TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Model Driven Software Engineering creates tomorrow's legacy

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Overview of presentation

- Introduction
- Observations
- Model driven software engineering
- Legacy and model driven software engineering
- Legacy challenges
- Conclusions

Introduction

Joint work with

- Önder Babur
- Josh Mengerink
- Ramon Schiffelers
- Alexander Serebrenik

Introduction

1992 - 1997: Assistant professor at UvA (NL)

1997 - 2005: Senior researcher at CWI (NL)

2006 - now: Full professor TU/e (NL):

- Chair of Software Engineering and Technology (SET)
- SET focuses on Model Driven Software Engineering:
  - Domain specific language design
  - Analysis of models, meta-models, and model transformations
  - Modeling of Functional Safety in Automotive Domain
- Industry motivated research

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Introduction

The research area of the SET group is software engineering, and model-based software engineering in particular

- Given the high-tech software-intensive industry in the Eindhoven region, we consider time- and cost-efficient development of high-quality software as crucial

Introduction

SET focuses research-wise on two subareas:

- **meta-modeling/domain specific languages including semantics of domain specific languages, language workbenches, and verification of model transformations;**
- **Data Science applied to software engineering focusing on software evolution of (multi-lingual) systems, including advanced metrics, repository mining, and social aspects of software development to extract "relevant" information of existing software**

Introduction

Software Engineering and Technology (SET) group has strong cooperation with High Tech industrial partners via research projects:

- **Océ (document handling)**
- **VanDerLande Industries (luggage handling, warehouses)**
- **Philips Healthcare (medical equipment: MRI, CT, X-ray, invasive surgery)**
- **ASML (lithography systems)**
- **DAF ((long distance heavy) trucks)**

Observations

- Software quality research is vital for modern society
- Software is omnipresent, hardly any modern device or equipment is without software
- Software connects people and devices/equipment with ever increasing complexity
- Our society depends on software and improves the quality of living, among others in the following domains:
  - medical
  - automotive
  - domestic
  - social media

Observations

Software has become leading in high-tech equipment:

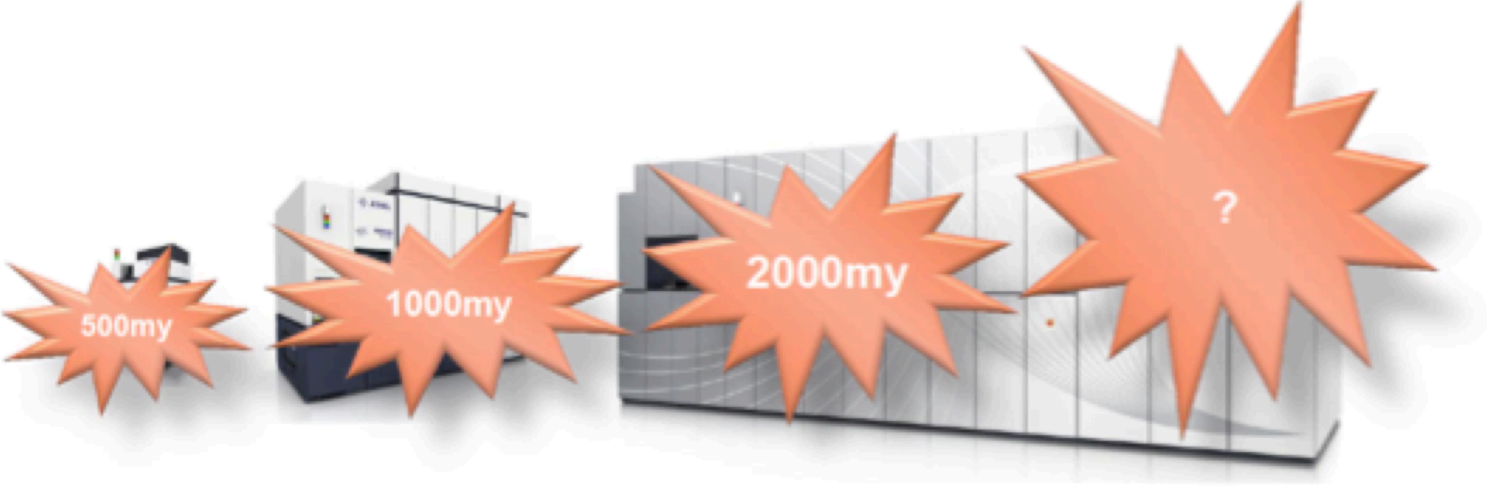
- without software no production

Increase in the amount of software has raised:

- correctness of the software
- need for efficient software development
- awareness with respect to legacy

Observations

Software effort doubles every new generation



We need to stop this trend, it is not sustainable

Observations

Software evolves, continuous growth in:

- size of software (amount of LOC)
- complexity of software
- features in (software) systems
- costs to build software
- number of languages in software systems

Observations

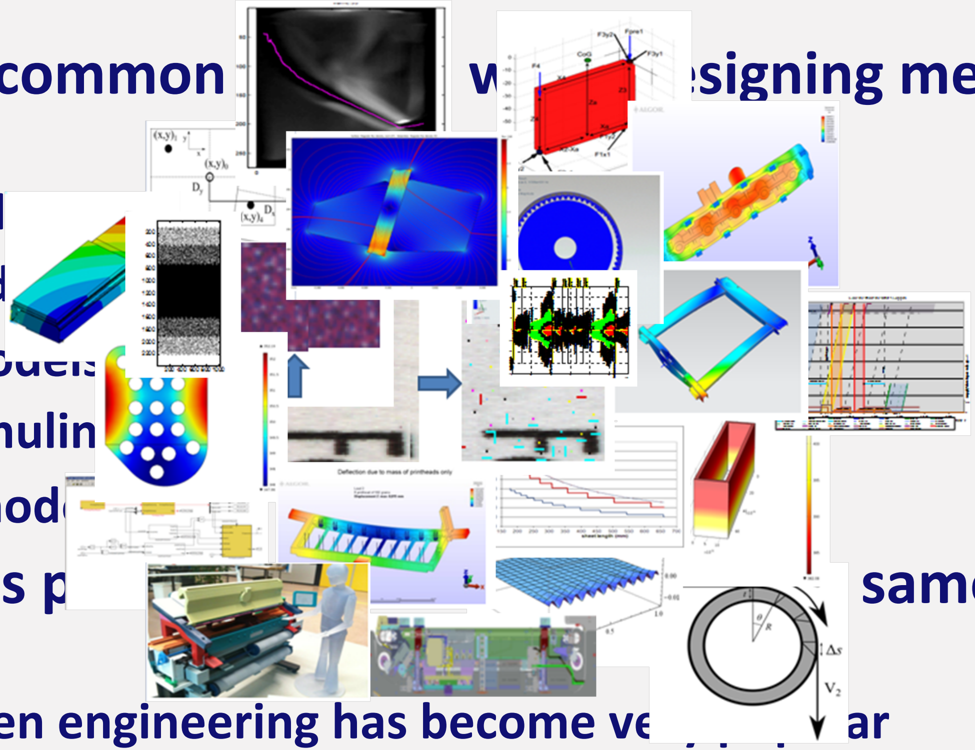
High tech industry in the Eindhoven region has embraced model driven software development

- To tackle the ever increasing amount of software
  - In-house DSLs are developed, using EMF and MPS, and applied
  - UML and SysML are used for modeling behavior
- To ensure correctness and robustness via (model) checking:
  - ASD (Verum) is intensively used to define interfaces and protocols
- To facilitate opportunities for virtualization (aka digital twin)
- To be afraid to miss the boat

Model driven software engineering

Models are common w esigning mechatronic systems

- hardware d
- electronic d
- physical mode
- Matlab/Simulin
- software mod



Software has p same time a challenge

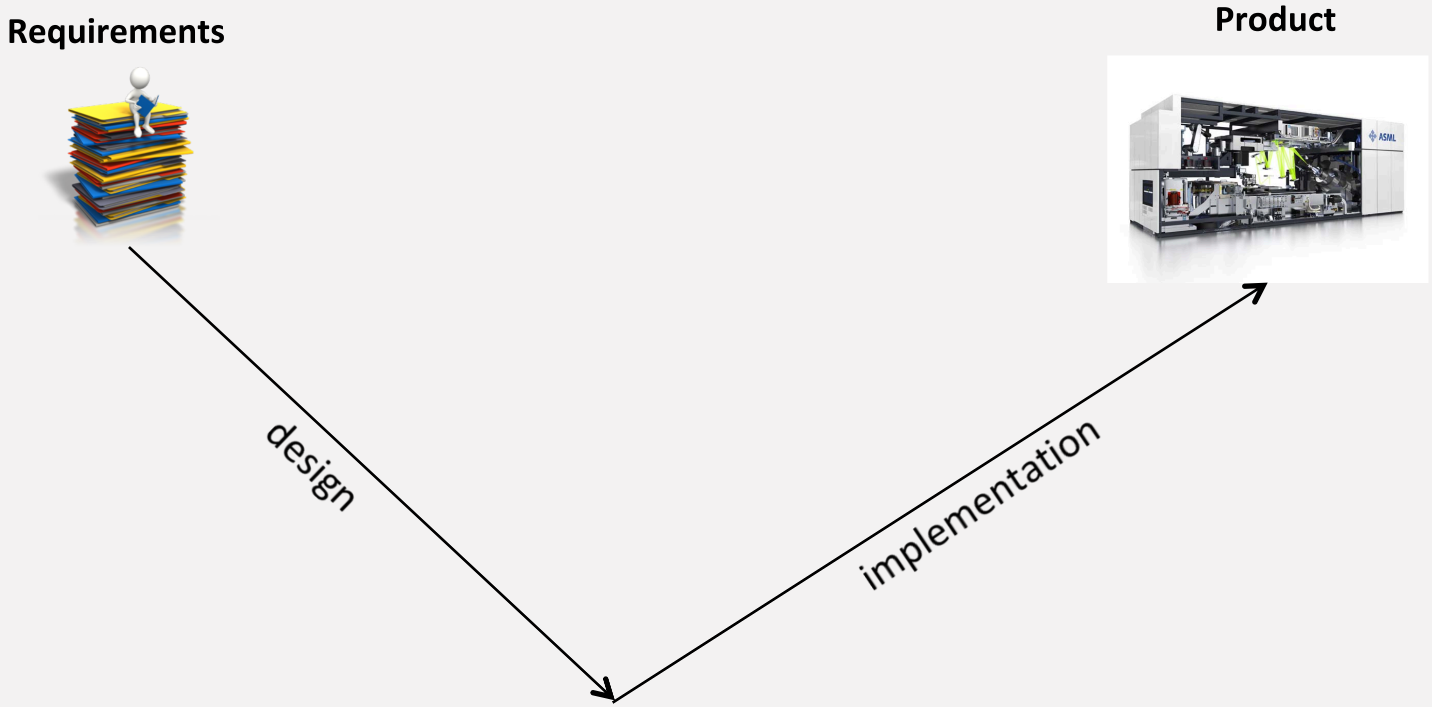
- model driven engineering has become ve ar

Model driven software engineering

Model driven engineering

- considers models as first class citizens
- increases level of abstraction because of the use of models
- offers the choice between general purpose modeling languages or domain specific languages
  - the first may lead to a vendor lock-in
  - the second may involve a huge investment in language design, implementation, and tooling

