Introduction to Model Engineering

A gentle introduction to a new way of considering the construction and maintenance of information systems

Jean Bézivin
Jean.Bezivin@univ-nantes.fr
ATLAS Group (INRIA & LINA), Nantes

Context of this work

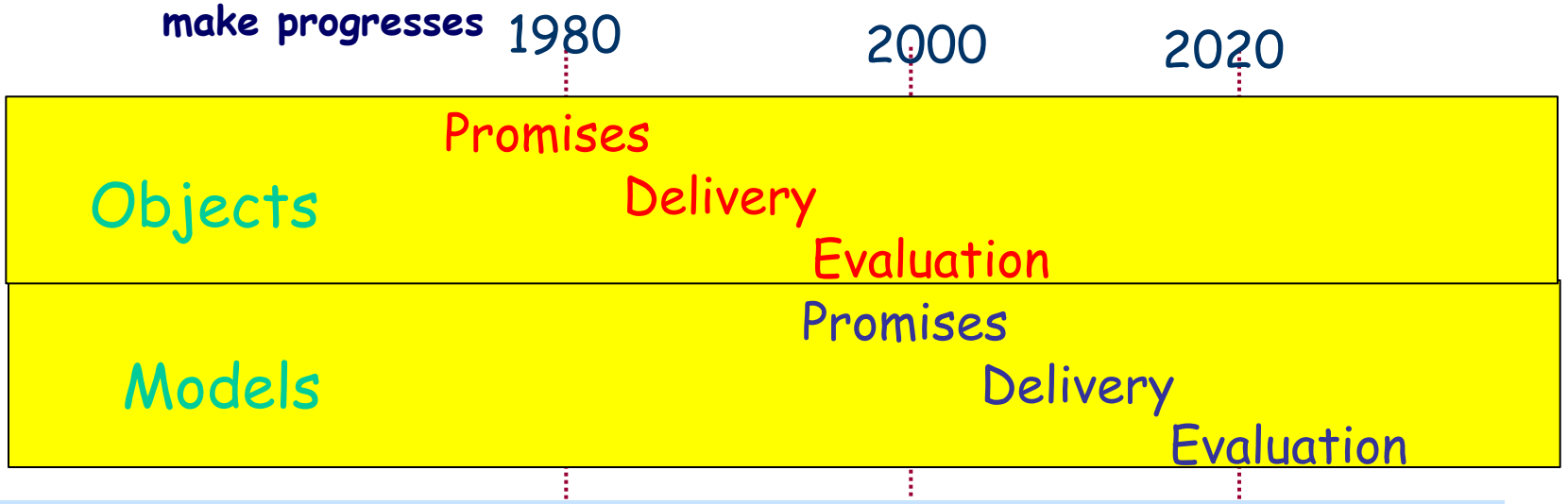
- The present courseware has been elaborated in the context of the MODELWARE European IST FP6 project (http://www.modelware-ist.org/).
- Co-funded by the European Commission, the MODELWARE project involves 19 partners from 8 European countries. MODELWARE aims to improve software productivity by capitalizing on techniques known as Model-Driven Development (MDD).
- To achieve the goal of large-scale adoption of these MDD techniques, MODELWARE promotes the idea of a collaborative development of courseware dedicated to this domain.
- The MDD courseware provided here with the status of open source software is produced under the EPL 1.0 license.

Presentation Schedule

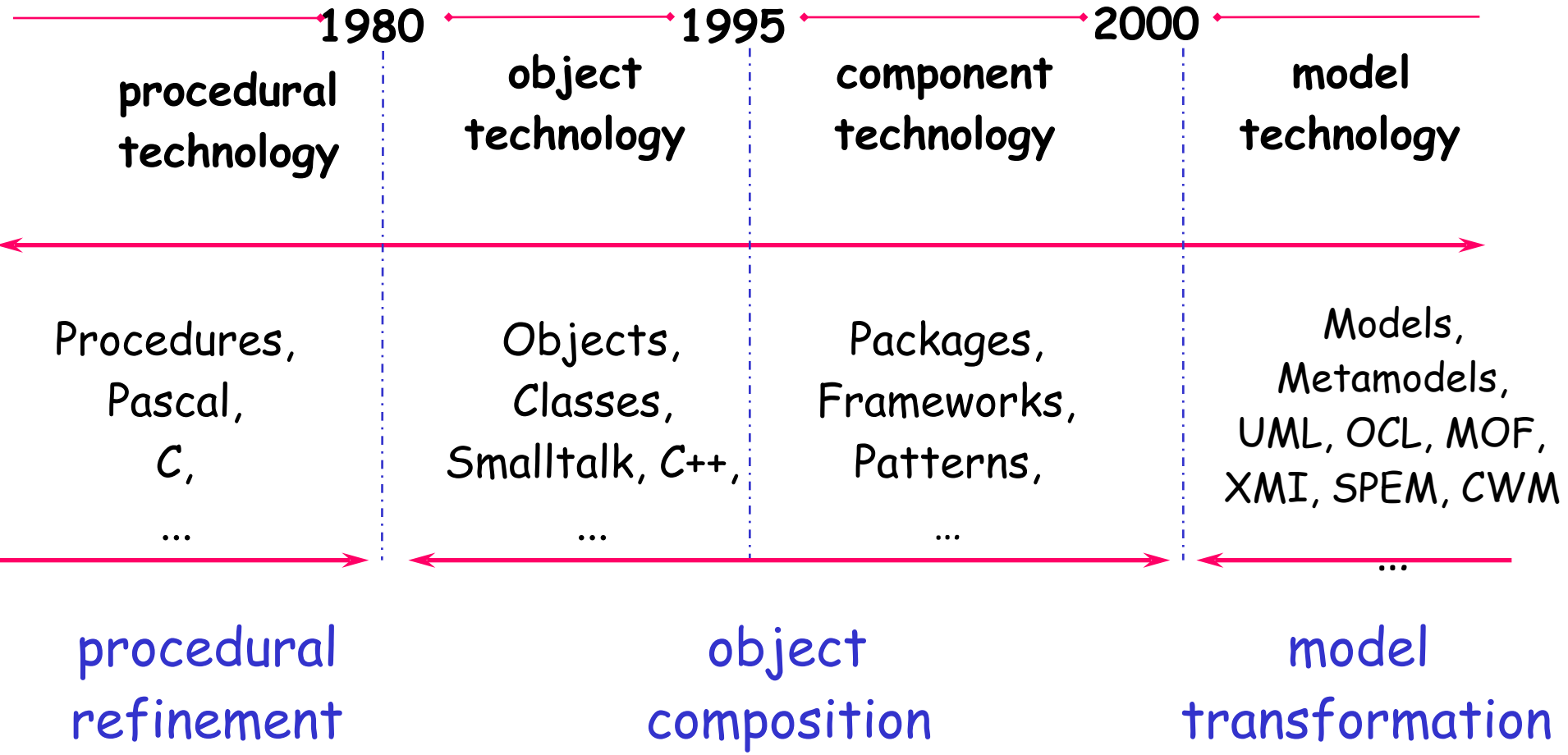
- Part 1 : Ubiquitous Models
  - What is a model?
  - What is a metamodel?
  - What is a metametamodel?
  - What is the purpose of a model?
- Part 2 : MDA™ vs. MDE
  - Glossary of acronyms
  - The three-level OMG stack
  - Automating model management

From Objects to Models

- Object technology realized some promises but failed to achieve others
  - Stopping the search for generality by unification may be one of the causes for this
- Model engineering is making many promises today
  - Will it be able to deliver correspondingly?
  - Sticking with the principle that "everything is a model" seems a good way to make progresses



A global view of software engineering evolution



Modeling is essential

- Modeling is essential to human activity because every action is preceded by the construction (implicit or explicit) of a model.
- The medical technique of bloodletting was based on an incorrect model of the body [1]. If the model is incorrect, the action may be inappropriate [2].
  - [1] Hippocrates and many others believed that the four crucial elements earth, air, water and fire were balanced within the human body as the four humors: blood, phlegm, and black and yellow bile. In this context, disease was due to an imbalance in the four humors and treatment involved restoring their balance through bloodletting.
  - [2] Georges Washington died after heavy blood loss sustained in a bloodletting treatment for laryngitis.

Want another advice?

