Meta-Modeling and Modeling Languages

Prof. Dr. Knut Hinkelmann

Models and Modelling

Model

A reproduction of the part of reality which contains the essential aspects to be investigated.

Modelling

Describing and Representing all relevant aspects of a domain in a defined language.

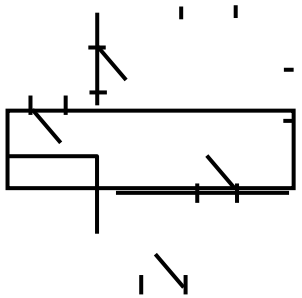
Result of modelling is a model.

Model in Architecture

real object

house

model



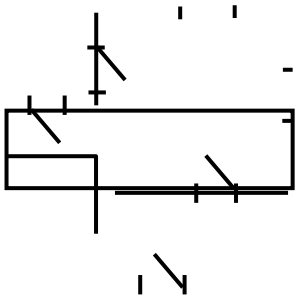
architect's drawing
(plan)

Model and Modeling Language in Architecture

real object

house

model

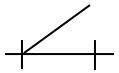


architect's drawing
(plan)

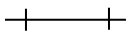
modeling language
(concrete syntax)

object types:

wall

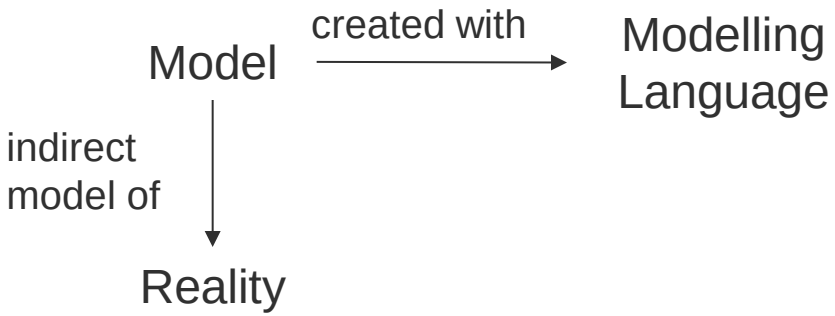


door



window

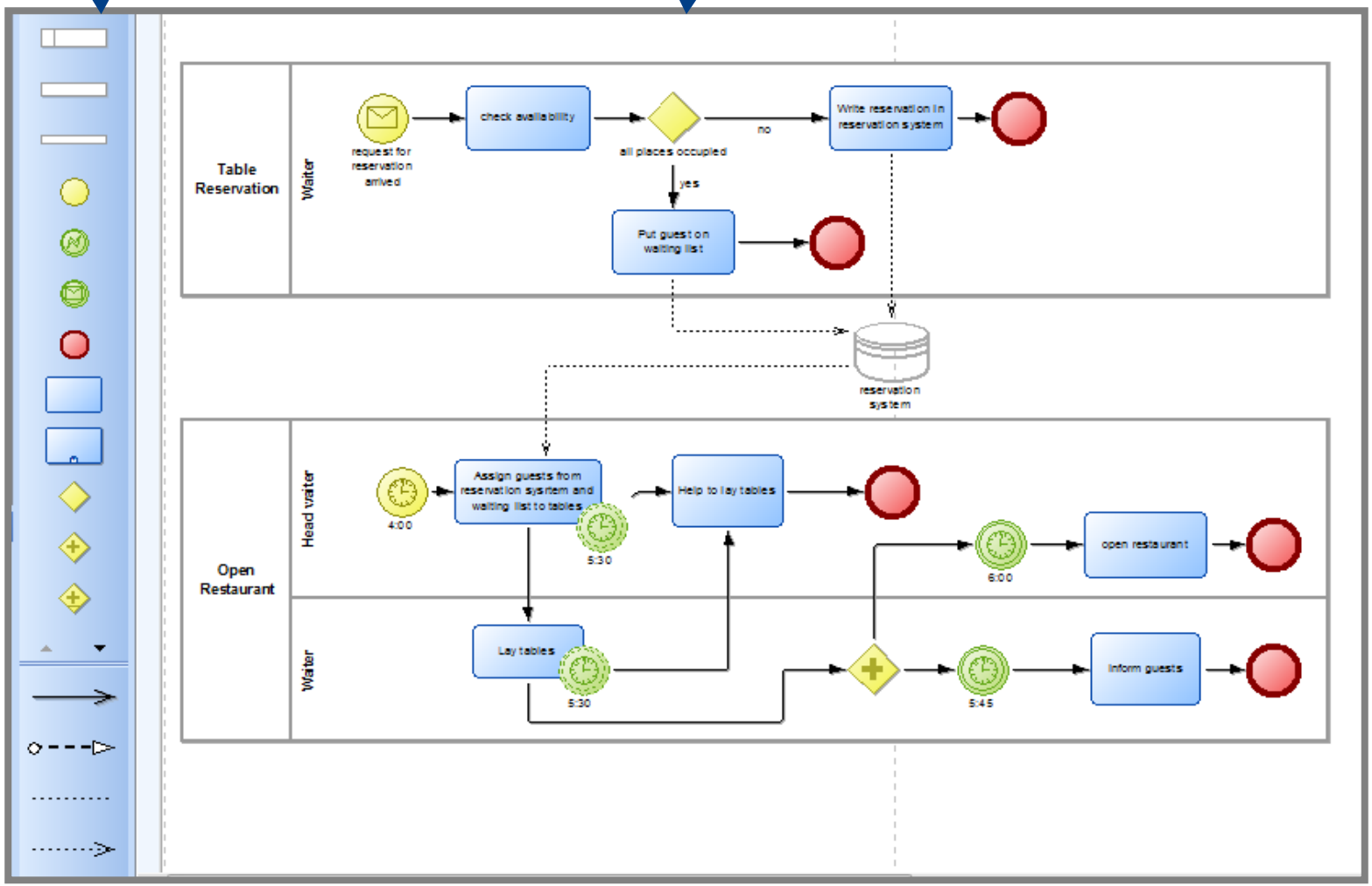
Modelling Language



- A modelling "language" specifies the building blocks (elements) from which a model can be made.
- There can be different types of modelling languages, depending on the kind of model
  - ♦ graphical model
  - ♦ textual description
  - ♦ mathematical model
  - ♦ conceptual model
  - ♦ physical model