Model driven software engineering



Model driven software engineering

Requirements

Product

Specification
In terms of problem domain

Expressive for concise specification of large multi-disciplinary systems

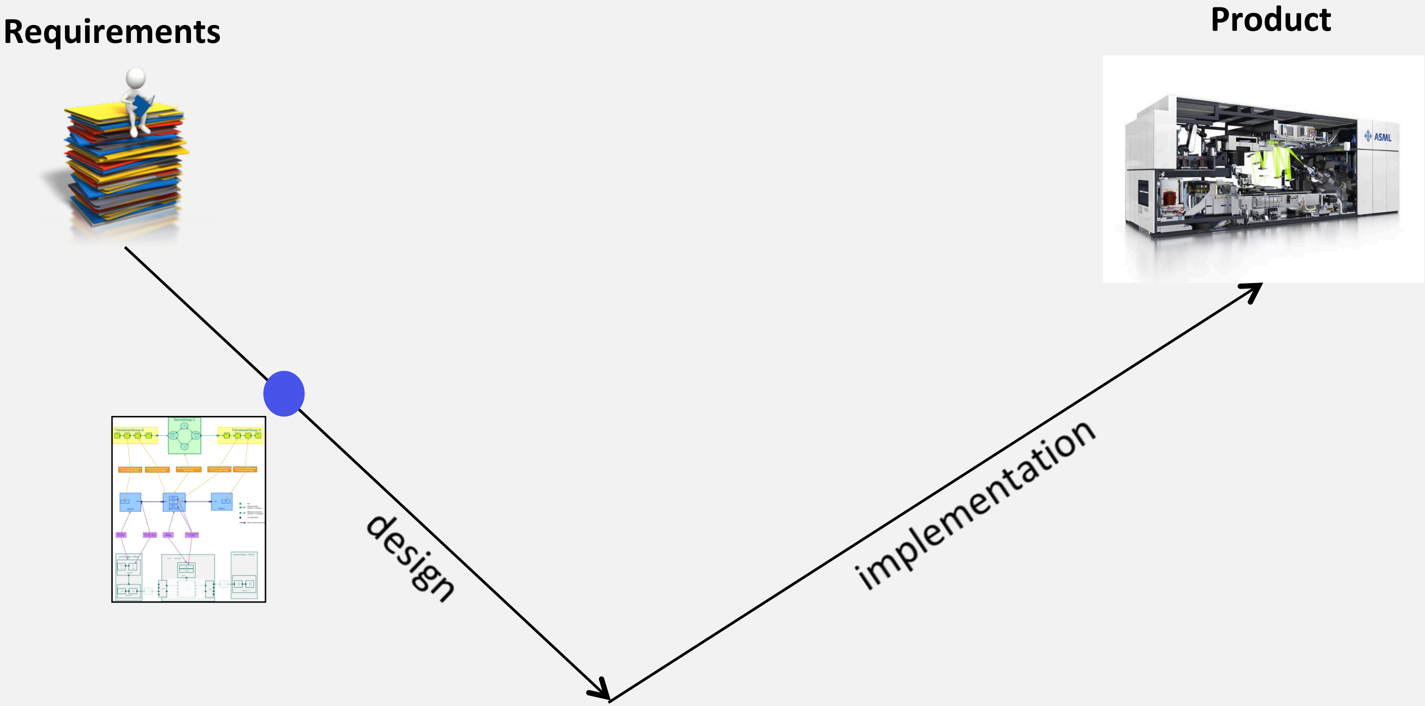
'Look-and-feel' primarily determined by domain experts

Crucial for adoption

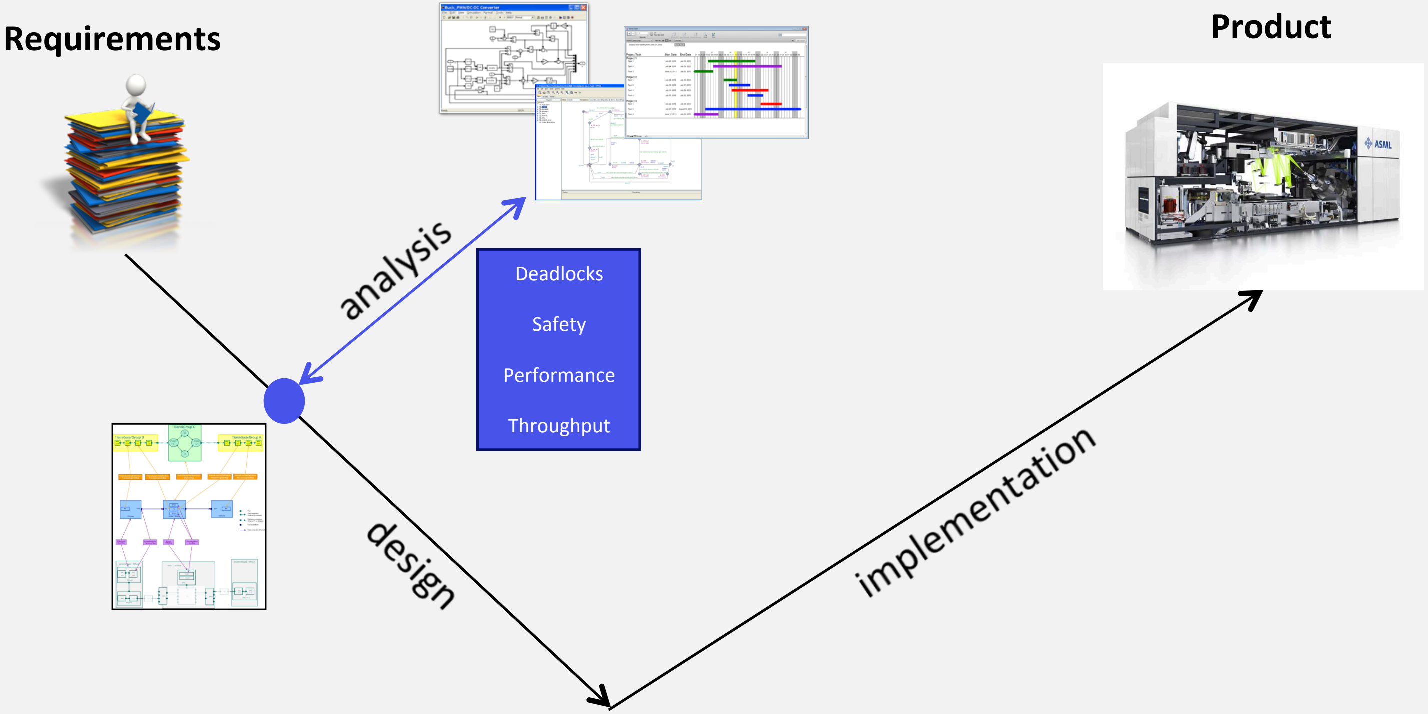
design

implementation

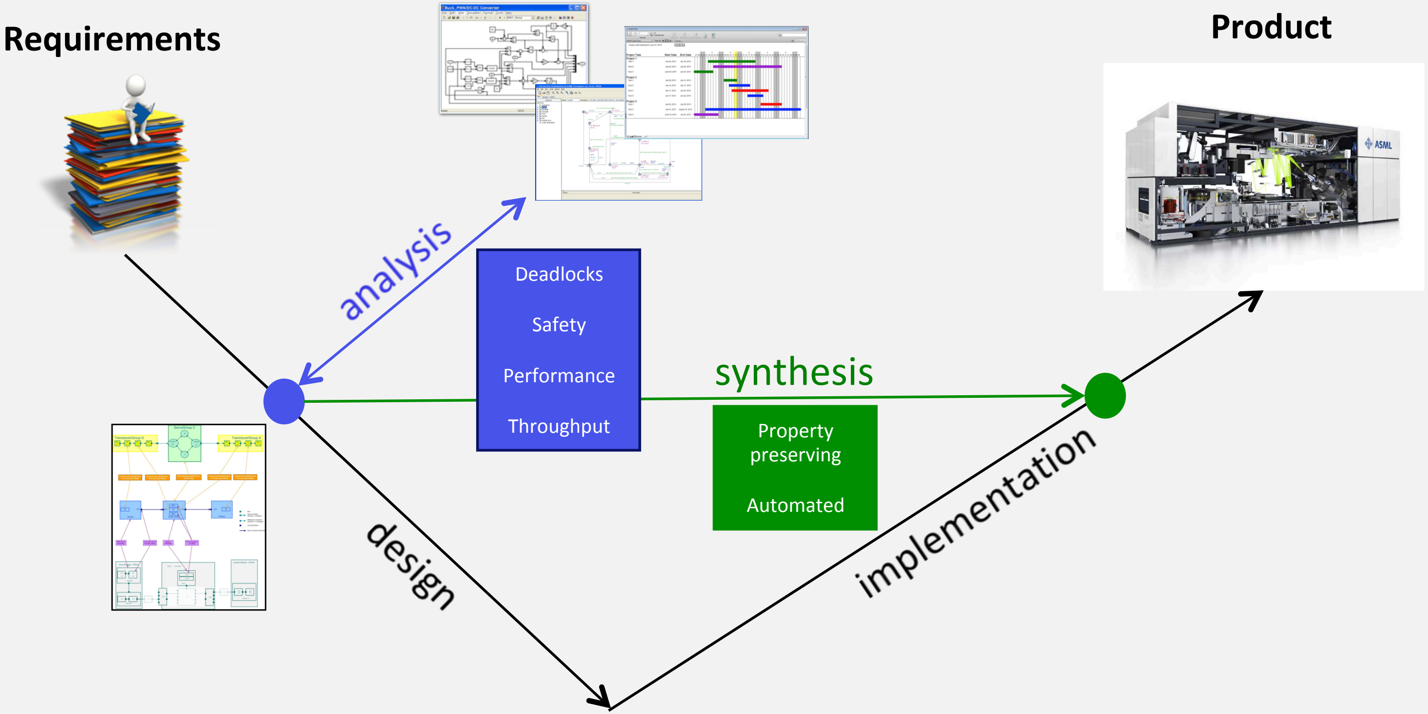
Model driven software engineering



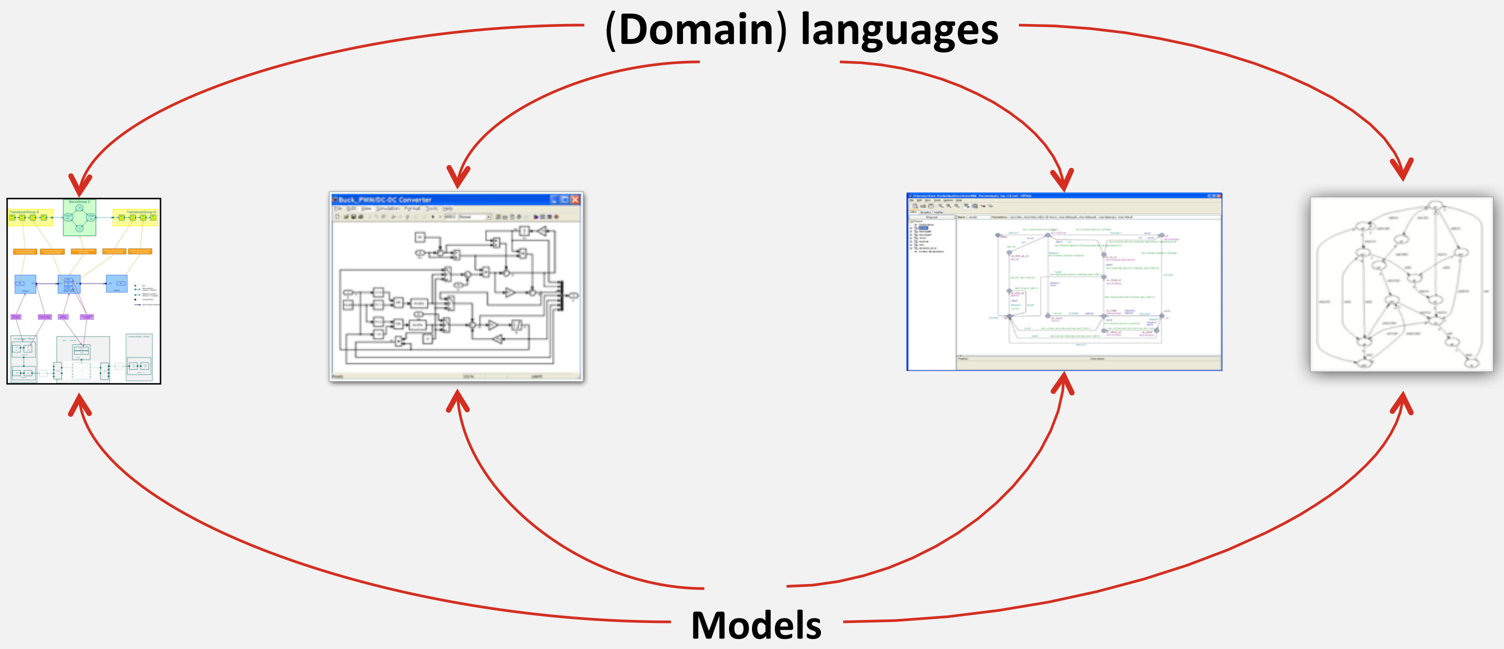
Model driven software engineering



Model driven software engineering

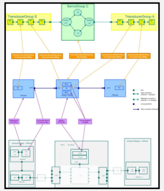


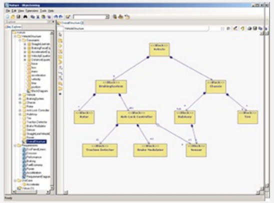
Model driven software engineering



Model driven software engineering

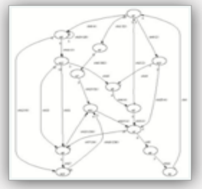
Domain models (specification)