"Modeling is the future …

And the promise here is that you write a lot less code, that you have a model of the business process …

So, modeling is pretty magic stuff, whether it's management problems or business customization problems or work-flow problems, visual modeling …

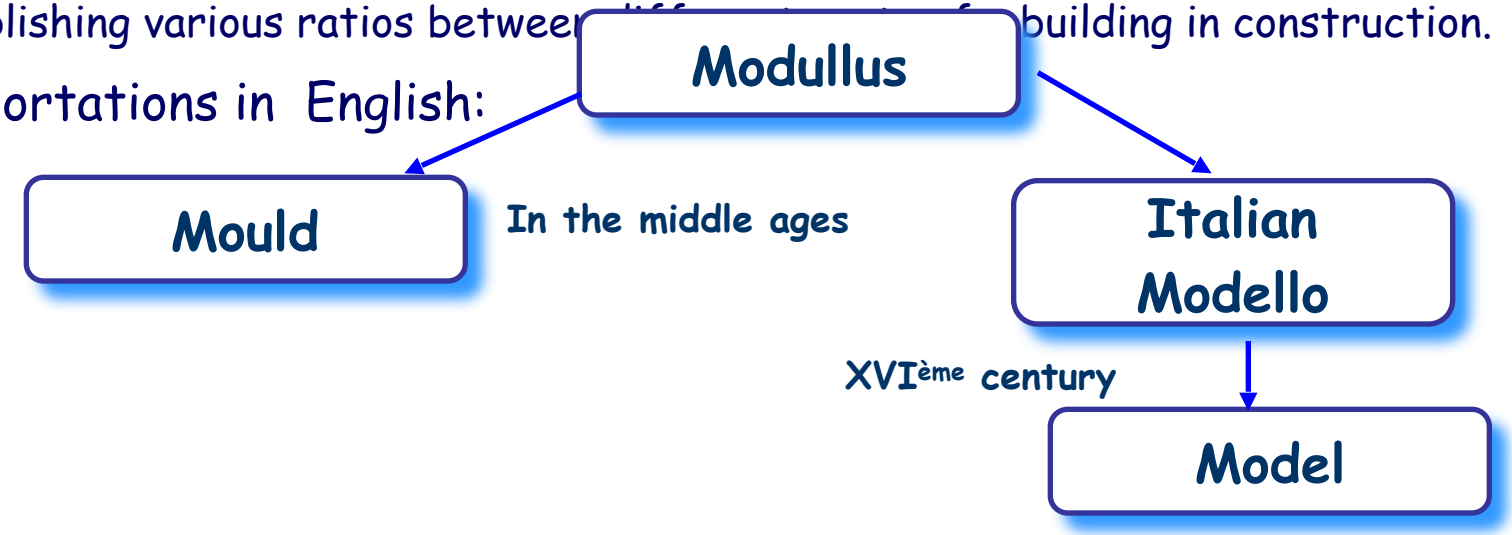
It's probably the biggest thing going on …"

Bill Gates

[What Is Bill Gates Thinking? Interview, eWEEK.com, 3/30/2004]

Definitions

- A model is the simplified image of a system
  - This short definition should be completed
- What is a system ?
  - "A system is a set of elements in interaction " (von Bertalanffy)
  - The word system comes from the Greek "sun-istémi" (I compose)
- Model comes from the Latin "modullus", diminutive of "modus" (measure)
  - Initially it was an architectural term meaning an arbitrary measure used for establishing various ratios betwee building in construction.
- Two importations in English:



What is a model?

Modeling, in the broadest sense, is the cost-effective use of something in place of something else for some cognitive purpose. It allows us to use something that is simpler, safer or cheaper than reality instead of reality for some purpose. A model represents reality for the given purpose; the model is an abstraction of reality in the sense that it cannot represent all aspects of reality. This allows us to deal with the world in a simplified manner, avoiding the complexity, danger and irreversibility of reality.

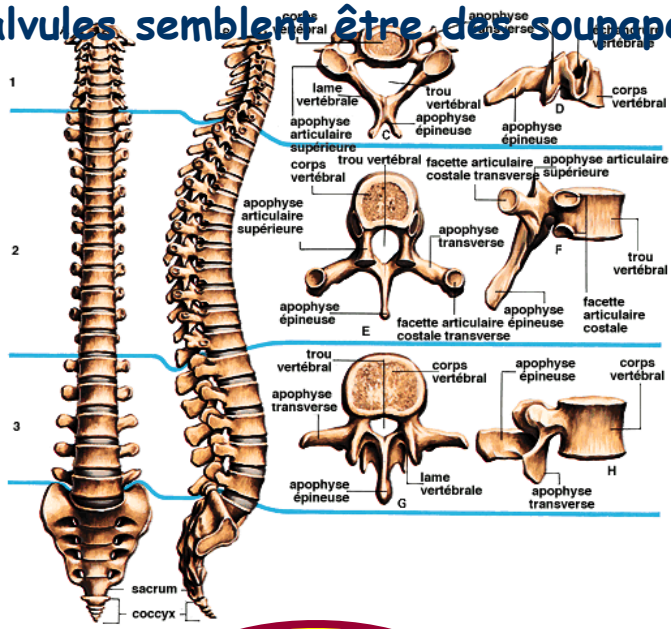
"The Nature of Modeling."
Jeff Rothenberg
in Artificial Intelligence, Simulation, and Modeling,
L.E. William, K.A. Loparo, N.R. Nelson, eds.
New York, John Wiley and Sons, Inc., 1989, pp. 75-92

http://poweredge.stanford.edu/BioinformaticsArchive/PrimarySite/NIHpanelModeling/RothenbergNatureModeling.pdf

The word is recent, the idea is old

Plato (427-347 before JC), in Timeus compares vertebras
to door hinges (74a) or blood vessels to irrigation channels.

This idea will be used again later by the english physiologist William Harvey (1578-1657)
who will discover the blood circulation principle:
"de ce que, dans le cœur des vivants,
les valvules semblent être des soupapes ou des portes d'écluse".



Model: multiple definitions

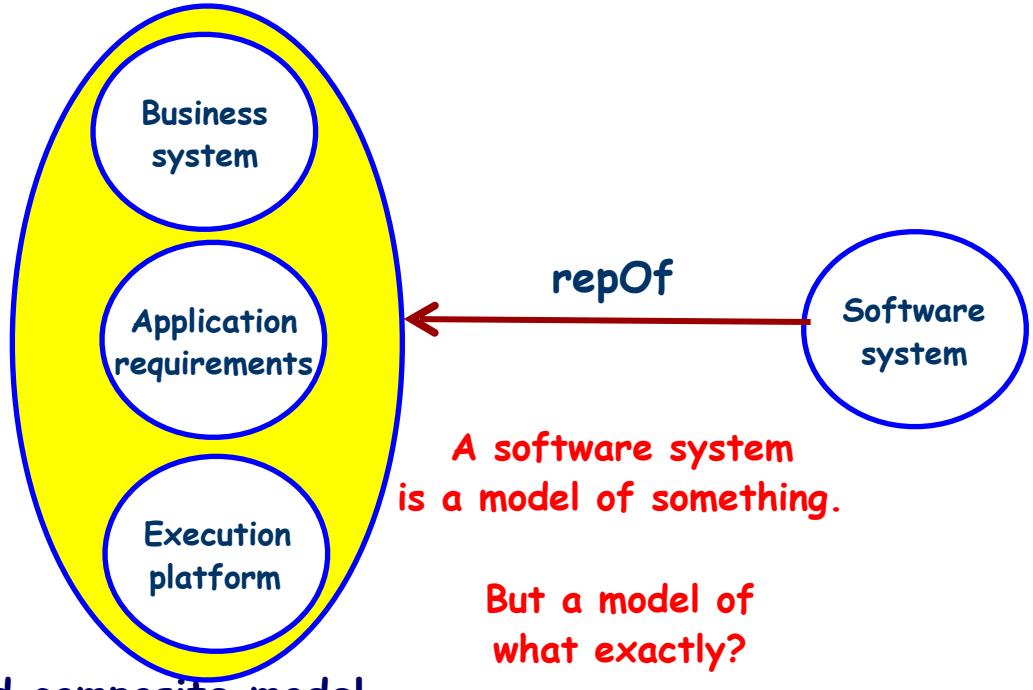
MSN Encarta

mod·el [módd'l] noun (plural mod·els)

1. **copy of an object:** a copy of an object, especially one made on a smaller scale than the original (often used before a noun)
2. **particular version of manufactured article:** a particular version of a manufactured article
   had traded in her car for the latest model
3. **something copied:** something that is copied or used as the basis for a related idea, process, or system
4. **somebody paid to wear clothes:** somebody who is paid to wear clothes and demonstrate merchandise as a profession, for example, in fashion shows and photographs for magazines and catalogues
5. **simplified version:** a simplified version of something complex used, for example, to analyze and solve problems or make predictions a financial model
6. **perfect example:** an excellent example that deserves to be imitated
7. **artist's subject:** somebody who poses for a painter, sculptor, photographer, or other artist
8. zoology **animal copied by another animal:** an animal species repellent to predators which another animal mimics for protection
9. logic **interpretation:** an interpretation of a theory arrived at by assigning referents in such a way as to make the theory true
10. U.K. fashion **exclusive garment:** the first sewn example of a couturier's or clothing manufacturer's design, from which a new line of garments is produced

Different kinds of models

- Numerous examples
  - Mathematical models
  - Hydrological models
  - Biological models
  - Ecological models
  - Economical models
  - Meteorological models
  - Simulation models
  - Descriptive or predictive models
  - etc.