Modeling Language

Model

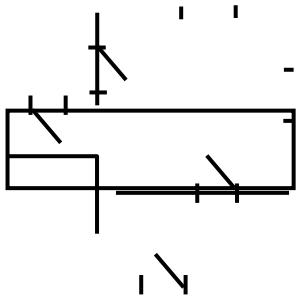


Model and Meta-Model in Architecture

real object

house

model

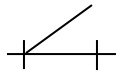


architect's drawing (plan)

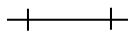
modeling language
(concrete syntax)

object types:

wall



door



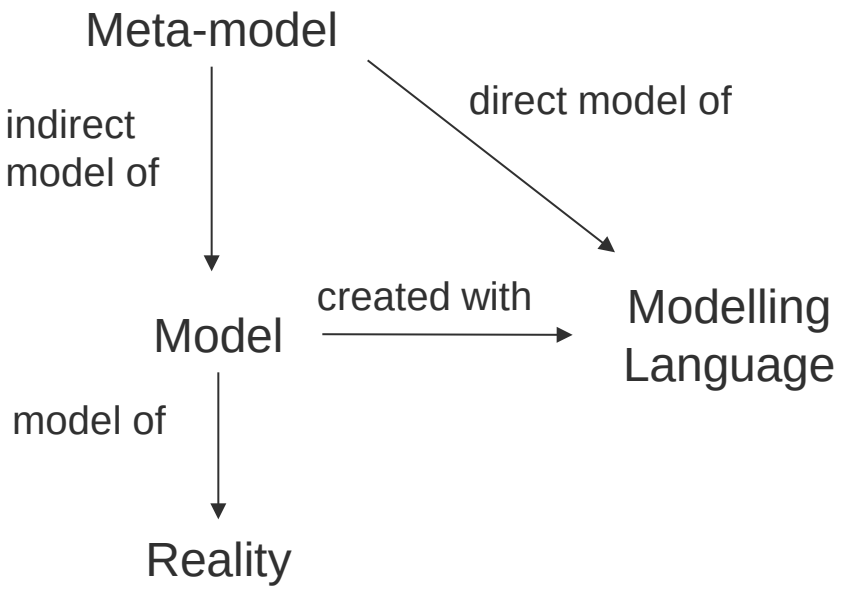
window

meta-model
(abstract syntax)

object types:
- wall
- door
- window

rules:
- a door is adjacent to a wall on both sides
- Windows are on outer walls.

Meta-model



A meta-model defines the semantics of the modelling language, i.e. the building blocks that can be used to make a model. It defines the

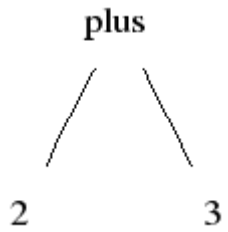
- object types that can be used to represent a model
- relations between object types
- attributes of the object types
- rules to combine object types and relations

- The meta-model is the abstract syntax, the modeling language is the concrete syntax.

Meta Model vs Model Language = Abstract vs. Concrete Syntax

Abstract Syntax

- Deep structure of a language.
- What are the significant parts of the expression?
- Example: a sum expression has two operand expressions as its significant parts



Concrete Syntax

- Surface level of a language.
- What does the expression look like?

Example: *the same* sum expression can look in different ways:

```
2 + 3                          -- infix

(+ 2 3)                        -- prefix

(2 3 +)                        -- postfix

bipush 2                       -- JVM
bipush 3
iadd

the sum of 2 and 3             -- English
```

http://www.cse.chalmers.se/edu/year/2011/course/TIN321/lectures/proglang-02.html

Metamodel and Modeling Language

Metamodel

- The *metamodel* is a model of a model. It defines the modeling elements (concepts, relations, constraints) without specifying the layout and notation
- The *metamodel* corresponds to the *abstract syntax*

Modeling language

- The *modeling language* defines the notation/appearance of the modeling elements
- The *modeling language* corresponds to the *concrete syntax*

Illustration: Meta-model and Model for Processes

Metamodel:

Abstract syntax:
Concepts which can be used to create models.

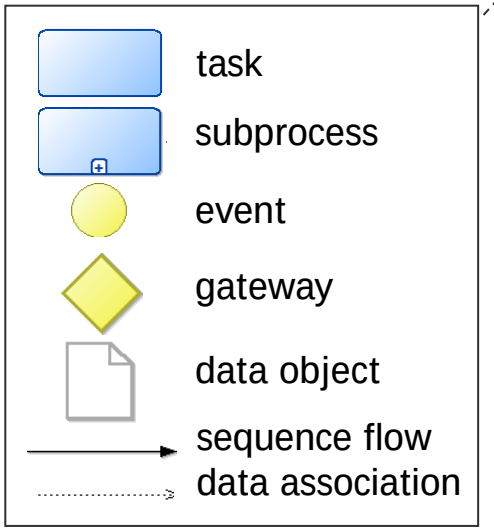
Example: A process model consists of concepts for

- «task», «subprocess», «event», «gateway», «data object»
- «sequence flow», «data association».

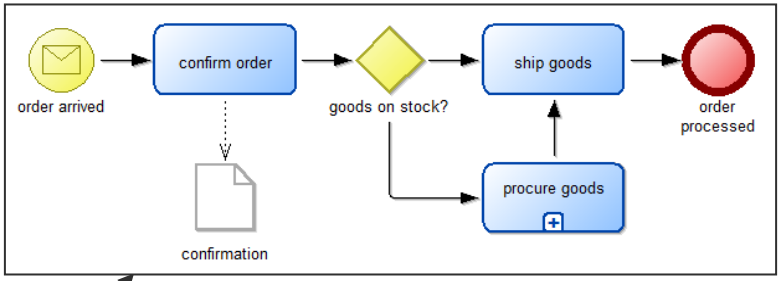
The elements have attributes and there are rules how the elements can be combined.

