Roboterkontrollarchitekturen

horizontale und vertikale Komposition

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RobMoSys - Composable Models and Software for Robotics Systems

www.robmosys.eu

01.01.2017 – 31.12.2020, EU H2020-ICT-2016

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732410.

SeRoNet – Eine Plattform zur arbeitsteiligen Entwicklung von Serviceroboter-Lösungen

www.seronet-projekt.de

01.03.2017 – 28.02.2021, BMWi – Technologieprogramm „PAiCE“

Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

LogiRob - Multi-Robot-Transportsystem im mit Menschen geteilten Arbeitsraum

http://www.softwaresysteme.pt-dlr.de/media/content/Infoblatt_LogiRob.pdf

01.06.2016 – 31.05.2019, BMBF KMU innovativ

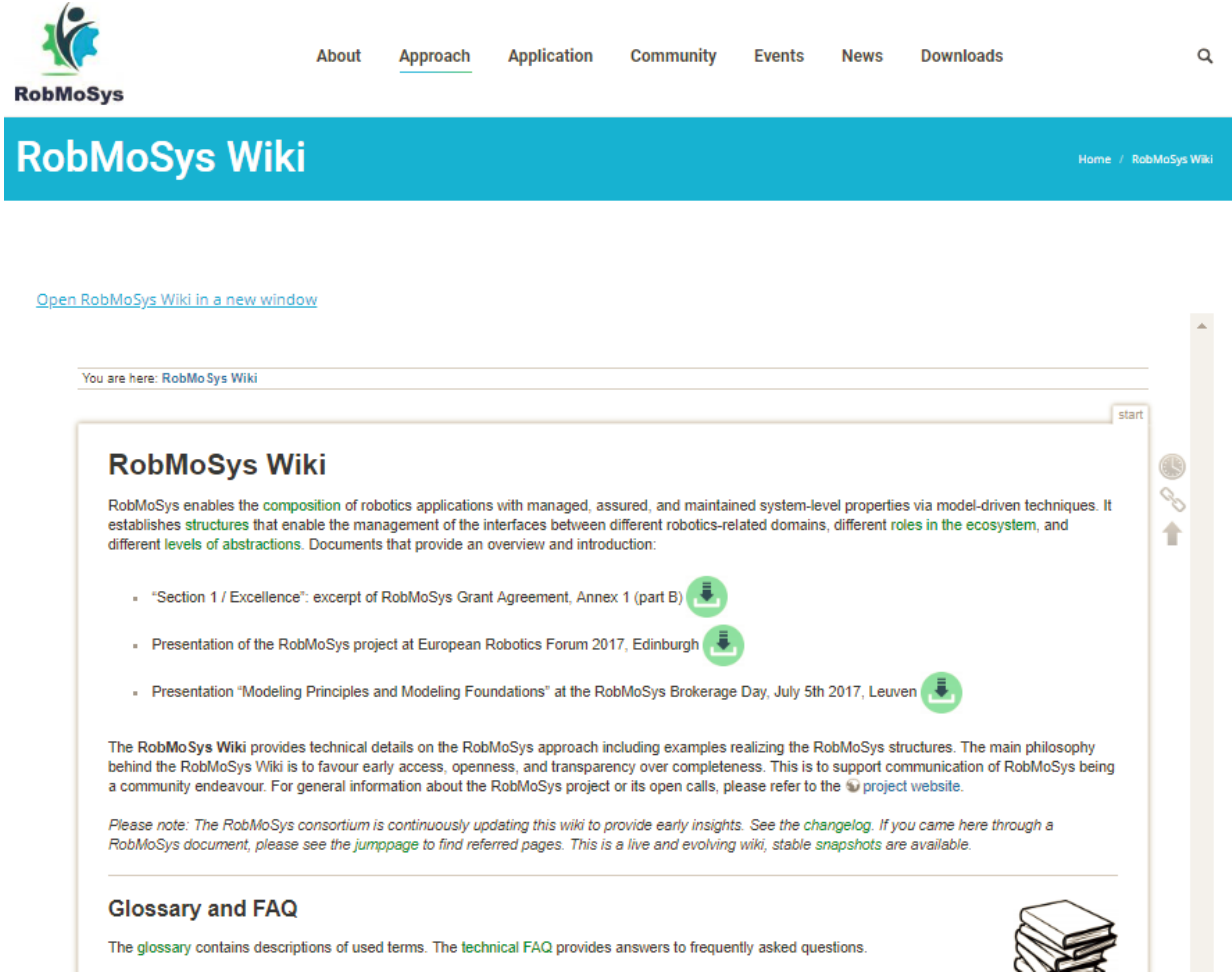
Bundesministerium für Bildung und Forschung

ZAFH Intralogistik - Kollaborative Systeme zur Flexibilisierung der Intralogistik

http://zafh-intralogistik.de/

01.03.2017 – 28.02.2020, Land Baden-Württemberg und EU EFRE

https://robmosys.eu/
https://robmosys.eu/wiki/



Robotics and Digitization

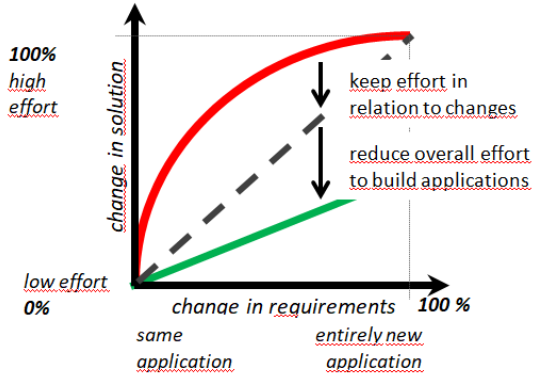
„Build multi-purpose robots“

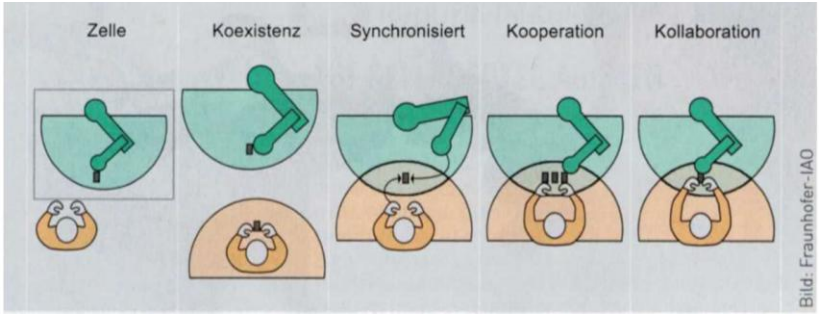
- *One of the big fat lies in robotics is that robots are flexible. We adapt the process to the robot, not the robot to the process*
- *Improved software and better modular robotics solutions, where robots could be arranged and re-arranged and tailored to the process each day, would dramatically improve customization*

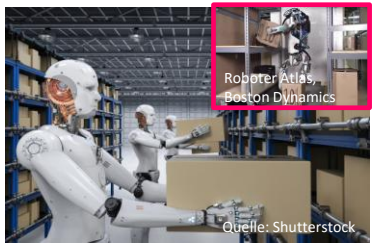
„Build robots that can be simply deployed“

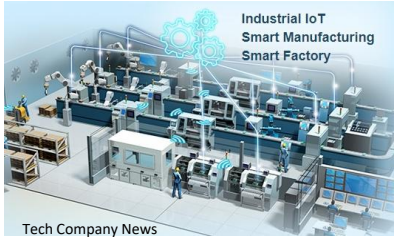
- *It takes time to deploy robots. Sometimes you can spend four to five times the cost of the robot, just integrating it into your system. For maybe 80% of those applications, deployment should be something as simple as downloading an app on your smartphone.*
- *We need to be able to make it so you can effectively plug and play and deploy that robot very quickly. Not only do we want to be able to deploy quickly, we want to make it easy to re-deploy.*

Prof. Howie Choset, CMU, 04.09.2017,, https://www.ri.cmu.edu/5-ways-to-advance-robotics-in-manufacturing/









Composition in Robotics

Freedom of Choice

- Not a universal positive
- High price to pay since there is **no guidance** with respect to ensuring composability and system level conformance

Freedom from Choice

- Not a universal negative
- Structures that **ensure composability** restrict freedom of choice to achieve system level conformance

- Structures enable collaboration: **organization by structure** rather than by “management”
- Structure and t**ooling** go hand-in-hand
- Tooling enables **access** to structures to benefit from them

Which patterns and structures form the *Sweet Spot* between *Freedom of Choice* and *Freedom from Choice*?

