TECHNISCHE UNIVERSITÄT DRESDEN

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Connecting Conceptual Models using Relational Reference Attribute Grammars

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connector.relational-rags.eu

Problem: Constructing cyber-physical systems (CPS)

Challenges for connecting runtime models

Distribution: transparent communication with locally and remotely accessible models

Multi-Paradigm: support for different paradigms and (programming as well as modelling) languages

Fast, reactive behaviour: changes in input lead to automatic recomputation for fast reaction

Goals for realizing connected runtime models

① **Minimize development effort:** reduce workload of developers, but also minimize errors and redundancy

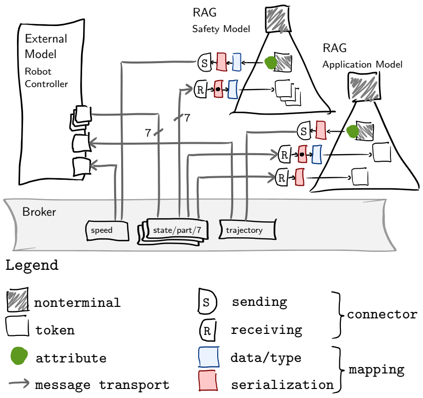
② **Minimize network usage:** cope with many updates, and/or little network bandwidth, prevent potential congestion

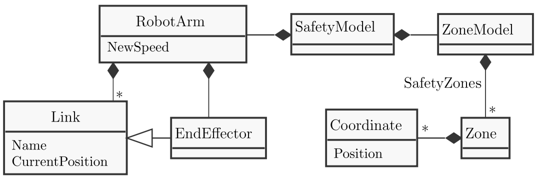
③ **Minimize computation effort:** enable faster reaction times

④ **Maximize interoperability:** not constrain models to be connected

Solution: Generation of model connectors

Idea: Use a small, dedicated language to specify endpoints (and necessary transformations) for a connection between two runtime models.





```
receive Link.CurrentPosition using
ParseState, Transform;
```

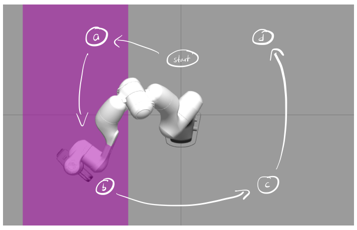
```
send RobotArm.NewSpeed using
CreateSpeedMessage, SerializeRobotConfig;
```

```
ParseState maps byte[] bytes to RobotState {:
  return RobotState.parseFrom(bytes);
:}
```

shared by both models

- Robot controller as external model controls robot
- Safety model describes position of robot parts and safety zones → sends speed updates as soon as one part is in a zone
- Application model steers movement of robot using a workflow → sends trajectory updates when one step in workflow is finished
- Recomputation only triggered if new input available (similar to reactive programming, unusual for RAGs)
- Generation with relational RAGs [1, 2]

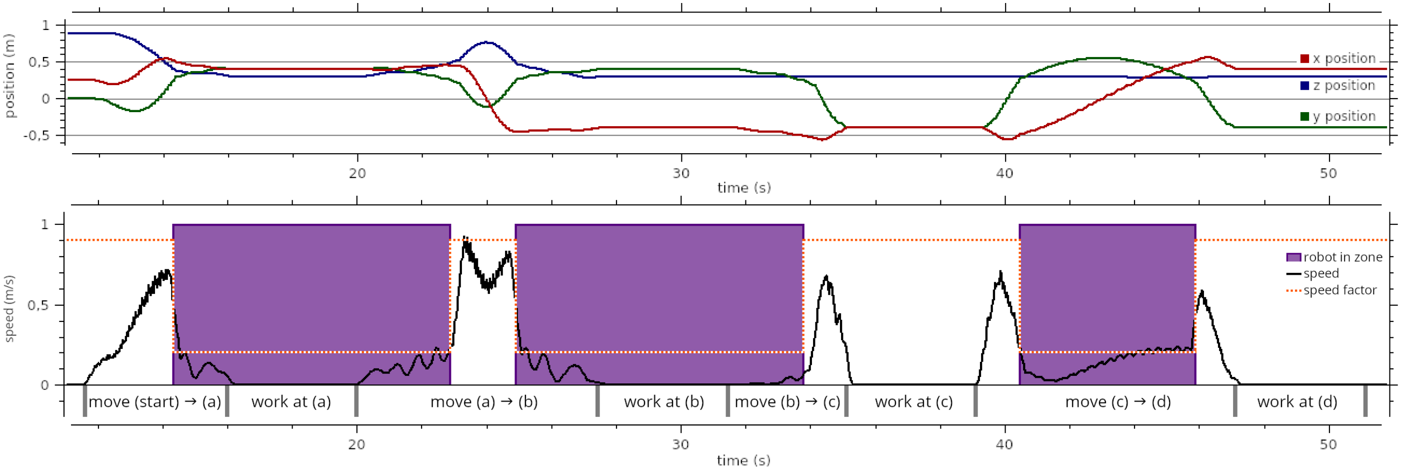
Evaluation with a robotic use case



← *View from above of the robot, showing its work plan and safety zone(s) in purple*

- With 18 and 28 LOC DSL-Code necessary 281 and 701 lines Java connection code is generated (safety model and application model, respectively) ①
- Over 38 000 position updates $\underset{③}{\rightarrow}$ 56 safety zone recomputations $\underset{②}{\rightarrow}$ necessary six speed updates sent
- External models connectable using standard communication protocols (e.g., MQTT) and any serialization format (e.g., Protocol Buffers) ④

coordinates of robot arm and when in safety zone



References

[1] Görel Hedin and Eva Magnusson. "JastAdd: an aspect-oriented compiler construction system". In: *Science of Computer Programming* 47.1 (2003), pp. 37–58. ISSN: 0167-6423. DOI: 10.1016/S0167-6423(02)00109-0.

[2] Johannes Mey et al. "Relational Reference Attribute Grammars: Improving Continuous Model Validation". In: *Journal of Computer Languages* 57 (Jan. 20, 2020), p. 21. ISSN: 2590-1184. DOI: 10.1016/j.cola.2019.100940.

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