Semantics in Software Engineering - Towards Ontology-Driven Software Development

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What does Dresden have to do with Ontologies?

Outline

Introduction

Differences of ontology languages and UML/MOF/OOP

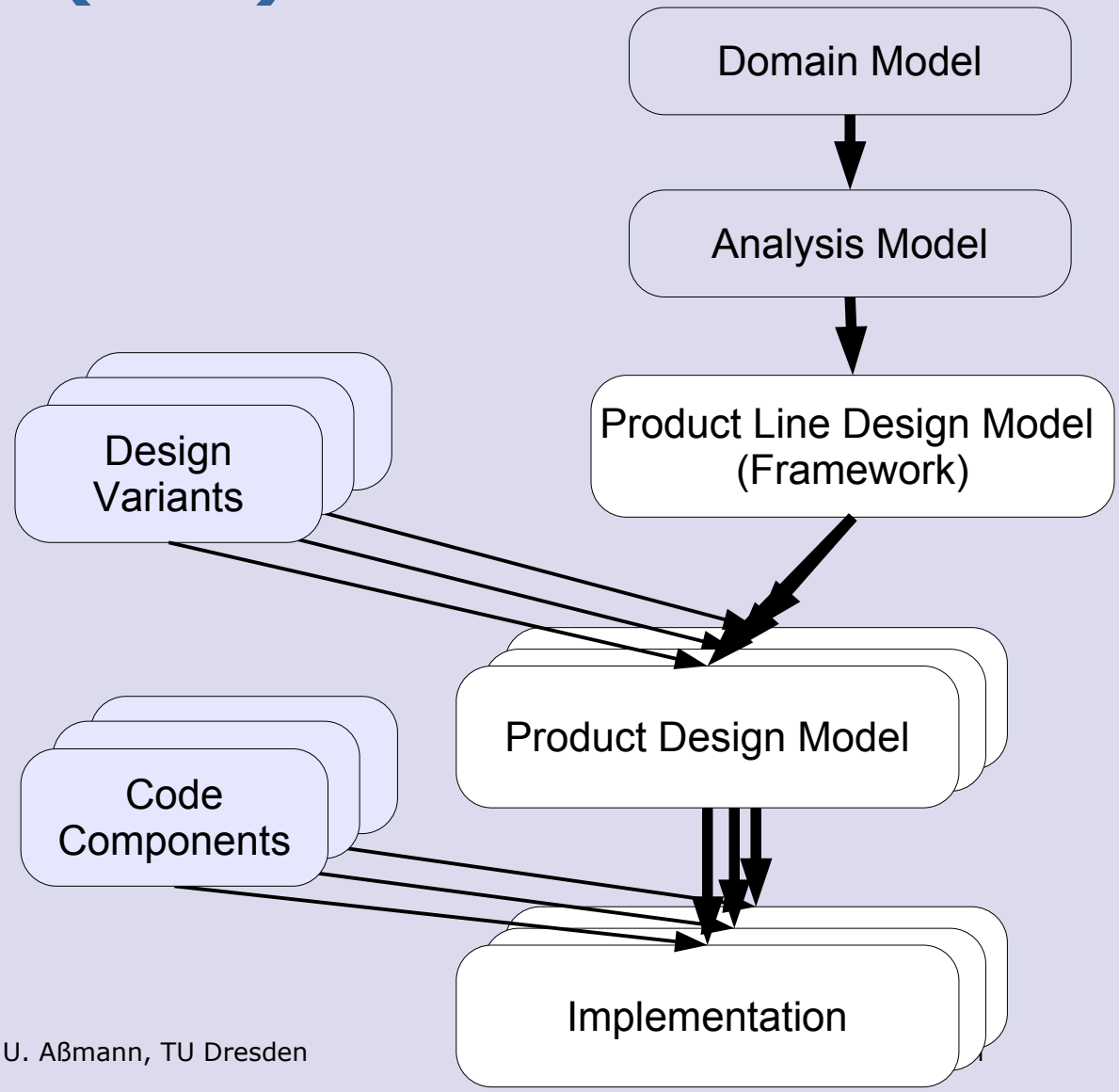
Advantages of ontologies in product-line engineering

- 1) Future domain models will be ontologies
- 2) Ontologies as constraints in product-lines

Integration technologies

[Challenges for integration and the EU MOST project]

Analysis and Design in Modern Product-Line Engineering (PLE)



