Informatik 2013
Technik Workshop - Roboterkontrollarchitekturen

Model-Driven Software Systems Engineering in Robotics: Covering the Complete Life-Cycle of a Robot

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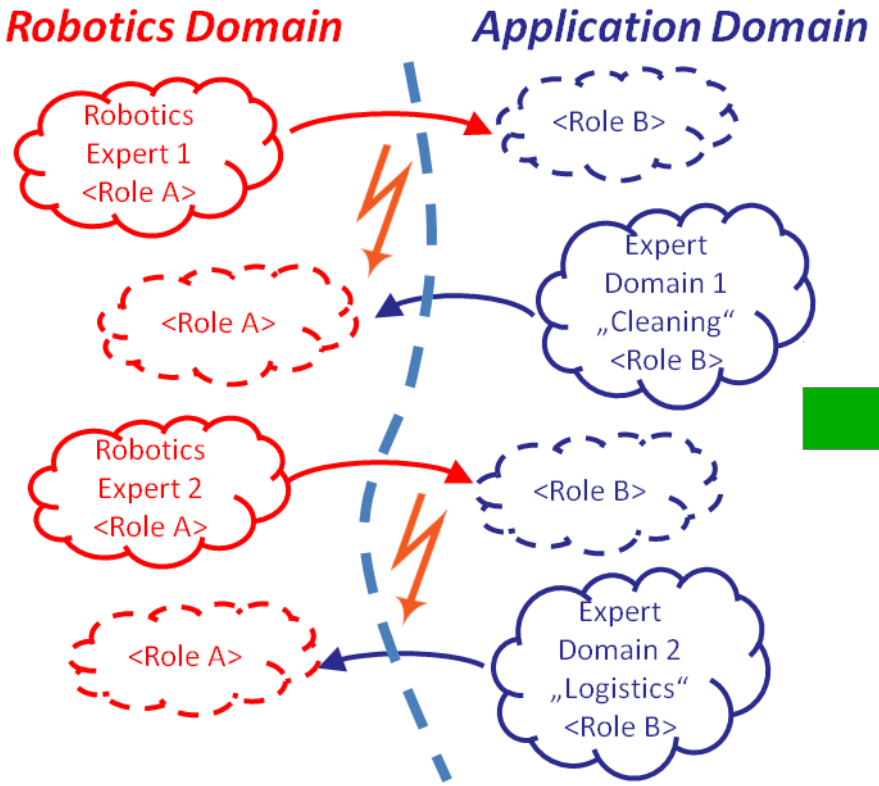
16 Sept. 2013, Koblenz

Cooperative Robot Butler Scenario

http://www.servicerobotik-ulm.de/ http://www.youtube.com/user/RoboticsAtHsUlm

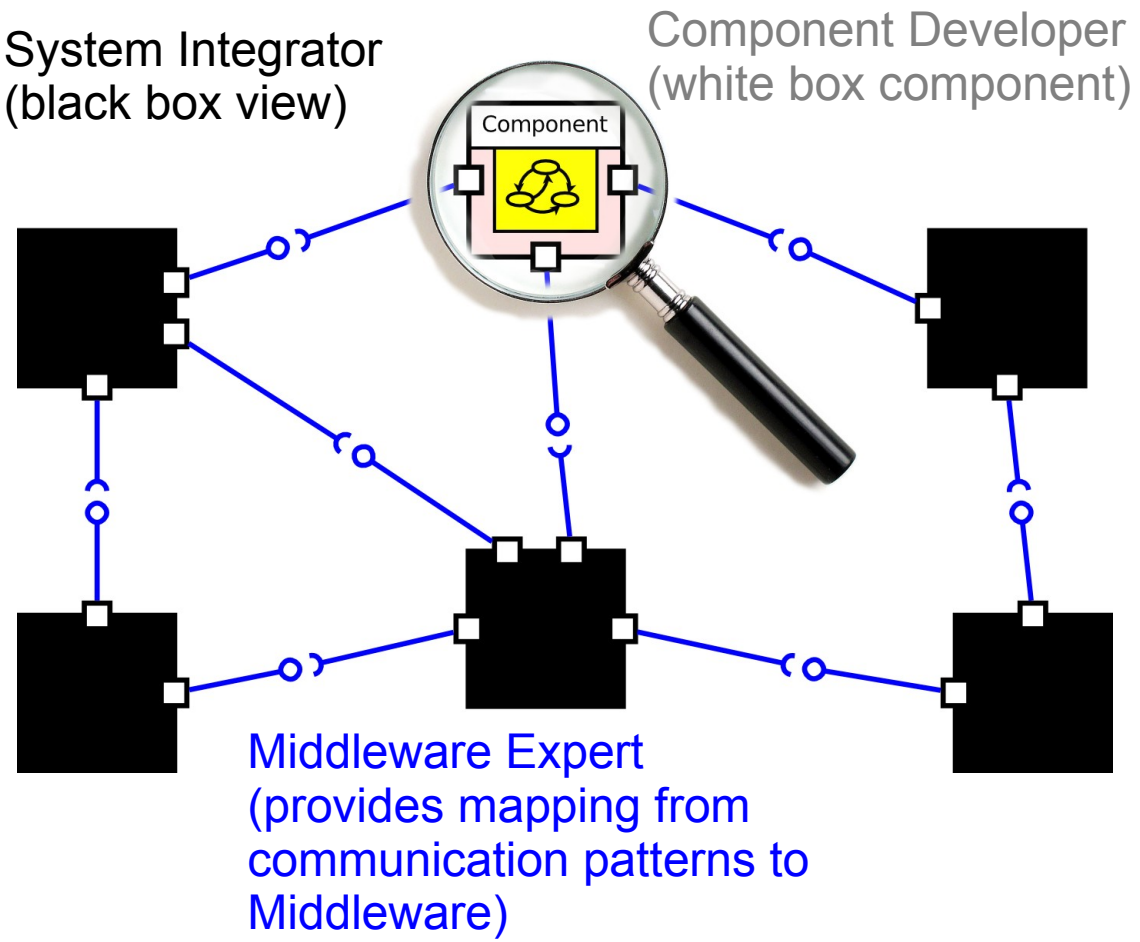
Towards a Software Business Ecosystem



Robotics Business Ecosystem:

- Separation of Roles
- Separation of Concerns
- MDSD (Model-Driven SW Developm.)