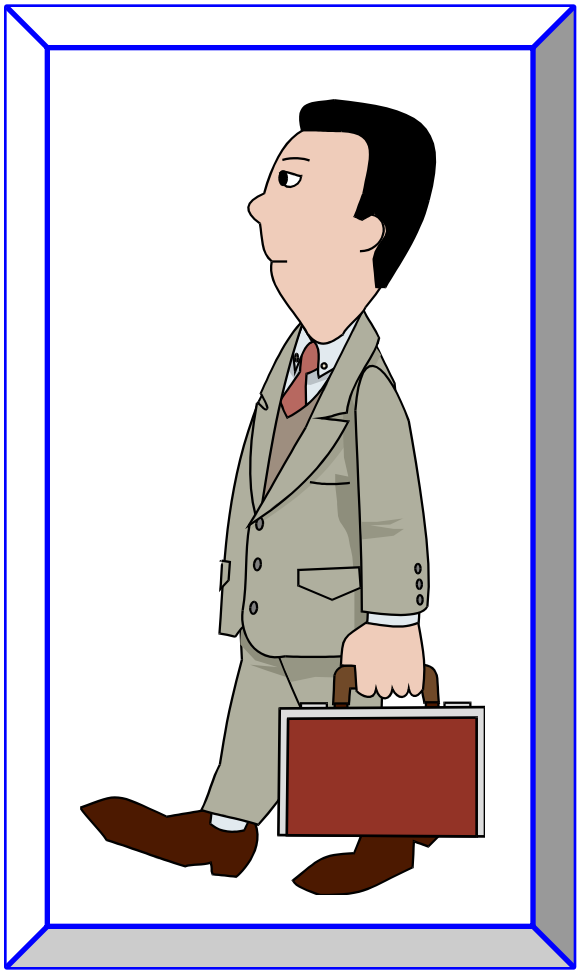
- Software are models:
  - **A software is a complex and composite model**
  - **But a model of what?**
    - Of the organization where it is supposed to function?
    - Of the architecture (hardware/software platform) on top of which it is supposed to function?
    - Of the applicative requirements it is supposed to satisfy ?
    - Of the team that elaborated the software?
  - **Expressed in which language?**
    - Until how software was mainly written in so-called programming languages like C# or Java
    - … but things are rapidly changing (code-centric to model-centric, DSLs)

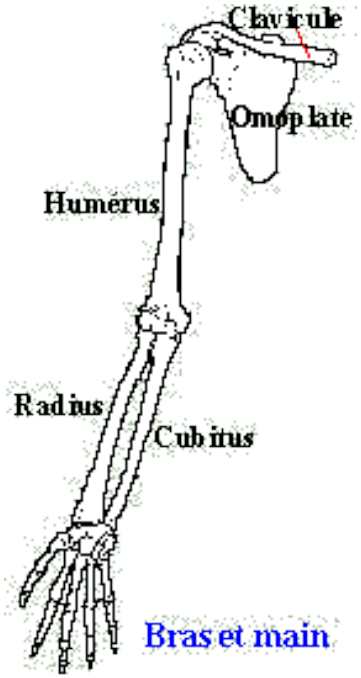
A model is a partial view of a system

A system

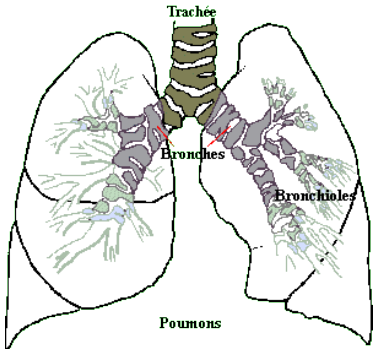
repOf

Several models of this system (partial views)





Skeleton model



Respiratory model

Other Models muscular, nervous, circulatory, digestive, endocrinous, etc.

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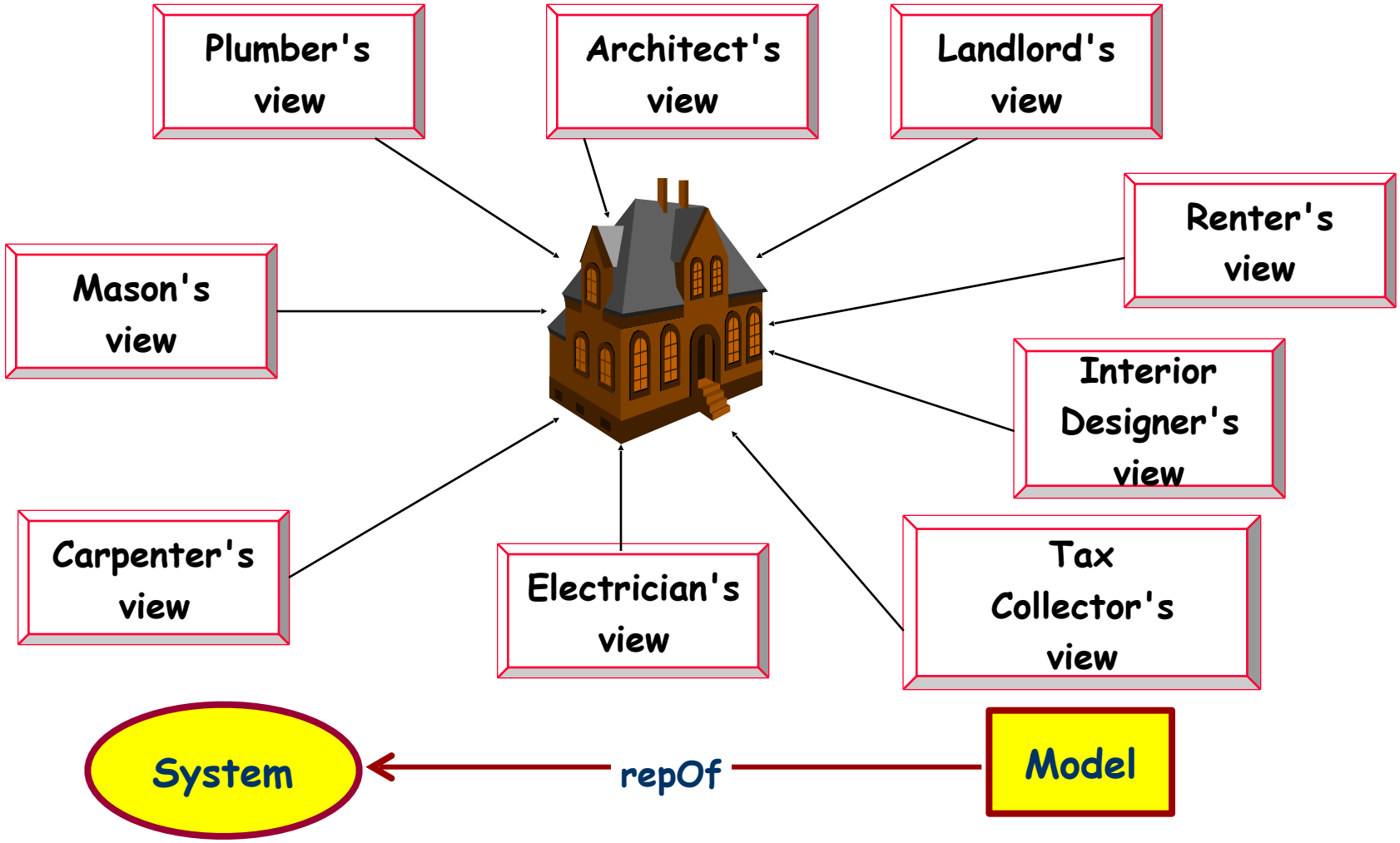
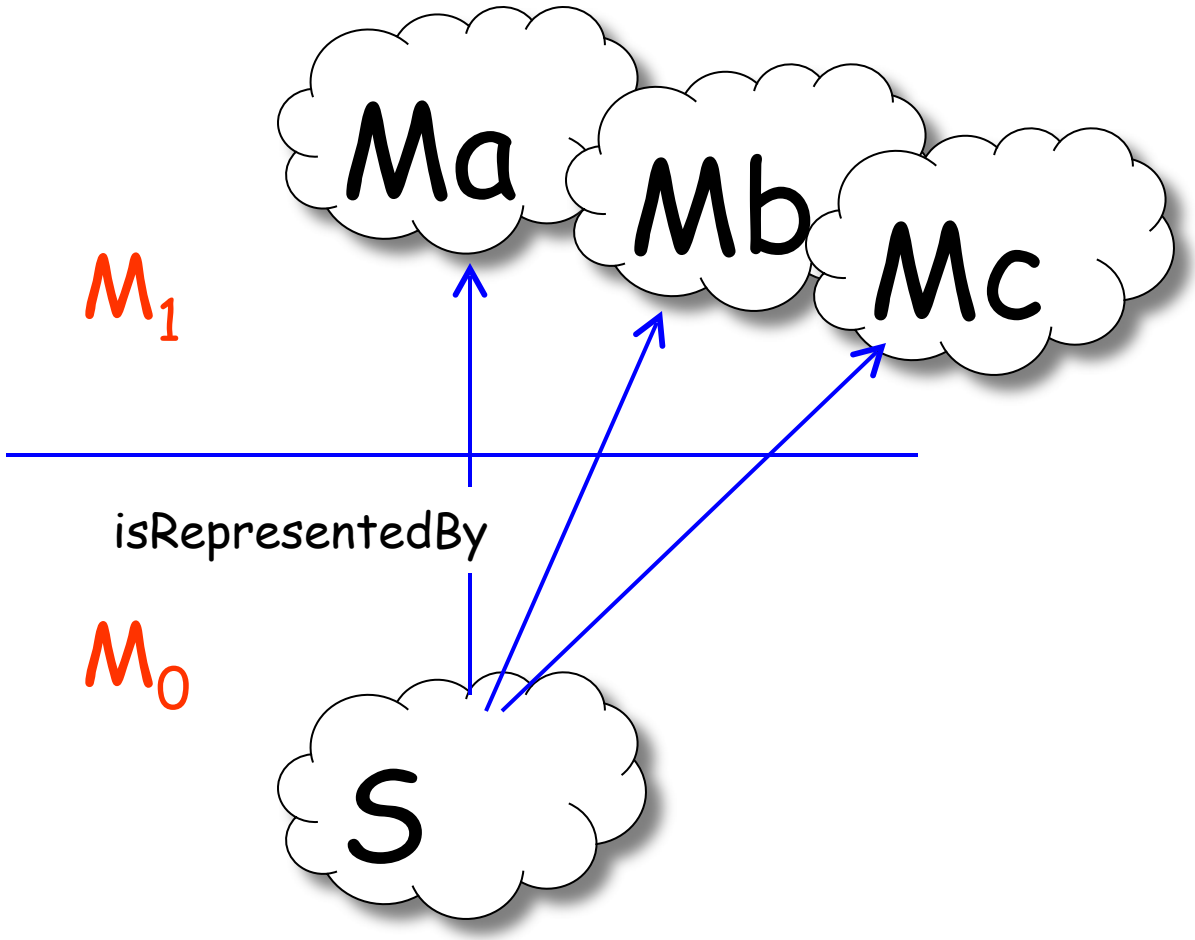
Multiples views and coordinated DSLs

Each view is expressed in a given domain language (DSL).
Vocabularies of different corporations are different;
However they allow talking about a common building.