Domain vocabulary of the product family

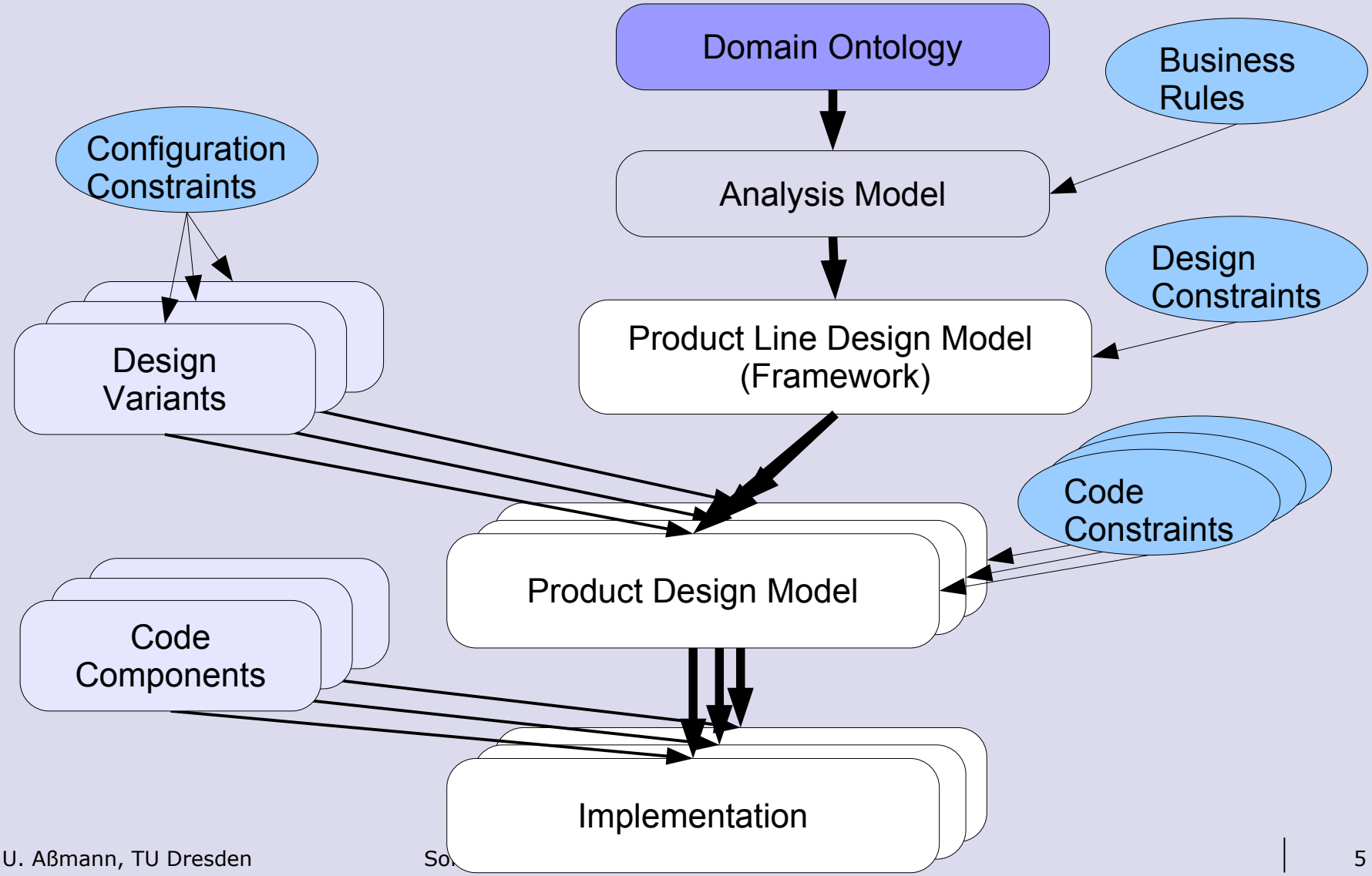
Specifications for requirements of a product family

Technical design of the product family (commonalities)

