Incremental Design and Formal Verification with UML/RT in the FUJABA Real-Time Tool Suite

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Mechatronic systems of the future will be …

- networked,
- hard real-time,
- safety-critical,
- embedded, and
- will contain complex software.

How to ensure correctness?

Case Study: New Railway Technology Paderborn

Verify UML models with Real-Time

Model checking: limited today due to two main obstacles:

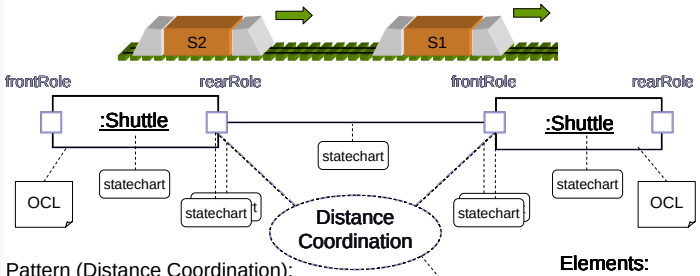
(1) state explosion ⇨ restricted model size
(2) batch style model checking vs. iterative design process

⇨ incremental design and verification with UML/RT (FUJABA Real-Time Tool Suite)

Underlying techniques (Outline):

I. Restrict approach to a UML/RT subset
II. compositional reasoning [ESEC03]
III. mapping of the UML/RT subset to HUppaal
IV. incremental checking of modified submodels

I. UML/RT Subset

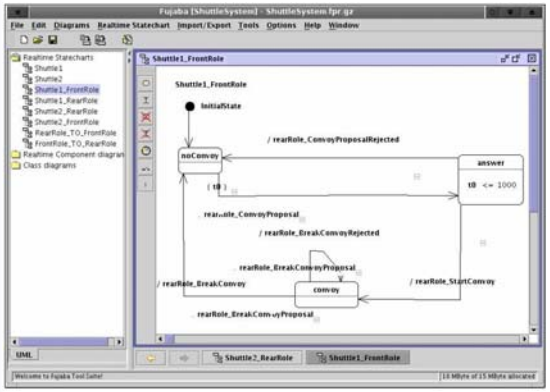


Pattern (Distance Coordination):
- Model: Statecharts for roles and connector
- Specification: required OCL RT properties

Components (Shuttles):
- Model: Statecharts for ports (refined roles) and synchronization
- Specification: local OCL constraints

Elements:
- Components
- Ports
- Connectors
- Patterns
- Roles

Real-Time Statecharts



RT @ PIM:

- Add Clocks (s. TA)
  - resets
  - guards
  - invariants
- Deadline intervals for each transition

Automatic code synthesis later ensures that the specified real-time properties are guaranteed

II. Compositional Reasoning

Pattern Specification & Verification

Example:

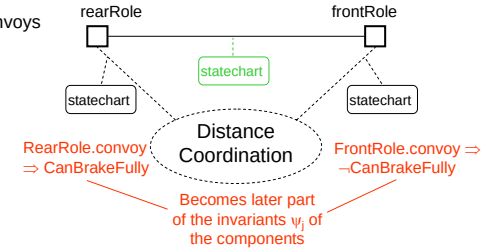
- No collision for convoys

Roles:

- Interface
- RT Statechart
- Invariants

Pattern:

- Set of roles
- Connector
- Properties

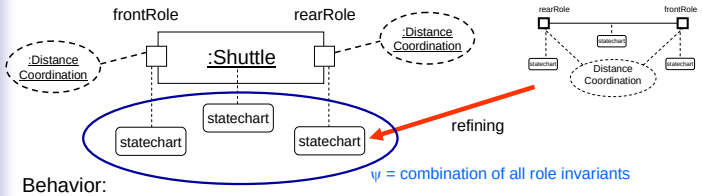


$\phi = AG\ \neg(RearRole.convoy \wedge FrontRole.noConvoy)$

Modelchecking:

$$M_{RearRole} \,||\, M_{FrontRole} \,||\, M_{Connector} \models \phi \wedge \neg\delta$$

Component Design & Verification



Behavior:

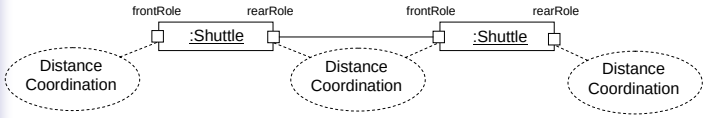
- **Port statecharts** which **refine** the related role protocols
- A **synchronization statechart** which coordinates **all** realized roles
- **Iterations** until appropriate component behavior has been found

Model checking:

$$M_{RearPort} \,||\, M_{FrontPort} \,||\, M_{Synchronisation} \models \psi \wedge \neg\delta$$

with $\psi = (RearPort.convoy \Rightarrow CanBrakeFully) \wedge (FrontPort.convoy \Rightarrow \neg CanBrakeFully)$

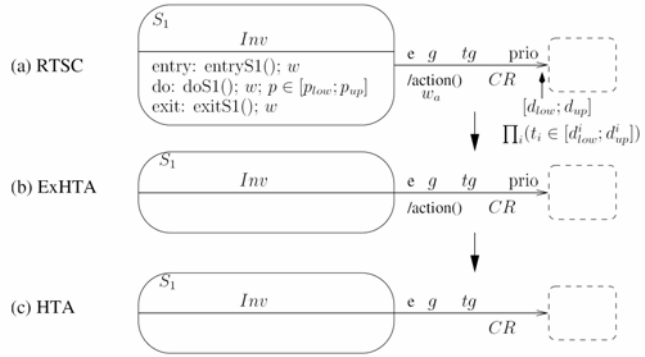
After Composition?