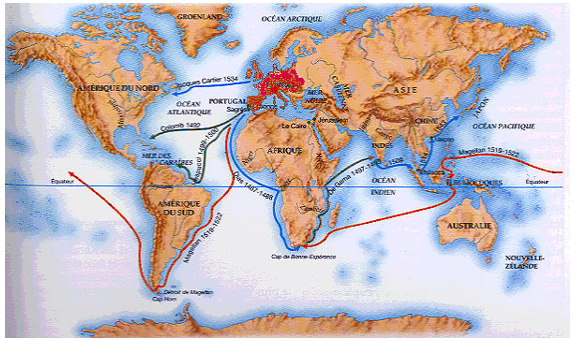
Aspects of a system represented by models



A given system may have plenty of different models.

Each model represents a given aspect of the system.

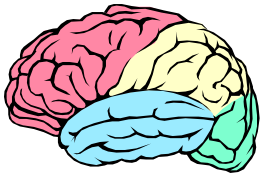
There are still a number of models to build



Magellan, Christophe Colomb, Marco Polo

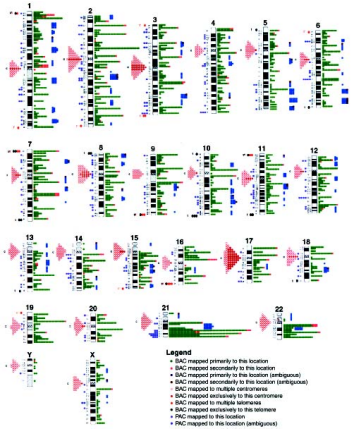
Vasco de Gama, Pizarre, etc.

Models of the earth, galaxy and space



Models of the brain

(localization of the main functions)



Models of Genetic legacy (Human genome map)

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Don't confuse the model and the system

This is not a pipe by Magritte

Don't confuse the model and the system

repOf

etc.)

repOf

System

repOf

Model

repOf

The system

A model

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The globe is a model of the earth

(Principle of limited substitutability).
A model M is said to be a representation of a system S
for a given set of questions Q if, for each question of this set Q,
the model M will provide exactly the same answer
that the system S would have provided in answering the same question.

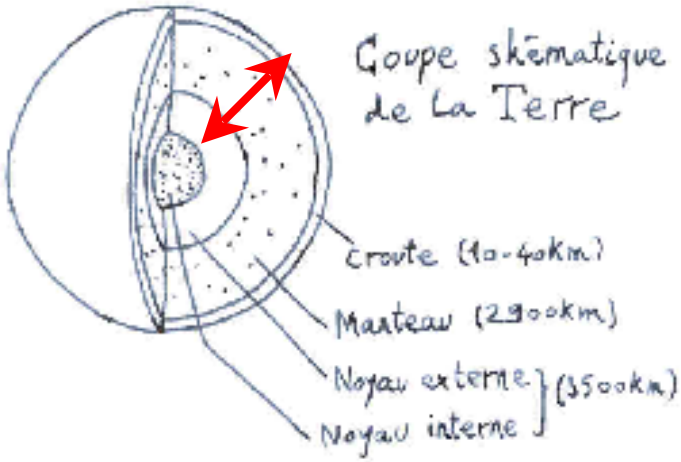
The globe is a model of the earth

- Allowing to ask certain questions …

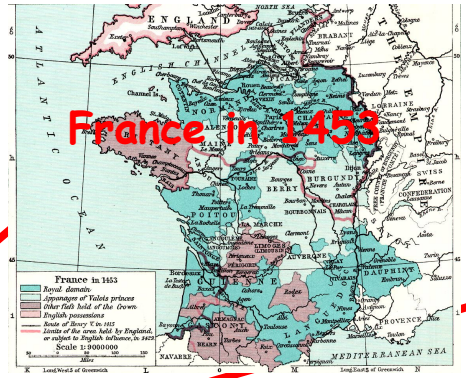
Could I travel from Paris to Anchorage without using a boat?

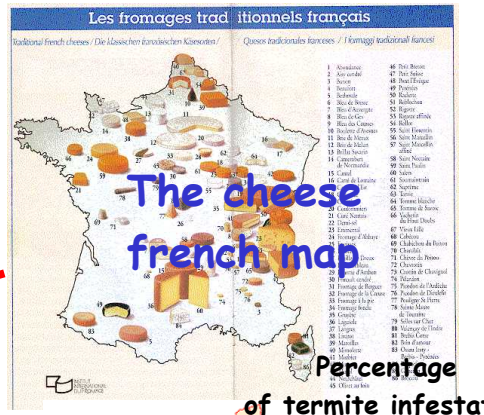
- But not others

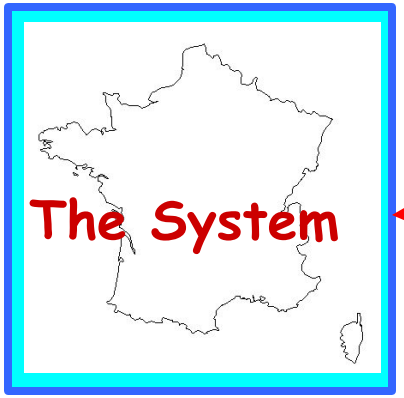
What is the temperature at the bottom if I dig a 100 km deep hole at the surface of the earth ?



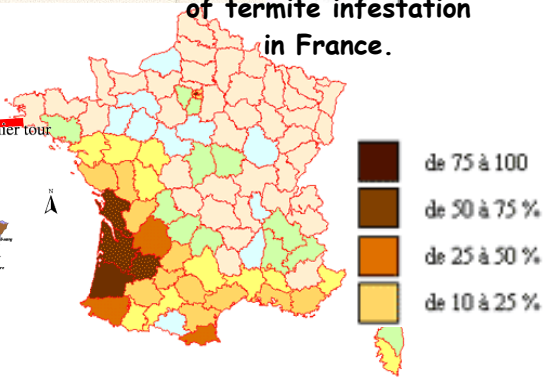
A very popular model: geographical maps



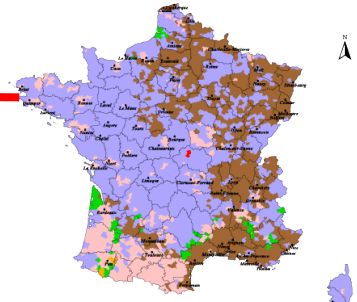




Percentage
of termite infestation
in France.



La France des "Huit présidents"
candidat arrivé en tête à l'issue du premier tour



Models

Every map has a legend (implicit or explicit)

Same visual notation, different context, different meaning (Thick red dotted lines for bicycle lanes)

Bicycle Lane

The legend is the metamodel

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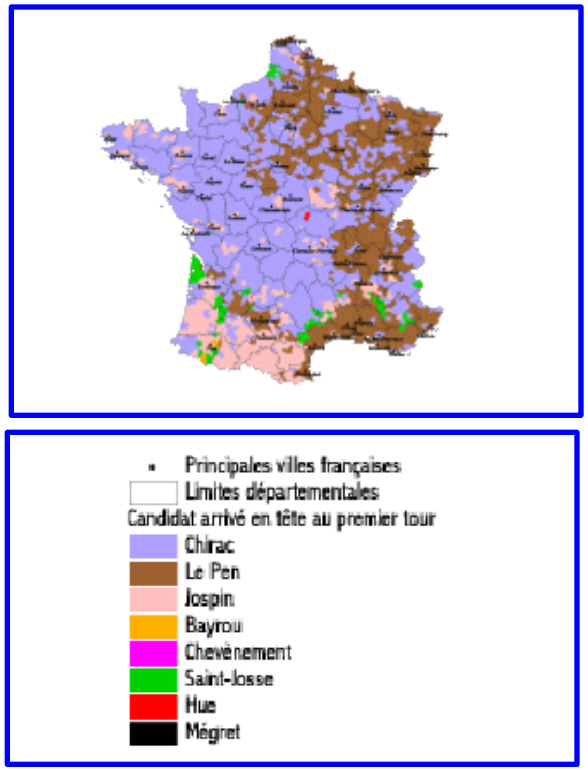
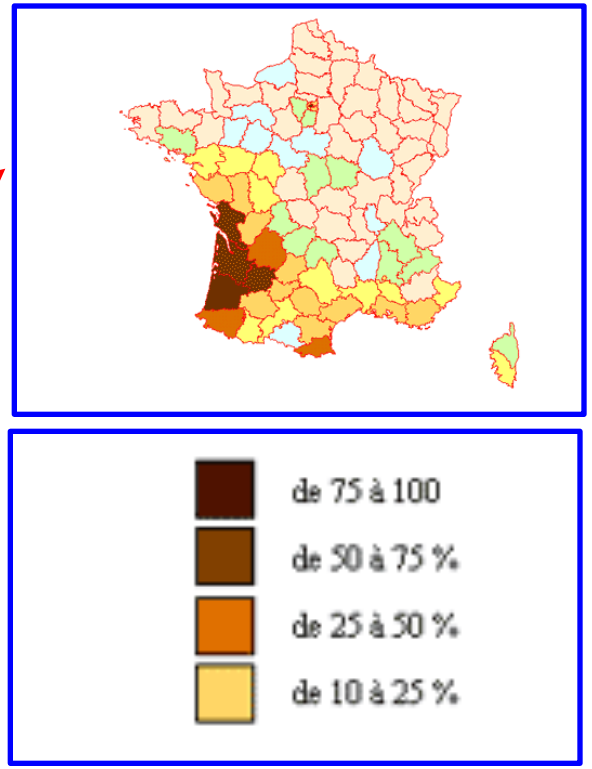
a Model has no meaning when separated from its metamodel

First round of political election in France in 2002.