Technical design of the products

Implementations of products

Product-Line Engineering with Ontologies



Considerable Differences of Ontology and Modeling languages

OWL vs UML

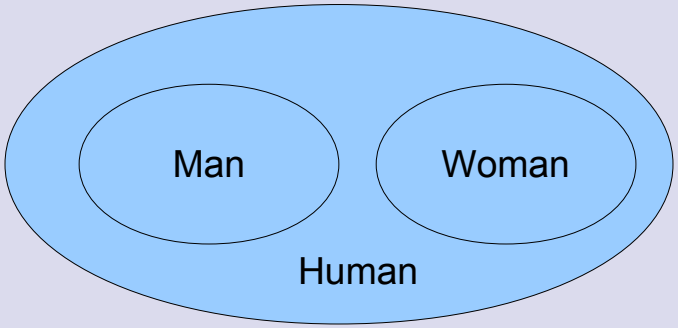
Technological spaces

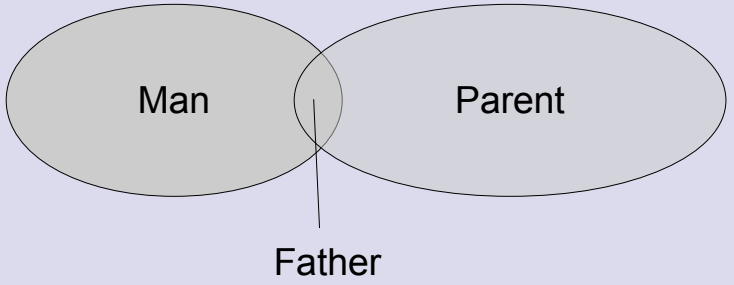
OWL

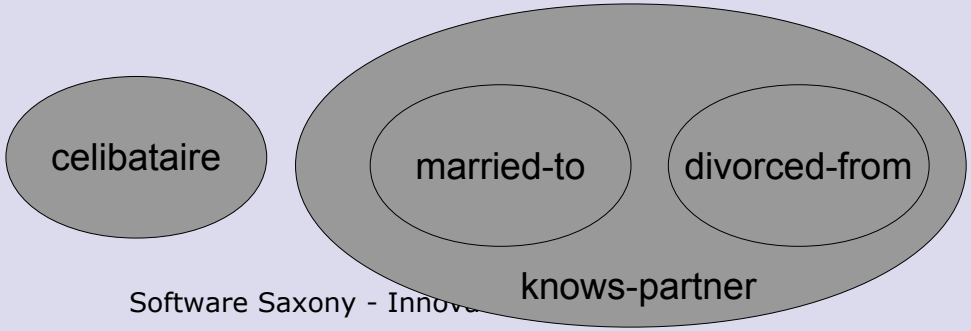
Classes are sets

Classes and relations can be defined by *expressions*

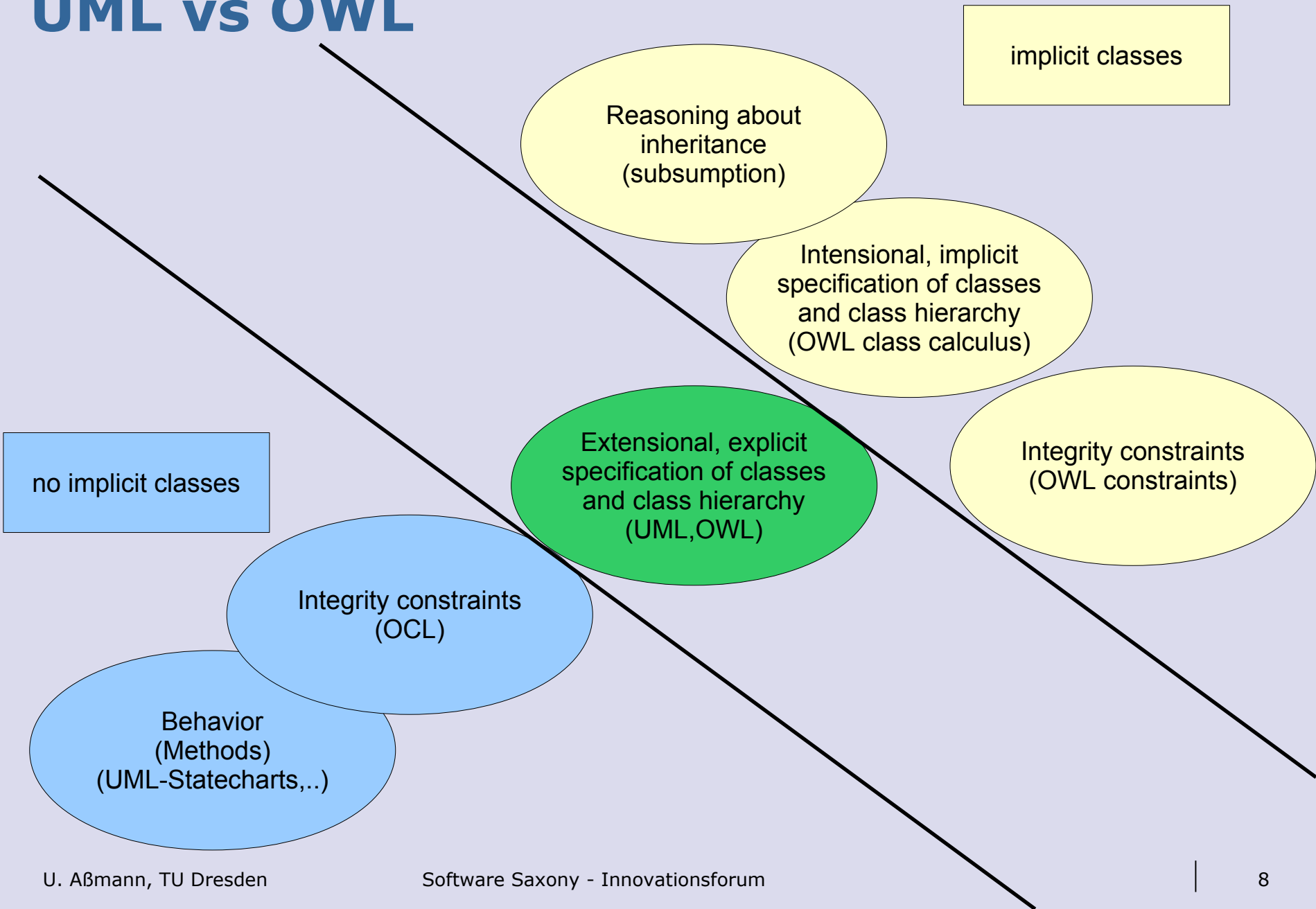
- with set union, difference, intersection (Venn diagrams)







UML vs OWL


implicit classes
Reasoning about inheritance (subsumption)
Intensional, implicit specification of classes and class hierarchy (OWL class calculus)
Integrity constraints (OWL constraints)
Extensional, explicit specification of classes and class hierarchy (UML,OWL)
no implicit classes
Integrity constraints (OCL)
Behavior (Methods) (UML-Statecharts,..)