Towards a Robotics Software Component Model



- Think **SOA** rather than message centric:

  A SOA (service-oriented architecture) has to ensure that services don‘t get reduced to the status of interfaces, rather they have an identity of their own

- Think **business ecosystem**:

  Share risks and efforts between different stakeholders, reduce costs and development time and increase robustness and quality of products

- Think **model driven**:

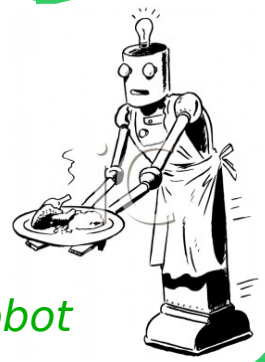
  Provide a black-box view for components with explicated services, properties and configurations

Stepwise Model Refinement with different Roles

navi-
gation

hand over

hand over



Component Builder

System Integrator

Robot

„freedom from choice“ in order to ensure system-level conformity

„inner view“

specialist with deep expertise (return-of-investment based on multiple use of components)

provide „black box“ view including model-based variation points

uses black-box view „outer view“

exploit variation points

Application domain experts

make system-level bindings and adjustments

Component must be bindable to execution platform at deployment time without recompilation !!

purposefully left-open variability in order to deal with open-ended environments (models@runtime)

exploit variation points

Component Development

System Integration

Deployment

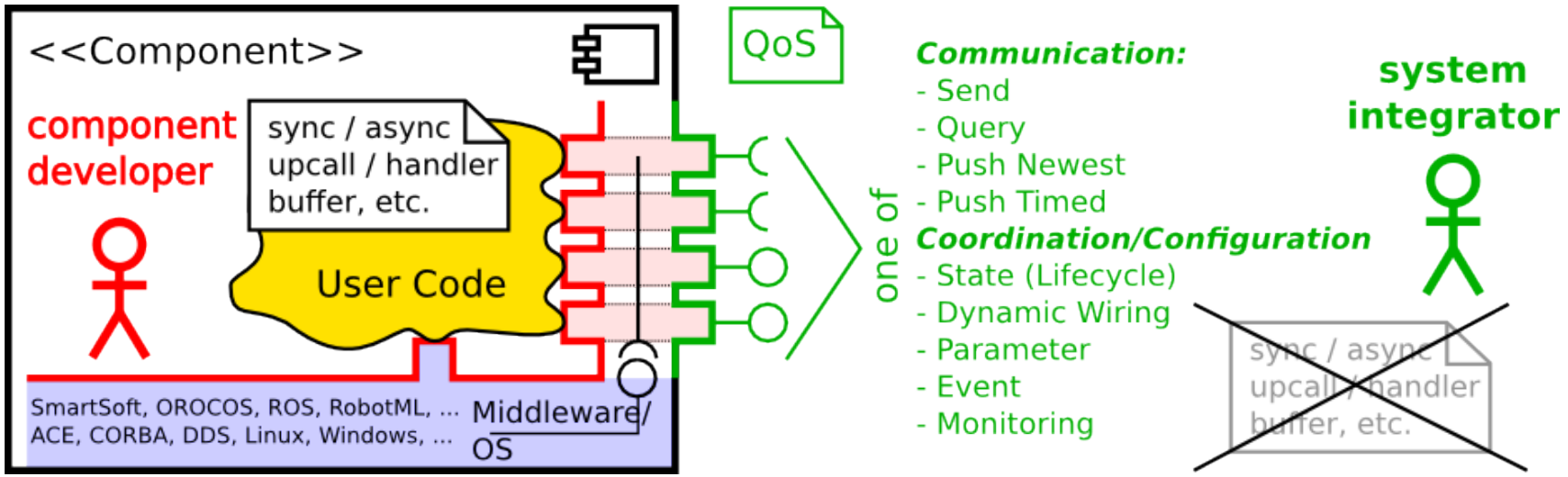
Deployment (add new components at run-time)

Design-Time

Run-Time

stepwise refinement: (1) add more and more information, (2) bind more and more variability

Communication Patterns*



not missing guidance inside components

but flexible interface consistent with outer semantics to ease the job of the component developer:

- give freedom to use desired access methods (sync, async, upcall, etc.)
- give freedom to install desired processing (passive, thread pool, pipeline, buffers, etc.)

not early platform binding

but late linking to execution container

not variety outside where it affects system integration, but:

- stable and distinct communication characteristics for each communication pattern
- avoid complexity of combinatorial explosion of policies, mechanisms, etc.
- ensure system level conformance (avoid distributed system deadlocks, etc.)
- avoid incompatible port variants of the same service

* Christian Schlegel, Andreas Steck, and Alex Lotz. "Model-Driven Software Development in Robotics: Communication Patterns as Key for a Robotics Component Model", in Introduction to Modern Robotics, ISBN 978-0980733068, iConcept Press, 2011