Modeling Language:

Concrete syntax:
Notation/appearance of meta-model elements



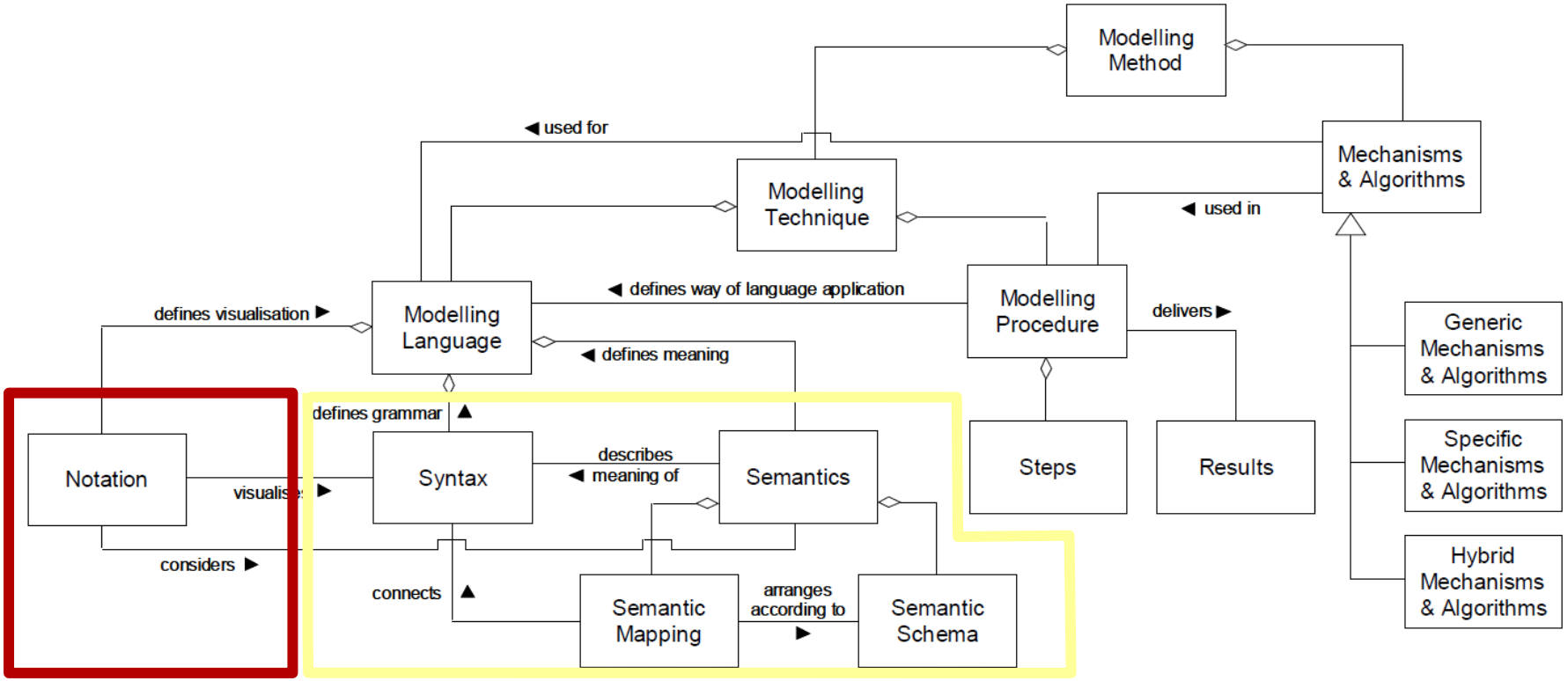
Model:



A model contains instances of the object types defined in the meta-model, according to the concrete syntax of the modeling language. The object „confirm order“ represents a real entity; it is an instance of the object type «task"

Components of Modeling Methods

A Modeling Language is Part of a Modeling Modeling
A Modeling Language consists of the Metamodel (Syntax and Semantics) and the Notation



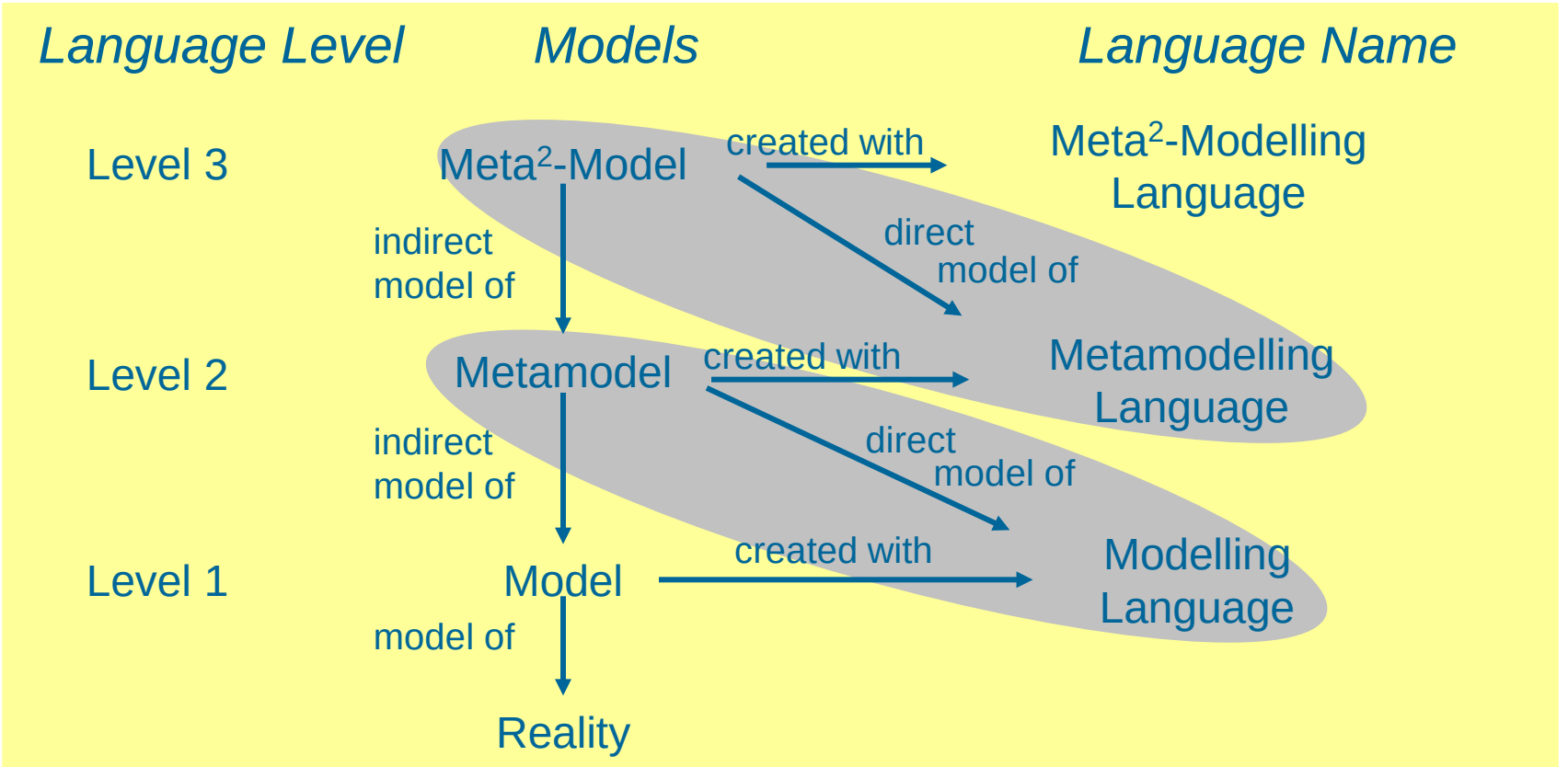
Concrete Syntax

Metamodel

(Karagiannis & Kühn 2002)

