

# Why Feature Dependencies Challenge the Requirements Engineering of Automotive Systems: An Empirical Study

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**Abstract:** Feature dependencies in automotive software systems are a major source of erroneous behavior. To overcome these problems, many approaches exist that focus on modeling these functional dependencies in early stages of system design. However, there are only few empirical studies that report on the extent of such dependencies in industrial software systems and how they are considered in an industrial development context. In this paper, we analyze the functional architecture of a productive automotive software system with the aim to assess the extent and awareness of interactions between features of a vehicle. Our results show that at least 85% of the analyzed vehicle features depend on each other. We furthermore show that the developers are not aware of a large number of these dependencies when they are modeled solely on an architectural level. These results challenge the current development methods and emphasize the need for an extensive modeling of features and their dependencies in requirements engineering.

## 1 Introduction

Feature dependencies are a major challenge in the development of software-intensive systems [Zav01]. They increase the complexity of the system and frequently entail unwanted and deficient system behavior [CKMRM03]. Nevertheless, feature dependencies are rarely considered in specifications of industrial systems. We analyzed an automotive software system and especially its functional architecture to contribute data on the amount and distribution of feature dependencies, and to evaluate to what extent developers are aware of these. A complete version of the paper and the study can be found in [VF13].

## 2 Study and Results

The purpose of our study was to obtain quantitative results from a sample and then follow up with a few individuals to explore those results in depth. In the first phase, a quantitative research question addresses the extent of feature dependencies in a productive automotive software system. In the second phase, we conducted qualitative interviews to probe the developer's awareness of the found dependencies. The analyzed system comprised 94 vehicle features and 325 leaf functions. Leaf functions may be used for the realization of more than one vehicle feature (see Figure 1a). Two vehicle features are dependent if at least two of their leaf functions exchange data. Based on this definition, we extracted a vehicle feature graph from the functional architecture, where each node is a vehicle feature

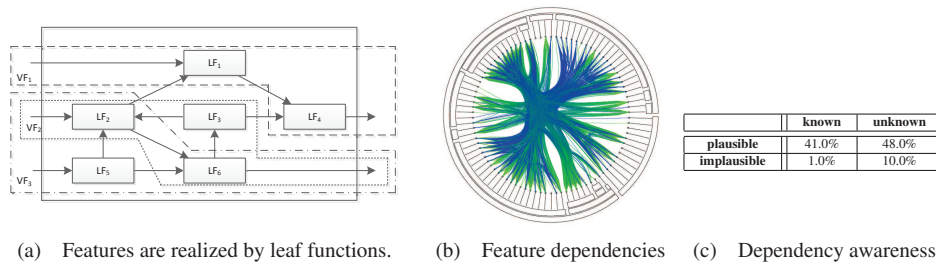
and a directed edge indicates a feature dependency. By the study results, we were able to answer the following research questions.

**RQ 1: What is the overall extent and distribution of feature dependencies?**

Analyzing the vehicle feature graph, we found 1,451 dependencies between the 94 vehicle features. Only 9 out of the 94 vehicle features were completely independent from any other vehicle feature. 81 vehicle features were dependent on another vehicle feature (i.e., had incoming dependencies) and 72 vehicle features had an influence on another vehicle feature (i.e., had outgoing dependencies). Figure 1b illustrates this intermeshed structure.

**RQ 2: To what extent are developers aware of feature dependencies?**

Table 1c summarizes the results of the expert interviews that we conducted to assess the plausibility and awareness of the analyzed feature dependencies. Most of the feature dependencies that we examined were considered as unknown but plausible, i.e., the experts were not aware of the dependency between the features but when examining the affected signals and leaf functions they found reasonable explanations for them.



### 3 Conclusions

The results show that feature dependencies pose a great challenge for the development of automotive software systems. Not only that almost every vehicle feature depends on and/or influences another vehicle feature, we have also seen that modeling the dependencies on an architectural level is insufficient for analyzing them, leading to a 50% chance that a developer is not aware of a specific dependency. Therefore, we argue that these dependencies need to be modeled precisely on the level of vehicle features, still independent from any architectural design decisions (cf. [Bro10]).

### References

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