Model-Driven Software Development Toolchain

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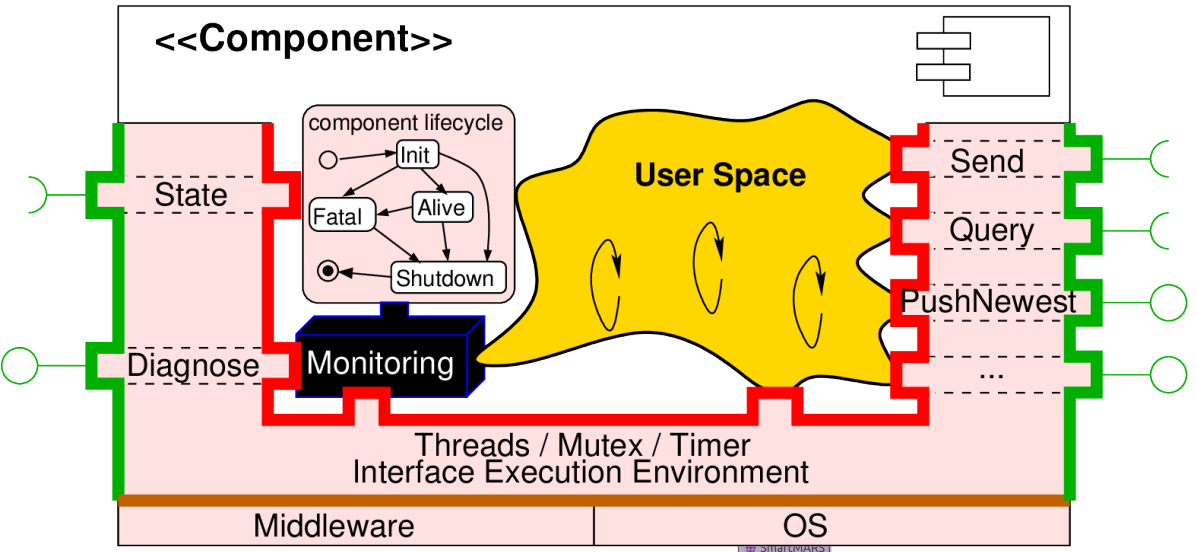
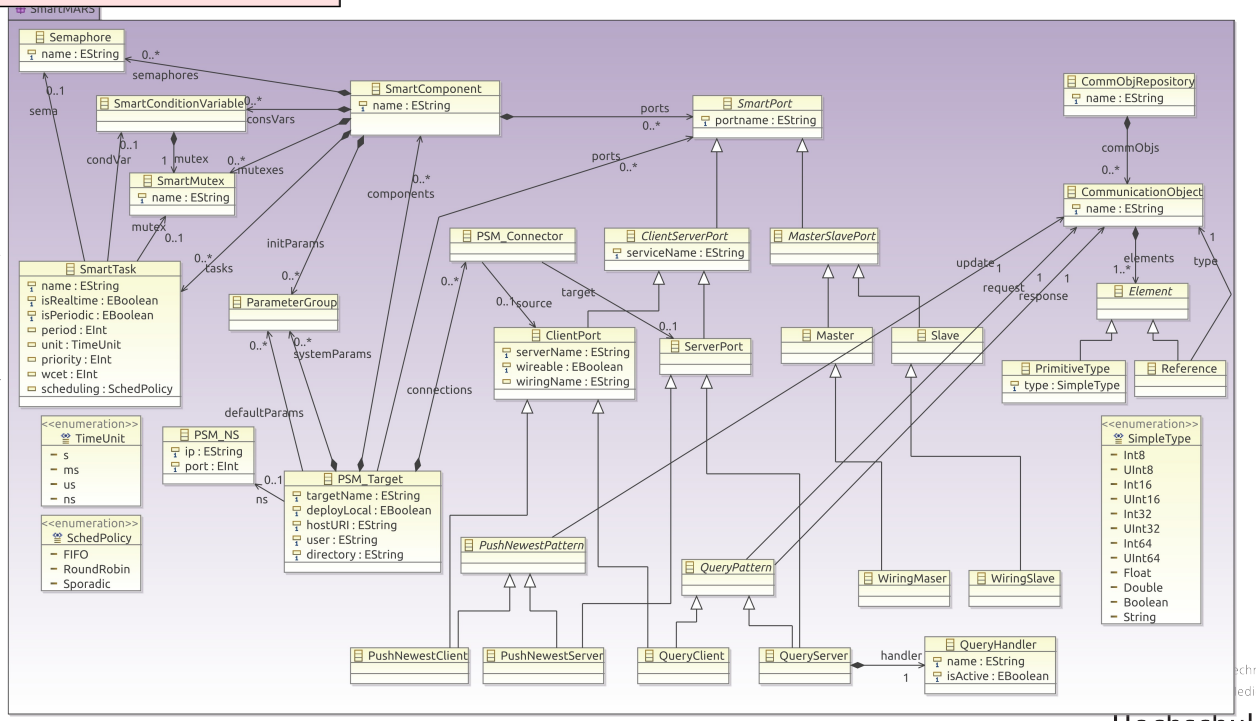
Robotics Software Component Model + MDSD



- component life-cycle
- monitoring/debugging
- separated internal interface from outer communication characteristics
- middleware abstraction

