runtime, like Car2X

A joint (co-)simulation need to incooperate

- ***Autonomy*** of decision making
- ***Dynamics*** of participants, i.e. changing participants



[5] Vector Informatik GmbH

Tasks are solved cooperatively by autonomously interconnecting systems which join and leave a simulation

Co-Simulation Approaches

Different concepts can be used in various domains for the purposes of simulation.

High Level Architecture

Federating (combat) simulation

IEEE standard for distributed simulation and co-simulation developed by the US Department of Defense mainly for flight simulation.

[6]

IT Middleware and Architectures

IT to interconnect multiple (Co-)Simulation

OSGi: Java object communication framework for coupling software during runtime.

OPC UA is a service-oriented architecture mainly used for industrial automation.

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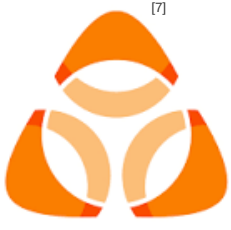

[7]

[8]

Functional Mock-up Interface

A tool independent standard to support co-simulation and model exchange, mainly used in the automobile design and manufacturing sector.

- Improves the exchange of simulation models between suppliers and OEMs, deployed world-wide
- FMI is ***supported by over 100 tools***, such as MATLAB Simulink, OpenModelica, CANoe
- Is based on XML and C-Headers

However, dedicated to “offline” simulation, i.e. ***no simulation can be integrated during runtime***

[9] https://fmi-standard.org/

Research approach: Software-Agents build a Co-Simulation-Framework

A „Plug-and-Simulate“ Framework for co-simulation during runtime is under research, in which simulation can be added during runtime.

Dynamic integration while in operation

Agents ***encapsulate simulation tools*** and enable them to be integrated into a Co-Simulation during runtime.

All other Co-Simulation can run and do not have to be paused or stopped, but need to give up their lead.

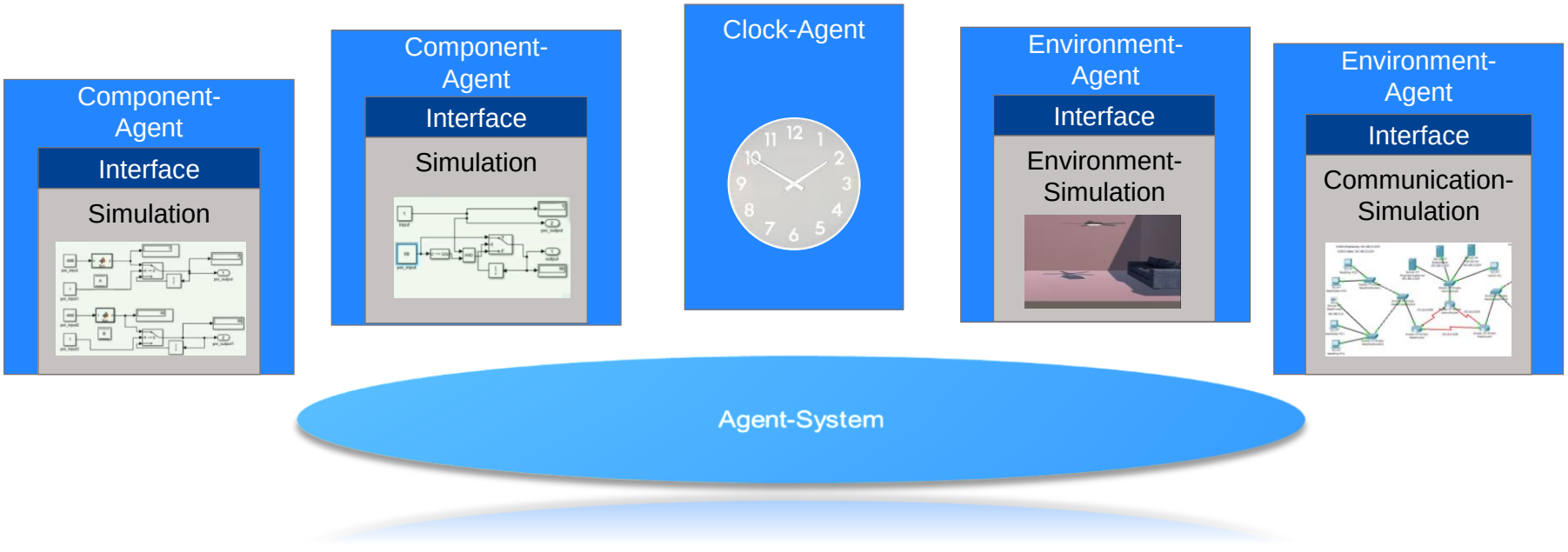
Smooth “plug-in” despite heterogeneous interfaces

An agent-wrapper encapsulates simulation tools, i.e. all ***tools with open interfaces can be used*** for Co-Simulation.