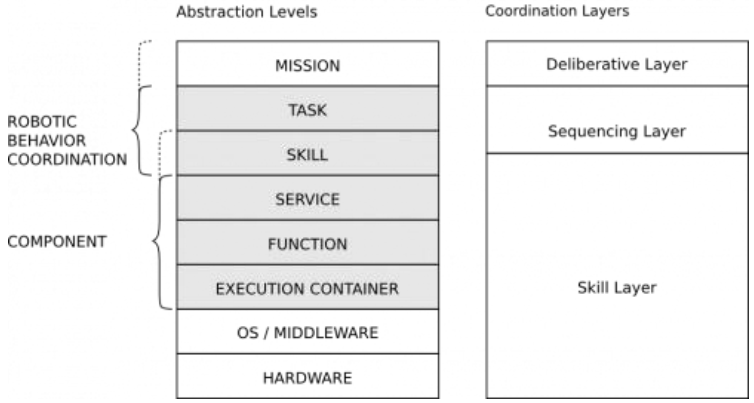
Guidance for separation of concerns by superordinate objectives like the need for separation of roles and the need for composition

Support as much freedom as possible while still ensuring composability despite separation of roles

computation
communication
coordination
configuration

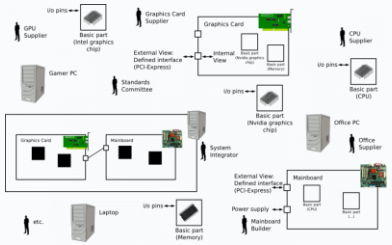
achieve separation of roles
support composition

Composition in Robotics



- All can be ***blocks*** with hierarchy (containment, collection).
- Blocks define structure where ***ports*** link inner parts of a block with the outer view on the block.
- Ports are linked via ***connectors***.
- Blocks come with ***data sheets***

- building blocks with data sheets (outer view on block)
- different stakeholders in different roles
- composition instead of integration

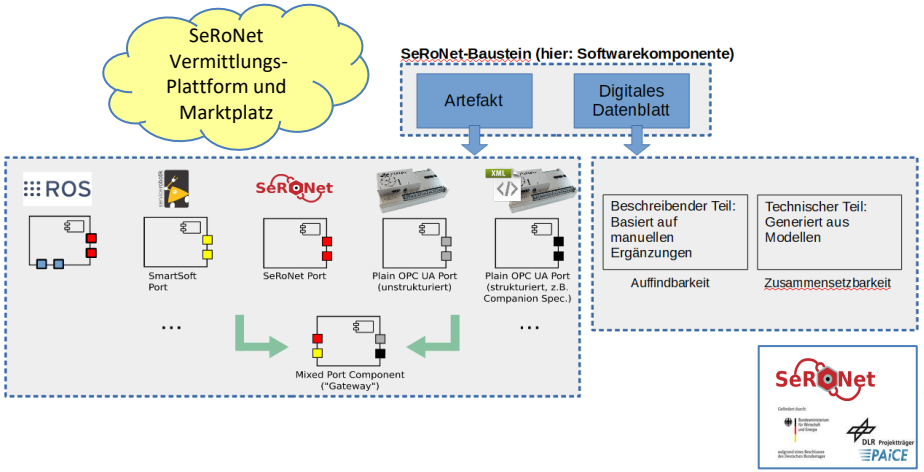


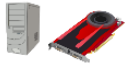
- Composition is about the **management** of the **interfaces** between different **roles** (participants in an ecosystem) in an efficient and systematic way.
- Composition is about guiding the roles via **superordinate composition-structures**.
- Composition is about explicating and managing **properties**.
- Composition is about the right **levels of abstraction and views** for roles.

- **composability** is the ability to combine and recombine as-is building blocks into different systems for different purposes. It requires that properties of sub-systems are invariant („remain satisfied“) under composition.
- **splittability** is the „inverse“ relationship of composability.
- compositionality requires that the behavior of a system is predictable from its sub-systems and that of the composition „glue“.
- **system composition (activity):** the activity of putting together a set of existing building blocks to match system needs with a focus on flexible (re-)combination.
- **system integration (activity)**: the activity that requires effort to combine components, requiring modifications or additional actions to make them work with others.

Composition in Robotics

RobMoSys - Composable Models and Software for Robotics Systems



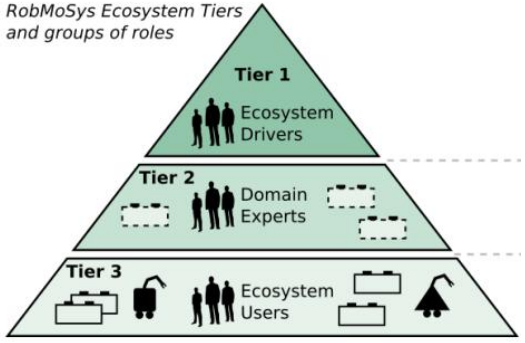


Examples of the PC Analogy

e.g. Semiconductor standards, architecture, USB, PCIe, mode ethernet, etc.

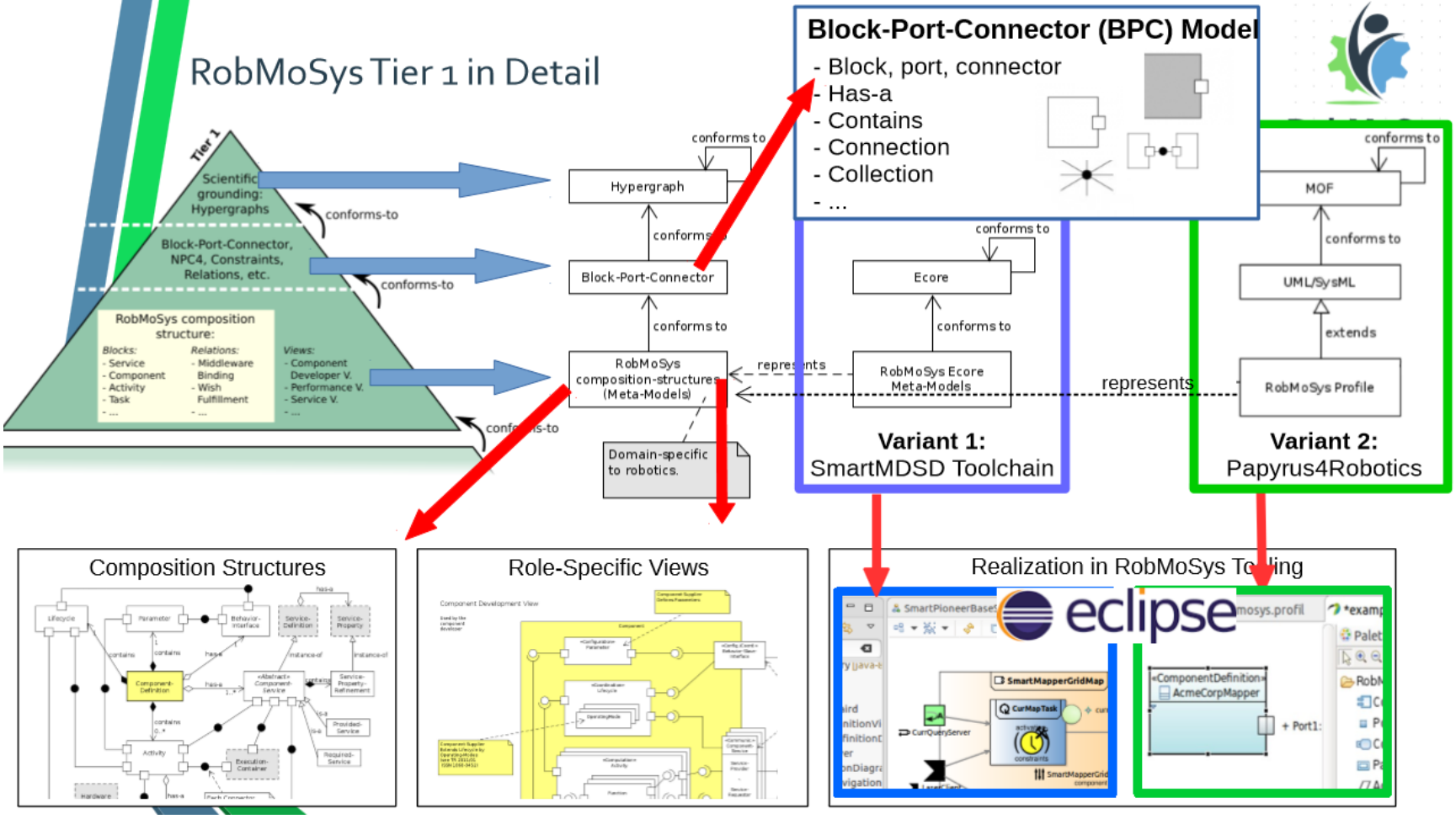
e.g. laptop PC, desktop PC, inc ATX, ITX, Mini-ITX, VGA, HDM CPU socket, GPU socket, USB storage, etc.