Metamodel



MDSD Toolchain

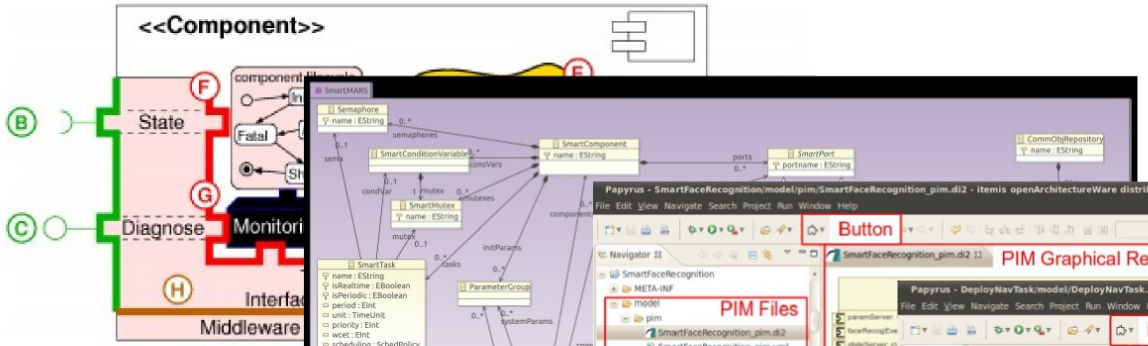
SmartMDSD
(service oriented component model)
- Meta-Model
- Toolchain

SmartSoft
(implementation)
- CORBA / SmartSoft
- ACE / SmartSoft

SmartTCL
(Task Coordination Language)

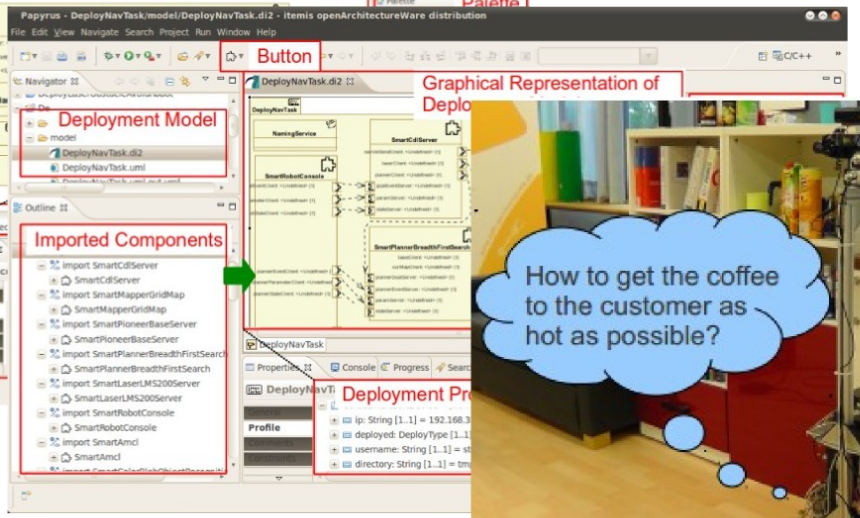
VML
(Variability Modeling Language)

Domain Specific Languages



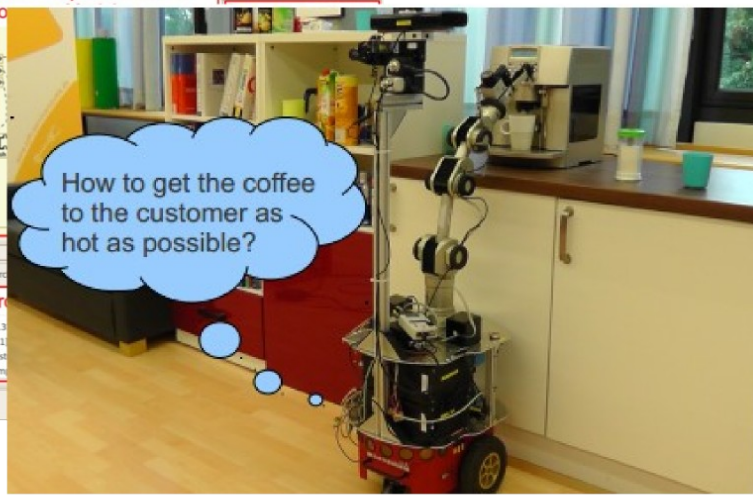
- *Software component*
- *execution container*

