OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

INF FAKULTÄT FÜR INFORMATIK

# Potential Synergies of Theorem Proving and Model Checking for Software Product Lines

Thomas Thüm[1], Jens Meinicke[1], Fabian Benduhn[1], Martin Hentschel[2], Alexander von Rhein[3], Gunter Saake[1]

May 7th, 2014

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[2] University of Darmstadt, Germany
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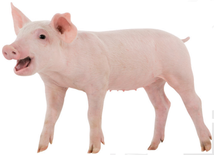
# Variability in Single-System Engineering

1. Strategy: clone-and-own, copy-and-modify, branching, ...

**David W. Stefan Tassio**



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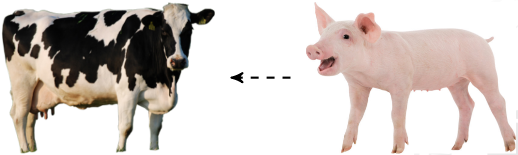

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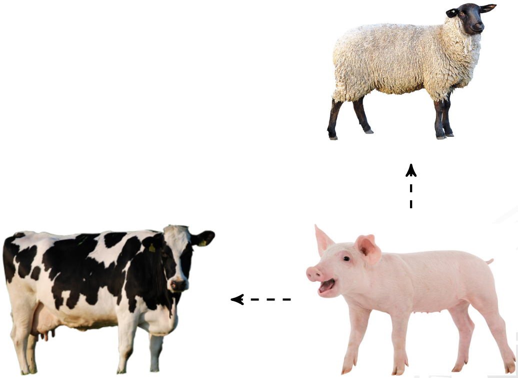

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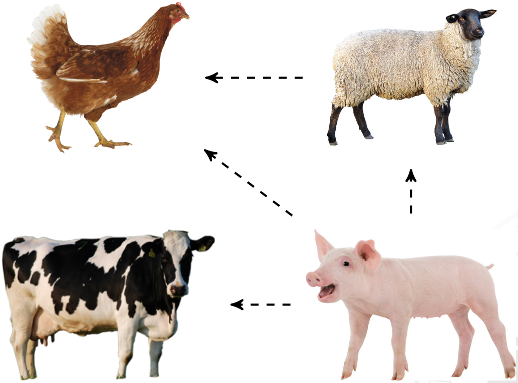

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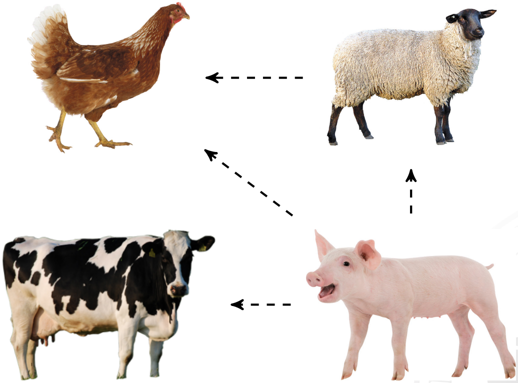

Problems: creation, bug fixes, extension, ... [code-clones problems]

# Variability in Single-System Engineering

2. Strategy: runtime variability/parameters, all-in-one-solution, swiss army knife (German: Eierlegende Wollmilchsau), . . .

Max

# Variability in Single-System Engineering

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Problems: footprint, performance, safety, security, ... [unused functionality]

Max

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Compile-time variability: components, plug-ins, feature modules, aspects, build scripts, preprocessors, virtual separation, . . .

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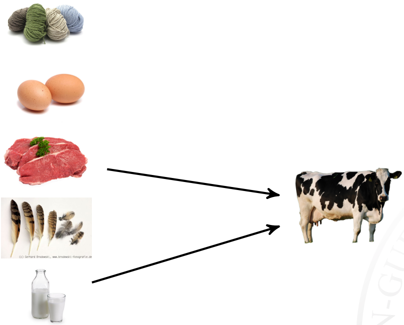

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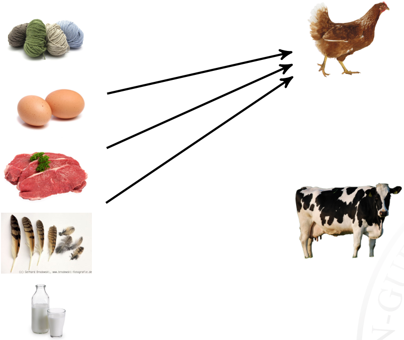

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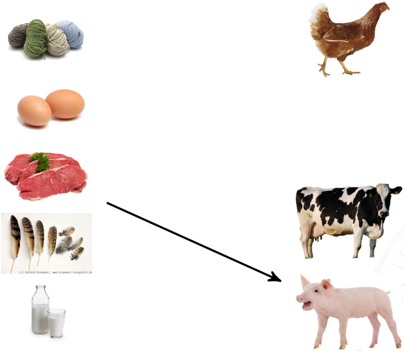

