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Component and Connector Views in Practice: An Experience Report (extended abstract)

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Abstract:

C&C views are a means for formal yet intuitive structural specification of C&C models. In [Be17] we report on our experience how C&C views and their verification help to address challenges of traceability and evolution in automotive industry. We analyzed the development process at Daimler AG and evaluated our C&C views verification tool on five Simulink models with more than 7700 subsystems in total and C&C views created for 183 textual requirements provided by Daimler AG. We describe our experience in detail and discuss a list of lessons learned, including, e.g., a missing abstraction concept in C&C models and C&C views that we have identified and added to the views language and tool, that engineers can create graphical C&C views quite easily, and how verification algorithms scale on real-size industry models. Furthermore, we report on the non-negligible technical effort needed to translate Simulink block diagrams to C&C models. We make all materials mentioned and used in our experience electronically available for inspection and further research.

Keywords: component and connector models, Simulink, architecture, industrial case study

C&C models, described using languages such as SysML, AADL, and related block diagram languages, are used extensively in software and systems engineering. Simulink/Stateflow [Ma16] are prevalent tools used in the automotive industry for model-based prototype implementation, simulation, and testing.

In recent work [MRR13; MRR14] we presented C&C views, as a means to formally and intuitively specify constraints on the structure of C&C models. The views allow engineers to specify constraints on hierarchy and connectivity, using partial examples, while crosscutting the implementation-oriented system/subsystem hierarchy of the target model.

In [Be17] we report on our experience in applying C&C views in practice, in an industrial, automotive setting, guided by the following questions:

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Q1 Which industrial contexts in automotive domain are relevant for C&C views and what challenges can the use of C&C views address?

Q2 Can domain experts create C&C views with reasonable effort and are they missing any language features?

Q3 Is C&C views verification applicable to automotive industry models and does it scale to deal with their size?

Q4 Are the verification outputs of use for the engineers?

Since the answer to **Q1** influences the experiment setup for the other questions, we decided to do a two-stage study. In the preliminary study, we interviewed industrial partners to investigate the automotive development processes and challenges of developers. Based on the findings of the preliminary study, we chose Daimler AG as an automotive partner and collected relevant documents and models for evaluation. We then executed the main study, to address questions **Q2** to **Q4**. We chose the automotive domain as representative for safety-critical, distributed control systems.

In the main case study, two domain experts created 50 C&C views based on 183 industrial textual requirements and design decisions of two automotive software systems: Advanced Driver Assistance Systems (ADAS), available in four different evolution versions, and Adaptive Light System (ALS). We devised a translation from Simulink block diagrams to C&C models to check the created C&C views using our existing verification tool [MRR14]. The translation from Simulink to C&C models involved non-negligible technical efforts. Finally, we presented the tool's generated witnesses, which demonstrate reasons for satisfaction or non-satisfaction, to the industrial partner who evaluated their usefulness with regard to two identified industrial challenges: traceability and evolution.

As part of our results, the industrial partner identified a missing abstraction concept in C&C views that we implemented. We found that given textual requirements, domain experts can create C&C views that highlight the implementation details of requirements in a Simulink model of hundreds of blocks with reasonable effort. We found that C&C views verification scales well for sizes of industrial models and average running times were below two seconds in all our experiments. Finally, C&C views helped the domain experts to discover several inconsistencies between requirements and their implementation.

We consider it an important contribution of our work that we have made **all artifacts we used and created available from** [www]. These materials include the four ADAS and the one ALS Simulink models (web export) by Daimler AG, their original requirements in German with an English translation, C&C views in textual and graphical representation, and all verification results. We encourage the reader to inspect these materials and use them for their own research.

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