OWL uses Sets

big class universe

Intensional specification

- Creating new classes by expressions (class calculus)
- Father = Male ∩ Parent

Reasoning about the inheritance relations in the resulting lattice

complex class relations

- disjointness of classes
- finding out whether a specific class exists (concept satisfiability)

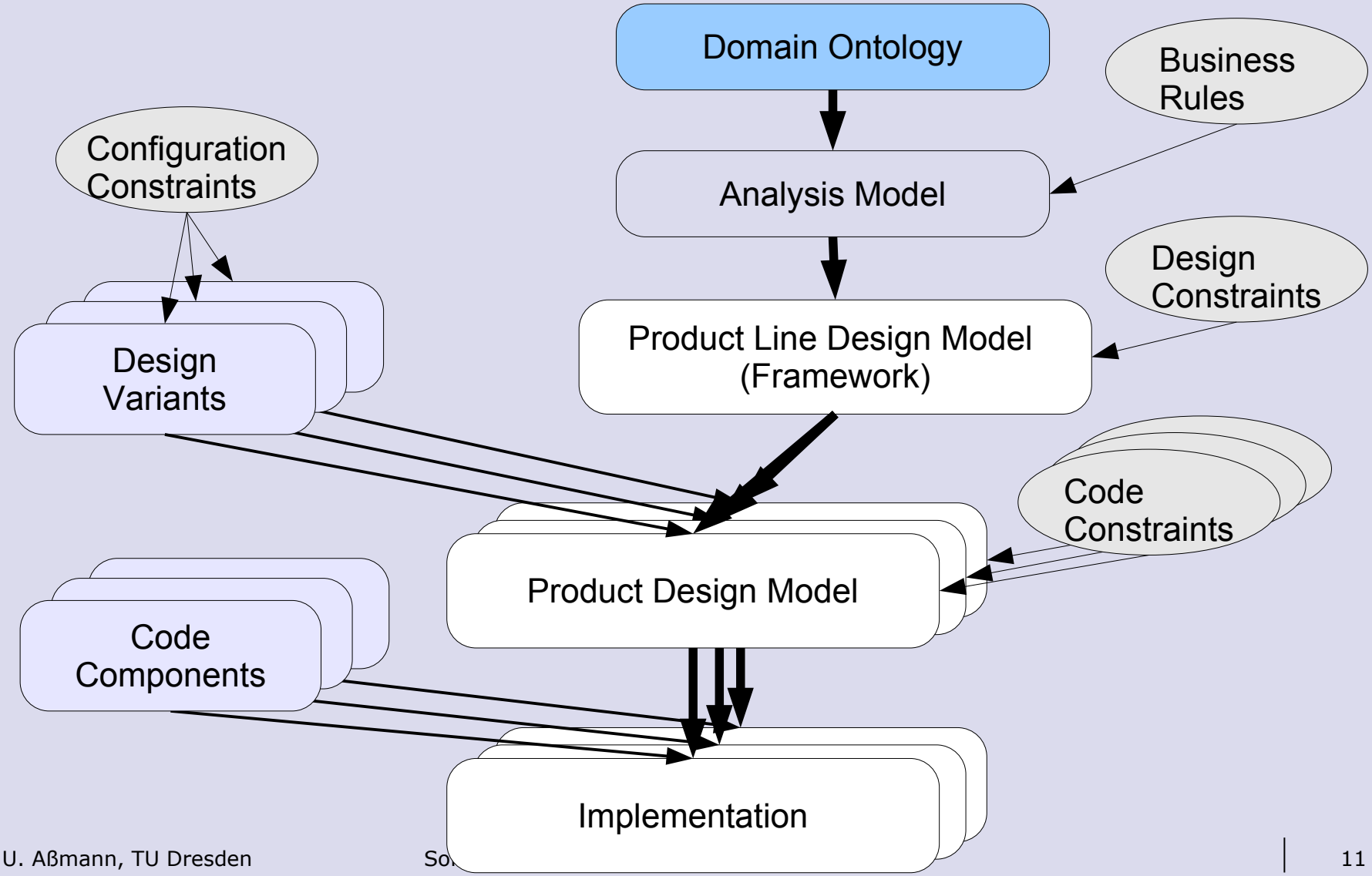
Integrity constraints

- All Father: Male

wellformed models

Advantages of Ontology Languages in Product-Line Engineering

Product-Line Engineering with Ontologies as Domain Models



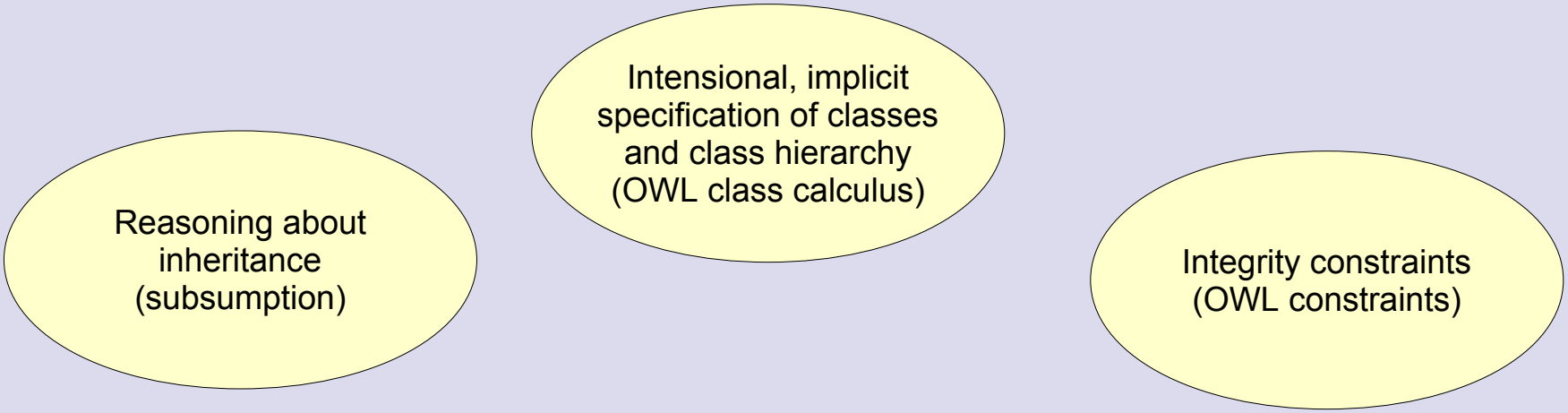
1) Future Domain Models will be Ontologies