e.g. graphics card, CPU, TPM, Memory, power supply, USB SSD Hard disc, USB stick, etc.



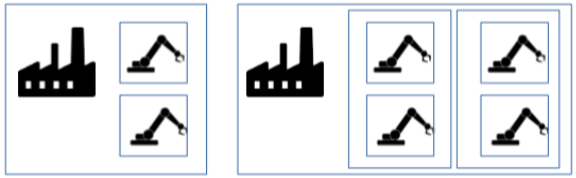
Tier Elements	In terms of modeling	RobMoSys	OPC UA World
Composition Structure	meta-meta-model	e.g. service-oriented software component model, robotics task models, communication patterns	OPC UA *Standard* — e.g. information models, variables, methods
conforms to			
Domain-Models	meta-model	e.g. vision, flexible navigation stack, motion-perception-world model stack, manipulation.	OPC UA *Companion Specifications* — e.g. vision, robotics, devices, kitchen equipment
conforms to			
Content for Exchange	model	e.g. vision, flexible navigation stack, motion-perception-world model stack, manipulation.	OPC UA *Building Blocks and Systems* (Clients/Servers) — e.g. SPS, coffee machine, sensors, robots

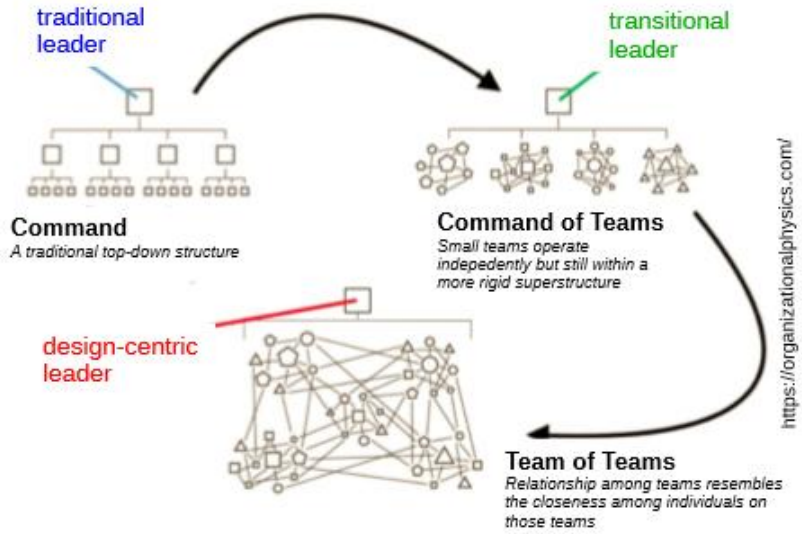
RobMoSys Tier 1 in Detail



See RobMoSys for further details on Meta-Meta-Models, Meta-Models, Models, Tooling, Components, Systems etc.

Horizontal and Vertical Interaction in Organizations



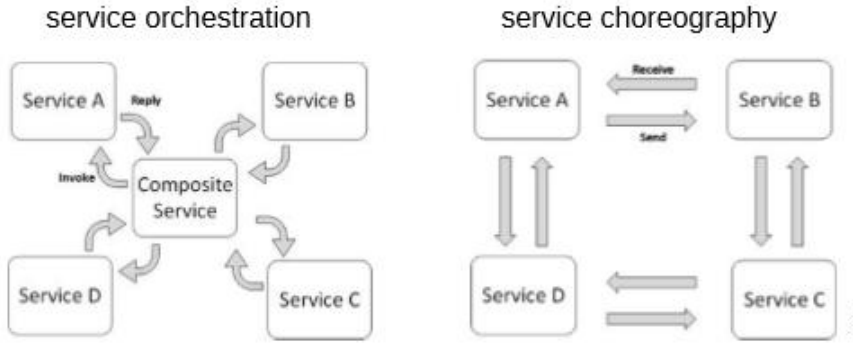


Horizontal and vertical interaction:

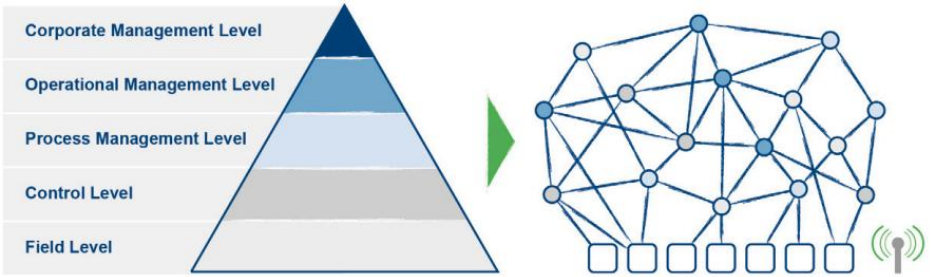
- technical aspect
- process aspect
- organizational aspect
- decision making aspect
- …

Challenge:

- resource management
- proper granularity and size of „entities“



Horizontal and Vertical Interaction in I4.0



Verein Deutscher Ingenieure e.V.: Thesen und Handlungsfelder Cyber-Physical Systems: Chancen und Nutzen aus Sicht der Automation, April 2013