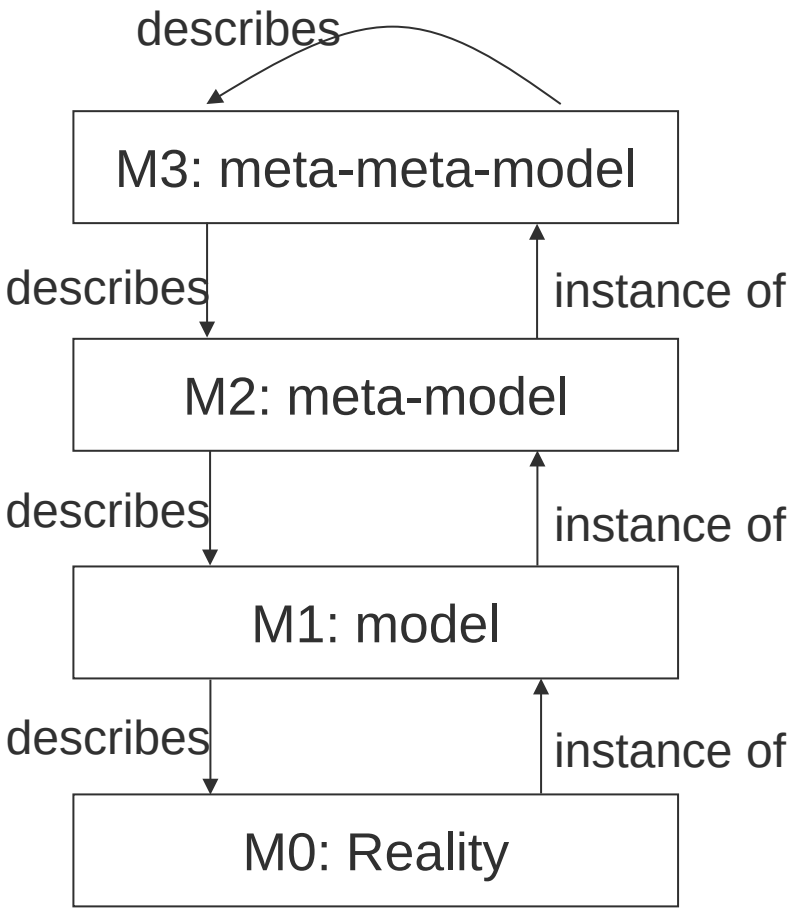
Meta Model Hierarchy

The meta-model must again be described in some language, which has to be specified in a meta-meta-model



Karagiannis, D. & Kühn, H., 2002. Metamodelling Platforms. In K. Bauknecht, A. Min Tjoa, & G. Quirchmayer, eds. *Proceedings of the Third International Conference EC-Web at DEXA 2002*. Berlin: Springer-Verlag.

The Model Stack



- A model is a ***simplified representation of a reality***
- A meta-model defines a **modeling language** in which a model can be expressed.
- A meta-meta model defines the **language in which a meta-model** can be expressed.

Domain-specific vs. General-purpose Modeling Languages

- Domain-specific languages are notations which are defined to model knowledge about a specific domain

- General-purpose modeling languages can be used to represent any kind of knowledge

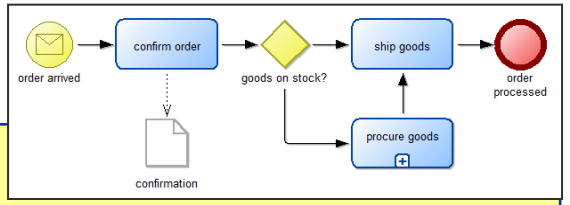
Domain-specific Modeling Languages

- Domain-specific modeling languages have modeling elements for typical concepts and relations of a domain of discourse
  - ♦ Predefined classes, relations and constraints
  - ♦ Specific shapes for modeling elements and relations
- Modeling means to create instances of theses classes and relations

Domain-specific Modeling Languages

- Domain-specific modeling languages correspond to *model kinds* which have modeling elements for concepts and relations to represent specific *views*
- Examples of domain-specific modeling languages:
  - **BPMN** is a domain-specific language for business processes
    - Modeling elements: task, event, gateway, ….
    - relations: sequence flow, message flow, data association, …
  - **ArchiMate** is a domain-specific language for enterprise architectures
    - Modeling elements: process, actor, role, business object, …
    - relations: uses, realizes, …
  - **BMM** is a domain-specific language for business motivation
    - Modeling elements: vision, mission, goal, strategy, influencer, …
    - relations: judges, channels efforts, …

A Business Process Model and Metamodel



Modeling Language

Flow object

event

activity

gateway

data object

subclass of

subclass of

subclass of

subclass of

start event

end event

task

subprocess

instance of

instance of

instance of

instance of

instance of

instance of

instance of

order processed

confirmation

order arrived

triggers

confirm order

ship goods

procure goods

goods on stock?