A domain may be very large and complicated

- Expressions describe it
- Integrity constraints are checked by reasoner

Domain experts aren't software engineers

This influences Product Data Engineering



Example: Car Industry

A Phaeton has 10000 parts

- Life-time tracked
- Many different variants (individualized), many integrity constraints
  - "diesel ∩ catalysator" does not exist
  - "gas ∩ russfilter" does not exist
  - "diesel ∩ 10-cylinder ∩ cabriolet" exists

How to model this appropriately?

Ontologies are good for product data engineering (PDE) in supply chains

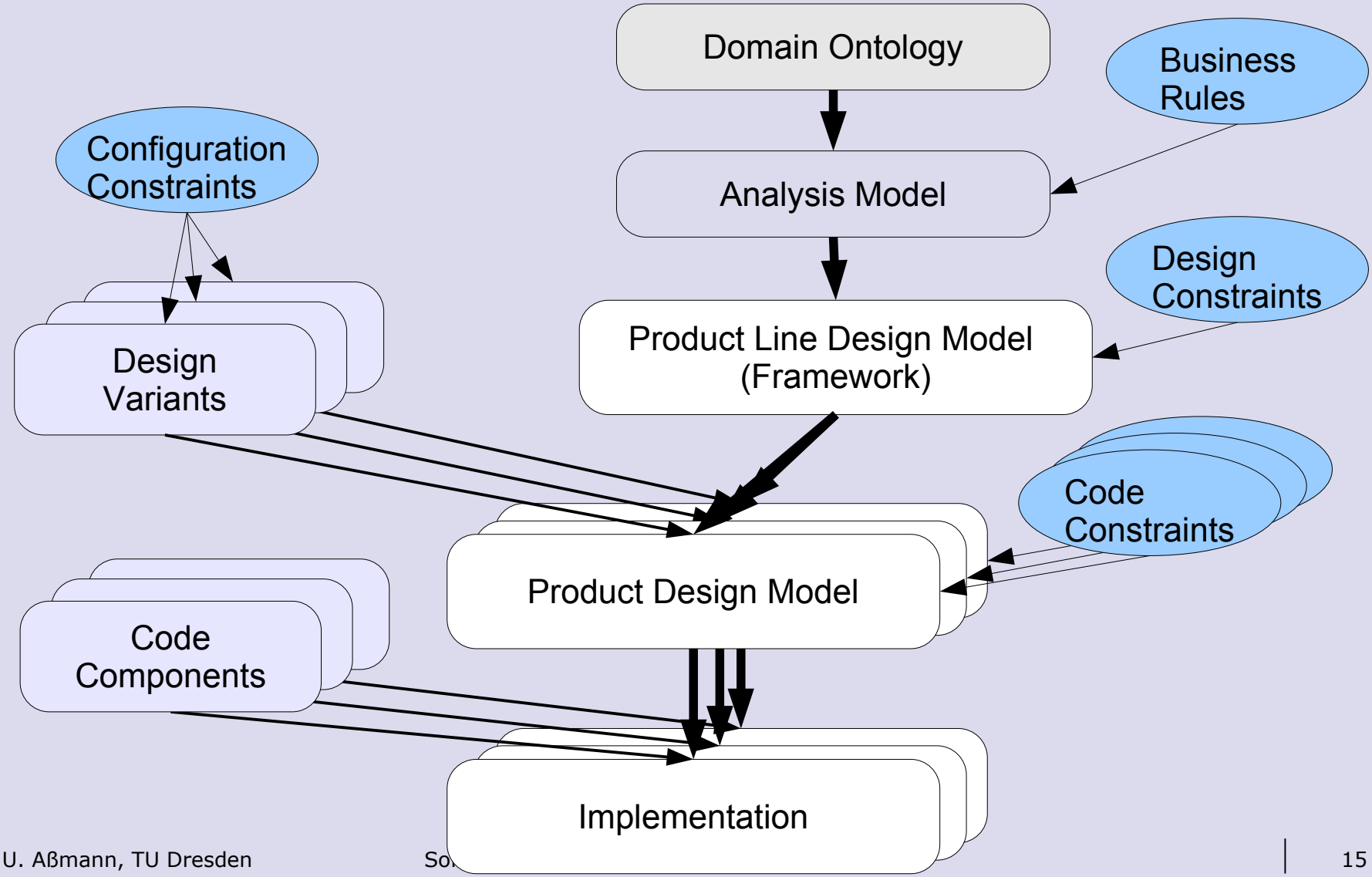
Ex.: Gene Ontology

Saxony wants to be a Bio-technology region

Checkout www.geneontology.org

- Component Ontology:
  - Rules governing content and stylistic aspects of GO terms in the cellular component ontology.
  - The Cell Protein Complexes Membranes and Envelopes ..
- Function Ontology:
  - Rules governing content and stylistic aspects of GO terms, standard definitions and term relationships in the molecular function ontology.
- Process Ontology:
  - Rules governing content and stylistic aspects of GO terms, standard definitions and term relationships in the biological process ontology.
  - The Cell Cycle The Development Node Interaction Between Organisms ...