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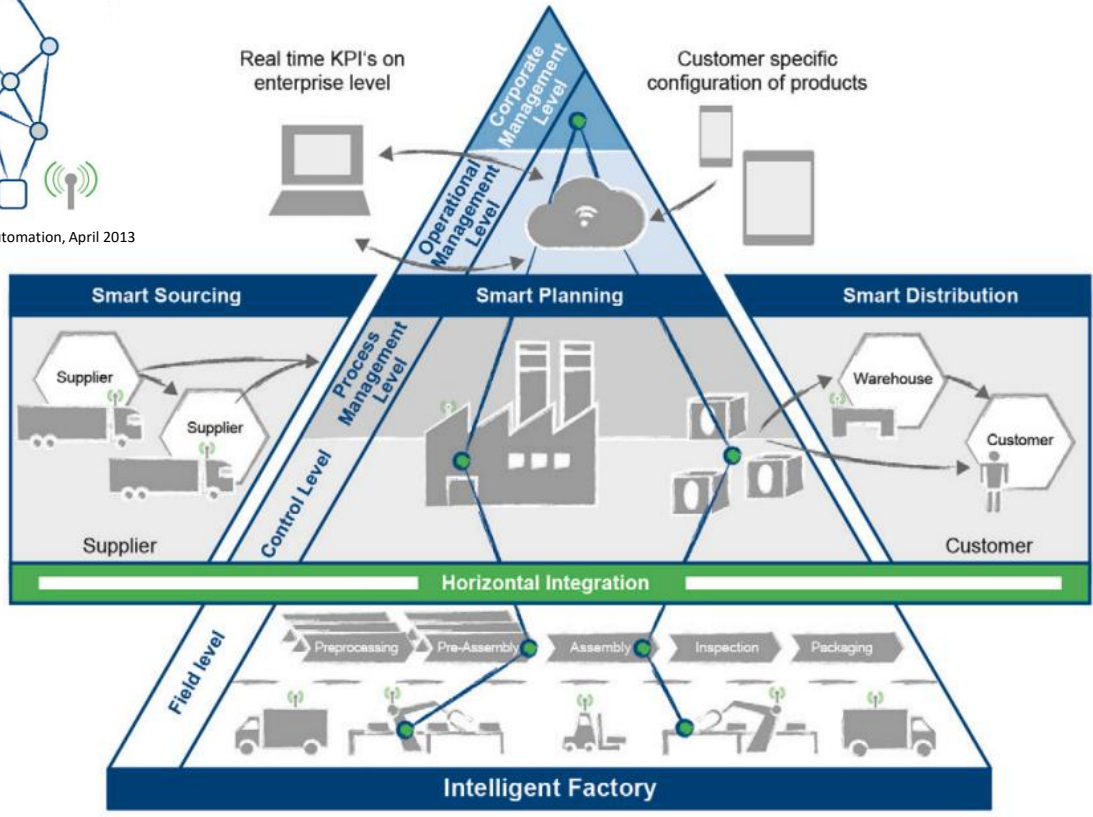
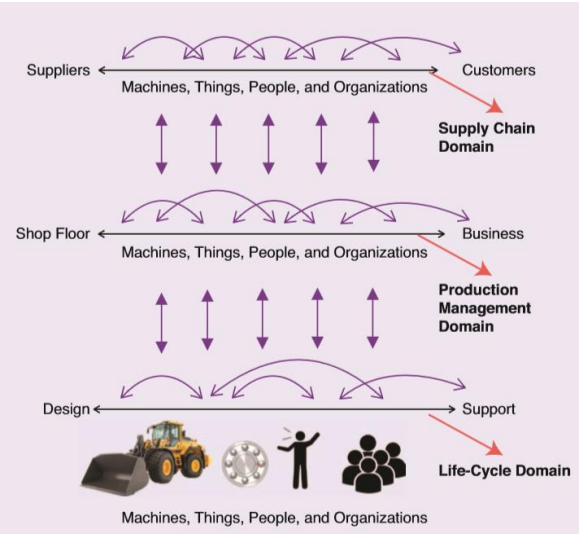
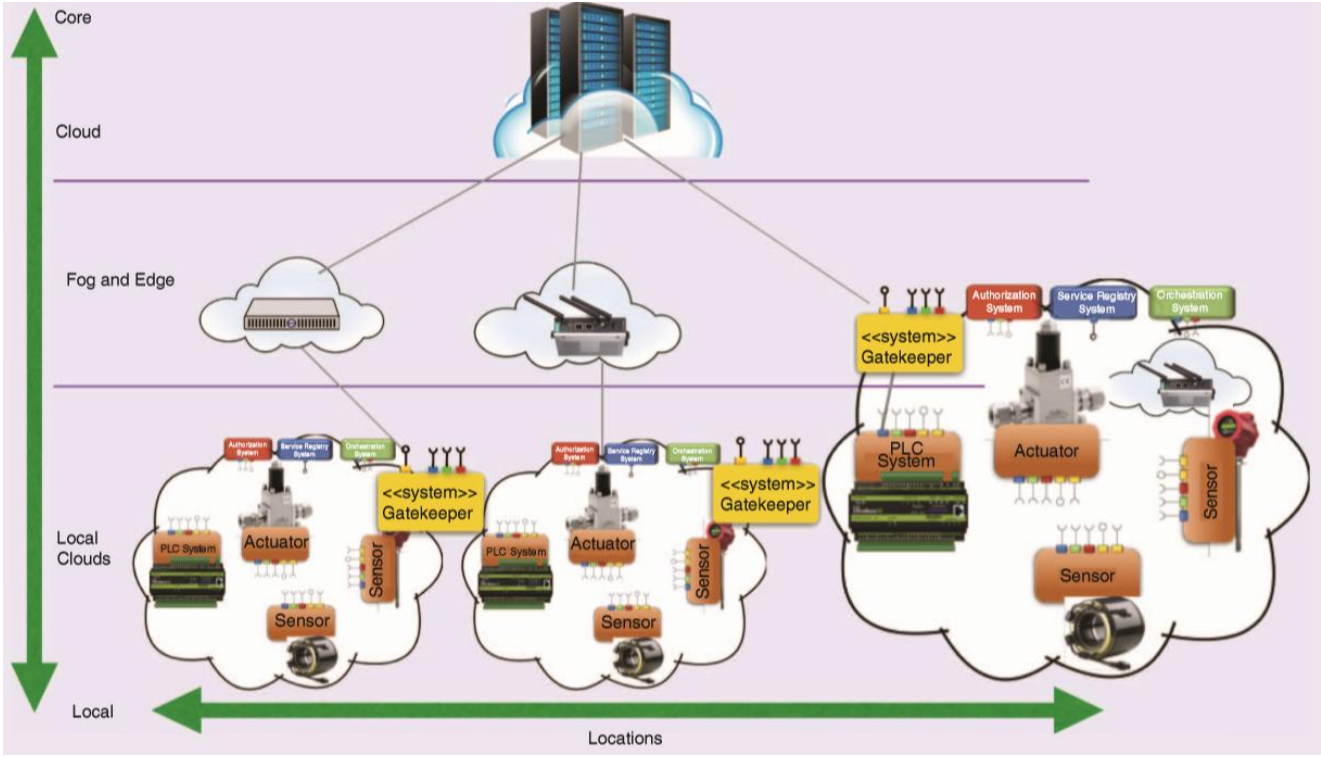


https://www.unity.at/fileadmin/Insights/OPPORTUNITY/OPPORTUNITY_Seize_OPPORTUNITY_Industrie_4.0.pdf

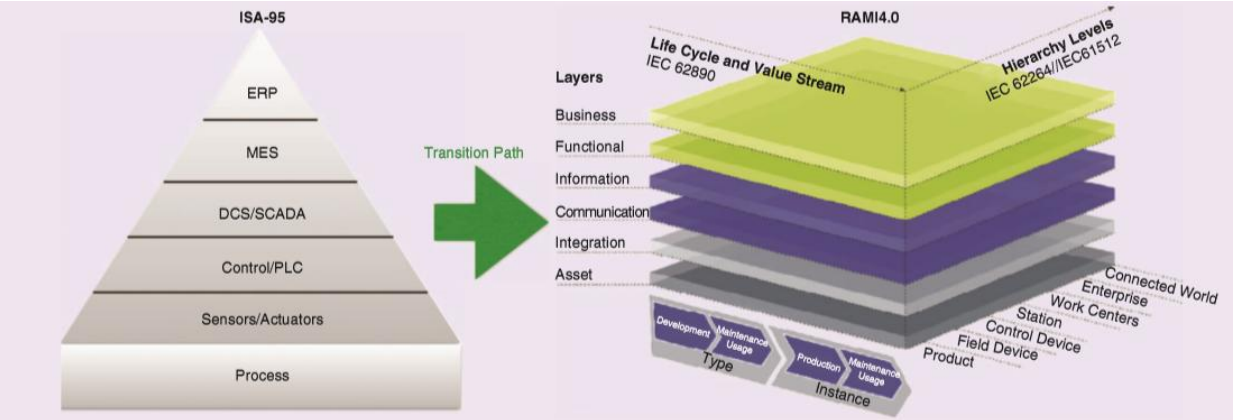
Horizontal and Vertical Interaction in I4.0