Transformations

Aspect models (analysis)



Model driven software engineering

A few (research/engineering) challenges:

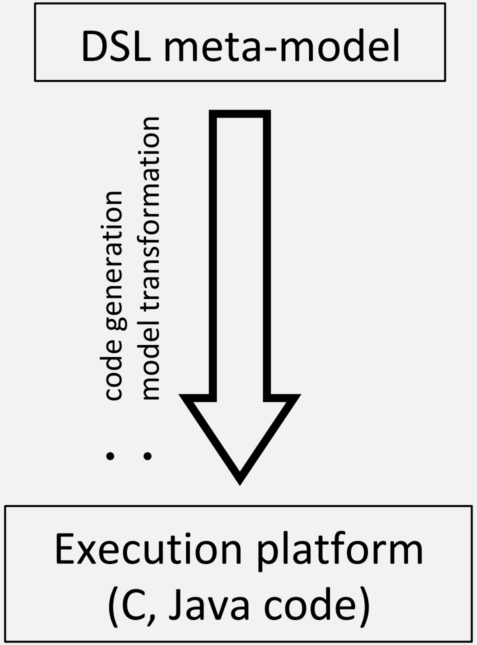
- Identification of common semantic concepts in a certain domain:
  - High-Tech Industry
    - real-time, state machines, supervisory control, material flow (paper, wafers), etc.
  - Capturing these concepts in domain specific languages
- Quality and correctness of model transformations wrt
  - property preservation
  - underlying semantics
- Modularity of meta-models and composition semantic building blocks
- Evolution of meta-models and co-evolution of models
- Mixing multiple domain specific languages

Model driven software engineering

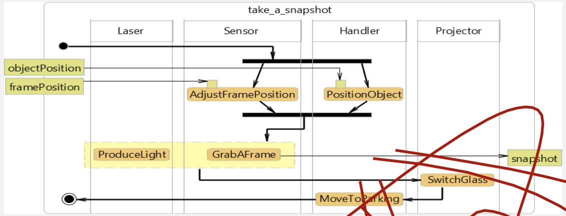
What is a Domain Specific Language (DSL)?

- **A DSL is a formal, procesable language targeting at a specific aspect of a system**
- **Its semantics, flexibility and notation is designed in order to support working with that aspect as efficiently as possible**
- ***"A language that offers, through appropriate notations and abstractions, expressive power focused on, and usually restricted to, a particular problem domain"***

Model driven software engineering



Model driven software engineering



Model transformations
and
Code generation

Model driven software engineering

Domain specific languages offer

- Reduction of development time via increase of abstraction
- Increase of robustness via verification of models and model transformations

However,

- efficient design of domain specific languages and corresponding tooling has to be implemented and maintained as well

Model driven software engineering

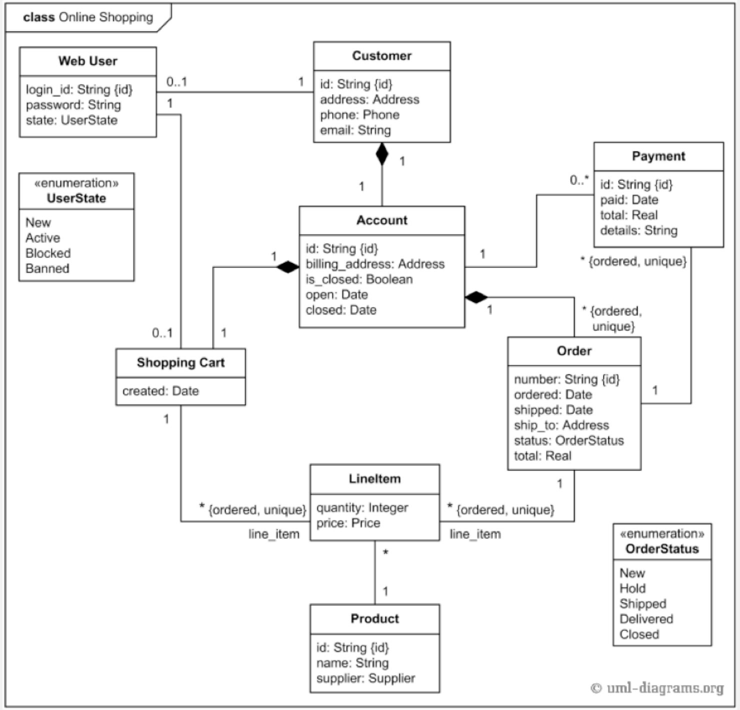
Modeling in practice

- Used across many disciplines
- Abstraction mechanism, used for
  - communication, guidance
  - sketch, blueprint, prototype
  - analysis, verification, optimization
  - automated production

Model driven software engineering

Models

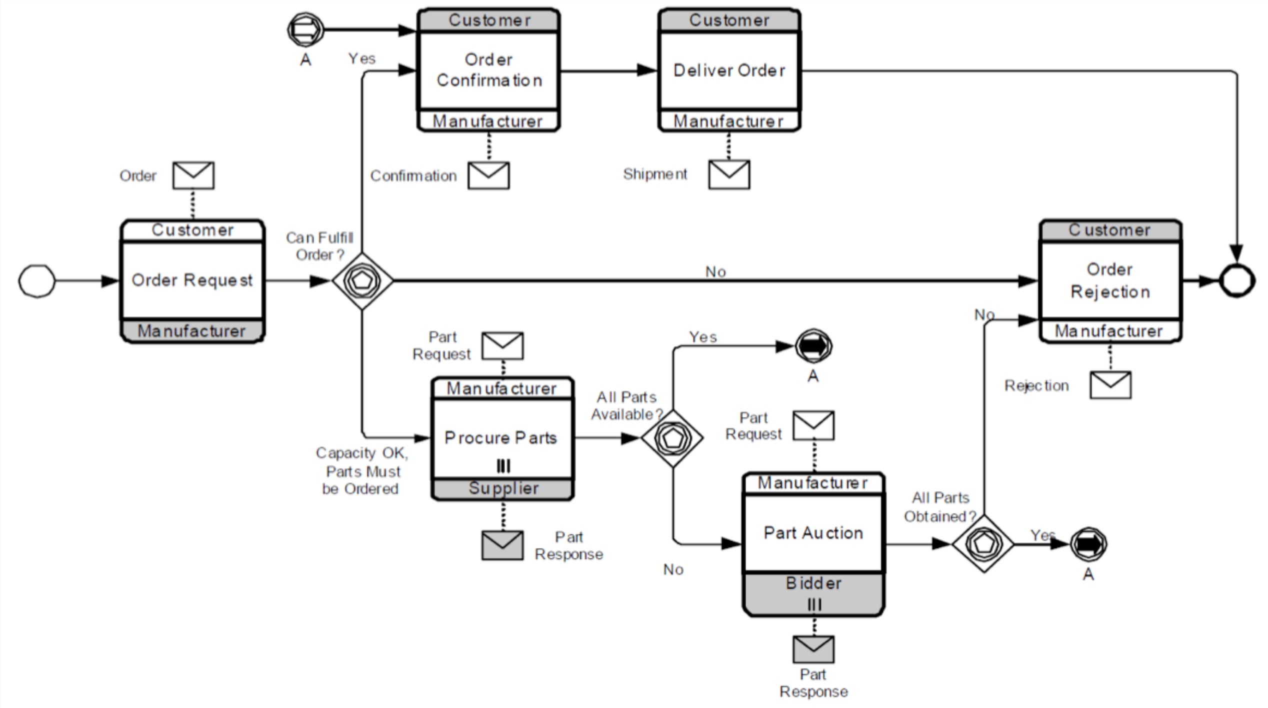
- UML



Model driven software engineering

Models

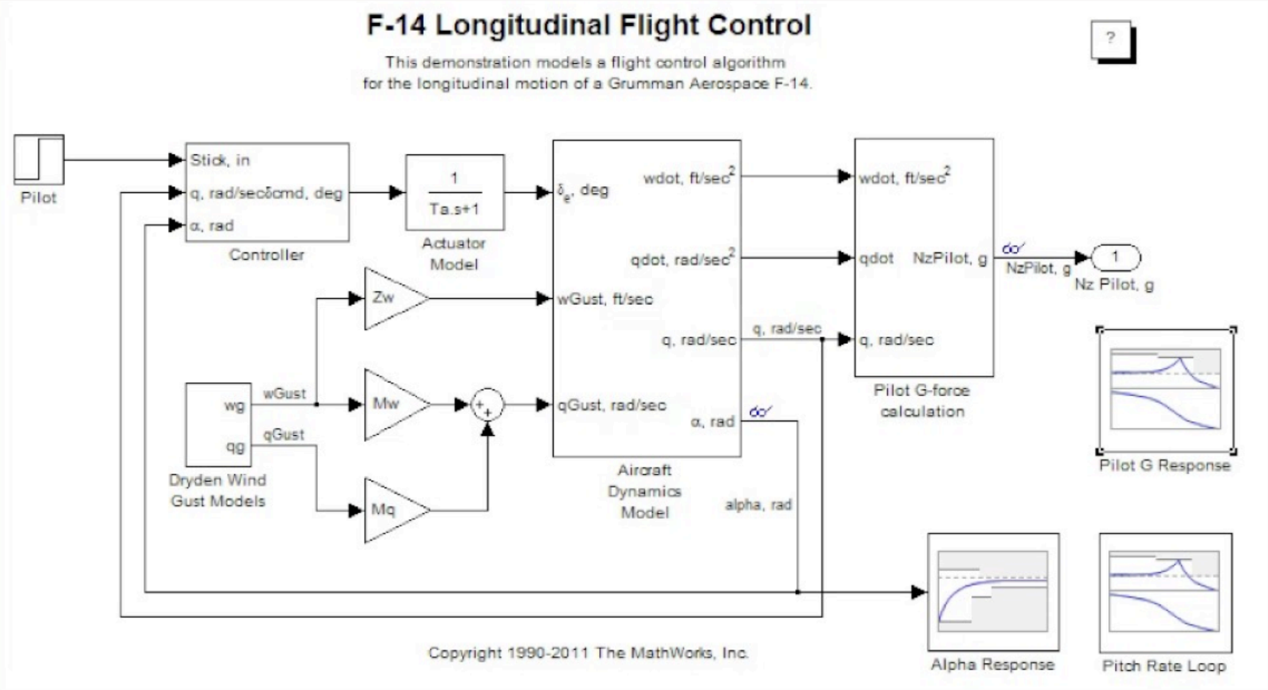
- **BPM**



Model driven software engineering

Models

- Simulink



Legacy and model driven software engineering

- Number of modeling languages, including Domain Specific Languages, is growing
- Number of models created via these modeling languages is also growing
- What are the consequences? But first some figures!

Legacy and model driven software engineering

Expanding the universe of modeling

- Widespread adoption of modeling, industrial cases

→ Too many modeling artifacts (models, transformations, …)

→ Possibly heterogeneous as well (software + hardware, software + business, …)

→ Impossible to manage them ad-hoc

Legacy and model driven software engineering

Expanding the universe of modeling

- Widespread adoption of modeling, industrial cases

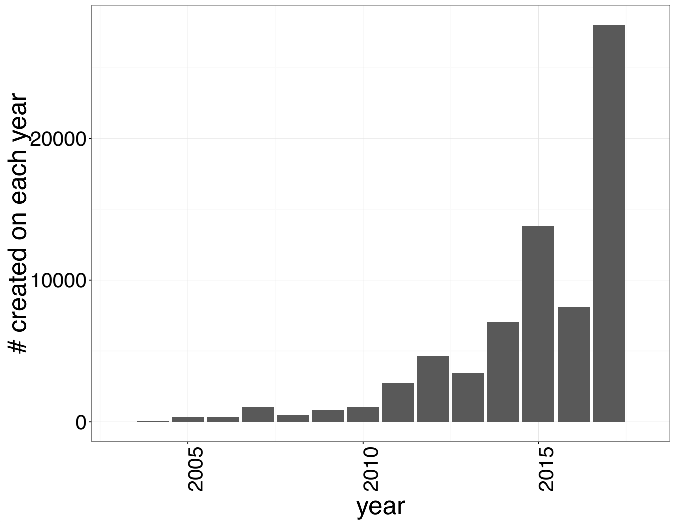
  → Too many modeling artifacts (models, transformations, …)

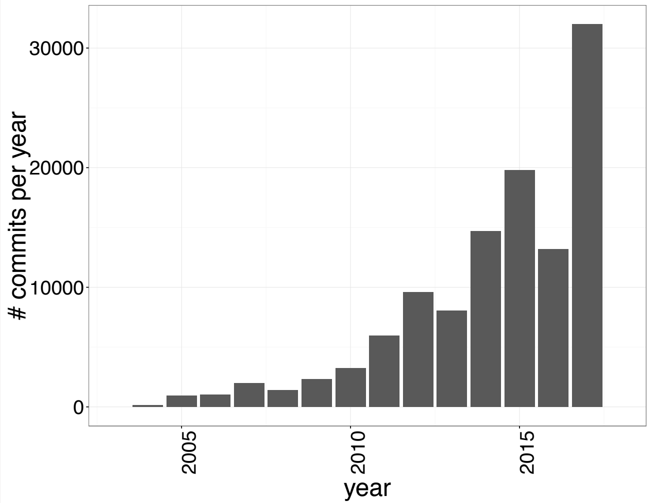
- Examples (software domain)
  - Repositories
    - ATL Zoo: ~300 meta-models
    - SPLOT: >900 feature models, growing
    - GitHub Ecore crawl: ~7k meta-models
    - Lindholmen UML dataset:~90k models!