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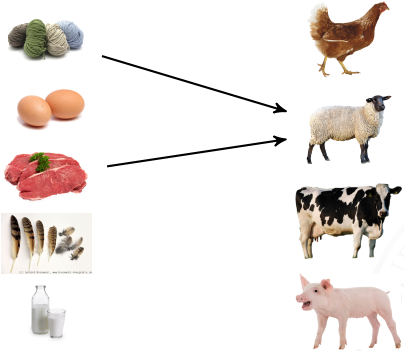

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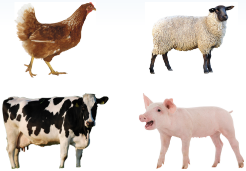
Challenges: testing, verification, specification, ...

# Transition between Variability Representations



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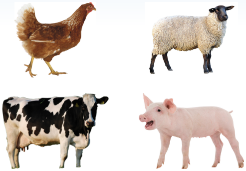

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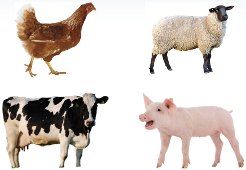

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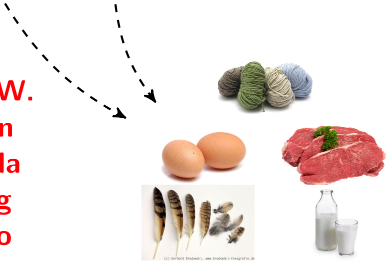

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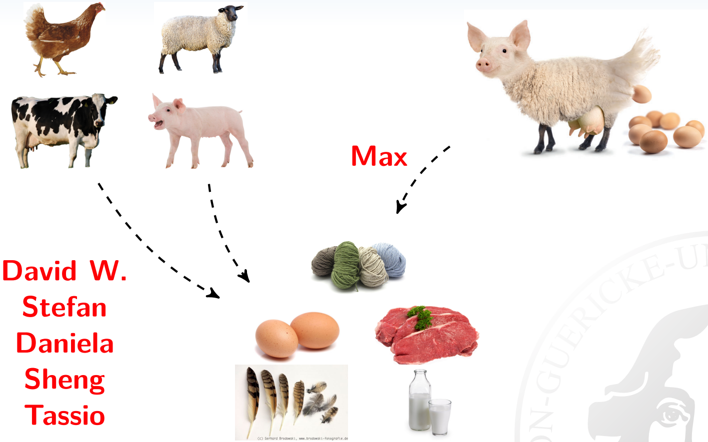

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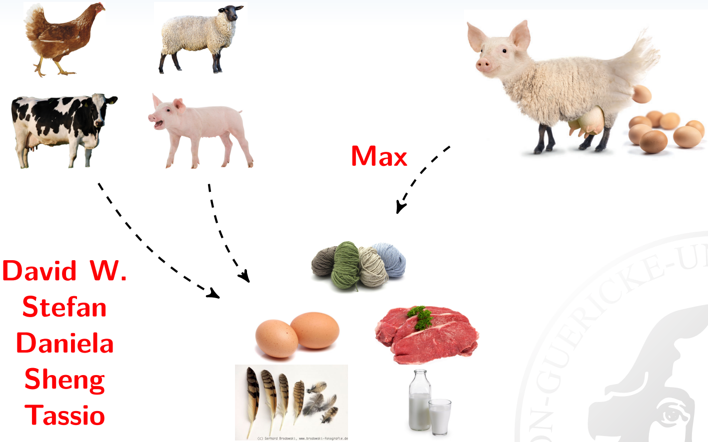


High manual effort

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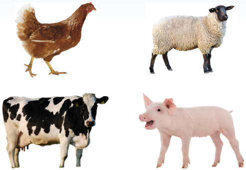

Christoph
Max

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High manual effort vs. automatic generation

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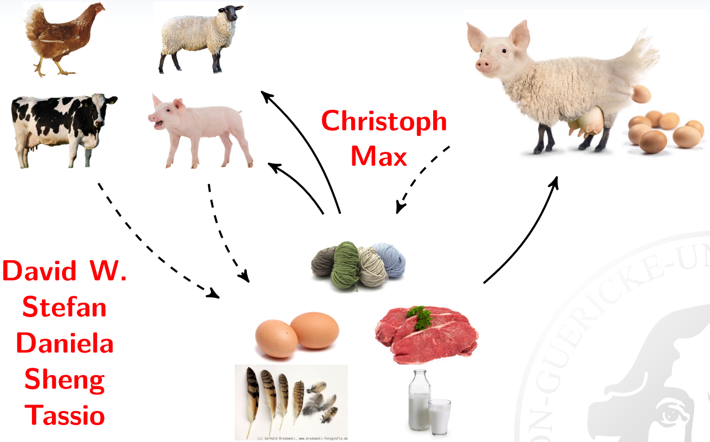