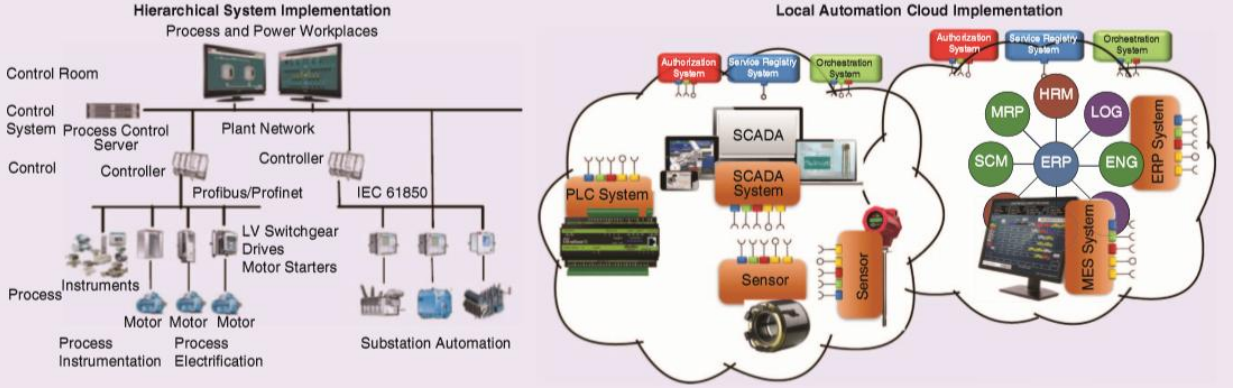


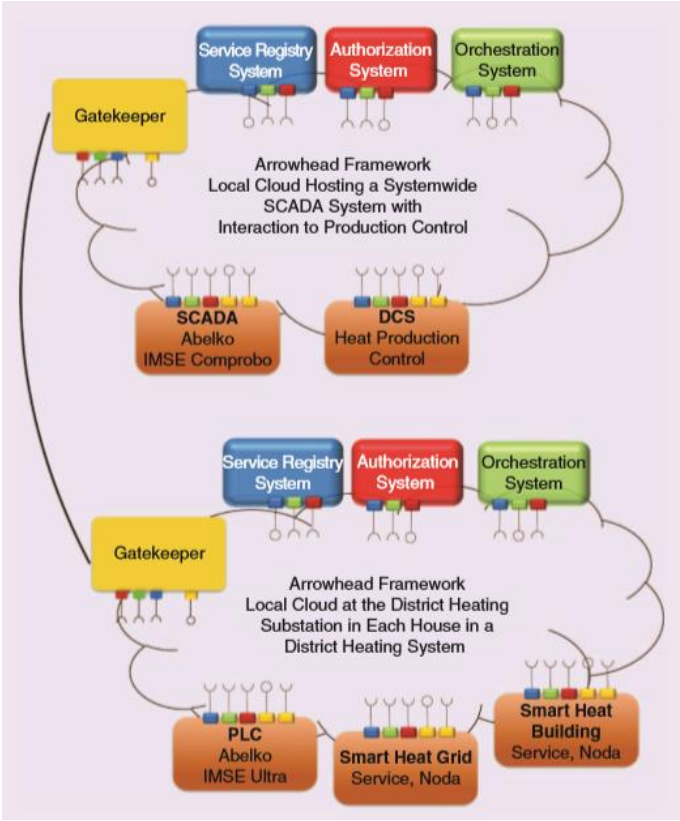


J. Delsing, "Local Cloud Internet of Things Automation: Technology and Business Model Features of Distributed Internet of Things Automation Solutions," in *IEEE Industrial Electronics Magazine*, vol. 11, no. 4, pp. 8-21, Dec. 2017.

Horizontal and Vertical Interaction in I4.0







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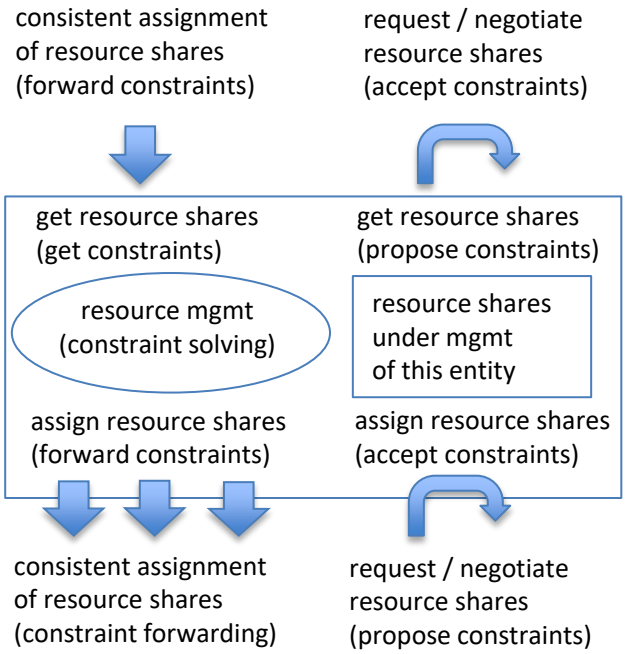
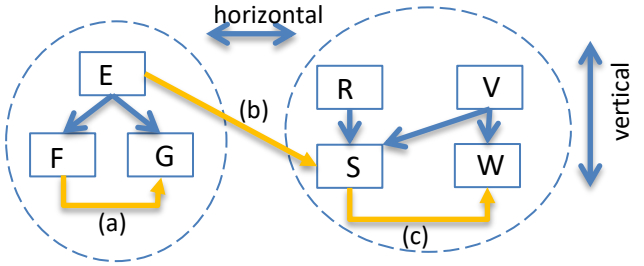
Horizontal and Vertical Interaction in Robotics



Dynamically changing control hierarchy but with always a consistent and clear responsibility for resource shares

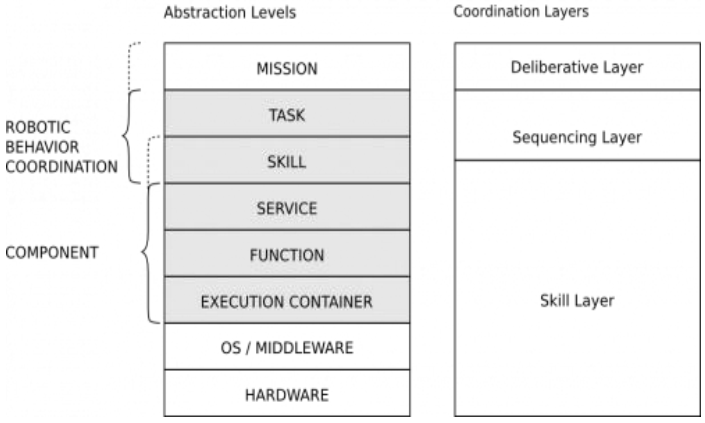
- best effort, contract based with guarantees, orthogonal assignment, …
- design time, deployment time, run time, …

(a) Consistent because of either vertical coordination by E or horizontal coordination F asking G
(b) Consistent because of either vertical coordination above EFG and RSVW or just horizontal coordination E asking S
(c) Consistent because of either vertical coordination by RV for SW or S asking W
(d) …

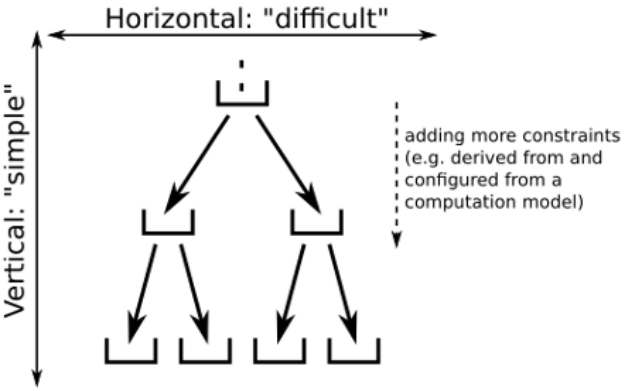


Distributed and linked Models:

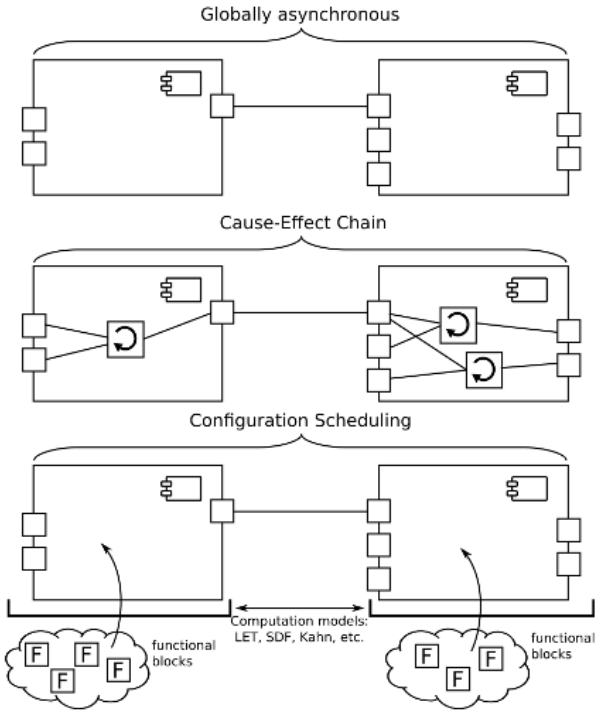
- Model of factory
- Model of production cell
- Model of robot resources and skills in the robot knowledge base
- Model of object in object recognition skill
- …

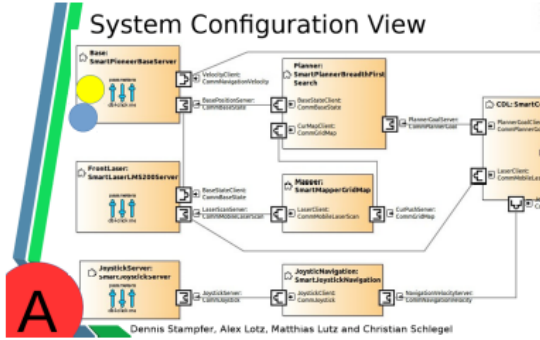


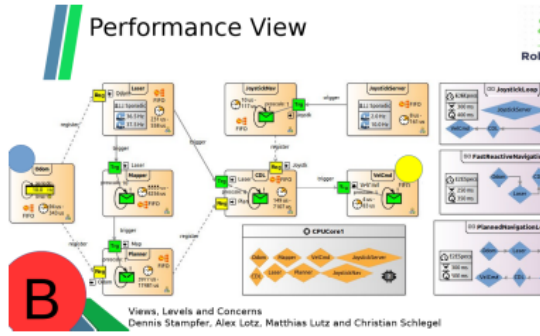
Horizontal and Vertical **Composition**

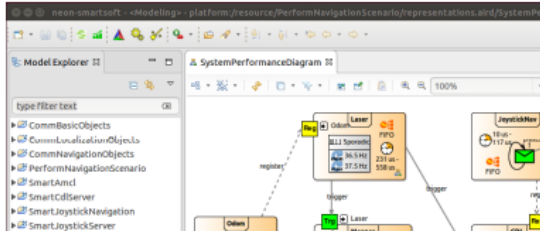


resource budgets, resource shares
local sync, global async
nesting vs. flattening
...



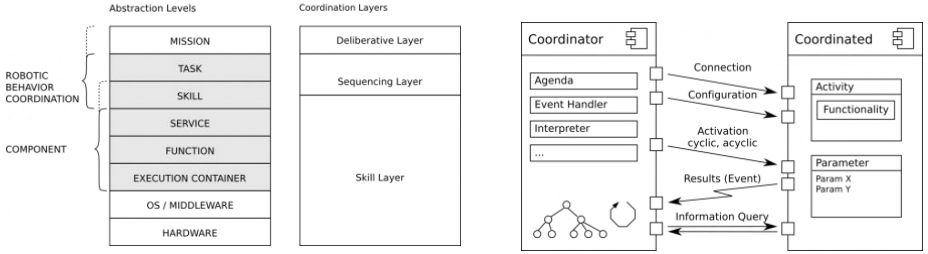


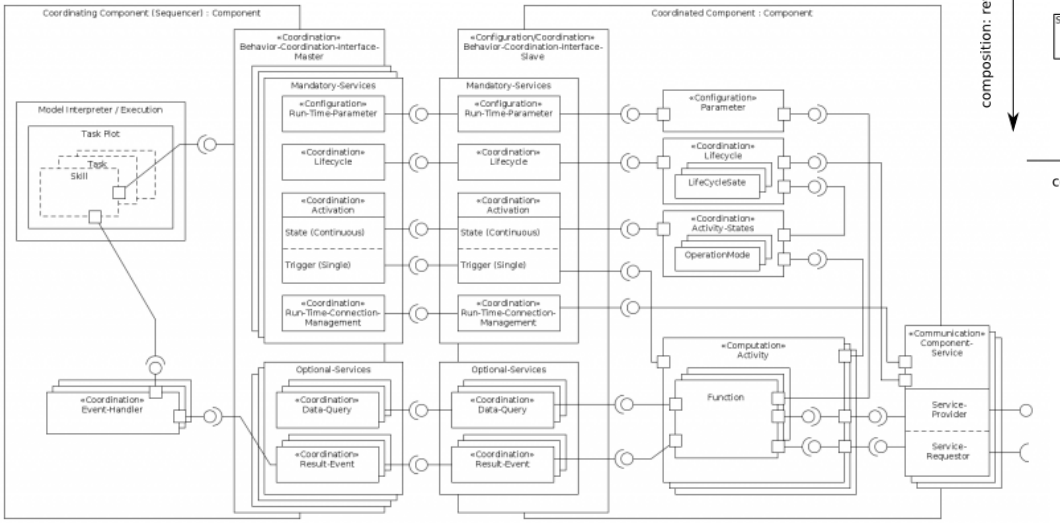


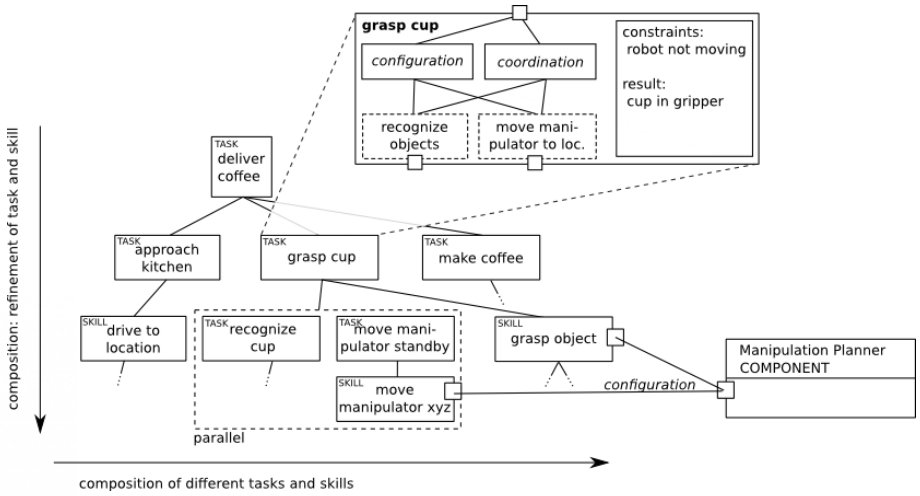


Examples of System Composition

Examples of System Composition: Task Coordination







Management of resource shares, execution context constraints, configuration constraints in horizontal and vertical task interactions

Examples of System Composition: Robot Fleet

Kommissionierung Servicerobotik Fachbodenregal

- Distributionslogistik, stückgenau, Pharmaartikel in Schachteln
- kombiniert Ware-zu-Kommissioniergasse und Person/Roboter-zu-Ware in Kommissioniergasse
- Fokus: Pickaufgaben