Percentage of places infested by termites in France.





Another Notation (DSL)

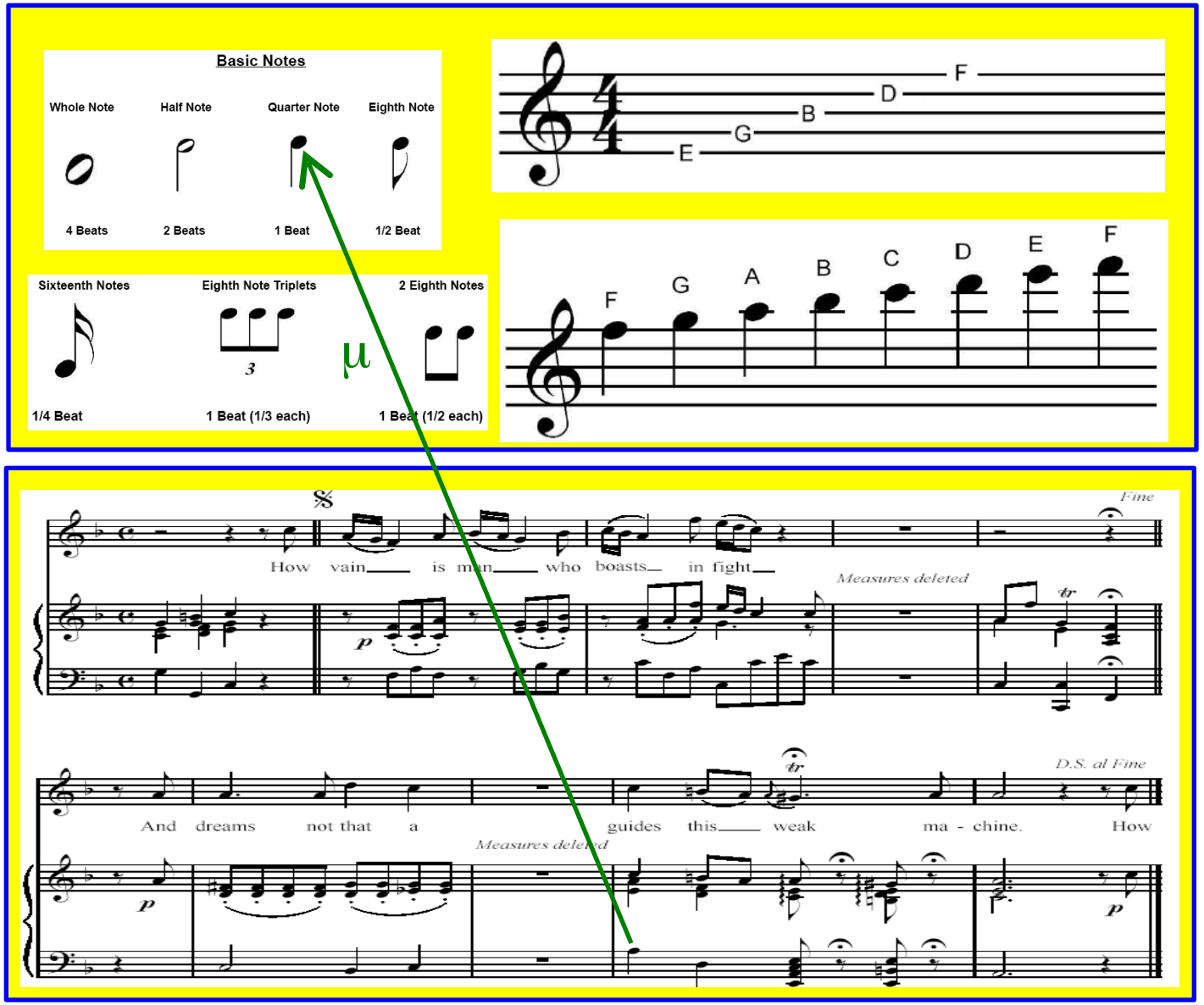
Music notation

Metamodel

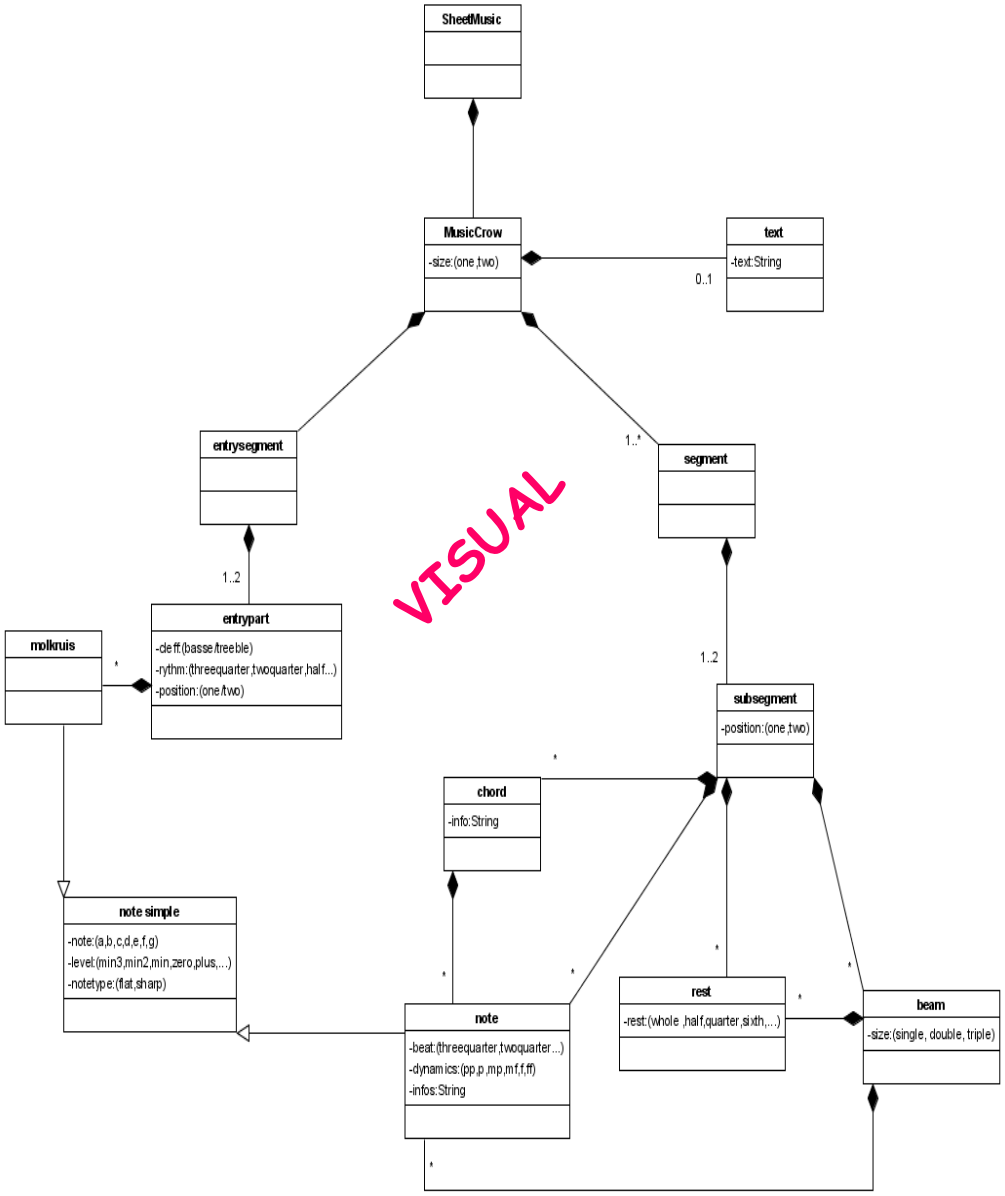
c2

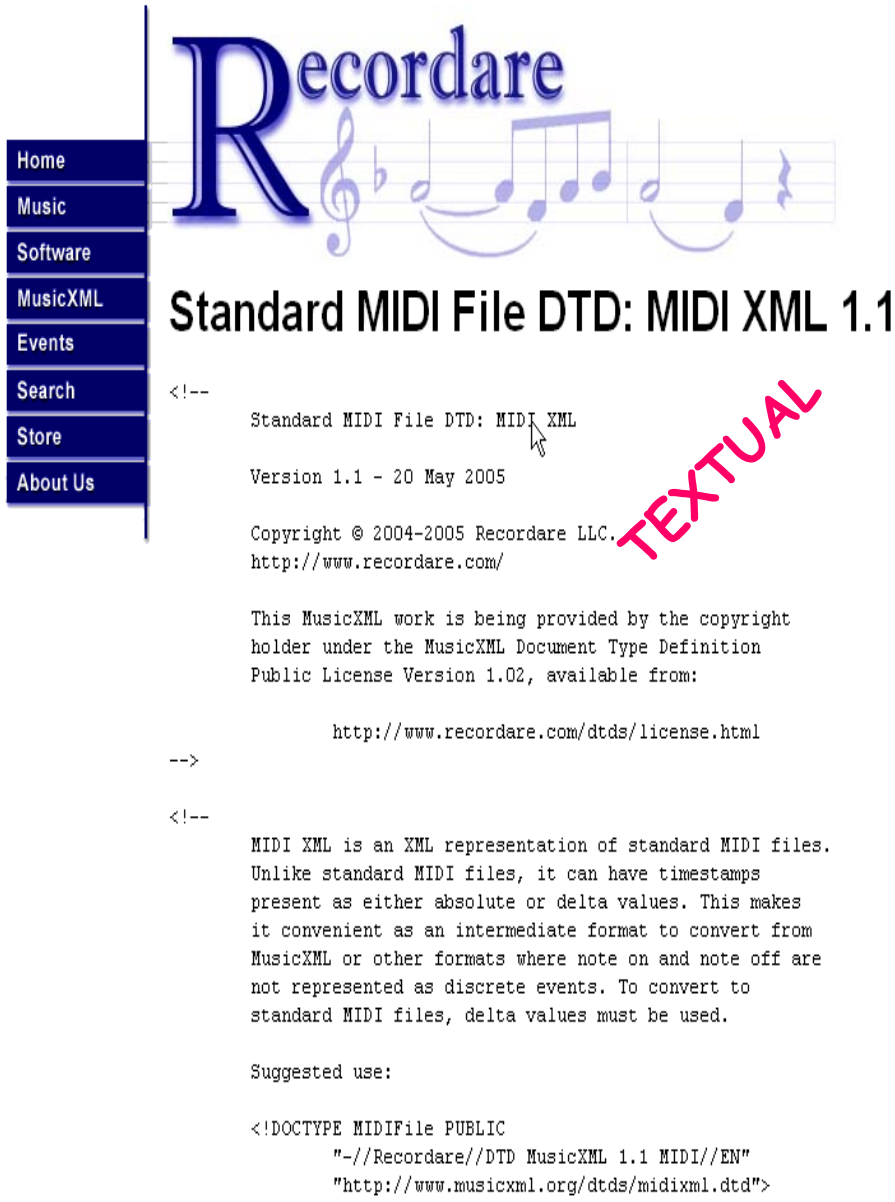
Model

Music sheet



musicXML: several concrete syntaxes for a DSL