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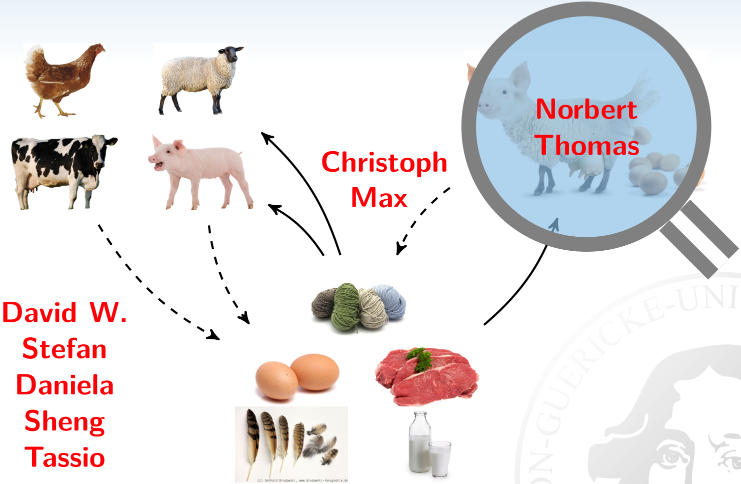


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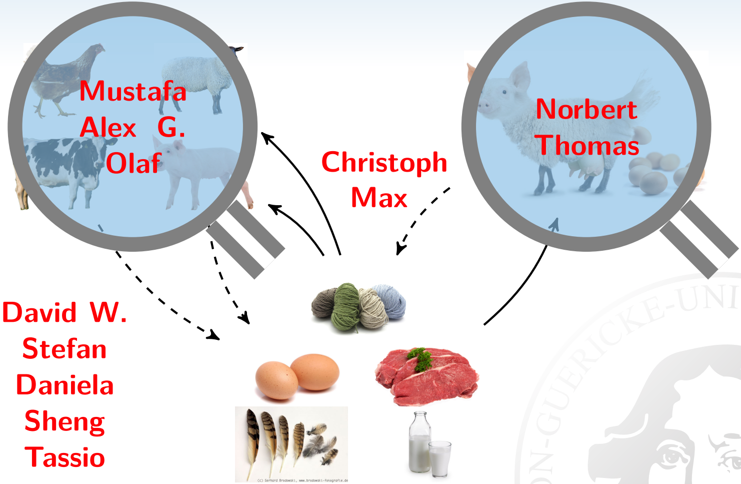


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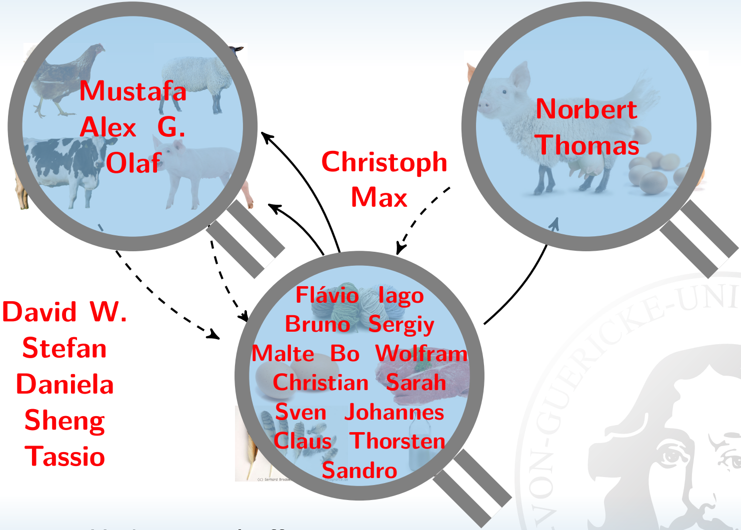


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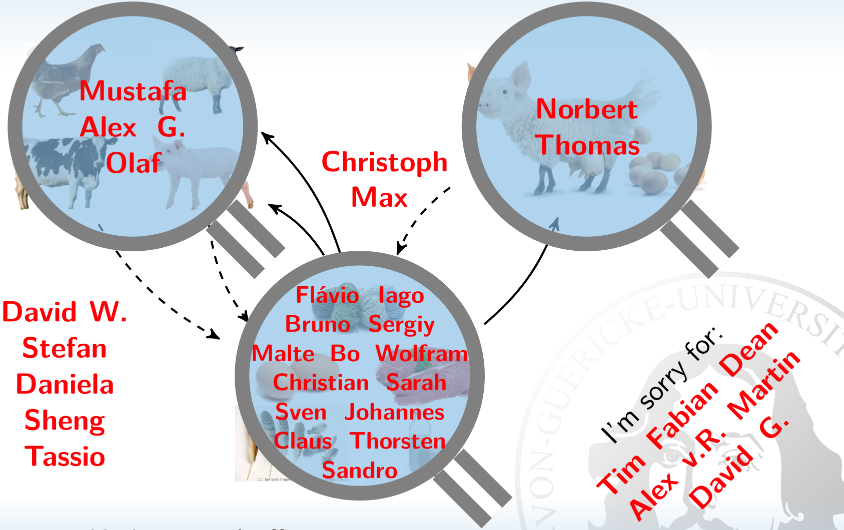