Legacy and model driven software engineering

Expanding the universe of modeling

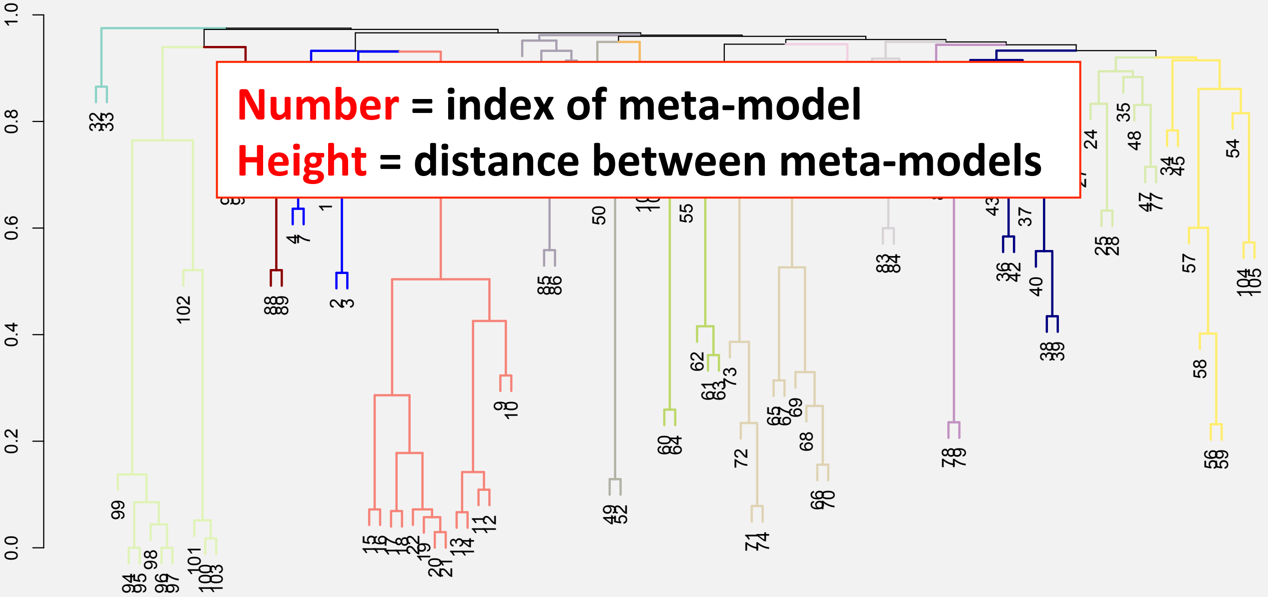
- Ecore meta-models in GitHub





Legacy and model driven software engineering

Domain clustering analysis results on the ATL Meta-model Zoo



Number = index of meta-model

Height = distance between meta-models

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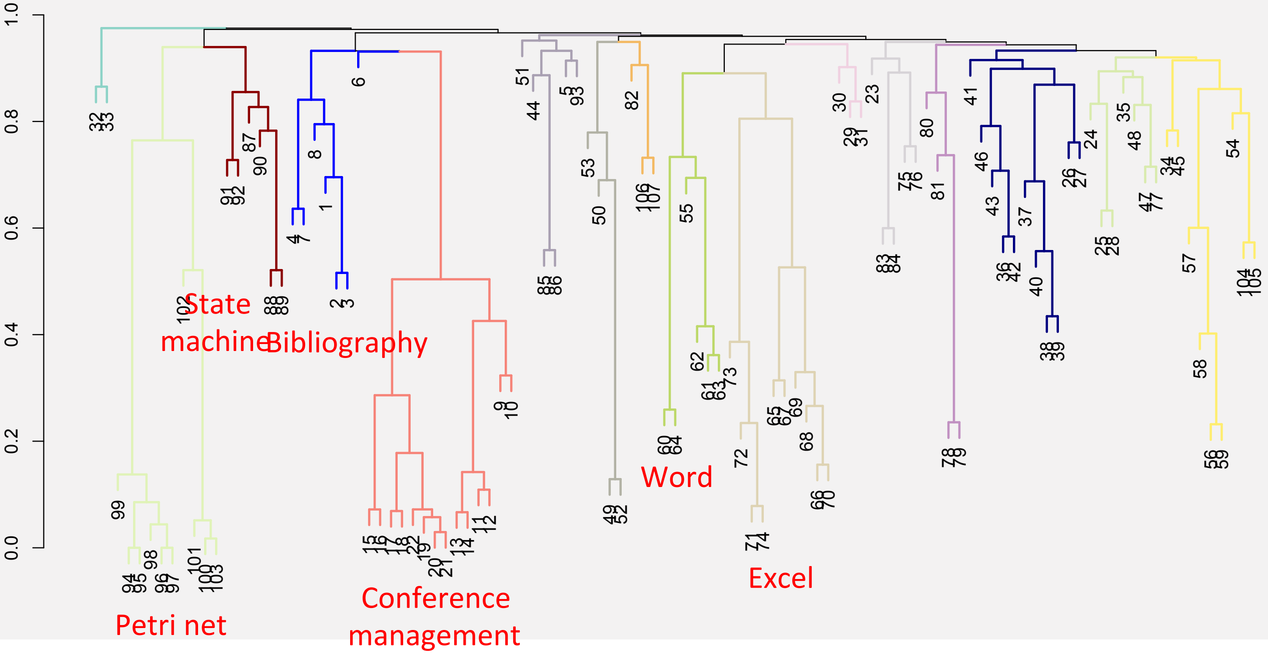
Legacy and model driven software engineering

Domain clustering analysis results on the ATL Meta-model Zoo



Legacy and model driven software engineering

Expanding the universe of modeling

- Widespread adoption of modeling, industrial cases

  → Too many modeling artifacts (models, transformations, …)

- Examples (software domain)
  - Industrial case 1: just one of the DSL eco-systems of an OEM-er:
    - >20 DSLs
    - >40 meta-models
    - >90 QVTo files, >90k LOC, >600 rules/helpers
    - >5000 models

Legacy and model driven software engineering

Expanding the universe of modeling

- Widespread adoption of modeling, industrial cases

  → Too many modeling artifacts (models, transformations, …)

- Examples (software domain)
  - Industrial case 2: 6 projects (~eco-systems) of a supplier, some figures:
    - 19 DSLs, 43 meta-models
    - 1670 models
    - *QVTo*: 107 files, 34k LOC, 80 transformations, 979 mappings, 1872 helper/queries
    - *Xpand/Xtend*: 368 files, 67k LOC, 6 transformations, 501 templates, 2004 queries
    - *Acceleo*: 251 files, 41k LOC, 1298 templates, 1377 queries

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Legacy and model driven software engineering

Expanding the universe of modeling

- Widespread adoption of modeling, industrial cases

  → Too many modeling artifacts (models, transformations, …)

- Examples (software domain)
  - What about evolution?
    - Industrial case 1: > 50K artifacts
    - Industrial case 2: 10K artifacts
  - What kind of evolution?

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Legacy and model driven software engineering

Statistical Analysis of MOdelS (SAMOS)

- SAMOS is developed by Önder Babur
- SAMOS is capable of:
  - feature extraction (fragmentation)
    - n-grams, subtrees, metrics, …
  - feature comparison
    - natural language processing
    - elaborate weight and comparison schemes
  - Vector Space Model computation
  - distance measures, statistical analyses in R

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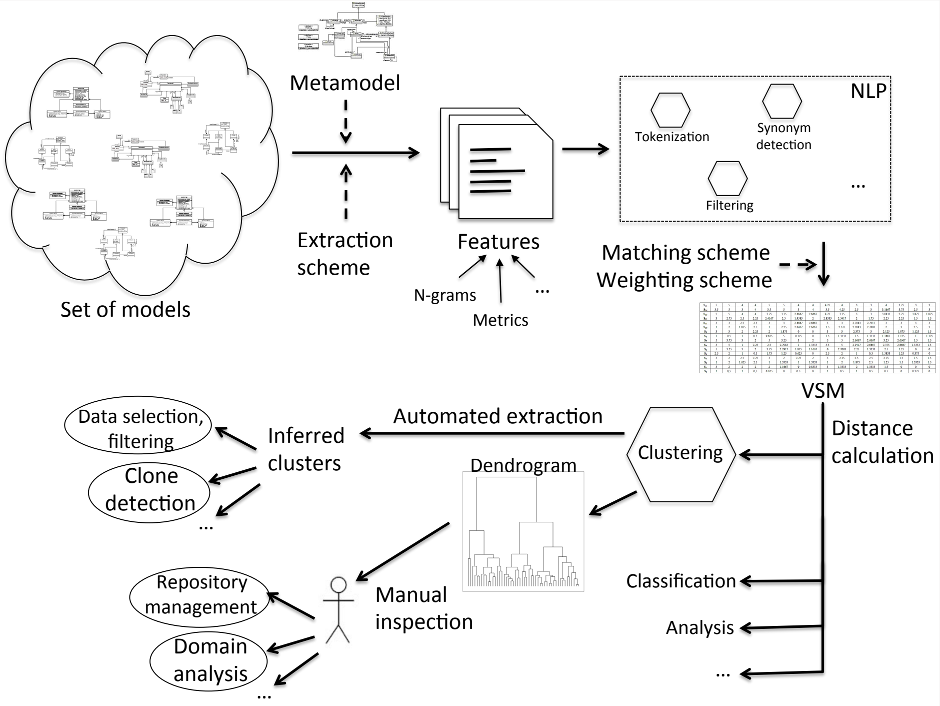
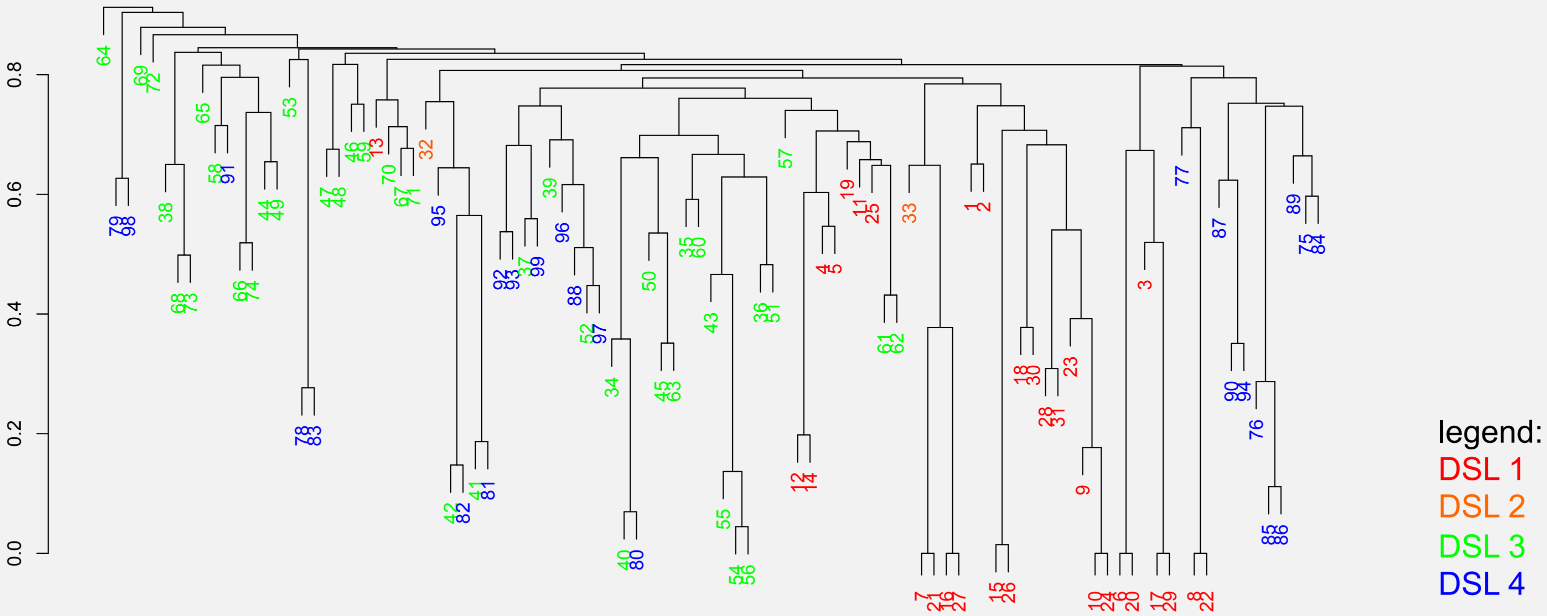
Legacy and model driven software engineering