LogiRob

ZARH

Hochschule Ulm

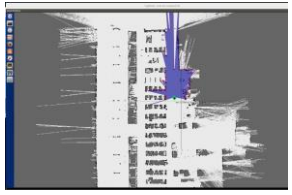
REC Robotics Equipment Corporation

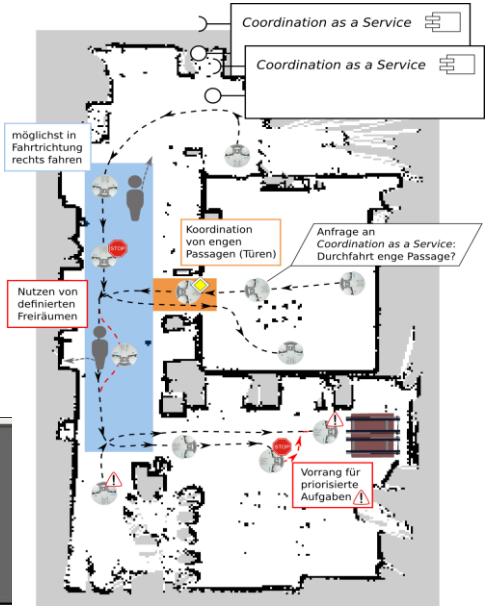
FESTO

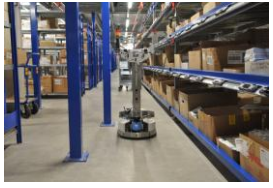
TRANSPHARM competence.connection.courage

Kommissionierung Person-zu-Ware

- Distributionslogistik, sehr große Vielfalt einschließlich loser Artikel
- Roboter/Person-zu-Ware, Zone-Picking
- Fokus: gemischte Roboterflotte, mit Menschen geteilter Arbeitsraum, kollaborative Pick- und Transportaufgaben





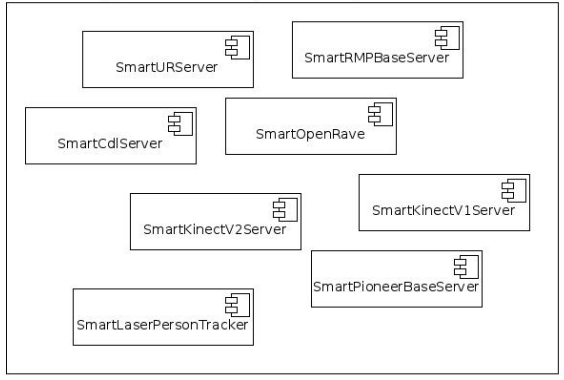


Examples of System Composition: Robot Fleet

Composition:

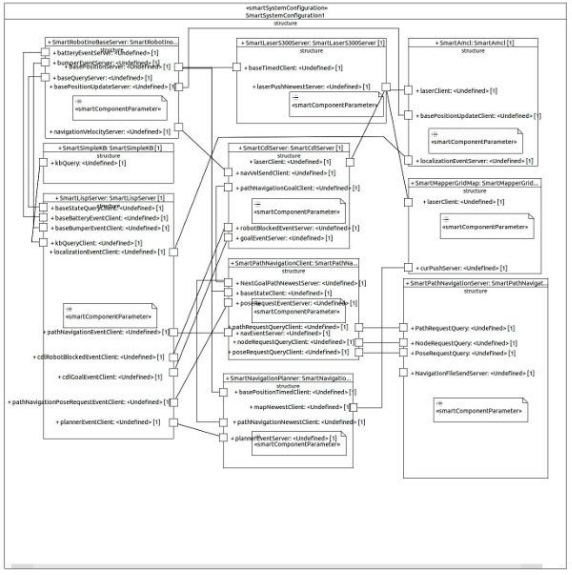
- Components to Robot System
- Skills to Robot Tasks and Fleet Tasks
- Robots to Fleet