High manual effort vs. automatic generation

# Variability Encoding

Translating compile-time into run-time/load-time variability for:

- Model checking — Post and Sinz [2008], Apel et al. [2011], Classen et al. [2011], Apel et al. [2013]
- Theorem proving — Thüm et al. [2012]
- Testing — Kästner et al. [2012]
- Predicting non-functional properties — Siegmund et al. [2013] **Norbert**
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We can reuse tools from single-system engineering!

# Theorem Proving vs. Model Checking

- Deductive reasoning
- Code translated into first-order logic
- Transformation of logic formulas
- Methods in isolation
- Applicable to incomplete code
- Theorem provers: KeY, Coq, ...

- Exhaustive search
- Specification translated into runtime assertions
- Code (symbolically) executed
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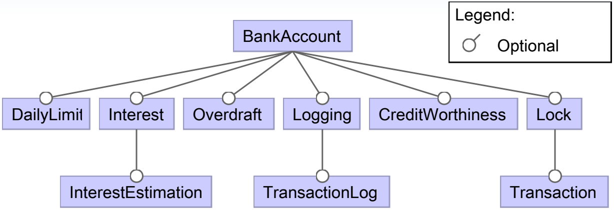
What is more efficient/effective?

# Empirical Comparison




Logging ∧ Transaction ⇔ TransactionLog

- Feature modules with feature-oriented contracts
- Dependent variables: verification time, effectiveness
- Independent variables: number of features, number of defects

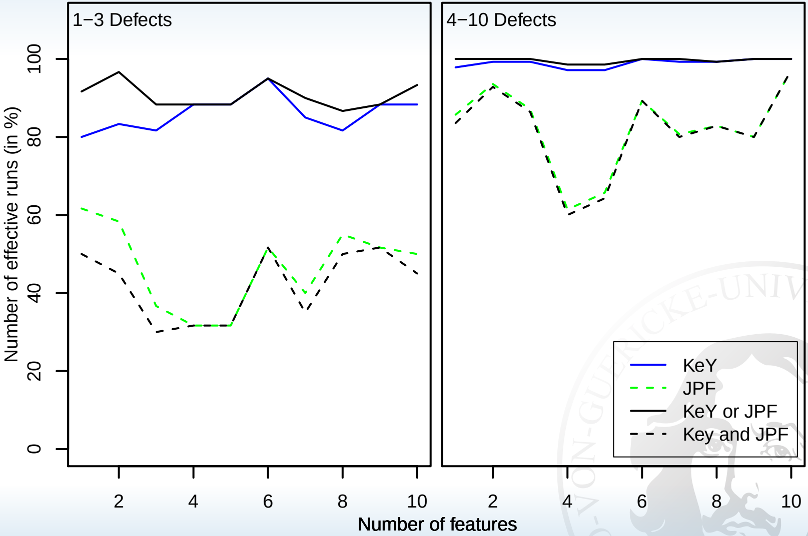
# Automatic Generation of Defects

Typical mutations from mutation testing — Jia and Harman [2011]

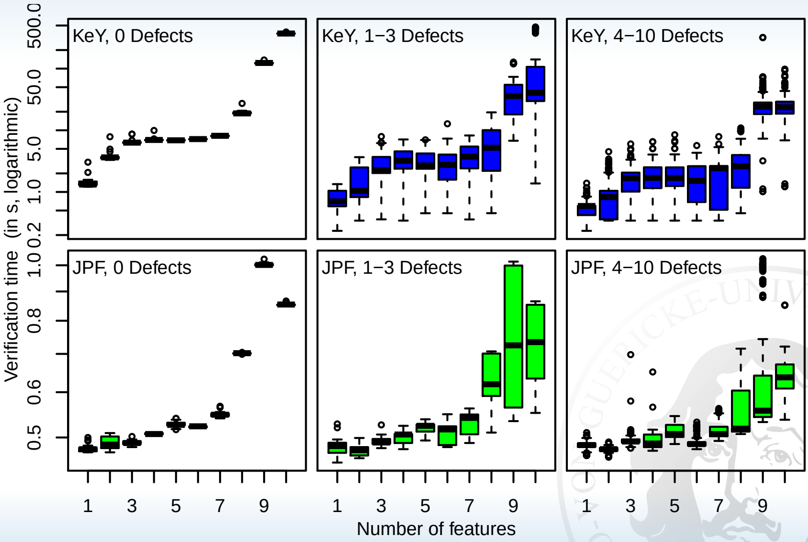
| Source/Target | Target/Source | In Java | In JML |
|---|---|---|---|
| `<` | `>` | 6 | 0 |
| `<=` | `>=` | 2 | 17 |
| `!=` | `==` | 0 | 39 |
| `&&` | `\|\|` | 0 | 11 |
| `==>` | `<==>` | 0 | 27 |
| `+` | `-` | 7 | 8 |
| `*` | `/` | 11 | 0 |
| `+=` | `-=` | 4 | 0 |
| `false` | `true` | 27 | 1 |