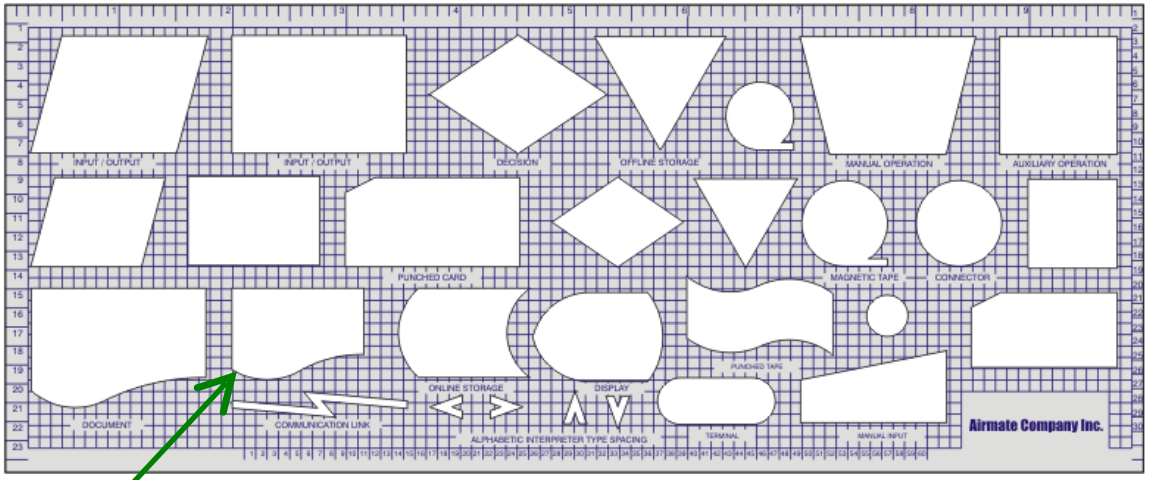


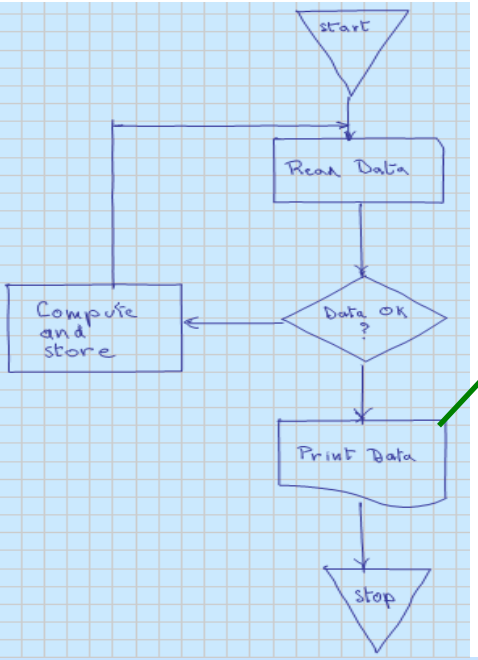
Flowcharting DSL in the 60's

Metamodel

c2

Model





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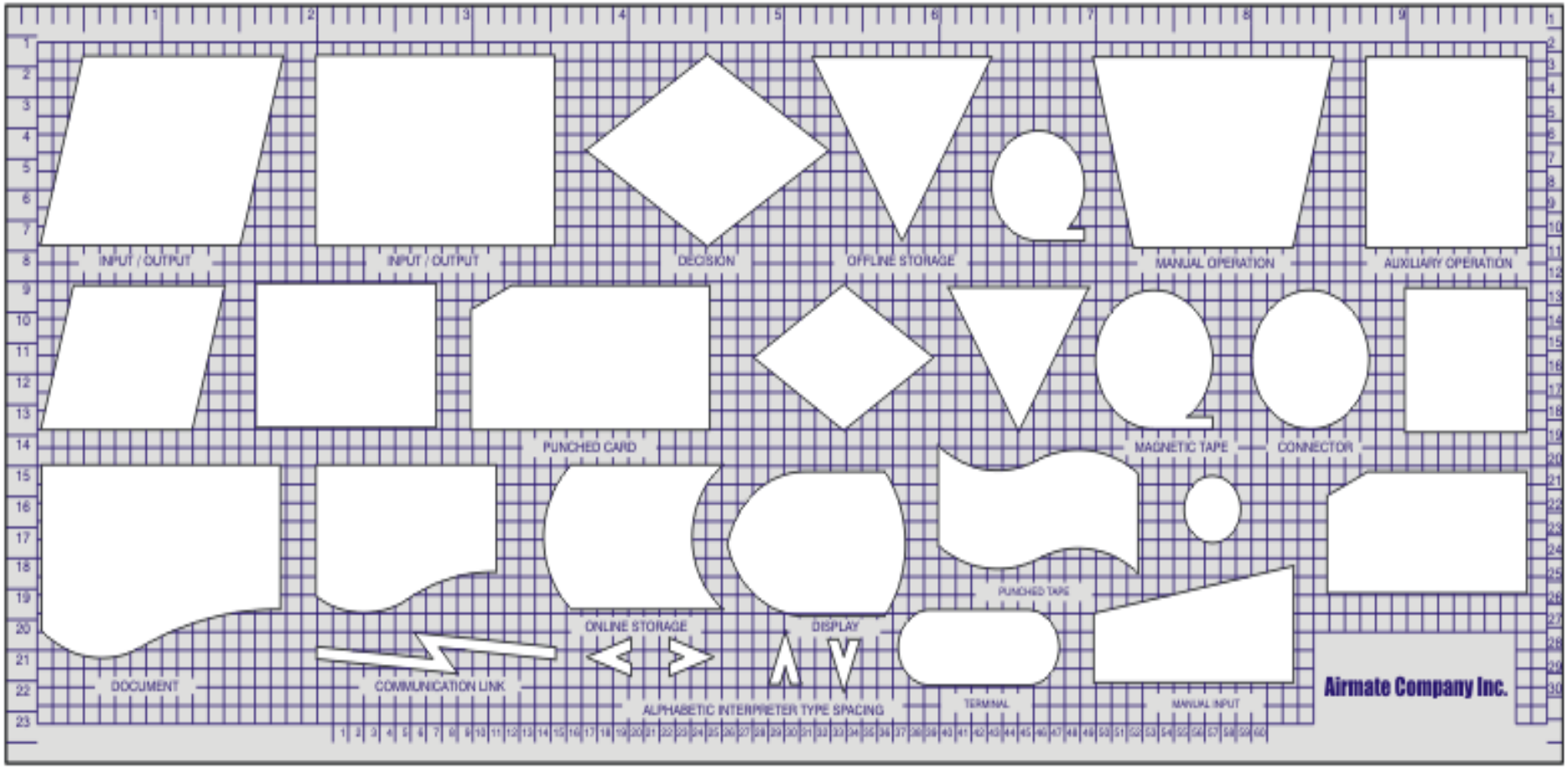
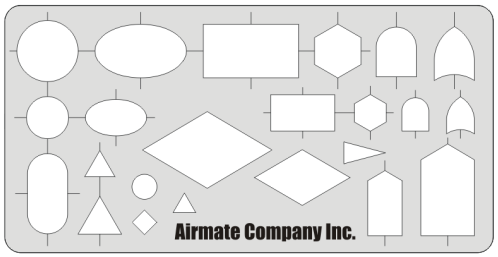
A metamodel is an explicit specification of a shared conceptualization