has name

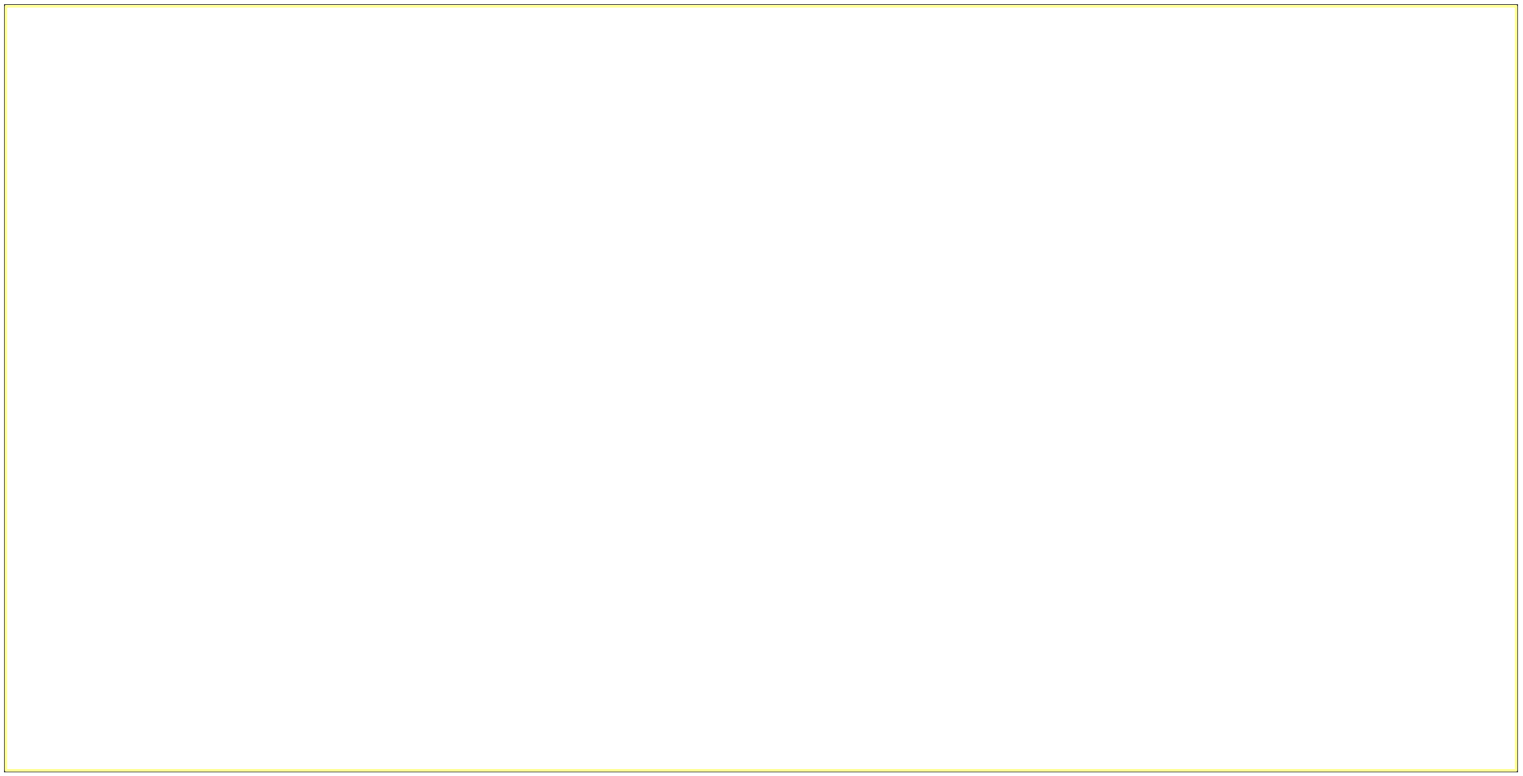
output

"Confirm order"

Model

Metamodels can be defined as Class Diagrams

To model a metamodel one can use (a subset of) UML class diagrams

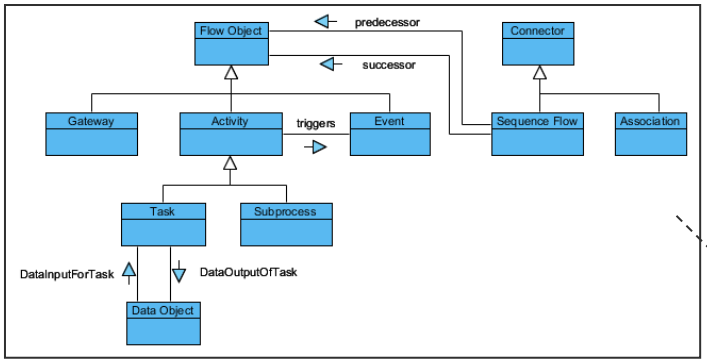


(UML Class diagrams where originally designed for modeling in object-oriented programming. This is why they contain operations and other features, which are not relevant for most modeling languages)

A Domain-specific Metamodel for Processes

Meta-model:

- Classes and relations that can be used for modeling
- Abstract syntax and semantics



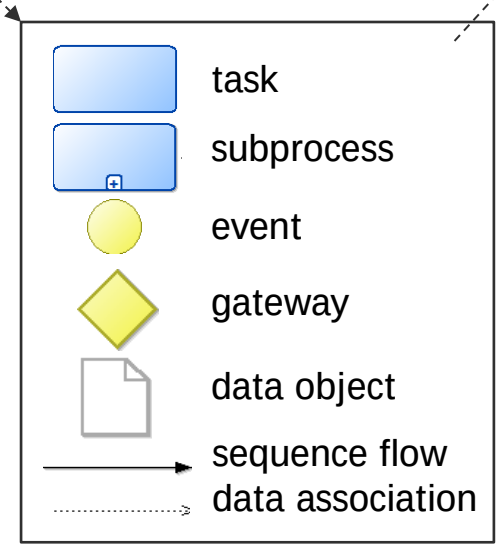
Example: A process model consists of object types for

- «task», «subprocess», «event», «gateway», «data object»
- «sequence flow», «data association».

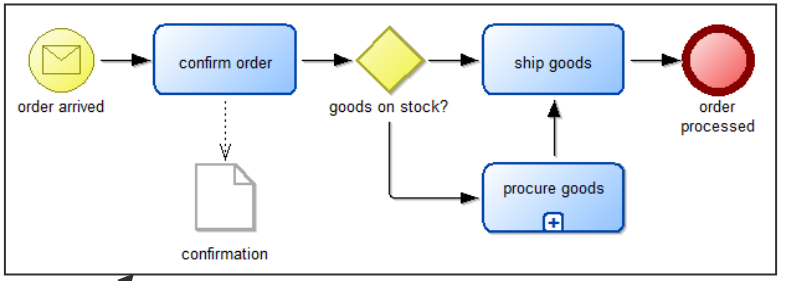
The elements have attributes and there are rules how the elements can be combined.