To simulate different stages during development

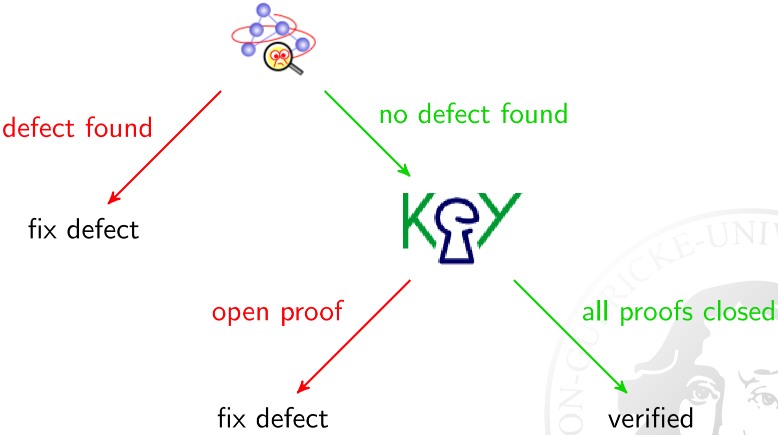
# Effectiveness of Theorem Proving and Model Checking



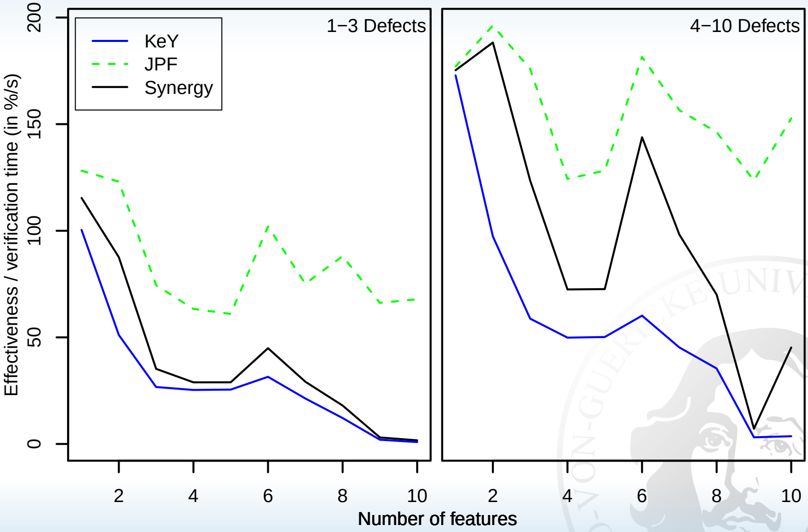
# Performance of Theorem Proving and Model Checking



# Combining Theorem Proving and Model Checking



# Efficiency of Theorem Proving and Model Checking



# Conclusion

- Theorem proving and model checking are more effective *and* efficient for many than for few defects
- Model checking is more efficient, but less effective
- Combination improves efficiency and effectiveness
- Combination especially more effective for few defects

# FOSD Meeting 2014

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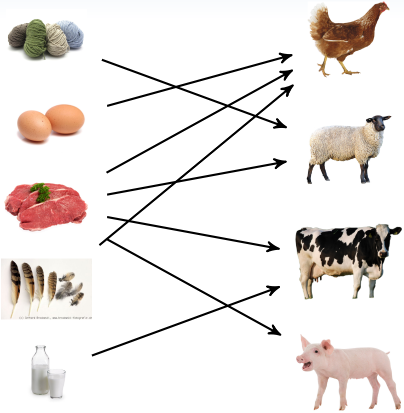

