Collaborative Embedded Systems CrESt

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Offen im Denken

Orthogonal Uncertainty Modeling

Motivation

Why uncertainty modeling?

- Collaborative embedded systems operate in highly dynamic environments and face various uncertainties during operation, e.g. caused by sensor imprecision or communication and coordination with other collaborating systems
- Systems need to be able to cope with such uncertainty autonomously during operation
- During development such capabilities need to be systematically planned and built into the system
- Especially in early phases, engineers and stakeholders need support in analyzing potential runtime uncertainty

The Modeling Language

Why *orthogonal* uncertainty modeling?

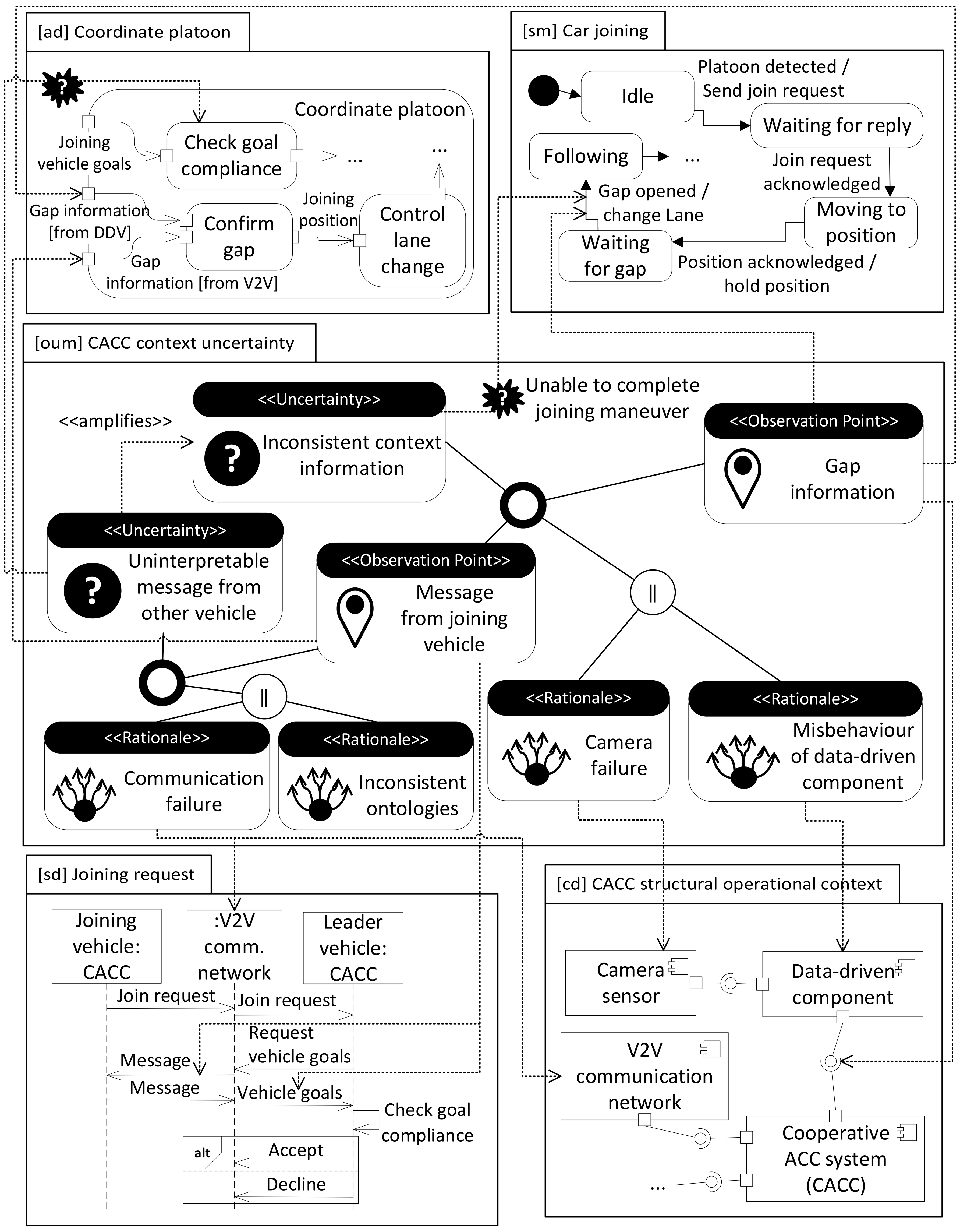
- Uncertainty is a multi-faceted and cross-cutting concern, similar to variability
- Uncertainty needs to be considered in different engineering artifacts throughout the entire development process
- Goal: Avoid redundancy of specified uncertainty information by means of a dedicated artifact that can be linked to any other engineering artifact

Core modeling concepts (excerpt)

- *Uncertainty*: Names a specific uncertainty and groups information that further describes it
- *Uncertainty Rationale*: A root cause of uncertainty
- *Activation Condition*: A condition under which an uncertainty can become active during operation
- *Observation Point*: Artifacts given which the system can detect the uncertainty during operation
- *Uncertainty Effect*: Effects of uncertainty on the system or its operational context