Modeling Language:

Concrete Syntax (notation, appearance) of meta-model elements



Model:



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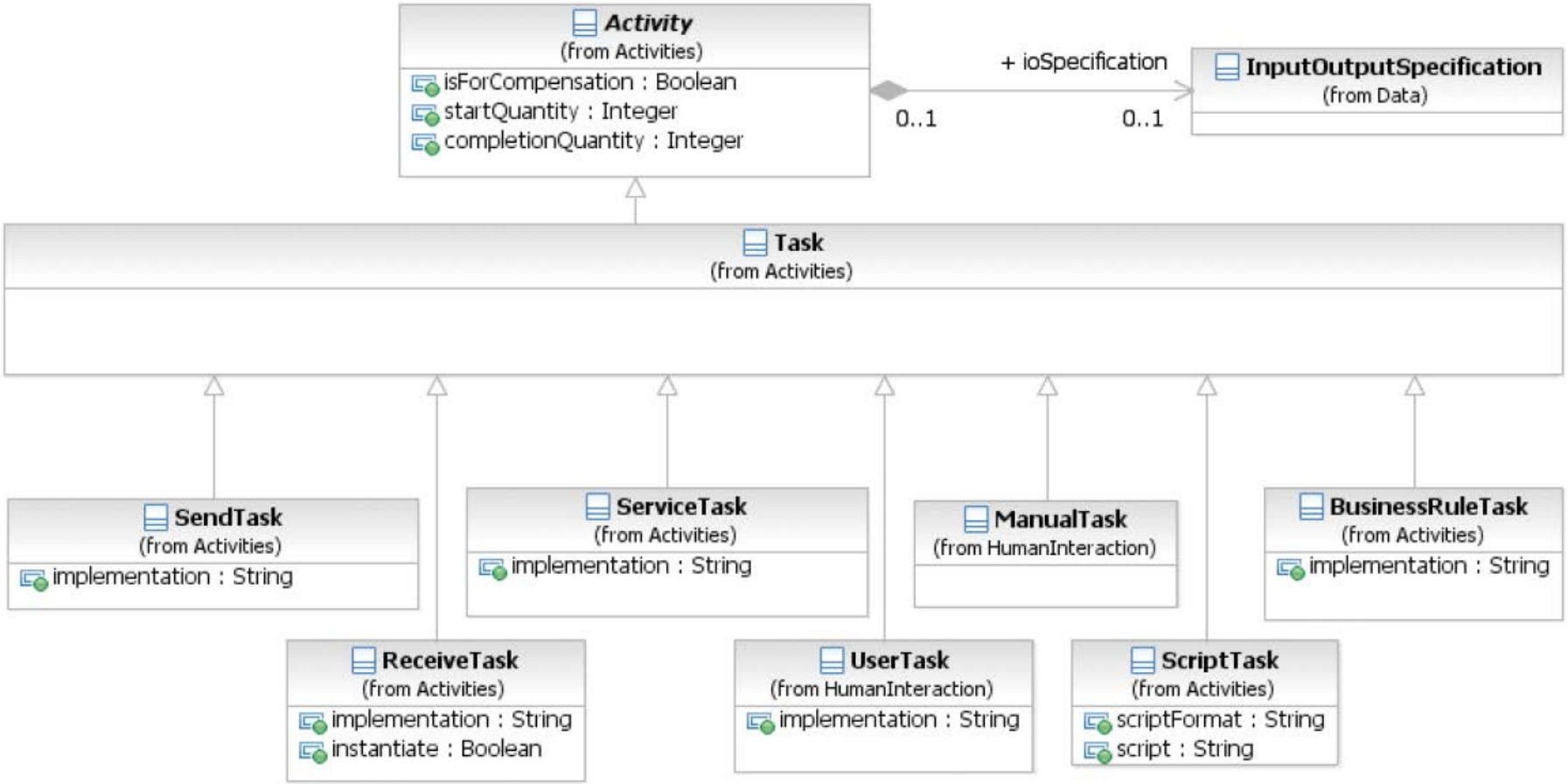
Subset of the BPMN Metamodel in UML



Source: BPMN 2.0 specification

Strengths and Weaknesses of Domain Modeling Languages

- Strengths
  - Comprehensiblity of models
    - elements and relations are adequate for stakeholders
    - domain-specific shapes
  - Reuse of models
    - domain-language can be standardized (e.g. BPMN, ArchiMate)
- Weaknesses
  - Restricted to a specific domain
    - Only what can be expressed with the modeling elements can be modeled

What do we do if there is no Domain-specific Modelling Language

- If there is no domain-specific modelling language for a domain of interest, we have two options
  1. Define a new domain-specific modelling language
     - meta model
     - modeling language
  2. Use a general-purpose modeling language

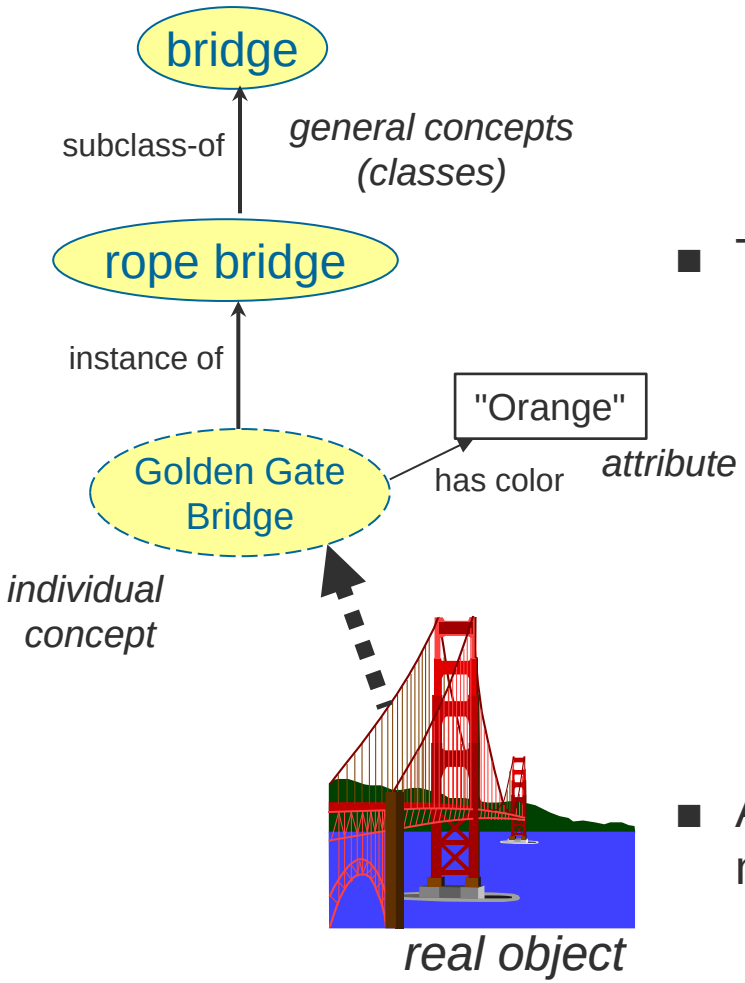
General-purpose Modeling Languages

- General-purpose modeling languages can be used to represent any kind of knowledge
- They can be used, if no domain-specific modeling language is available (for a view)
- There are a wide range of generalo-purpose modeling languages
  - Natural language allows to express any knowledge
  - Formal languages: Typically a subset of Logic
  - Graphical Diagrams
- General-purpose graphical modeling languages have been developed in a many difference fields:
  - Artificial Intelligence: Semantic networks, Description Logics
  - Data Modeling: Entity Relationship Diagrams
  - Object-Oriented Programming: UML Class Diagrams

