Extent and Characteristics of Dependencies between Vehicle Functions in Automotive Software Systems

Modeling in Software Engineering @ ICSE 2012

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MAN Truck & Bus AG
E/E System Vehicle Dynamic Functions

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Modeling System Functions
Modeling System Functions

Extent

Characteristics
A vehicle system consists of a set of **vehicle functions (VF)**

- ACC
- Central Locking
- Air Condition
- Navigation
- …

- Emergency Shutoff
- Cooling Control
- …
Vehicle Functions and Architecture at MAN

• A vehicle system consists of a set of **vehicle functions (VF)**
• A vehicle function is realized by a set of **logical components (LC)**
Vehicle Functions and Architecture at MAN

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- Two vehicle functions are **dependent** if their logical components exchange data
Vehicle Functions and Architecture at MAN

- A vehicle system consists of a set of vehicle functions (VF)
- A vehicle function is realized by a set of logical components (LC)
- Two vehicle functions are dependent if their logical components exchange data
Extract from a real world truck system
Extract from a real world truck system

Electronic Braking Assistant

ACC
Extract from a real world truck system
Research Questions
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**RQ 1:** To what extent do dependencies between vehicle functions exist?
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RQ 2: How are dependencies distributed over all vehicle functions?
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**RQ 3:** What categories of data characterize the dependencies?
Research Questions

**RQ 1:** To what extent do dependencies between vehicle functions exist?

**RQ 2:** How are dependencies distributed over all vehicle functions?

**RQ 3:** What categories of data characterize the dependencies?

→ Analysis of the vehicle function architecture of a compact truck
Results for RQ 1: Extent of Dependencies

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>all VFs</td>
<td>55</td>
<td>100%</td>
</tr>
<tr>
<td>VFs with incoming dependencies</td>
<td>36</td>
<td>65.5%</td>
</tr>
<tr>
<td>VFs with outgoing dependencies</td>
<td>29</td>
<td>52.7%</td>
</tr>
<tr>
<td>VFs with incoming and outgoing dependencies</td>
<td>27</td>
<td>49.1%</td>
</tr>
<tr>
<td>VFs without dependencies</td>
<td>17</td>
<td>31.0%</td>
</tr>
</tbody>
</table>
## Results for RQ 2: Distribution of Dependencies

<table>
<thead>
<tr>
<th></th>
<th>Dependencies (Ingoing)</th>
<th>Dependencies (Outgoing)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum</strong></td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>0</td>
<td>0</td>
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![Bar chart showing the distribution of dependencies (fan-in) and (fan-out)]
Results for RQ 3: Characterization of Dependencies

Categorization of the dependencies according to their data type as

- **Value**: continuous data type (mostly physical units)
- **Enum**: discrete finite data type (but not Bool)
- **Bool**: two-valued type
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<tr>
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<td>Number</td>
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<tr>
<td><strong>Value</strong></td>
<td>122</td>
<td>26%</td>
</tr>
<tr>
<td><strong>Enum</strong></td>
<td>314</td>
<td>66.8%</td>
</tr>
<tr>
<td><strong>Bool</strong></td>
<td>34</td>
<td>7.2%</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>470</td>
<td>100%</td>
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→ over 74% of the dependencies have a discrete and finite data type
Basic Conclusions:

1. Dependencies between vehicle functions are numerous and pervade the whole system
2. Dependencies between vehicle functions are distributed over the whole system
3. The information that represents a dependency is in most cases a value from a discrete finite set of possible fixed values

Future Work:

– Extend the study to other companies and vehicle systems
– Structuring system functions w.r.t. minimal dependencies
– Exhibit dependency characteristics to model these
Conclusion and Future Work

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Thanks for the attention.

Special thanks to:
Maximilian Junker, Florian Deißenböck, Lars Heinemann, and Martin Feilkas
Backup
2 Types of Dependencies

Dependent by exchanging data

Dependent by sharing a common component
2 Types of Dependencies

Dependent by exchanging data

Dependent by sharing a common component → Cannot be ensured definitely
Threats to Validity

Threats to the internal validity

- Realization/implementation vs. requirements
- Analyzed model was not completed entirely
- Definition of dependency
Threats to Validity

Threats to the internal validity
- Realization/implementation vs. requirements
- Analyzed model was not completed entirely
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Threats to the external Validity
- Analysis only performed on a single system
- Complexity of a truck vs. complexity of a car
Vehicle functions as isolated units of functionality
→ Explicit modeling of dependencies
Discussion and Interpretation

Vehicle functions as isolated units of functionality
→ Explicit modeling of dependencies

Groups of vehicle functions are strongly connected
→ Introduction of hierarchical concepts for vehicle functions
Discussion and Interpretation

Vehicle functions as isolated units of functionality
→ Explicit modeling of dependencies

Groups of vehicle functions are strongly connected
→ Introduction of hierarchical concepts for vehicle functions

A majority of the dependencies have a discrete and finite data type
→ Dependencies represent state information or control commands
Thanks for the attention.

Questions?

* Special thanks to:
Maximilian Junker, Florian Deißenböck, Lars Heinemann, and Martin Feilkas