Meta-Model



Eclipse-Toolchain
- *component developer*

Eclipse-Toolchain
- *system integrator*
- *deployment*



Real robot in real world

System Architecture: Managing Execution Variants at Run-Time

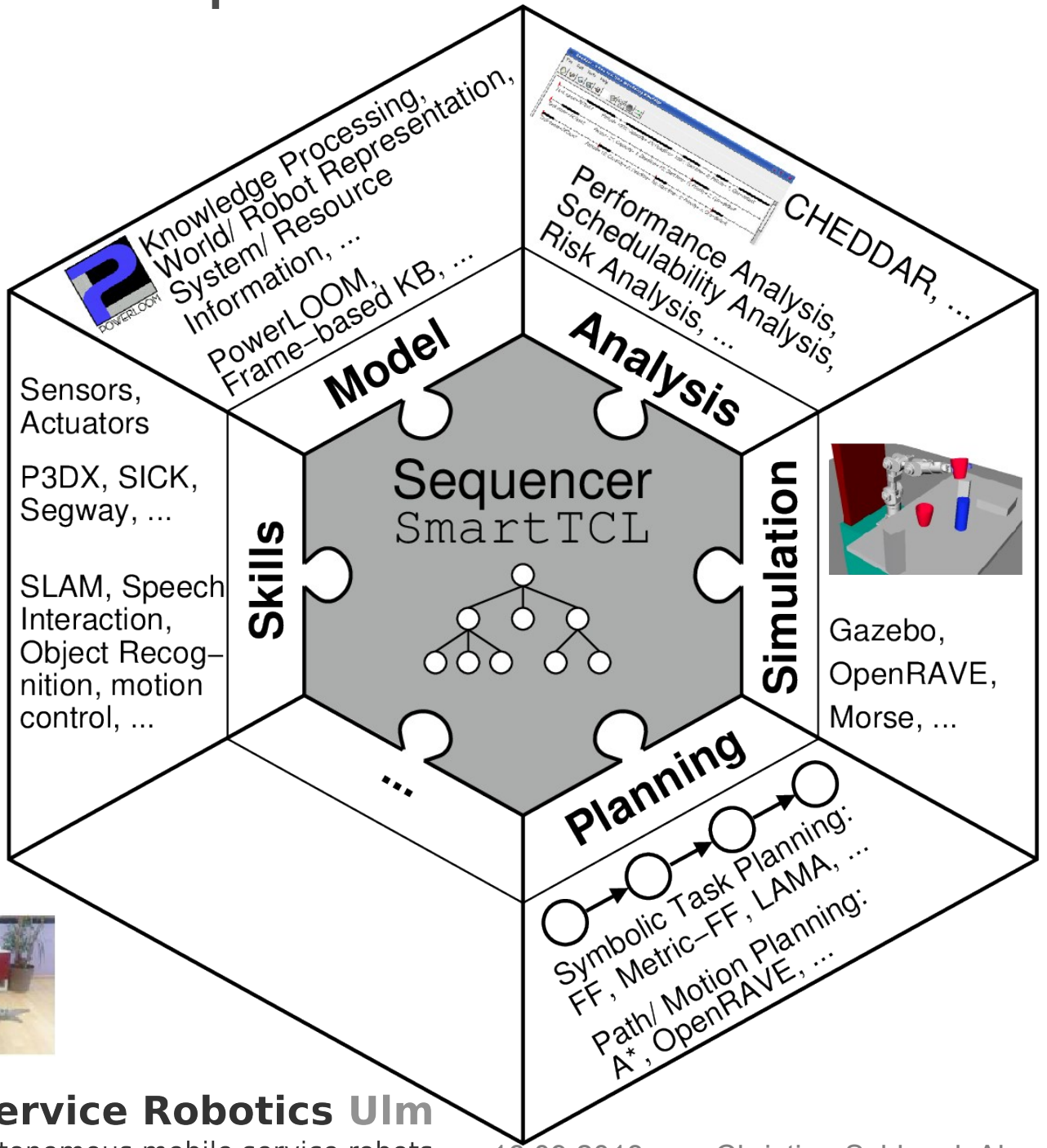
- **SmartTCL**:

  Managing Variability in Task Sequencing

- **VML**:

  Managing Variability in Task Execution Quality

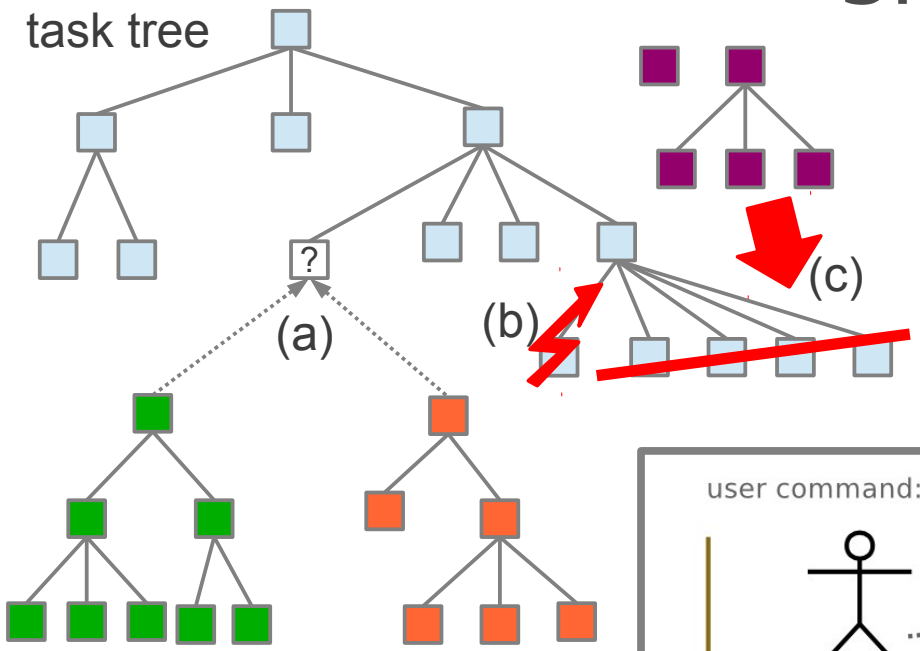
Sequencer orchestrates the system



The sequencing layer with SmartTCL:

- bridges between continuous processing and event-driven task execution
- orchestrates software components in the system
- assigns decision spaces to components
- involves dedicated expert components such as a symbolic planner for run-time bindings of designed variability
- uses a knowledge base to resolve symbols
- coordinates analysis, simulation and planning capabilities