The Metamodel for a General-purpose Modeling Language

- The metamodel for a general-purpose modeling language has only few modeling elements
  - Class
  - Attribute
  - Association
  - Object
- This can be modelled with Class Diagrams, e.g.
  - (a subset of) UML Class Diagrams
  - Ontology Languages
- Modeling means to
  - define classes
  - create instances of these classes

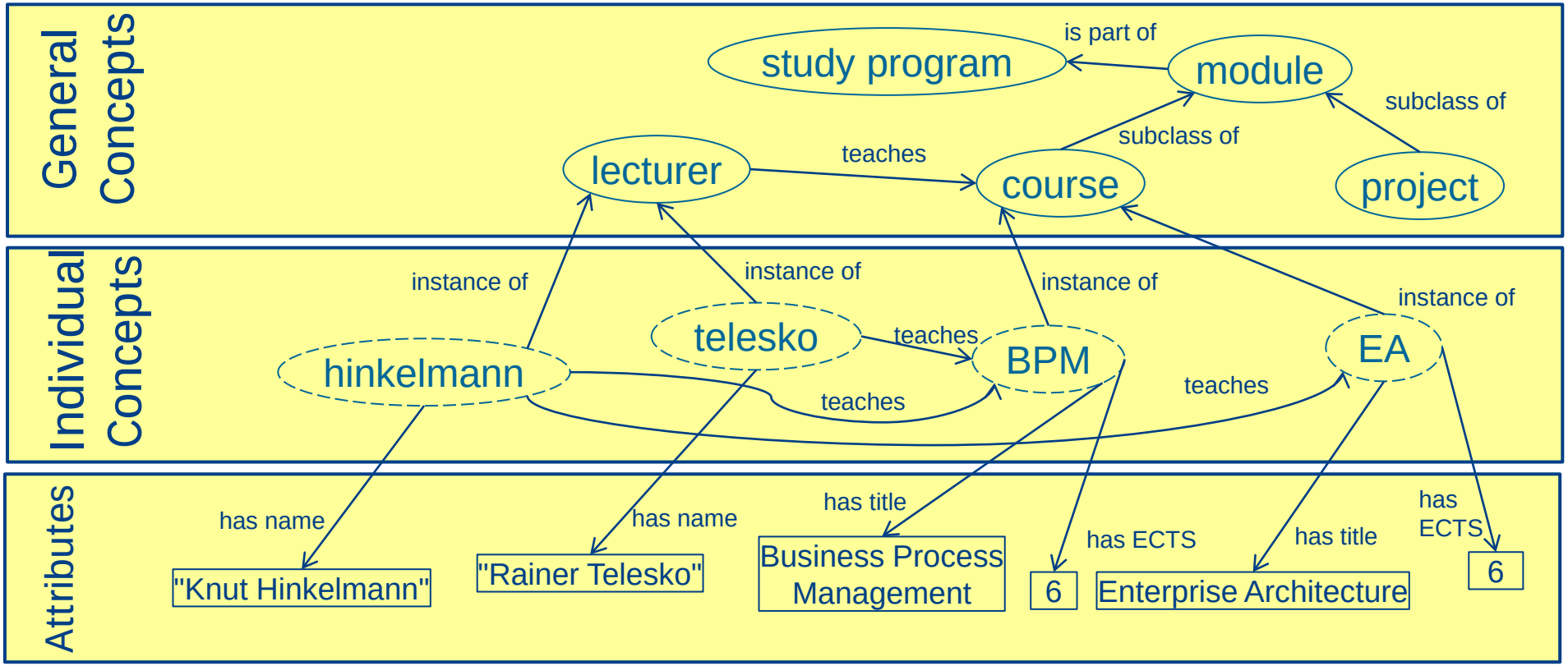
Concepts and Relations



- There are two kinds of concepts:
  - **general concepts** (also called classes)
  - **individual concepts** (also called objects, individuals or instances)
- There are different kinds of relations
  - **generalisation** ("is a")
    - between classes **(subclass of)**
    - between individual and class **(instance of)**
  - **aggregation and composition**
    - "part-of" relationship
  - **associations**
    - any other kind of relationship
- Attributes can be regarded as associations whose value is not node but is of a primitive type (number, string).

Modeling with a General-purpose Modeling Language

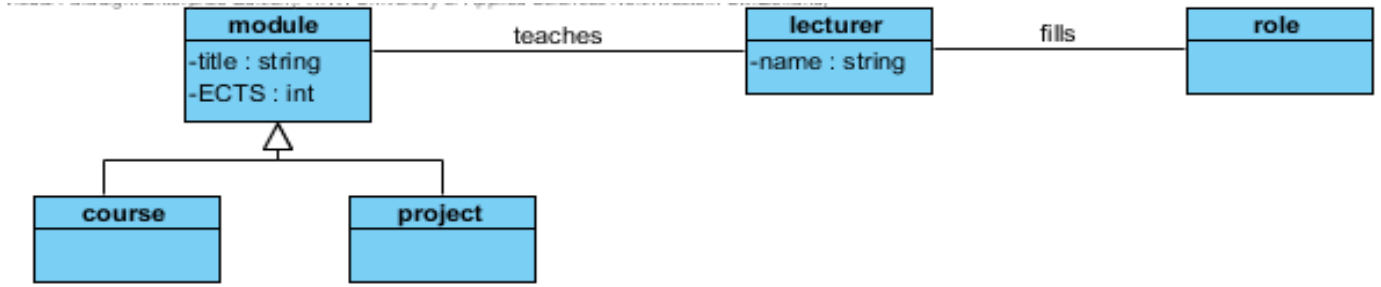
With a general-purpose modeling language, knowledge of any domain can be modeled. This is a model for modules of a study program.