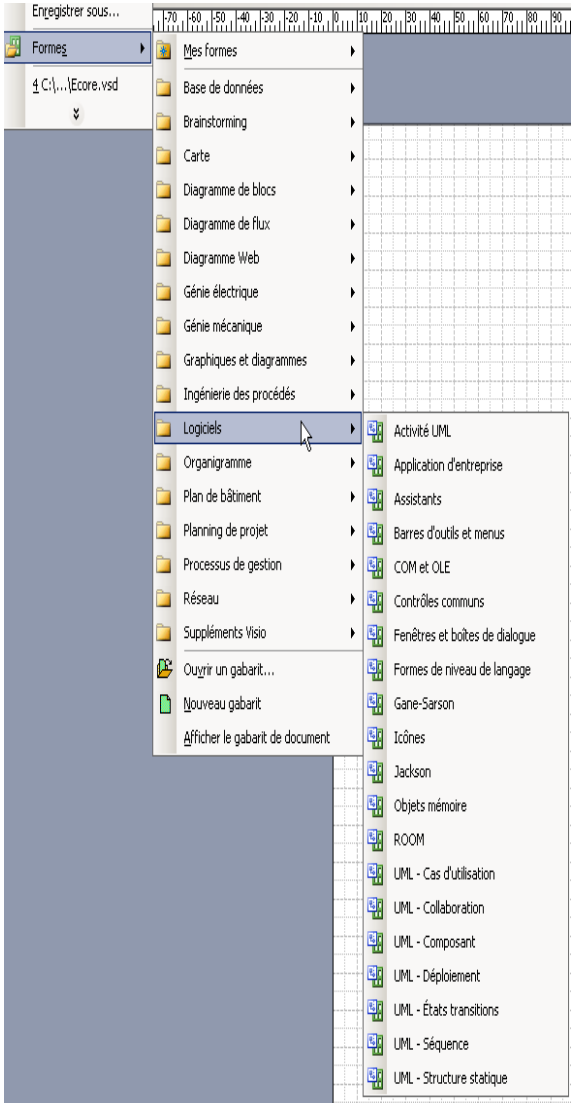
A set of concepts and relations between these concepts



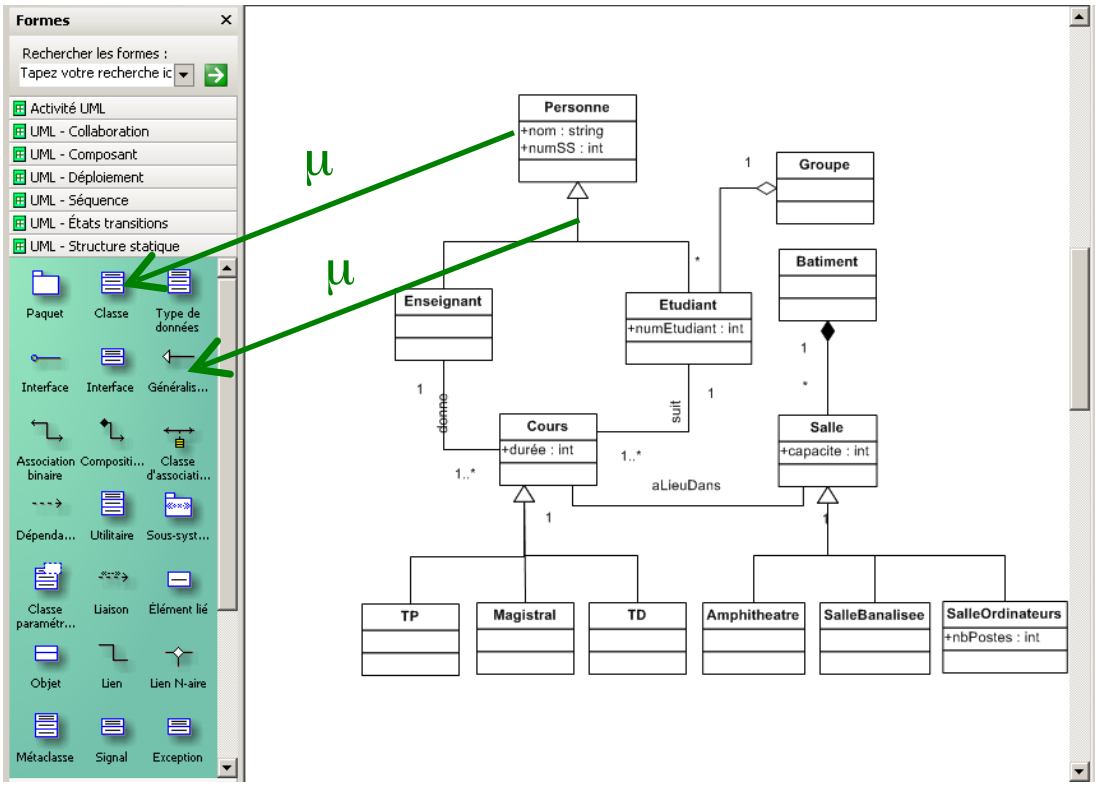


Many templates for several corporations and usages

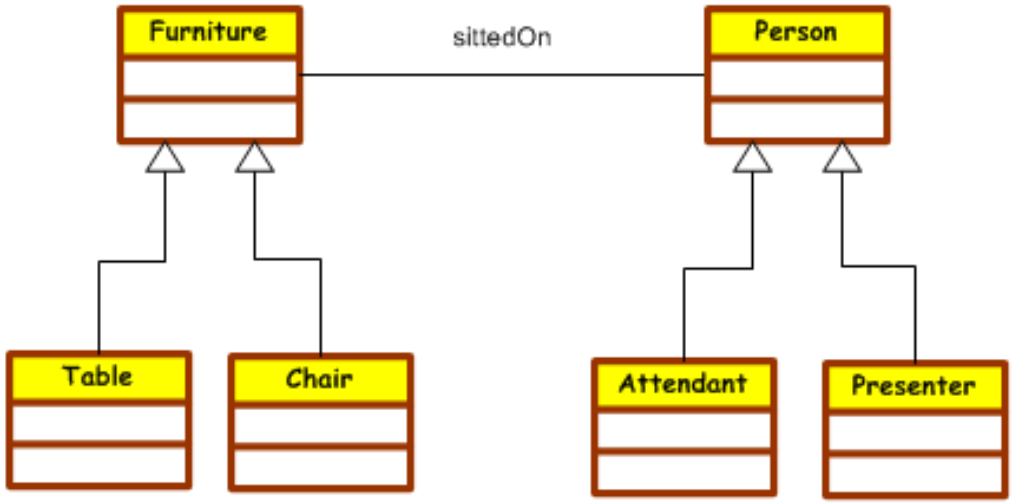
Assisted Drawing Tools (e.g. MS/Visio)



A library of stencils



Metamodels acting as filters

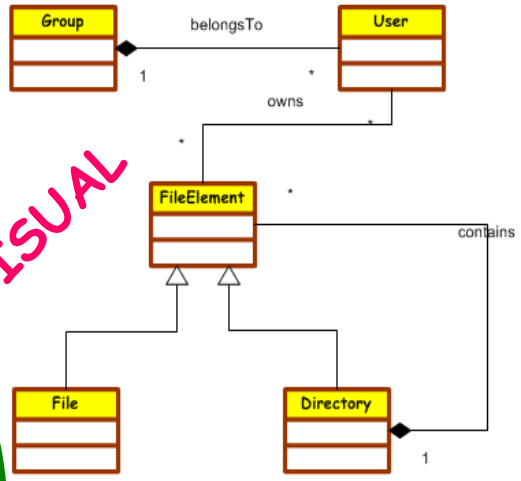


The metamodel

Mary
Table 237
Chair 34
Paul
Victor
Emily

A model

```
class(Group);
class(User);
class(FileElement);
class (File);
class (Directory);
association(belongsTo,User*,Group)
association(owns,User,FileElement*)
association(contains,Directory,FileElement*)
inherits(File,FileElement);
inherits(Directory,FileElement);
```