2) Product-Line Constraints in Ontologies



Examples: Integrity Constraints in Phaeton Product Line

Business rules

- FavoredCustomer = Customer and Customer.turnaroud > 50000
- “John Silver” instanceOf FavoredCustomer?

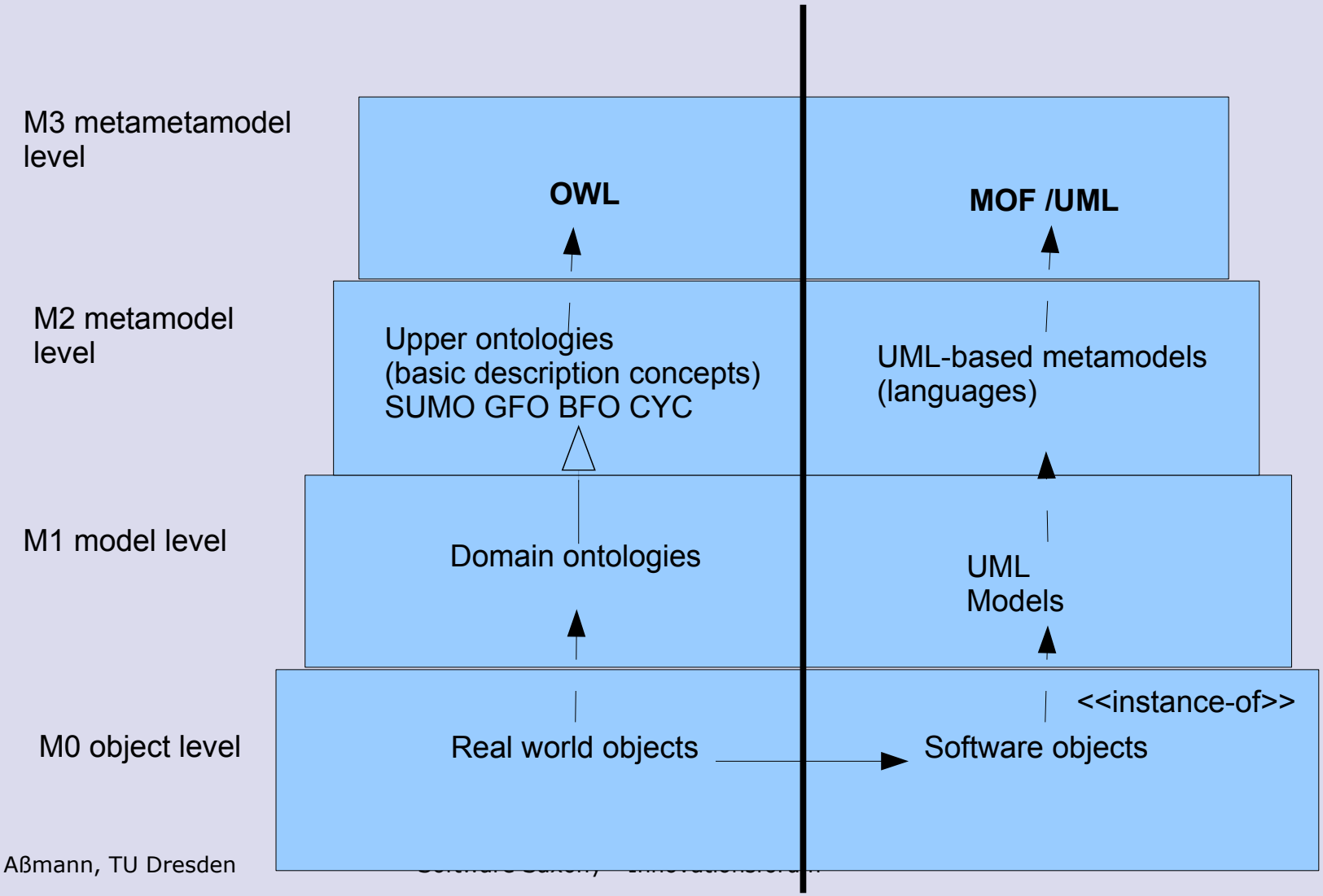
Configuration constraints

- CheapVersion = Phaeton ∩ 6-cylinder
- ExpensiveVersion = Phaeton ∩ 10-cylinder ∩ Diesel ∩ Cabriolet