SmartTCL



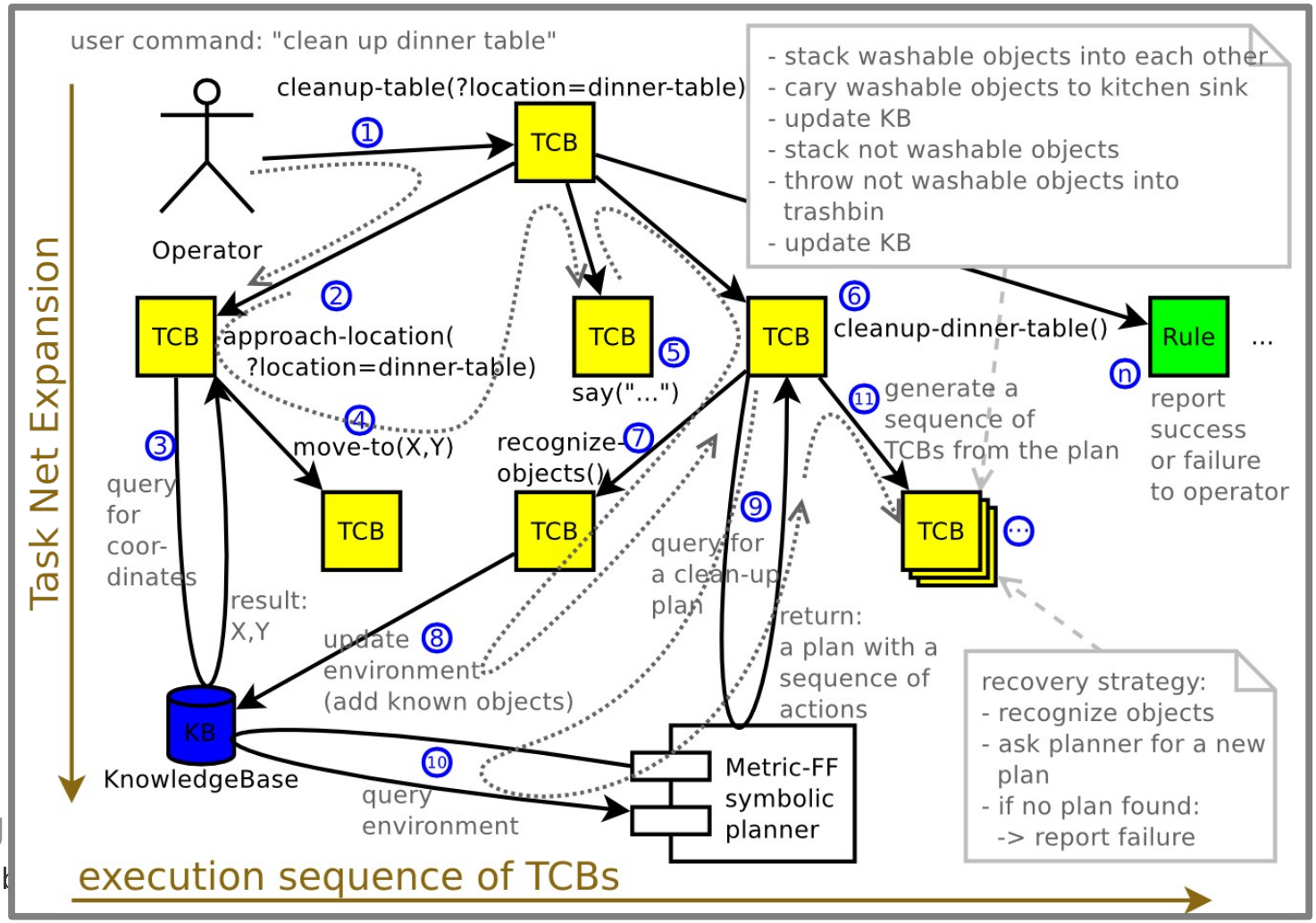
On the left:

(a) select between alternatives at run-time

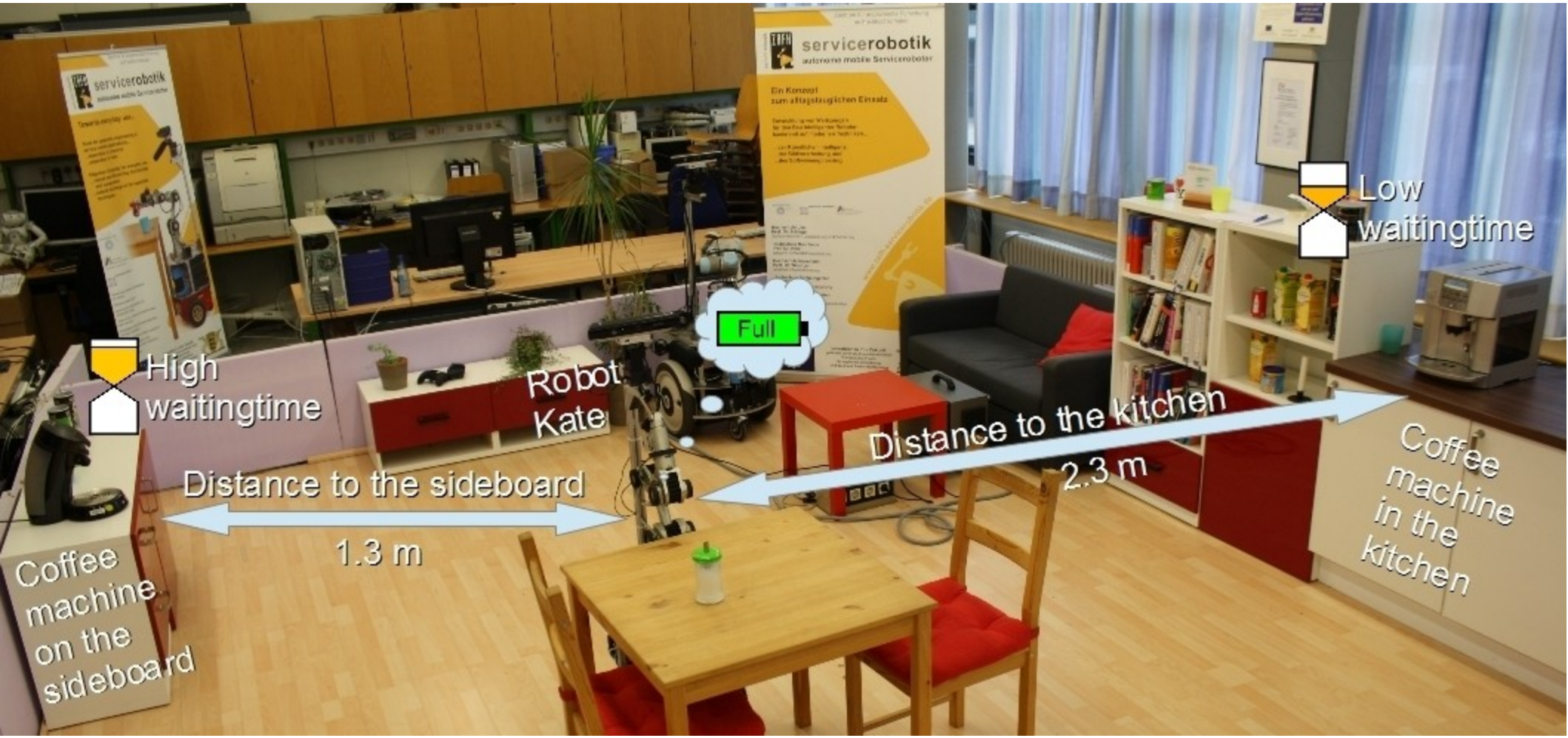
(b) handle contingencies

(c) delete, add or replace sub trees at run-time

On the right:
example for a refinement/
expansion of the task
“cleanup-table”

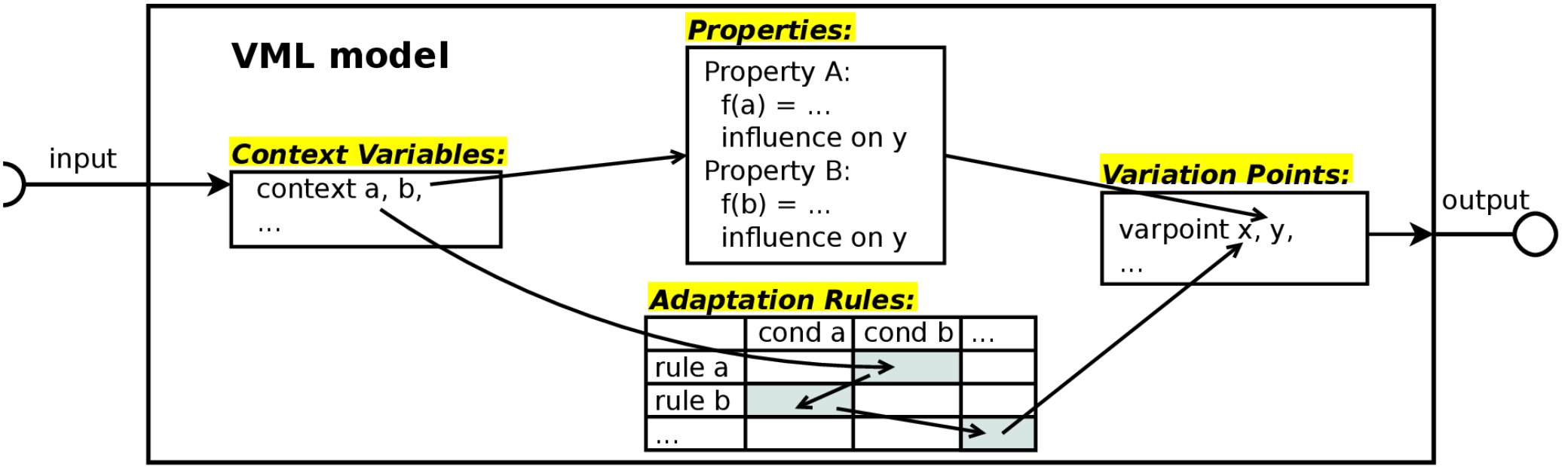


Non-Functional Properties at Run-Time



The robot needs to trade-off different non-functional properties such as **safety** and **performance** in order to select appropriate execution variants (in this case which coffee machine to use)