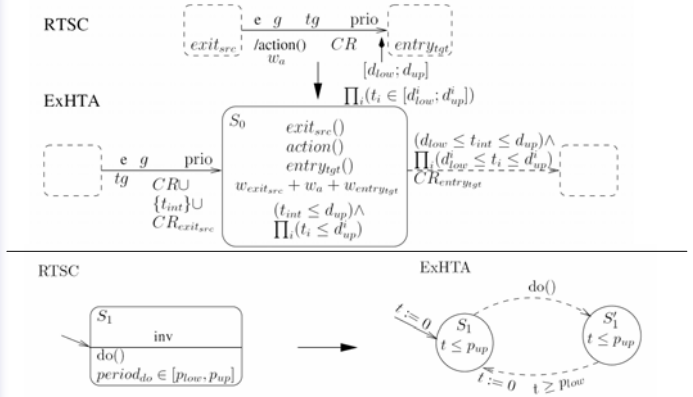
Theorem (in [ESEC03]):

All systems build of **verified components** that cooperate only via **verified patterns** via correctly refined pattern roles (= syntactical correct composition) will **behave correctly**.

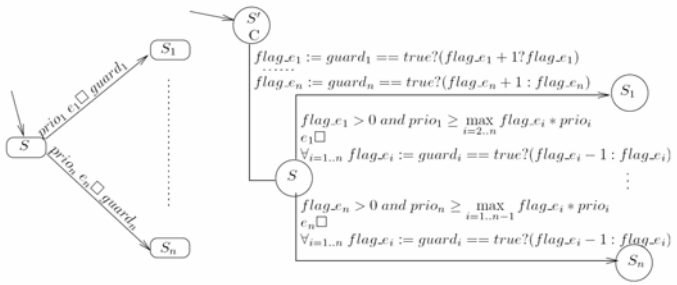
III. Mapping (RTSC ⇨ ExHTA ⇨ HTA)



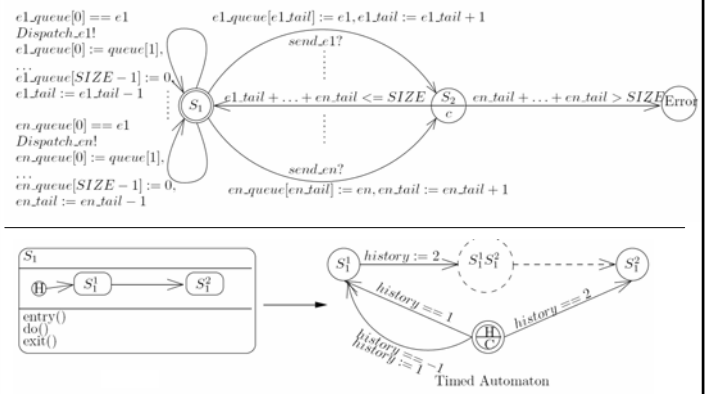
RTSC ⇨ ExHTA



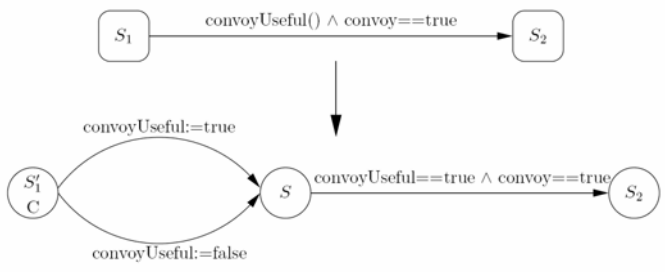
ExHTA ⇨ HTA: Priorities



Asynchronous Messages & History



Abstract form Methods …



Mapping Process

Compositional reasoning:

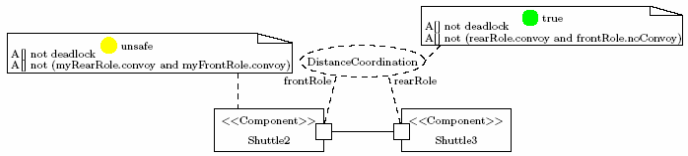
- Pattern mapping (closed model):
  - Map role statecharts
  - Map connector
  - Parallel composition
- Component Mapping (open model)
  - Map port statecharts
    - special treatment of external events (⇨ closed model)
  - Map synchronization statechart
  - Parallel composition

Also other submodels …

Remark: Currently no OCL Mapping ⇨ TCTL is used

IV. Incremental Design & Verification

- Consistency Management **detects** updates
- Model Checking of modified **parts** (background)
- Modes: true, false,
  unsafe (not up-to-date)



Conclusion

- Sufficient UML/RT subset (mechatronic control)
- Compositional Verification with Patterns & Components
- Automatic mapping of UML/RT models to HUPPAAL
- Consistency management for properties
  ⇨ ***incremental and iterative design and verification***

Current Work

- Other model checking back ends (RAVEN)
- Hybrid UML models (presented on FSE04)

Future Work

- Counter examples visualization

www.FUJABA.de Tool Suite