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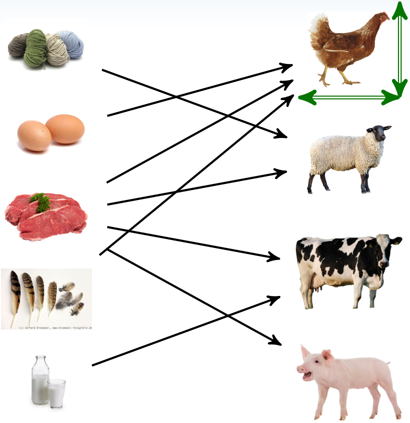

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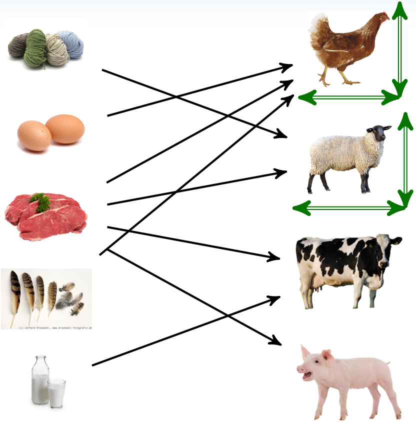

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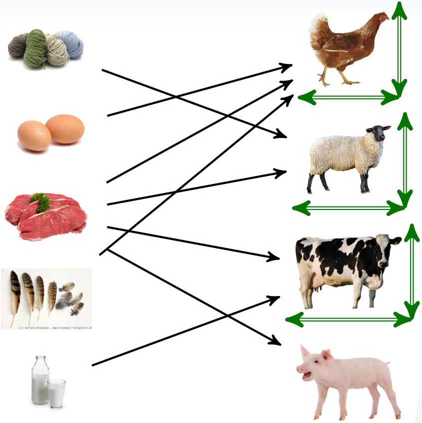

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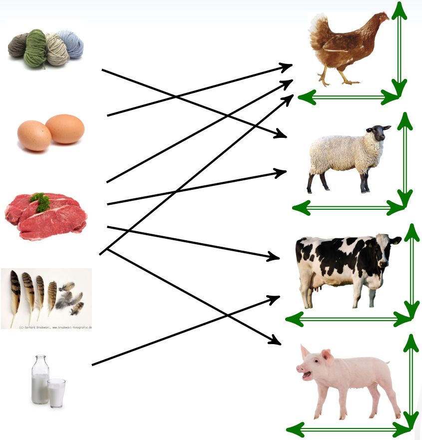

Problems: specification clones, scalability

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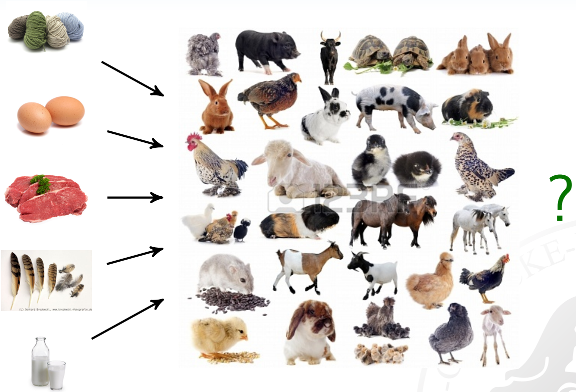


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FASE'12, CSUR'14:

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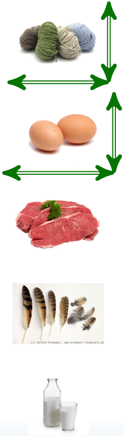

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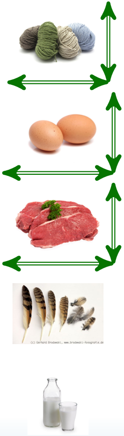

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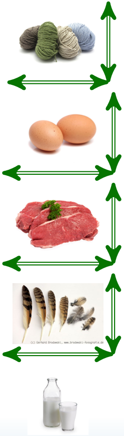

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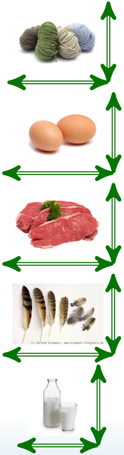

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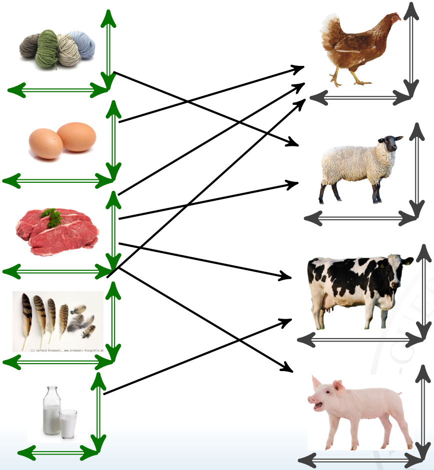

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CSUR'14:

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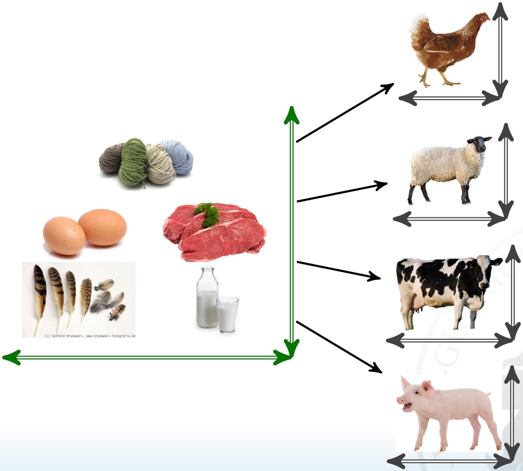

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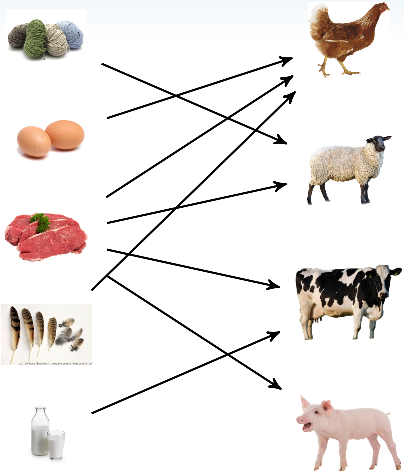

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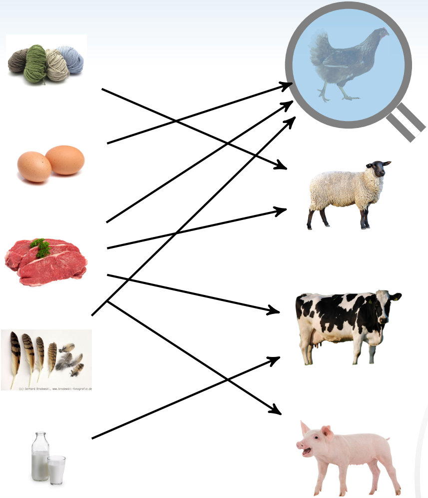

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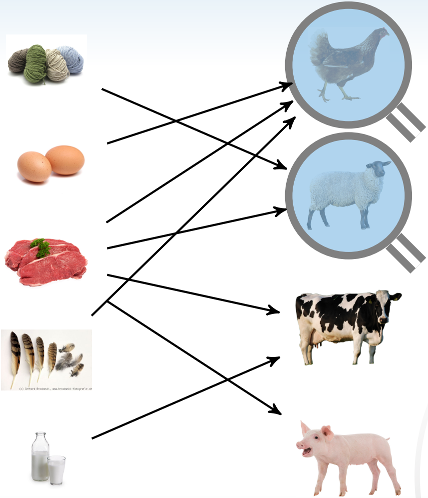

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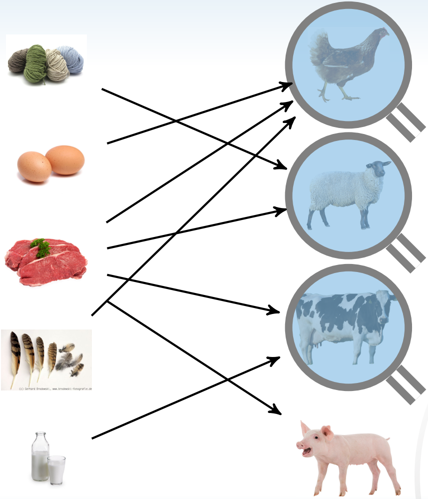

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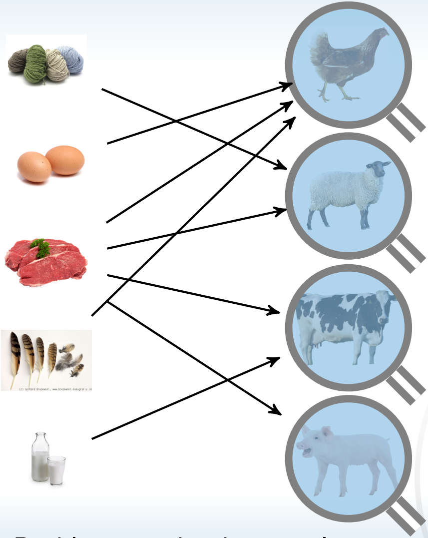

Problems: redundant analysis, scalability

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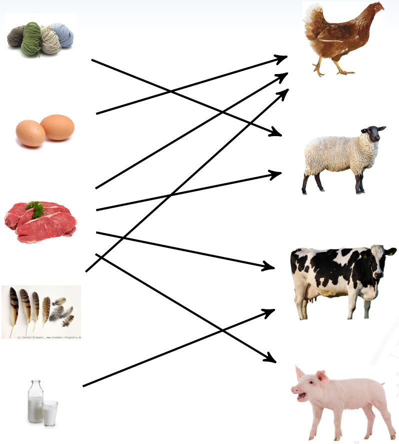