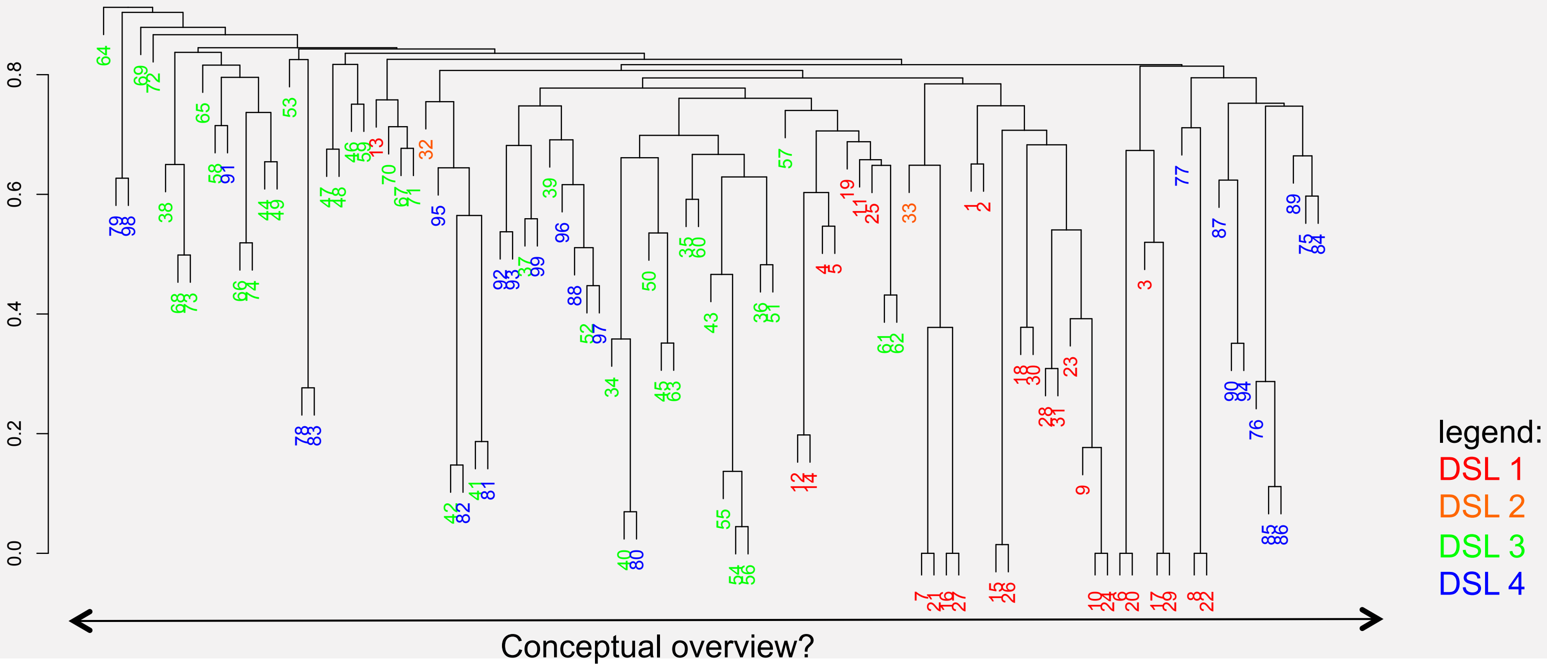
Legacy and model driven software engineering

Cross-DSL analysis: ~100 meta-models for 4 DSL eco systems



Legacy and model driven software engineering

Cross-DSL analysis: ~100 meta-models for 4 DSL eco systems



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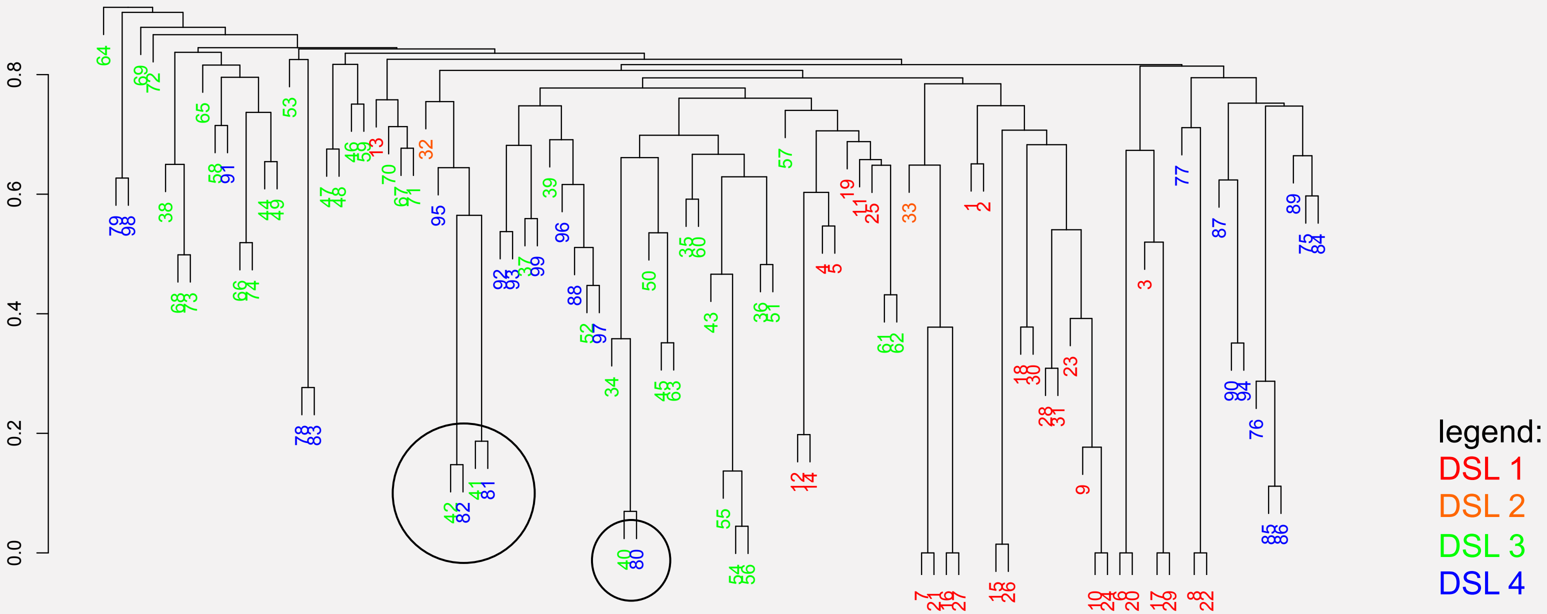
Legacy and model driven software engineering

Cross-DSL analysis: ~100 meta-models for 4 DSL eco systems



Copy-pasted at some point + evolved in time?

Legacy and model driven software engineering

An OEM-er in the Eindhoven region has

- 22 DSLs built using EMF + OCL
- 95 model transformations
- 5500 models created using the meta-models

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Legacy and model driven software engineering

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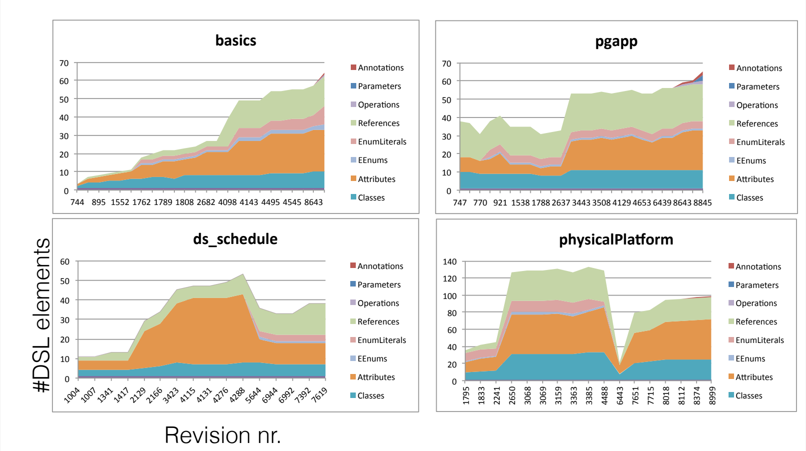
Legacy and model driven software engineering

What are legacy systems?

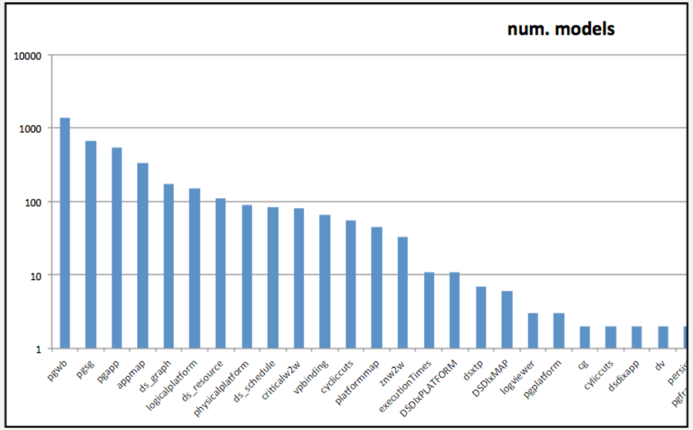
- Systems developed for a specific client that have been in service for a long-time
- Many of these systems were developed years ago using obsolete technologies
- They are likely to be business critical systems required for normal operation of a business

Legacy and model driven software engineering

DSLs evolve



±5000 of models and growing



#models per DSL
(logarithmic scale)

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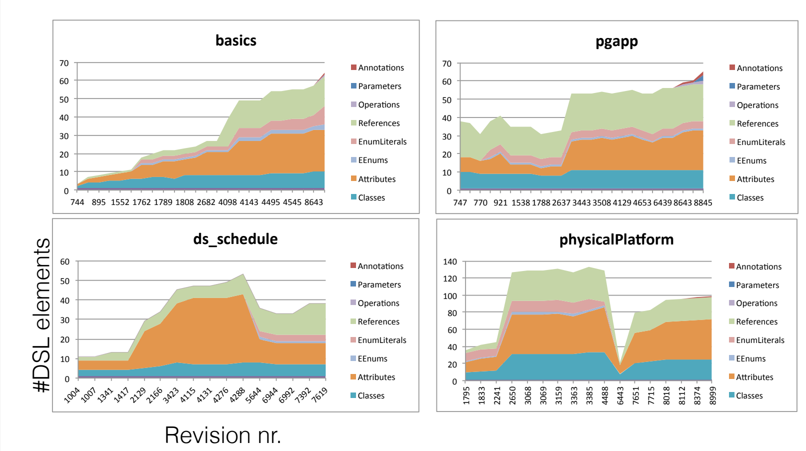
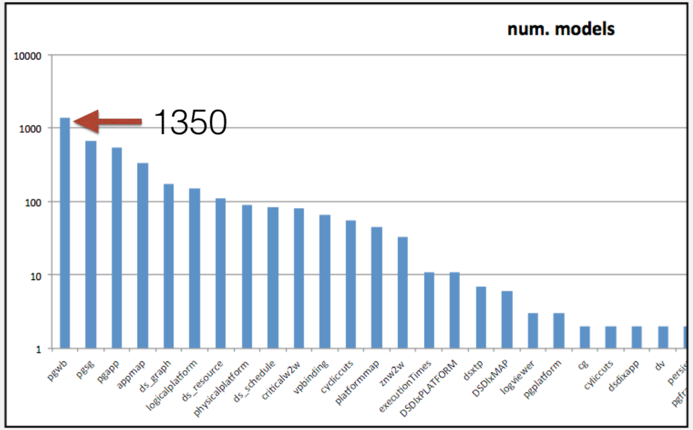
Legacy and model driven software engineering