Tools do not have to obey a specific Co-Simulation-Framework.

Agent-based Co-Simulation based on an Open IT-Architecture

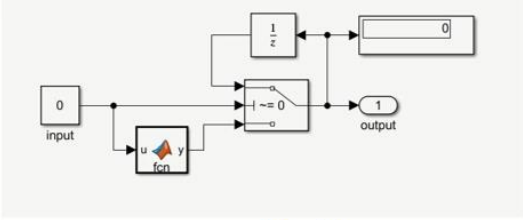
Simulations are coupled and synchronized by Software-Agents to enable „Plug-and-Simulate“.

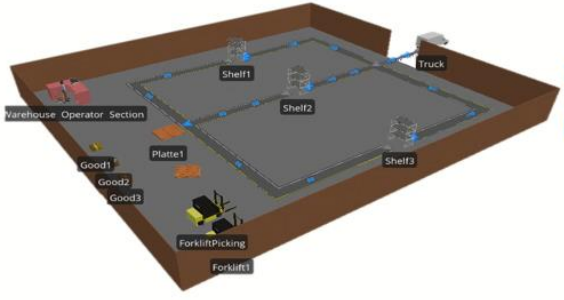


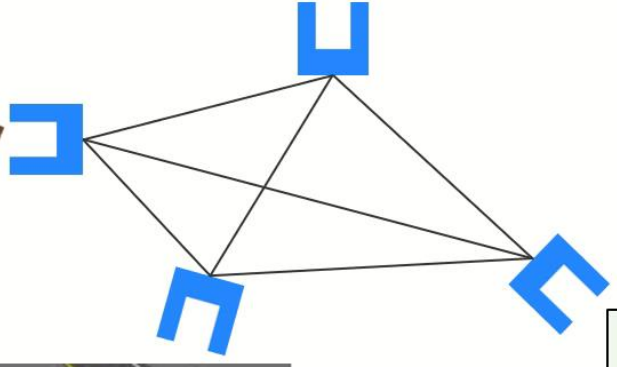
- Agent-system provides an IT-Architecture, by which the data exchange between the Co-Simulation-participants is enabled.
- Synchronization of the Co-Simulation-participants is also enabled by this Architecture.

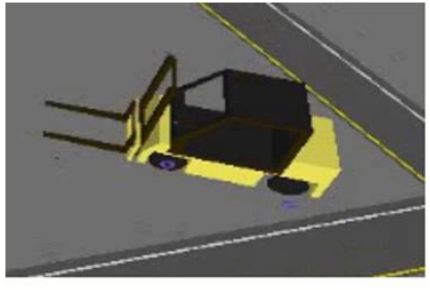
Example: Co-Simulation of a Smart Warehouse

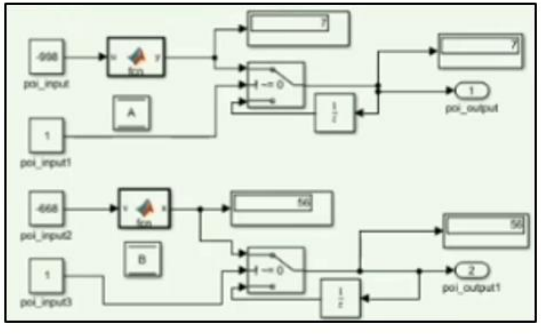
The Framework connects MATLAB and Unity models during runtime simulating a warehouse scenario.











Future Scenarios of Co-Simulation

More than 200 experts from the manufacturing domain share our assessment of co-simulation.

Experts were ask by TU Dresden [10] and claim:

- The future engineering is to a ***high degree integrated*** and simulation is an important basis.
- During the operation the virtual factory ***runs parallel to continuously optimize*** it.
- System integrators indicate a strong need for ***process models, simulation libraries, modeling standards and open interfaces***.

However,

Motivation (business model) for open interfaces and control of the lead (simulation flow) is required.

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Thank you!

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