Design and code constraints

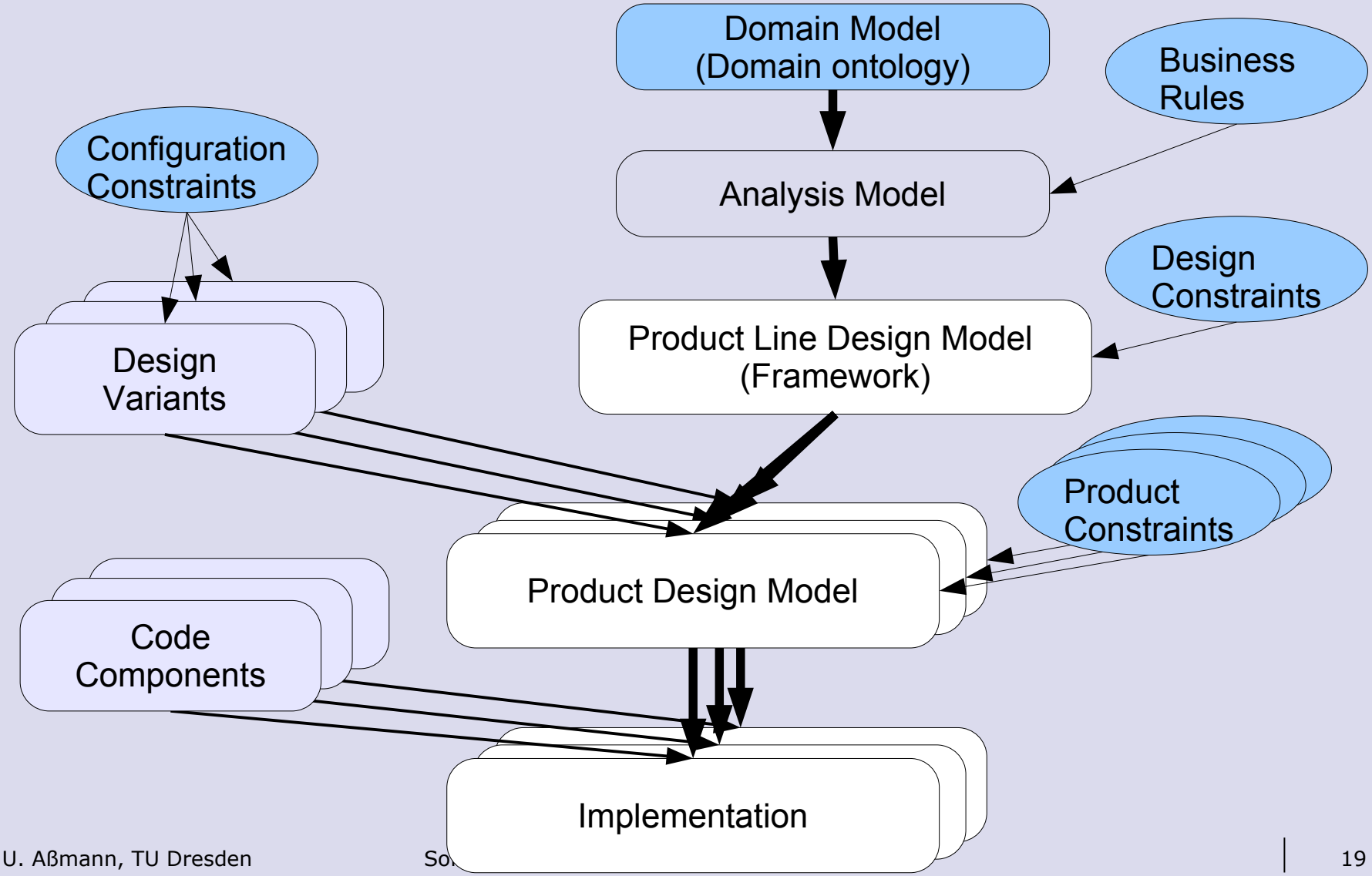
- #Component.neighbors < 10
- #Class.methods < 20

Unfortunately: Two Separate Technological Spaces



Integration Technologies for Ontologies and System Models

How to Access the Domain Model and the Constraint Ontologies?



Black-Box Integration of Ontologies

Using an ontology as data base

SPARQL, RDQL querying as with Embedded SQL

```
SELECT
   ?definition
WHERE
   (?concept, <wn:wordForm>, "car"),
   (?concept, <wn:glossaryEntry>, ?definition)
USING
   wn FOR <http://www.cogsci.edu/~wn/schema/>";
```

```
// Create a new query passing a String containing the RDQL to
xecute
uery query = new Query(queryString);
// Set the model to run the query against
query.setSource(model);

// Use the query to create a query engine
QueryEngine qe = new QueryEngine(query);
// Use the query engine to execute the query
QueryResults results = qe.exec();
```

[Philip McCarthy. Introduction to Jena - Use RDF models in your Java applications with the Jena Semantic Web Framework. http://www.ibm.com/developerworks/xml/library/j-jena/]

Problem: Speed

A tight integration of ontologies into programs would be much faster

Tight Integration of Ontologies

A tight integration of ontologies into programs would be much faster

Solution: Prova (Prolog+Java)

- Prof. Michael Schröder, TU Dresden
- http://prova.ws
- Java classes can contain Prolog rules

Solution 2: Language Integration by metamodel Integration

- e.g., as sublanguages for data definition and integrity
- There should be one universal metalanguage for ontologies and system models
  - But which one: MOF? OWL, SWRL, F-Logic? SUO? SUMO? GOL, ERDF?
- --> MOST Project

Challenges for Integration of Ontology and System Modeling Languages

Models vs Ontologies – A Big Difference
Description or Control

A model can be *descriptive* or *prescriptive*.
[Seidewitz CACM 03]

Models describe or control reality.
If they describe, they monitor reality and form true, or faithful, abstractions (Analysis, Reengineering)
If they control, they prescribe reality (Construction, Specification)

Ontologies need the **open-world assumption**

- Analysis perspective
- **Anything not explicitly expressed is unknown**
- Ontologies use a form of partial description to abstract

Descriptive

System models need **closed-world assumption**

- Design perspective
- **Anything not explicitly expressed is wrong**
- System models specify completely

Prescriptive

Analysis with Ontologies, Specification with System Models

An **ontology:**

a standardized,
descriptive model,

representing reality
by a set of concepts, their
interrelations, and constraints
under
open-world assumption.