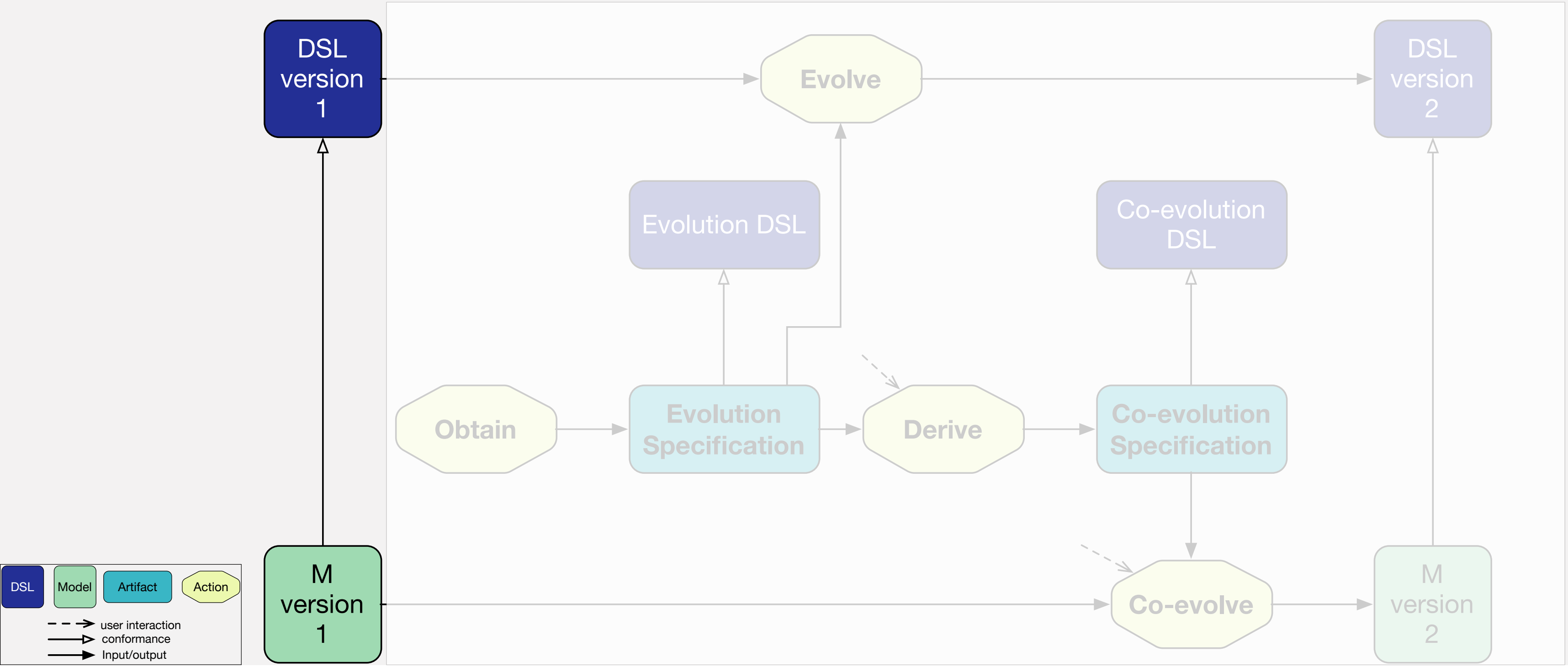
Manually maintaining models in response to DSL evolution is NOT feasible!



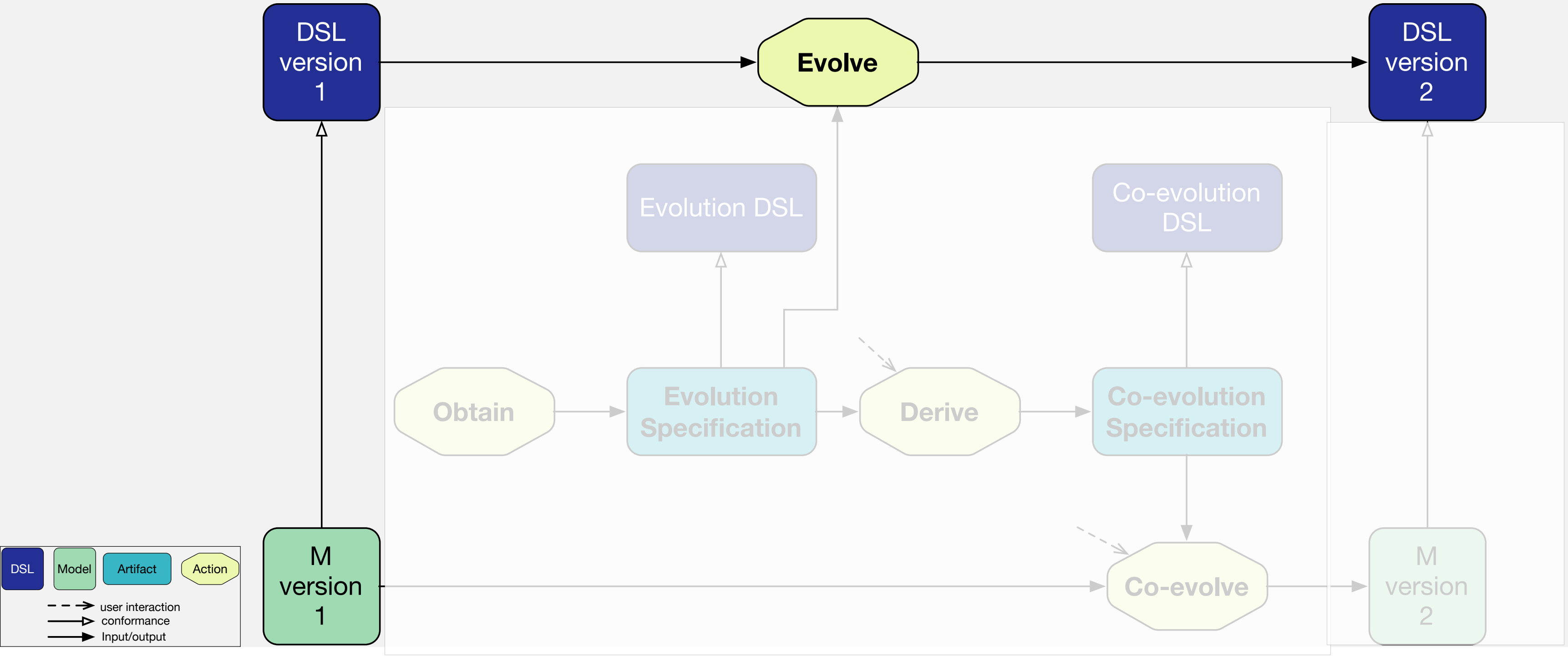


#models per DSL
(logarithmic scale)

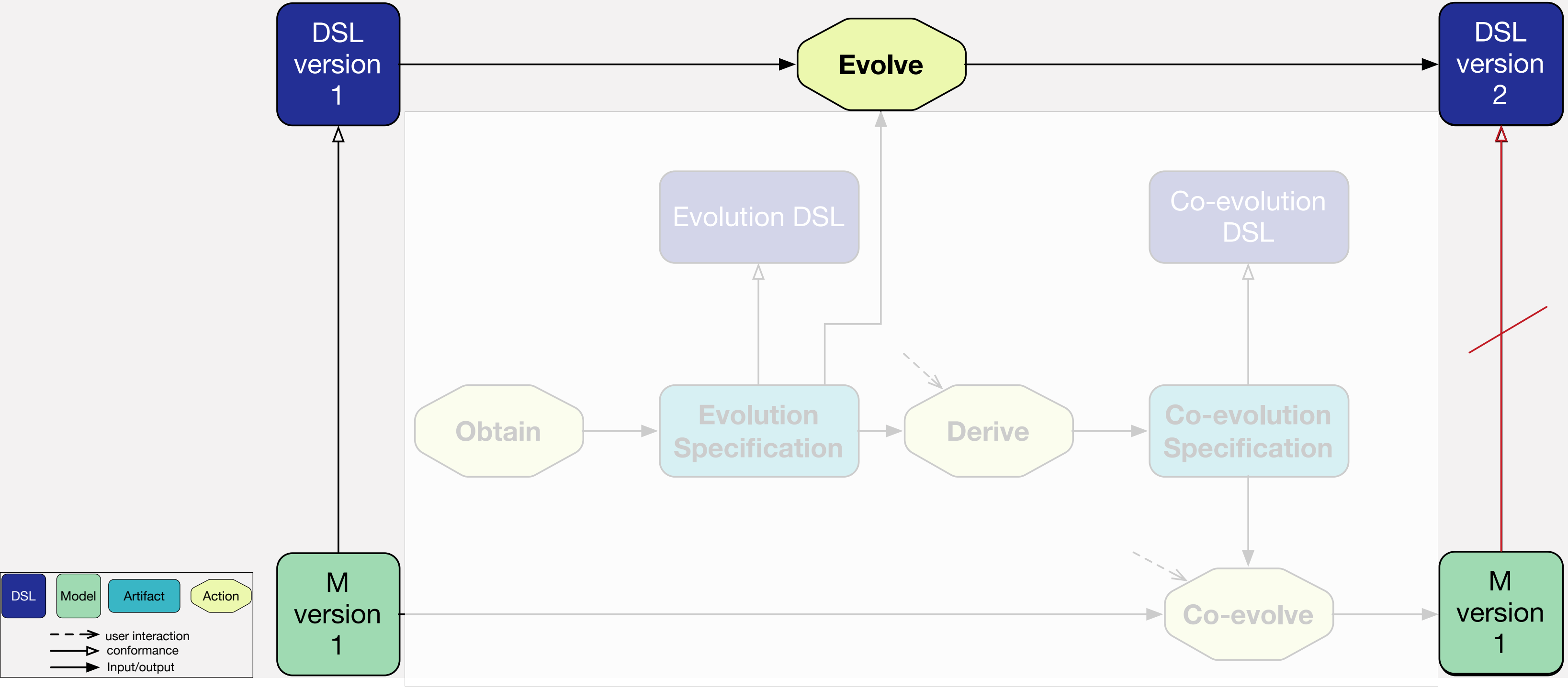
Legacy and model driven software engineering



Legacy and model driven software engineering



Legacy and model driven software engineering



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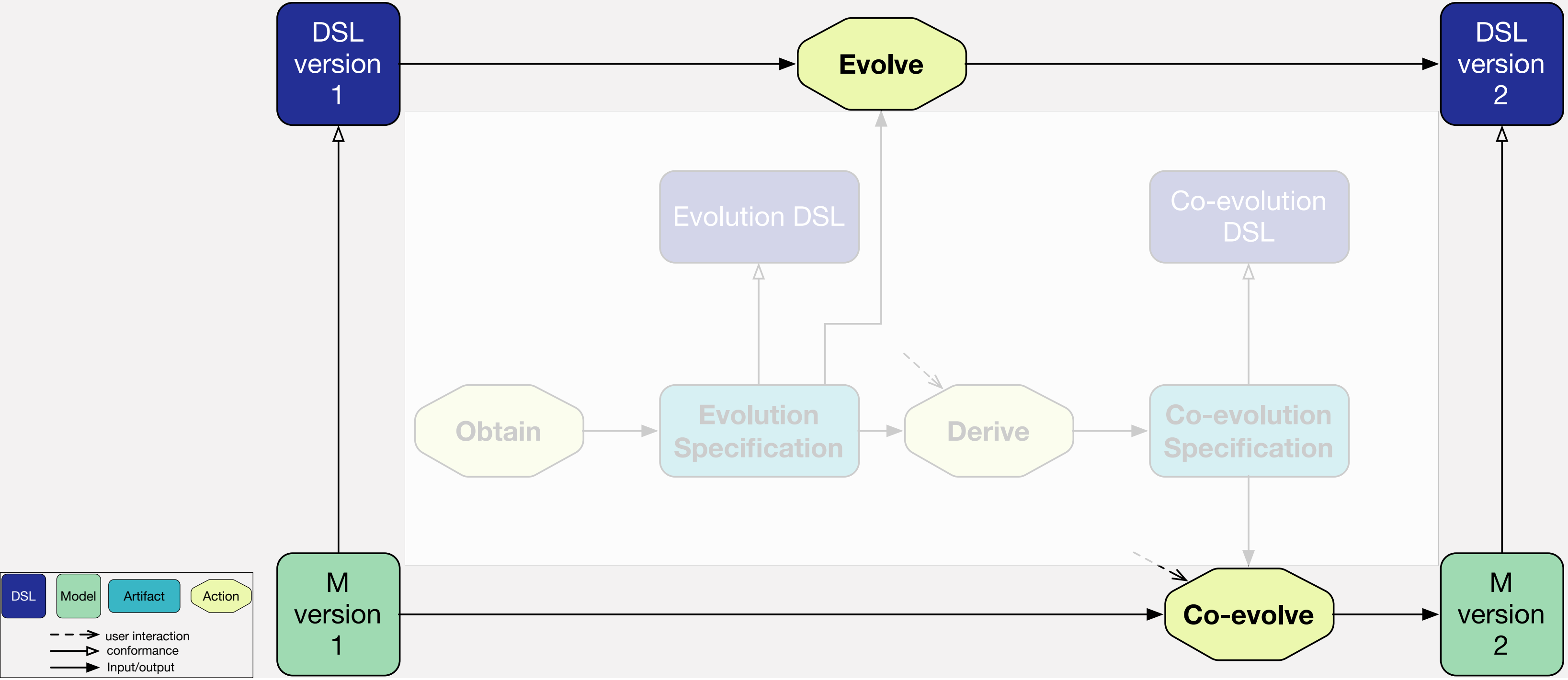