Variability Modeling Language (VML)*

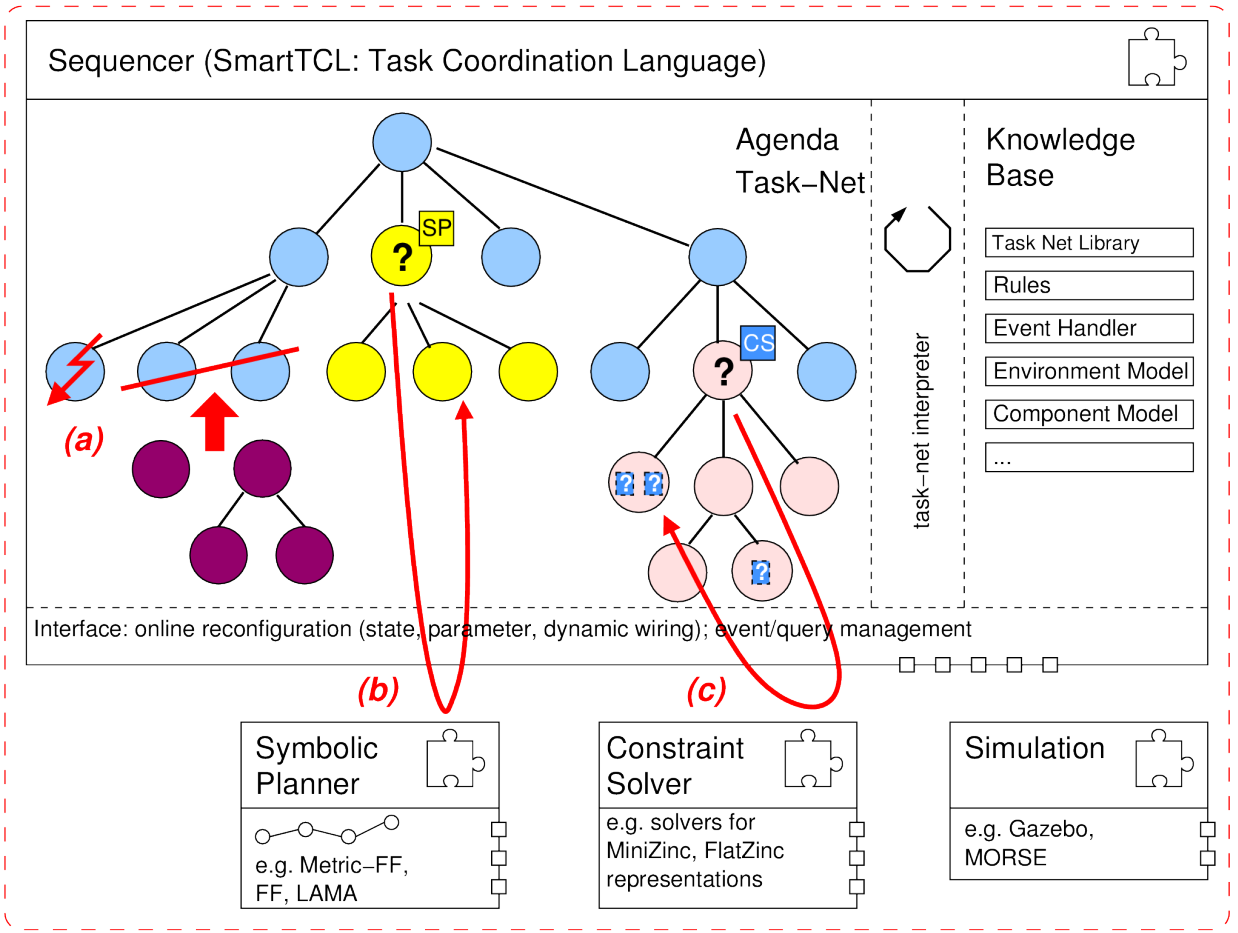


design-time:
the designer provides the models (action plots with variation points to be bound later by the robot, policies for task fulfillment, problem solvers to use for binding of variability).

run-time:
the robot decides at run-time on proper bindings for variation points by applying the policies taking the current context into account

* Alex Lotz, Juan F. Inglés-Romero, Cristina Vicente-Chicote, Christian Schlegel. Managing run-time variability in robotics software by modeling functional and non-functional behavior. EMMSAD 2013. ISBN 978-3-642-38483-7

System Architecture: Mapping Execution Variants at Run-Time



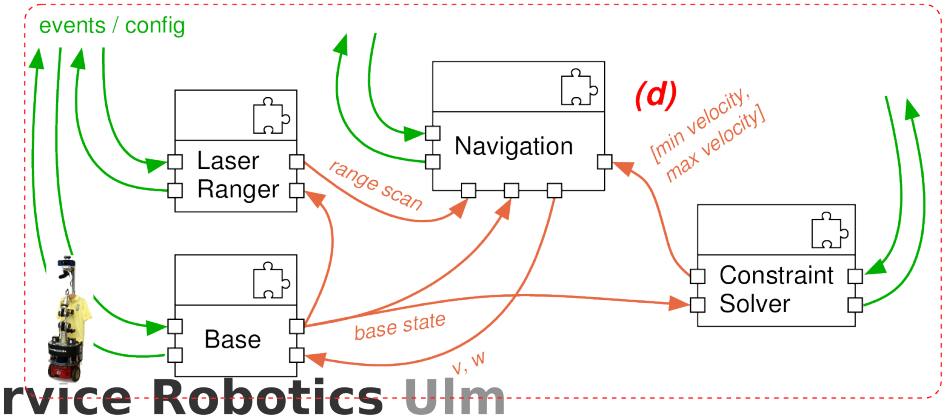
Integration of "Variability in Task **Sequencing**" and "Variability in Task **Execution Quality**"

(a) SmartTCL handles a contingency by exchanging a sub-tree

(b) SmartTCL uses a symbolic planner to refine a sub-tree

(c) VML as a **service on demand**

(d) VML as **continuous service**



Open Challenges and Future Work

- Enable designers to explicate the desired quality-of-service which the robot achieves at run-time by trading off different execution variants
- Extend the mechanisms for black-box handover from one role to another
- Link between S/W models (component settings, resources) and robot behavioral models (task nets) supported by MDSD approaches
- Improve the overall development workflow with different roles which refine the overall system model step by step
- Further improve the handover of knowledge and efforts between design-time and run-time

Thank you for your attention!

Any Questions?