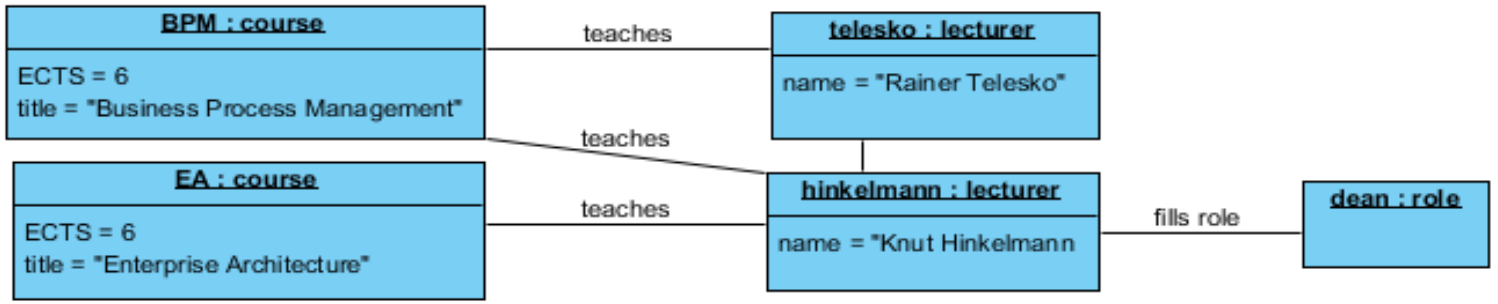
The Semantic Network modeled in UML

The metamodel for this generic modeling language corresponds to subsets of UML Class Diagrams and UML Object Diagrams

Classes



Objects

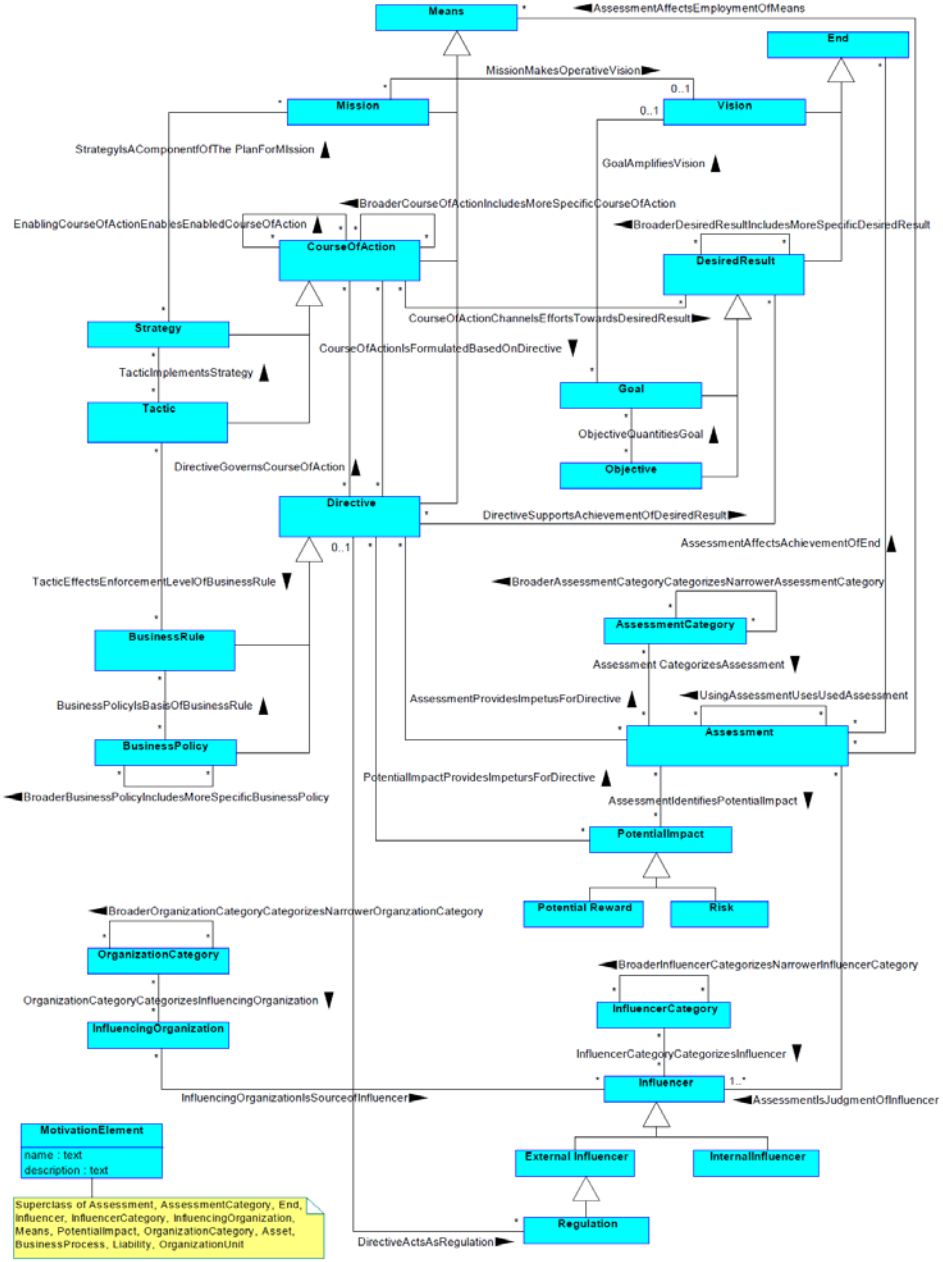


The classes specify a (new) domain-specific metamodel – In this case for modeling modules of a study program

Disadvantage: No specific modeling shapes

Meta-Meta Model: Modeling a Meta-Model

- We can use a general-purpose modeling language also as a meta-meta model for a domain-specific modeling language
- OMG uses (UML) Class Diagrams as Meta-Modeling language
- Example: Business Motivation Meta-Model



Modeling of Enterprise Architectures

- EA Frameworks provide a structure for the EA description
- The stakeholders and their concerns as well as the goals of the enterprise determine what should be in the EA description
- Based an that the metamodels are defined/select:
  - ♦ If available choose domain-specific metamodels/modeling languages
  - ♦ If there are no domain-specific modeling languages (in your tool) for some elements,
    - use a general-purpose modeling language (e.g. class diagrams)
    - define a domain-specifc modeling language / metamodel

Customizing Modeling Languages in ArchiMetric

- In the ArchiMetric tool we can use stereotypes to specialize UML class diagrams.
- Stereotypes can be defined and added to any model element.
- We can define a new stereotype for a class and
  - change color
  - add an icon
- Example: stereotypes for modules and lecturer