Example

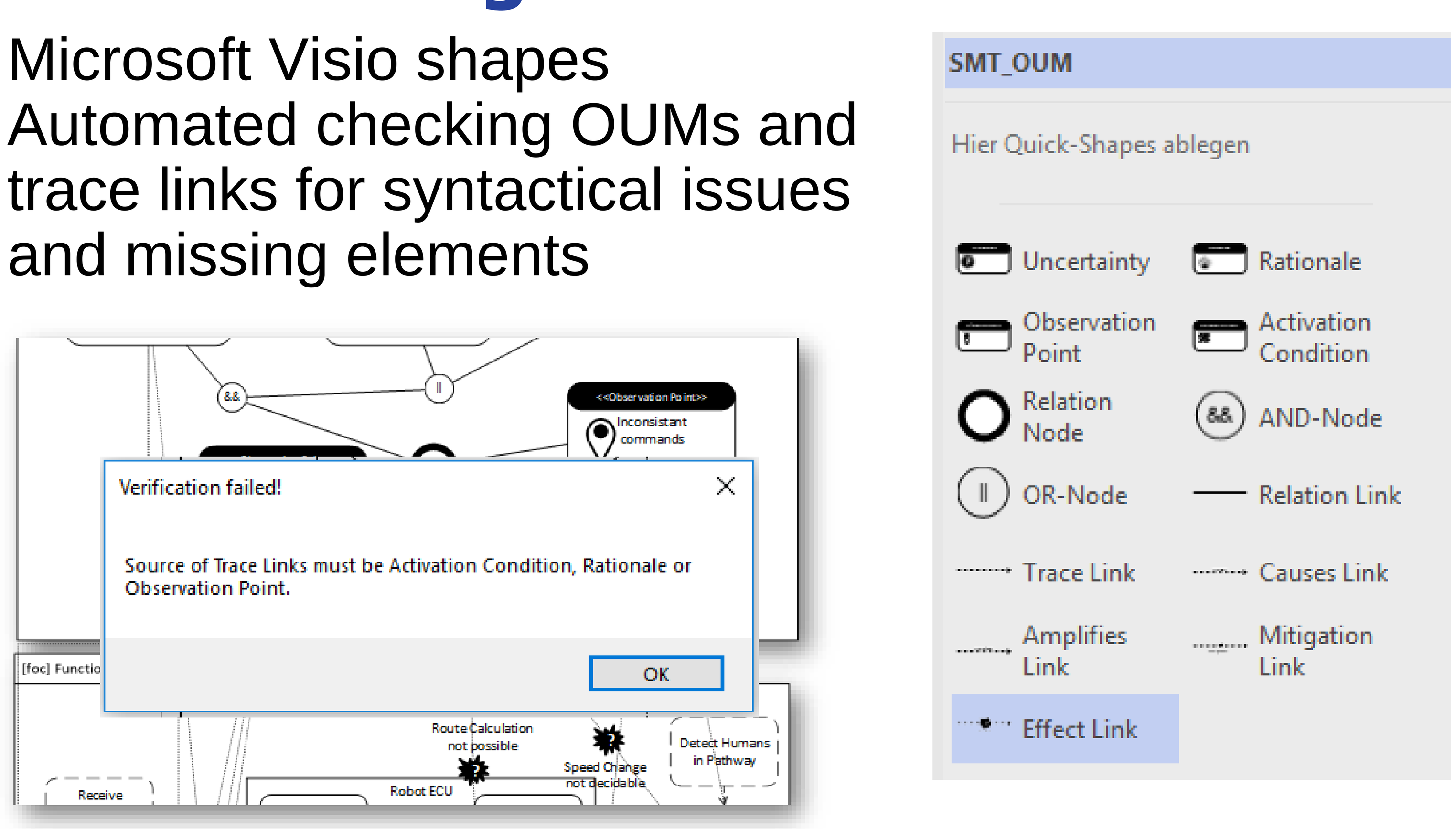
- Orthogonal uncertainty model (OUM) linked to models of a CACC system able to form platoons
- During the joining maneuver, uncertainty can occur due to failures of a camera sensor or misunderstandings of messages from other vehicles
- Uncertainty is related to structural, functional, behavioral and interaction models



Evaluation and Tool Support

OUM modeling tool

- Microsoft Visio shapes
- Automated checking OUMs and trace links for syntactical issues and missing elements



Evaluation results

- Applied to autonomous transport robots, vehicle platooning (see above) and smart & flexible factories
- Results indicate applicability to model various different kinds of uncertainties
- OUMs help structuring uncertainty information on different levels of abstraction

Further reading

- T. Bandyszak, M. Daun, B. Tenbergen, P. Kuhs, S. Wolf, T. Weyer: Orthogonal Uncertainty Modeling in the Engineering of Cyber-Physical Systems. IEEE T-ASE, Vol 17, No. 3, pp. 1250–1265, 2020, https://doi.org/10.1109/TASE.2020.29807263.
- T. Bandyszak, M. Daun, B. Tenbergen, T. Weyer: Model-based Documentation of Context Uncertainty for Cyber-Physical Systems. In 14th IEEE CASE, pp. 1087–1092, 2018, https://doi.org/10.1109/COASE.2018.85604802

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