Building-Block Repository

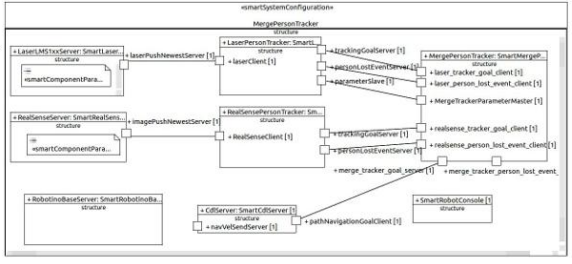


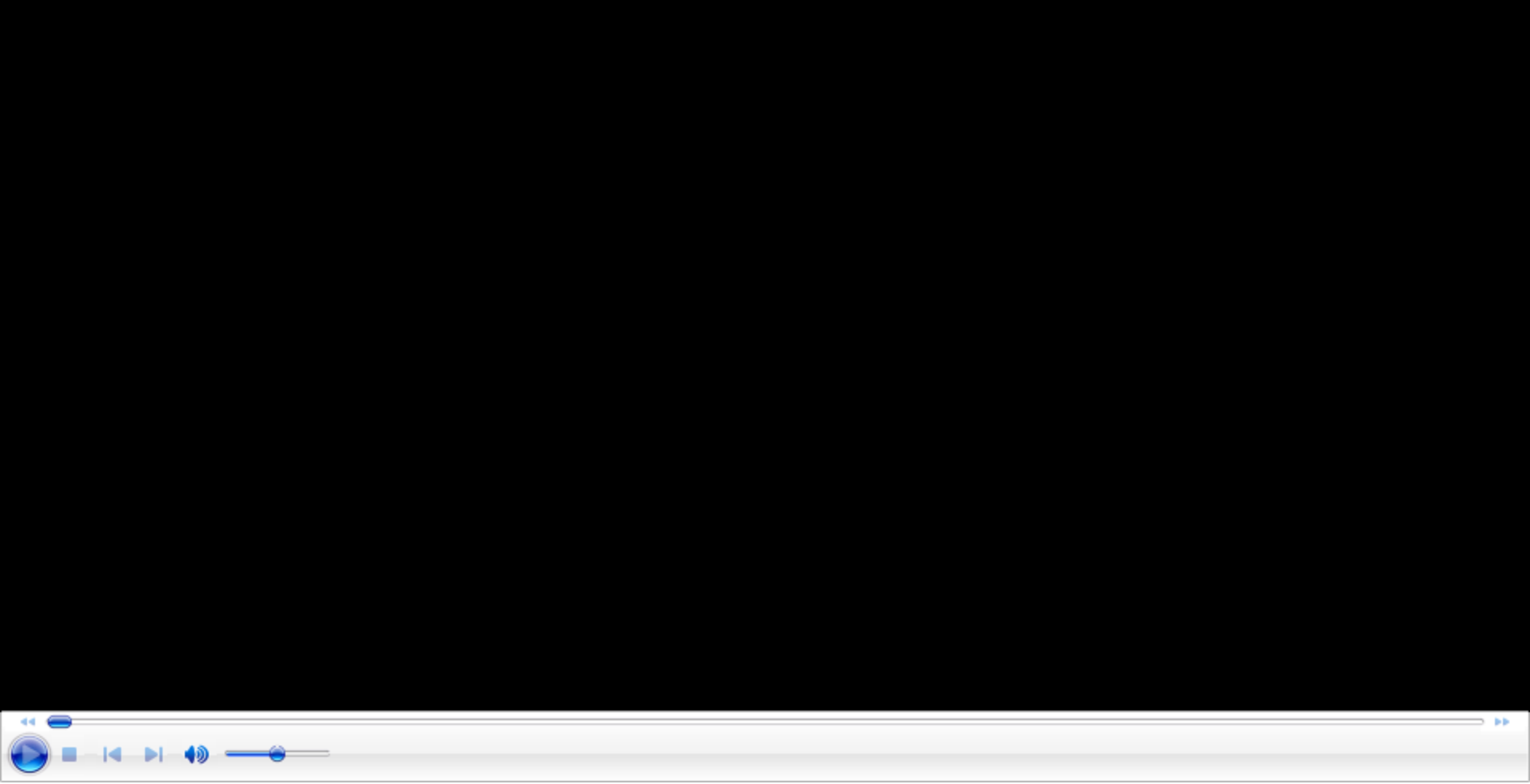
System Composition

System A

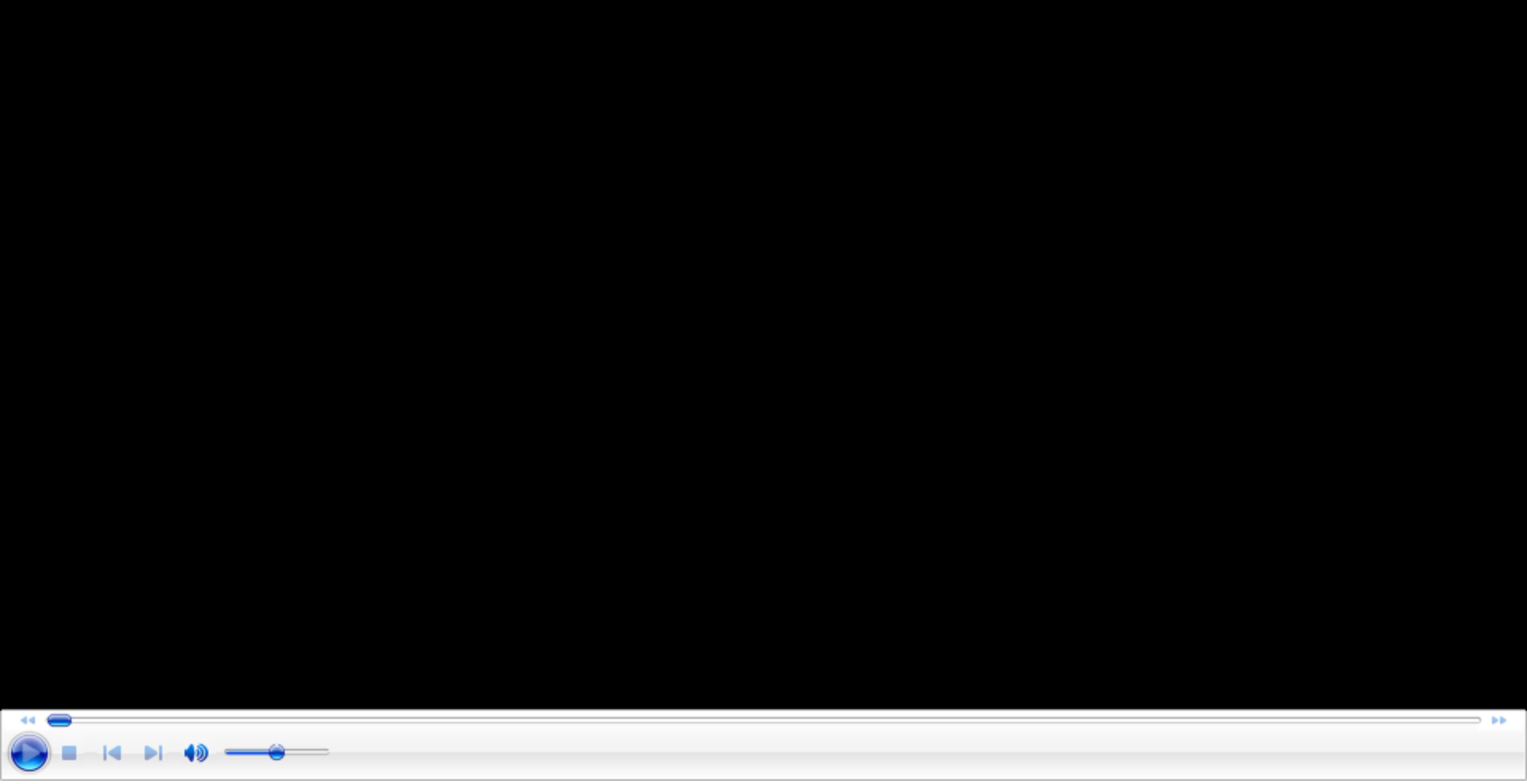


System B





Video Order Picking by Robot (https://youtu.be/cggCY-cvdJ8)



Video Person Following for Order Picking (https://youtu.be/r4mgPgyYISQ)

Examples of System Composition: Produktionslogistik

Pilot 3: Montage in der Produktion

klassische manuelle Montage mit unterschiedlich komplexen Teilprozessen im industriellen Umfeld sukzessive automatisieren und wandlungsfähiger gestalten.

Daimler TSS
Enabling Excellence

Hochschule Ulm

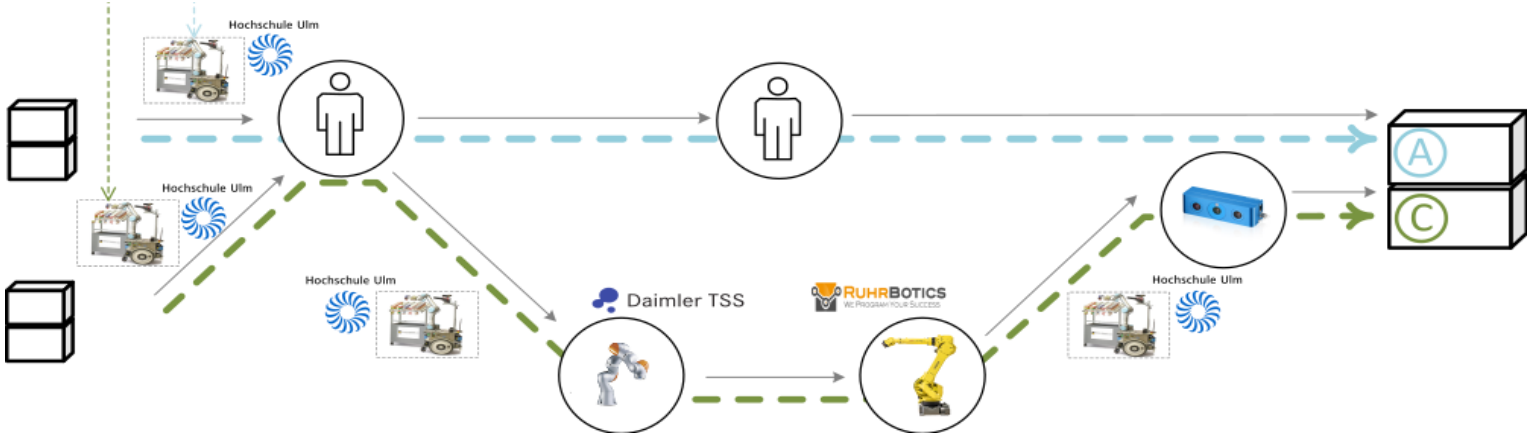
RUHRBOTICS

SeRoNet

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

DLR Projektträger

PAiCE



Roboterkontrollarchitekturen: Horizontale und vertikale Komposition

- Composition
  - Use the structural elements block, port, connector to bundle the four concerns (communication, coordination, computation, configuration) such that composability and separation of roles can be achieved
    - Tasks, skills, components, execution container, functional library, …
  - Go for allocation based mechanisms for resources and express their links and dependencies via constraints
    - Resource shares
    - Blocks with explicated variation points where constraint solving is used to exploit the offered variability for system level conformance – either at design time, at deployment time, at run-time, …
  - Introduce „digital data sheets“ for building blocks
    - Devices, Software Components, Capabilities, Task Plots, …
  - Address non-functional properties within a composition-based approach
    - know about propertiies of system compositions
    - inject properties via configuration of variation points
    - keep assured properties when modifying (adding, replacing, …)
    - know about adequateness => what you get with what resources
  - Generate trust into systems
    - By validation and verification, by simulation, by …
    - „not all possible combinations of activities are checked for safety but check that you can always reach a safe state“