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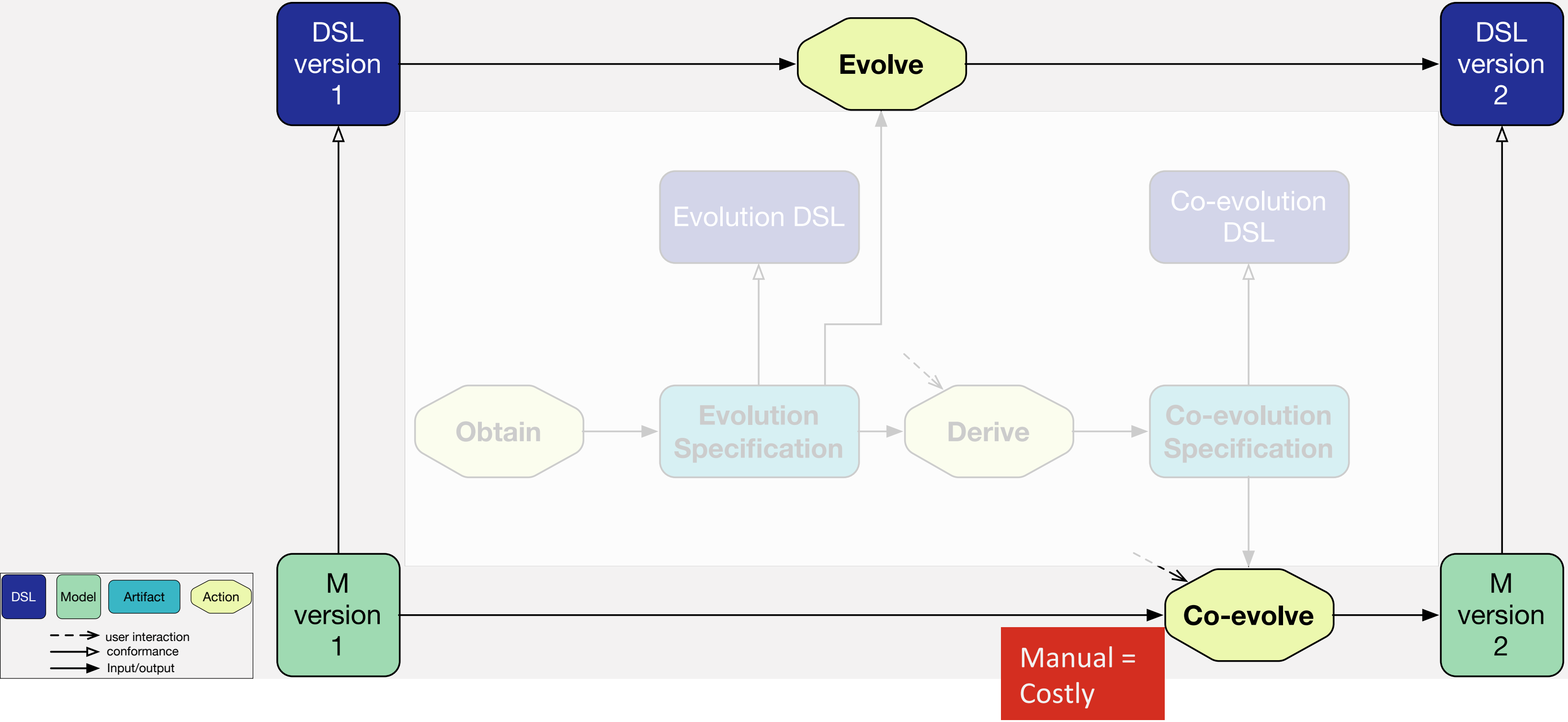

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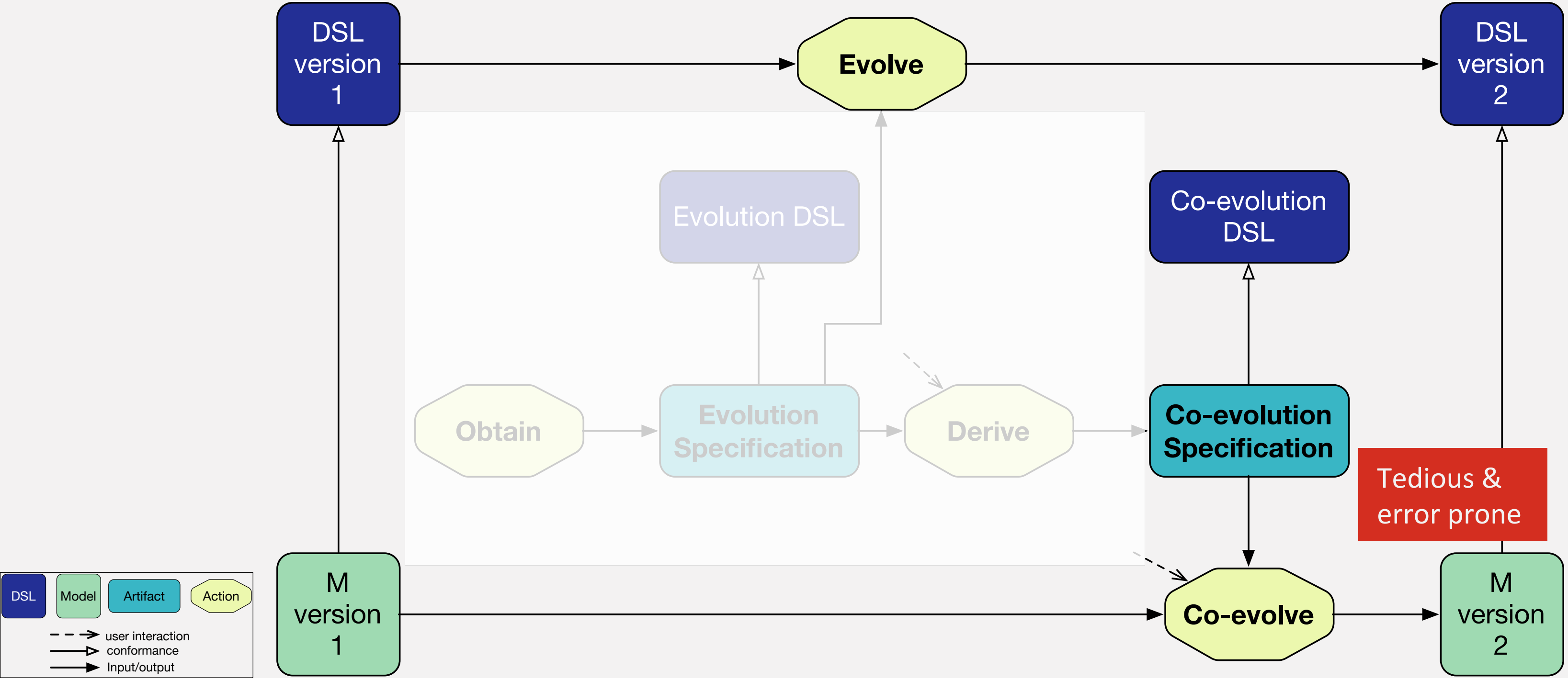
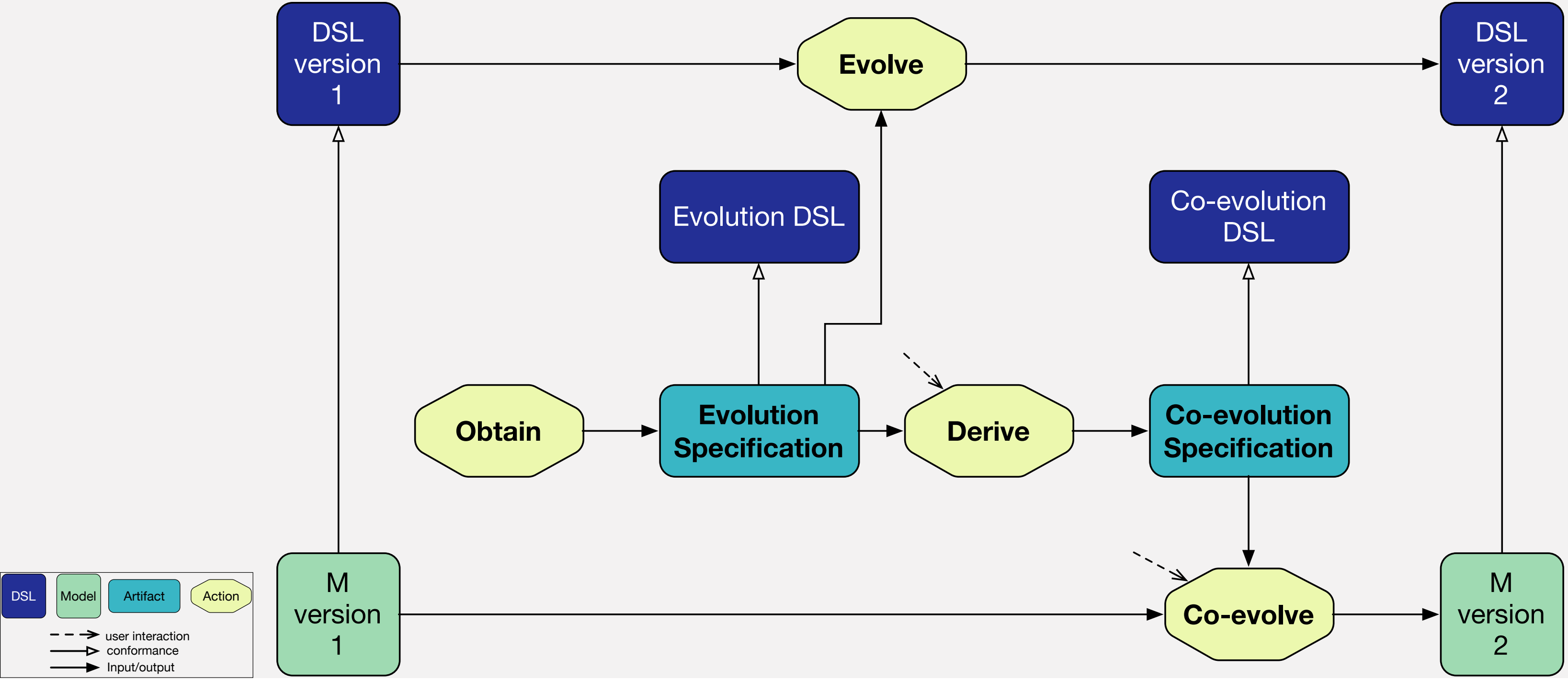
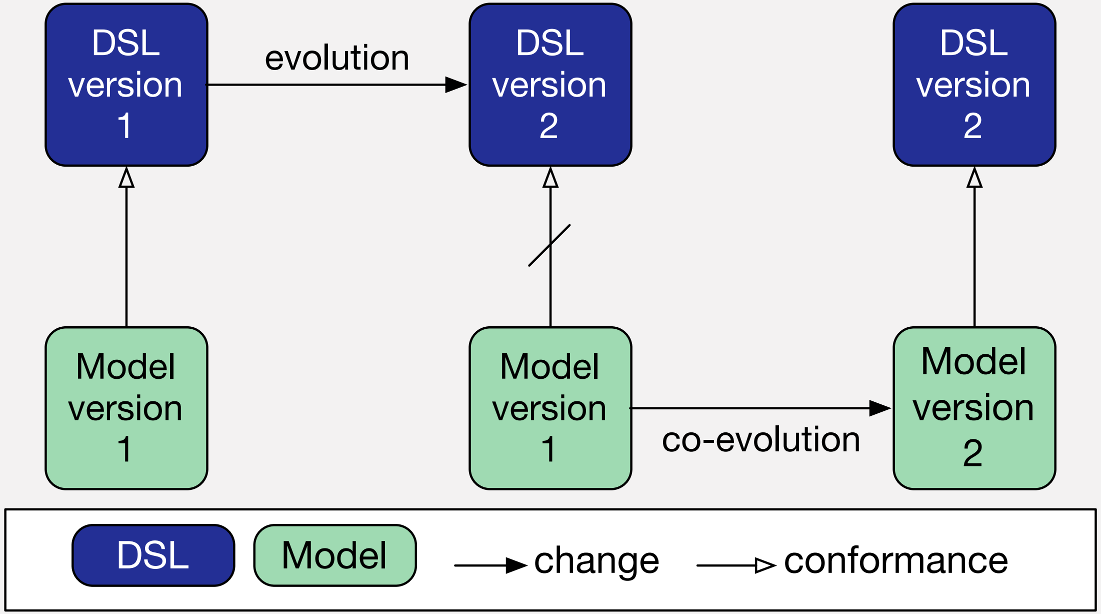