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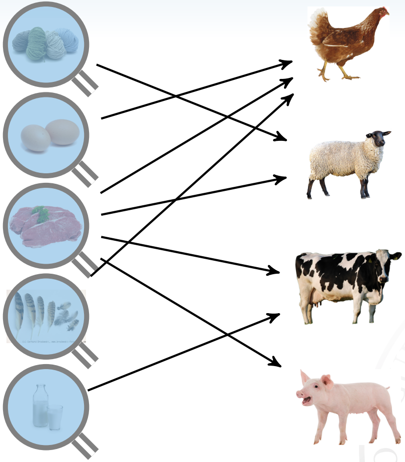

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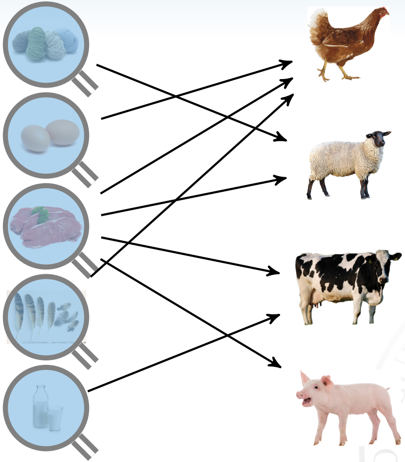

Limitation: only compositional properties

# Family-Based Analysis

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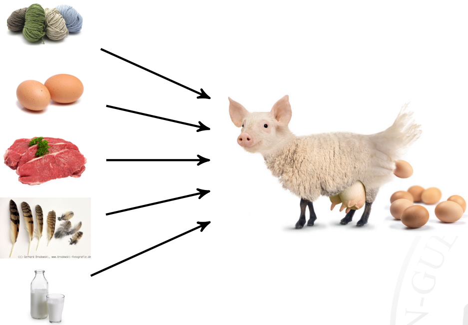
Automatic (!) transition of compile-time into runtime variability only for analysis



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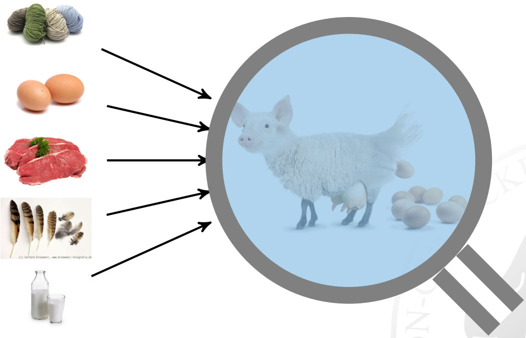

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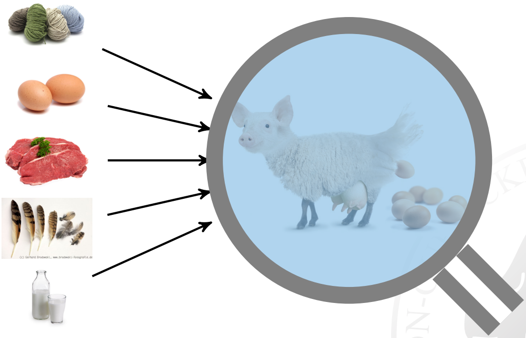

Enables reuse of analysis tools from single-system engineering

# Implementation vs. Specification vs. Analysis

Possible combinations of the strategies:

| Impl. \ Spec. | Product-based | Family-based | Feature-based |
|---|---|---|---|
| Product-based | | | |
| Family-based | | | |
| Feature-based | | | |

# Implementation vs. Specification vs. Analysis

Possible combinations of the strategies:

| Impl. \ Spec. | Product-based | Family-based | Feature-based |
|---|---|---|---|
| Product-based | P | P | P |
| Family-based | P | P | P |
| Feature-based | P | P | P |

Legend: P/F/f - product/family/feature-based analysis

# Implementation vs. Specification vs. Analysis

Possible combinations of the strategies:

| Impl. \ Spec. | Product-based | Family-based | Feature-based |
|---|---|---|---|
| Product-based | P | P | P |
| Family-based | P | P F | P F |
| Feature-based | P | P F | P F |

Legend: P/F/f - product/family/feature-based analysis

# Implementation vs. Specification vs. Analysis

Possible combinations of the strategies:

| Impl. \ Spec. | Product-based | Family-based | Feature-based |
|---|---|---|---|
| Product-based | P | P | P |
| Family-based | P | P F | P F |
| Feature-based | P | P F | P F f |

Legend: P/F/f - product/family/feature-based analysis