A **system model:**

a non-standardized,
prescriptive model,

representing a set of systems
by a set of concepts, their
interrelations, and constraints
under
closed-world assumption.

What to Do with What

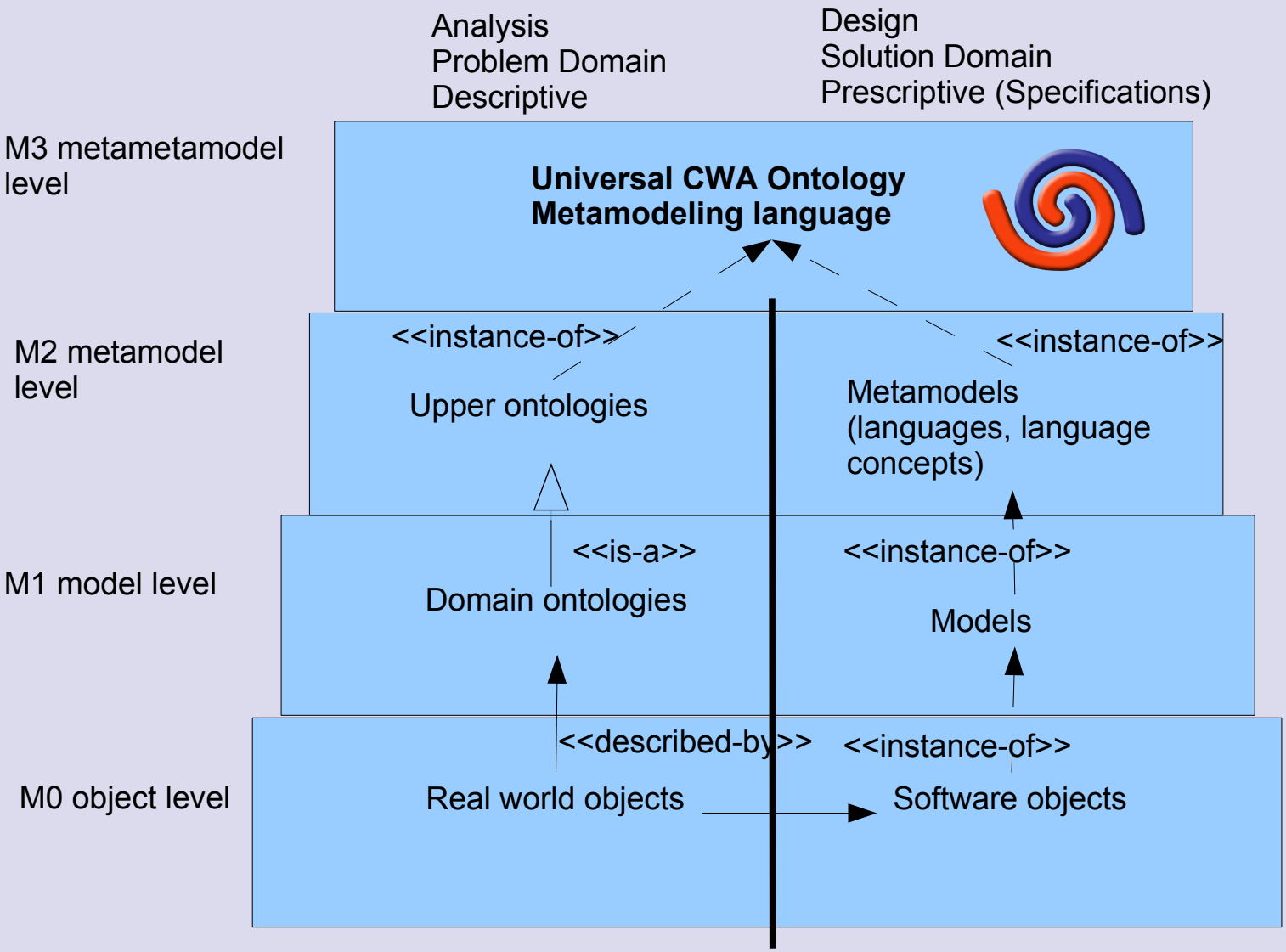
With Closed World Reasoning

- Querying
  - needs CWA to exclude erroneous data
- Metamodeling:
  - needs CWA to exclude erroneous programs
- Integrity constraints
  - needs CWA to exclude erroneous models

With Open World Reasoning

- Domain modeling
  - needs OWA because of partial specification of domain

Integration with a Universal Metalanguage



Conclusions

Ontologies are advantageous in PLE for

- domain ontologies
- integrity constraint ontologies in product lines

but...

- Ontologies should not be misused as system models
- Ontologies *complement* system models
- Ontologies in OWA for domain modeling, CWA for the rest

Integration technology and tools needed!

Solution to the Riddle

Dresden wants to be a factory automation region

- see Track 3 of Innovationsforum

Ontologies are good for product data engineering (PDE) in supply chains

Dresden needs ontologies in domain models and PLE

Looking for Partners

MOST www.most-project.eu

- Comarch, SAP, BOC

Integration into PLE

- Metamodel integration
- Process guidance with ontologies
- Ontology-aware software development (ODSD)

References

U. Aßmann, S. Zschaler, G. Wagner. Ontologies, Metamodels, and the Model-Driven Paradigm. Handbook on „Ontologies in Software Engineering“ 2006 (ed. Ruiz, Calero), Springer.

Ed Seidewitz. What models mean. IEEE Software, 20:26-32, September 2003.

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www.most-project.eu

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