Legacy and model driven software engineering



Legacy and model driven software engineering

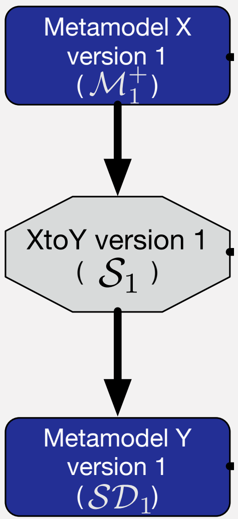
Co-evolution problem

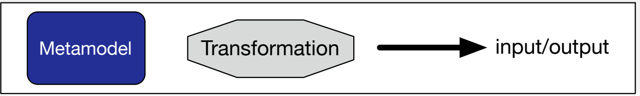


Legacy and model driven software engineering

Models evolve but meta-models evolve as well:

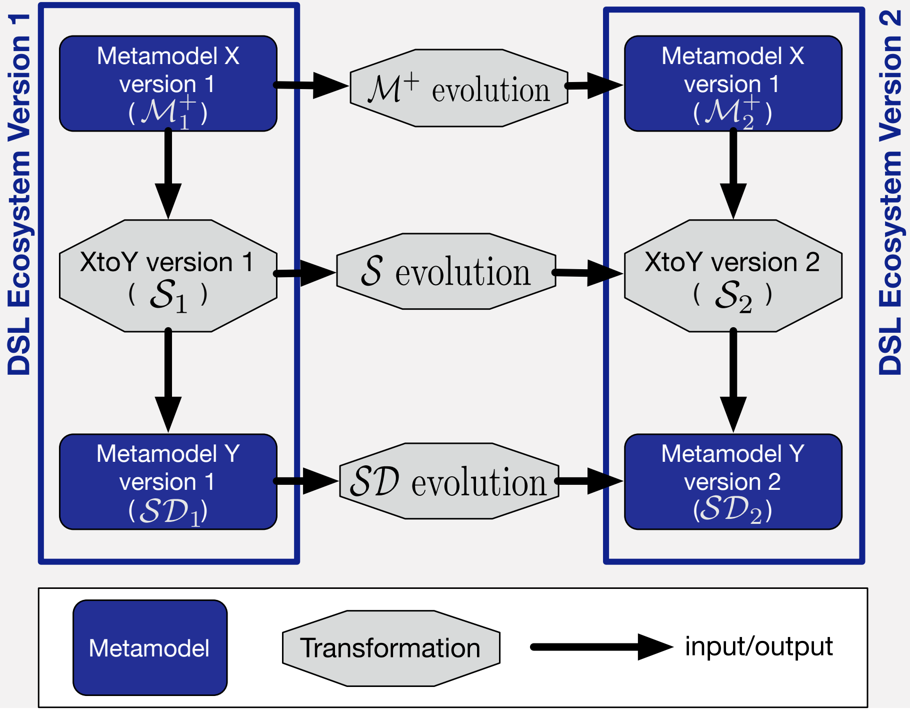
- Abstract syntax
- Constraints (static semantics)
- Semantics
- Semantic domain





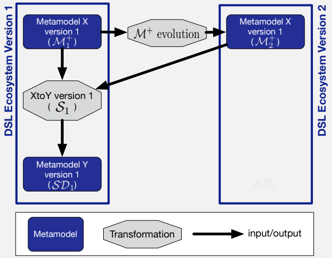
Legacy and model driven software engineering

Evolution on all levels

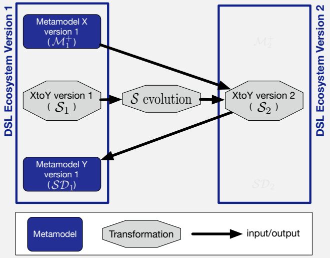


Legacy and model driven software engineering

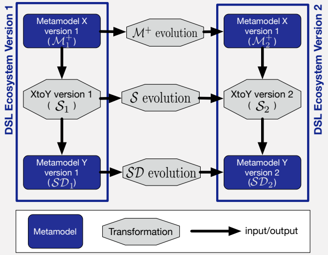
Syntax only



Semantics only



Multi level

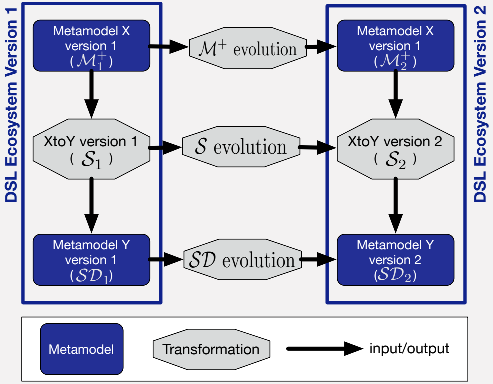


Which of these evolution patterns occur in practice?

Legacy and model driven software engineering

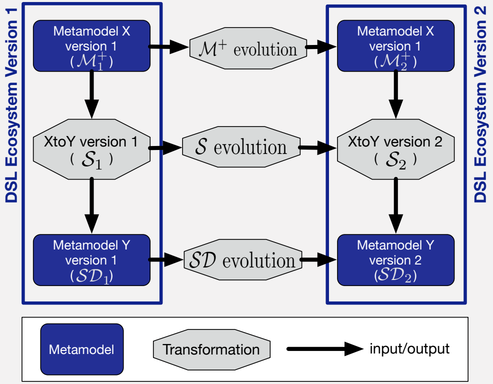
Which of these evolution patterns occur in practice?

- Industrial case study
  - 22 DSLs
  - 95 model-to-model transformations
  - >5500 models
- Look at subsequent versions in repository



Legacy and model driven software engineering

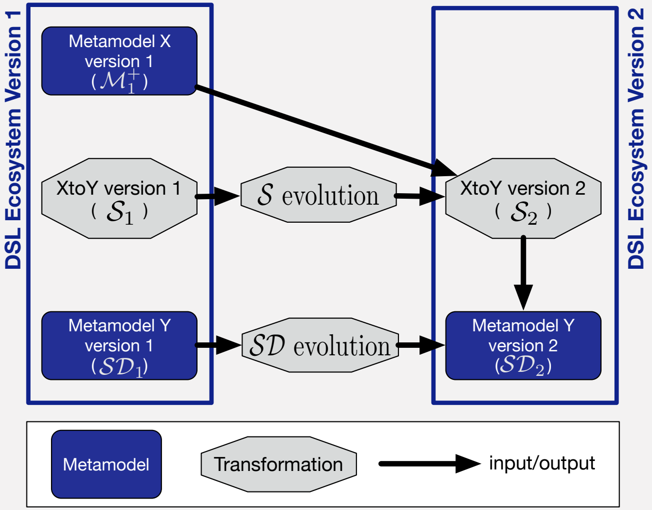
Code	Syntax evolves	Semantics evolves	Semantic domain evolves
E000	No	No	No
E001	No	No	Yes
E010	No	Yes	No
E100	Yes	No	No
E011	No	Yes	Yes
E101	Yes	No	Yes
E110	Yes	Yes	No
E111	Yes	Yes	Yes



Legacy and model driven software engineering

E011, example:

- Take snapshots at time *t=1* and *t=2*
- For every possible triple
  (*X* : MM, *Y* : M2M-trans, *Z* : MM)
- Does it hold that:
  - *Y* : *X* → *Z*
  - *X* does not evolve from *t=1* to *t=2*
  - *Y* evolves from *t=1* to *t=2*
  - *Z* evolves from *t=1* to *t=2*



Legacy and model driven software engineering

Code	Syntax evolves	Semantics evolves	Semantic domain evolves	# occurrences
E001	No	No	Yes	344
E010	No	Yes	No	865
E100	Yes	No	No	84
E011	No	Yes	Yes	368
E101	Yes	No	Yes	0
E110	Yes	Yes	No	86
E111	Yes	Yes	Yes	292

Legacy and model driven software engineering

Code	Description	# occurrences
E010	Only semantic change	865
E011	Only syntax change	368
E001	Only semantic domain change	344
E111	Full evolution	292
E110	Different syntax with different semantics expressed in the same semantic domain	86
E100	Same syntax gets new semantics in a different semantic domain	84
E101	Syntax and semantics domain are changed, but no new semantics is provided	0

Legacy and model driven software engineering

Code	Description	# occurrences
E010	**Only semantic change**	**865**
E011	**Only syntax change**	**368**
E001	**Only semantic domain change**	**344**
E111	Full evolution	292
E110	Different syntax with different semantics expressed in the same semantic domain	86
E100	Same syntax gets new semantics in a different semantic domain	84
E101	Syntax and semantics domain are changed, but no new semantics is provided	0

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Legacy challenges

The following challenges can be observed:

- The tooling to create and use DSLs is far from mature.
- The creation of a DSL involves understanding of the domain for which the languages are created.
- The increased level of abstraction and introduction of domain concepts makes the models harder to understand and maintain.
- The interactions between software models and models from other (system) engineering domains, e.g. describing physical behavior, are becoming more and more important.

Legacy challenges

The tooling to create and use DSLs is far from mature

- unstable
- badly documented
- deprecates rapidly

Industry uses

- standard tools (QVTo) with large user communities
- tools developed and maintained by companies, e.g. MPS, Sirius, Acceleo

Legacy challenges

The creation of a DSL involves understanding of the domain for which the languages are created

- having the capability of translating this knowledge to concepts at the right level of abstraction.

Industry applies different DSL development strategies:

- outsourcing to research institutes.
- team of software language engineers combined with domain experts
- in house prototyping and transfer to supplier for maturing and maintenance

Legacy challenges

The increased level of abstraction and introduction of domain concepts makes the models harder to understand and maintain.

- The use of DSLs involves also a risk, if the developer(s) of a DSL leaves the company then the maintenance of the DSL may be jeopardized.
- The number of developers that are able to understand and maintain DSLs is low; the number of developers understanding general purpose languages, e.g. C, will always be higher.

Industry asks for courses on modeling and meta-modeling

TU/e

Legacy challenges

The interactions between software models and models from other (system) engineering domains has become important.

- **For describing physical behavior**
- **For enabling virtualization**
- **For facilitating system engineering, moving from mono-disciplinary to multi-disciplinary modeling**

Conclusions

- Research on model driven software engineering should
  - move away from just focusing on tooling
  - start focusing on proper methodologies to extract domain concepts in order to create usable DSLs.
  - deal with evolutionary aspects of DSLs and created models
  - work on stabilizing the tooling needed to create languages and corresponding models, ensuring consistency
    - between languages and between models, and
    - between languages and models.

If we are able to make this happen then we might have a silver bullet after all and the promised increase in quality and productivity will be realized.