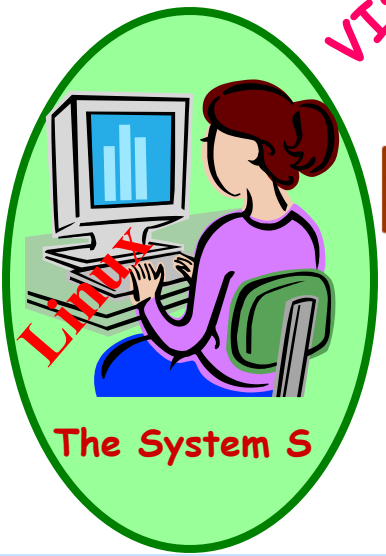


VISUAL

```
meta(Student,Group);
meta(Teacher,Group);
meta(Bob,User);
meta(Jim,User);
meta(Esther,User);
meta(Mary,User);
meta(F1,File);
meta(F2,File);
meta(F3,File);
meta(F4,File);
meta(F5,File);
meta(D1,Directory);
meta(D2,Directory);
meta(D3,Directory);
```

```
belongsTo(Esther,Teacher);
belongsTo(Mary,Teacher);
belongsTo(Jim,Student);
belongsTo(Bob,Student);
owns(Esther,D1);
owns(Esther,F1);
contains(D1,F1);
owns(Mary,D2);
owns(Mary,F2);
contains(D2,F2);
owns(Bob,D3);
owns(Bob,F3);
contains(D3,F3);
contains(D2,D3);
owns(Jim,F4);
owns(Jim,F5);
contains(D1,F4);
contains(D2,F5);
```

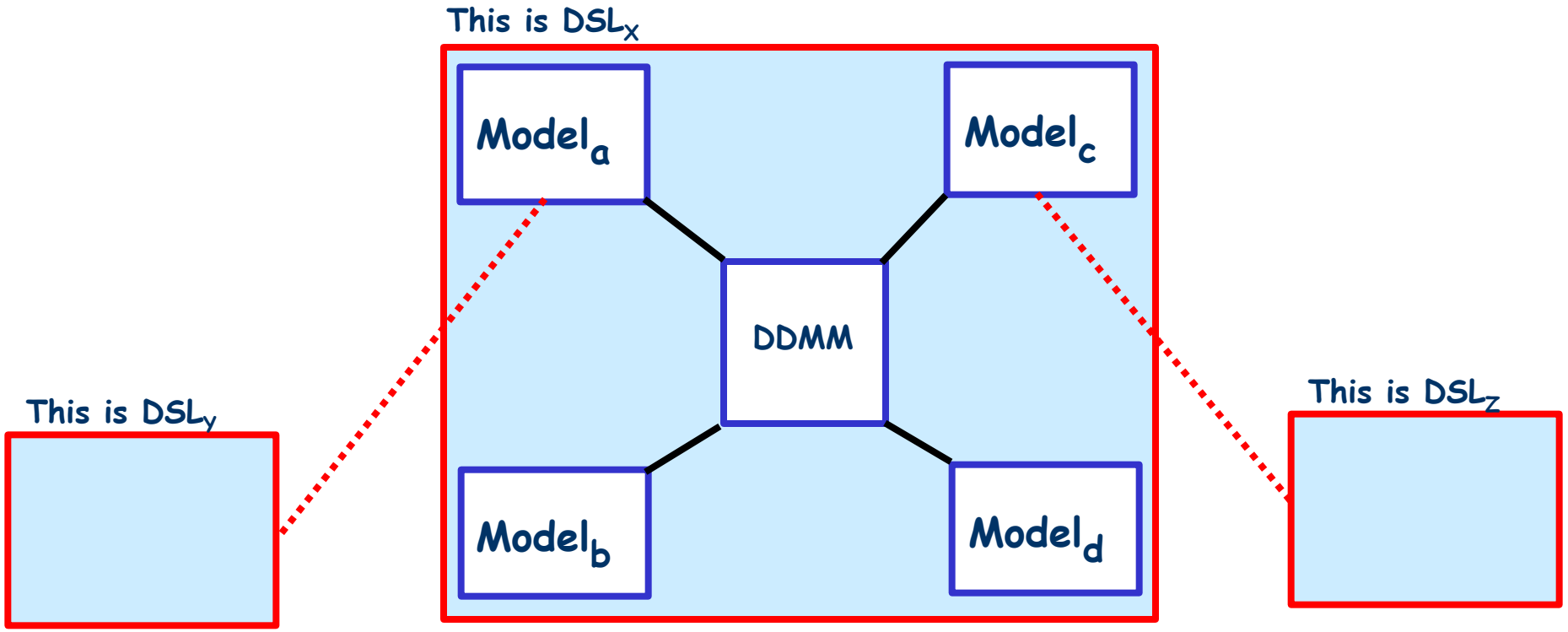
TEXTUAL



The Meta-model

A Model M

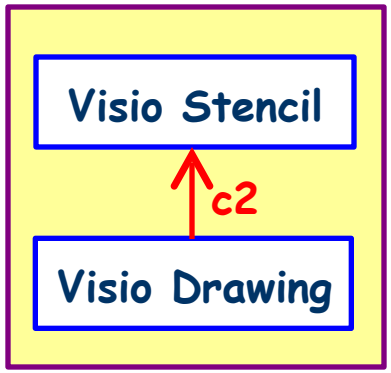
Metamodels define Domain Specific Languages (DSLs)

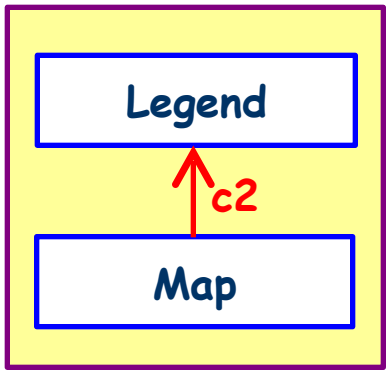


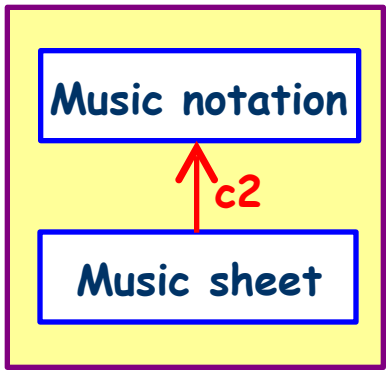
Definition: A DSL is a coordinated set of models

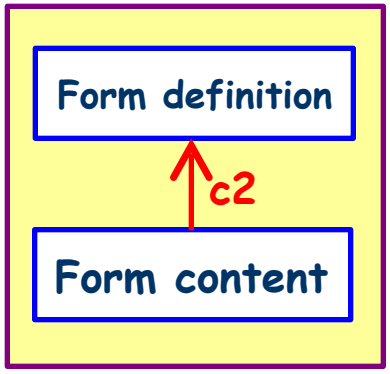
DDMM = Domain Definition MetaModel

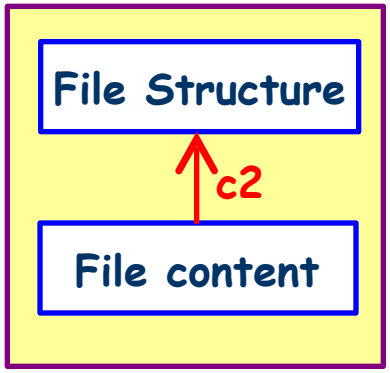
Typical Situations (only some)

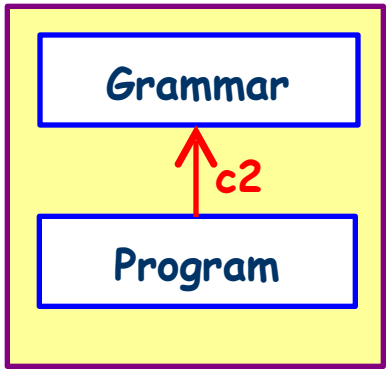


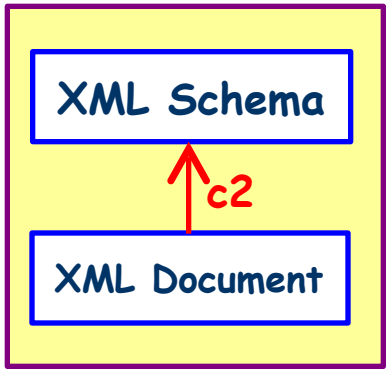


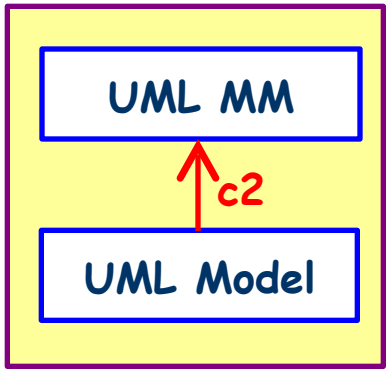


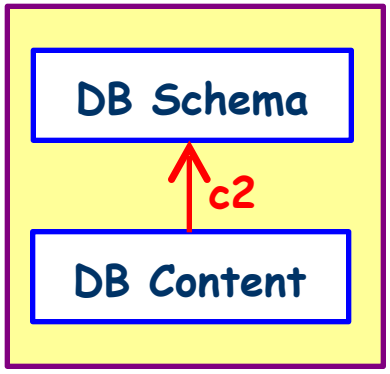




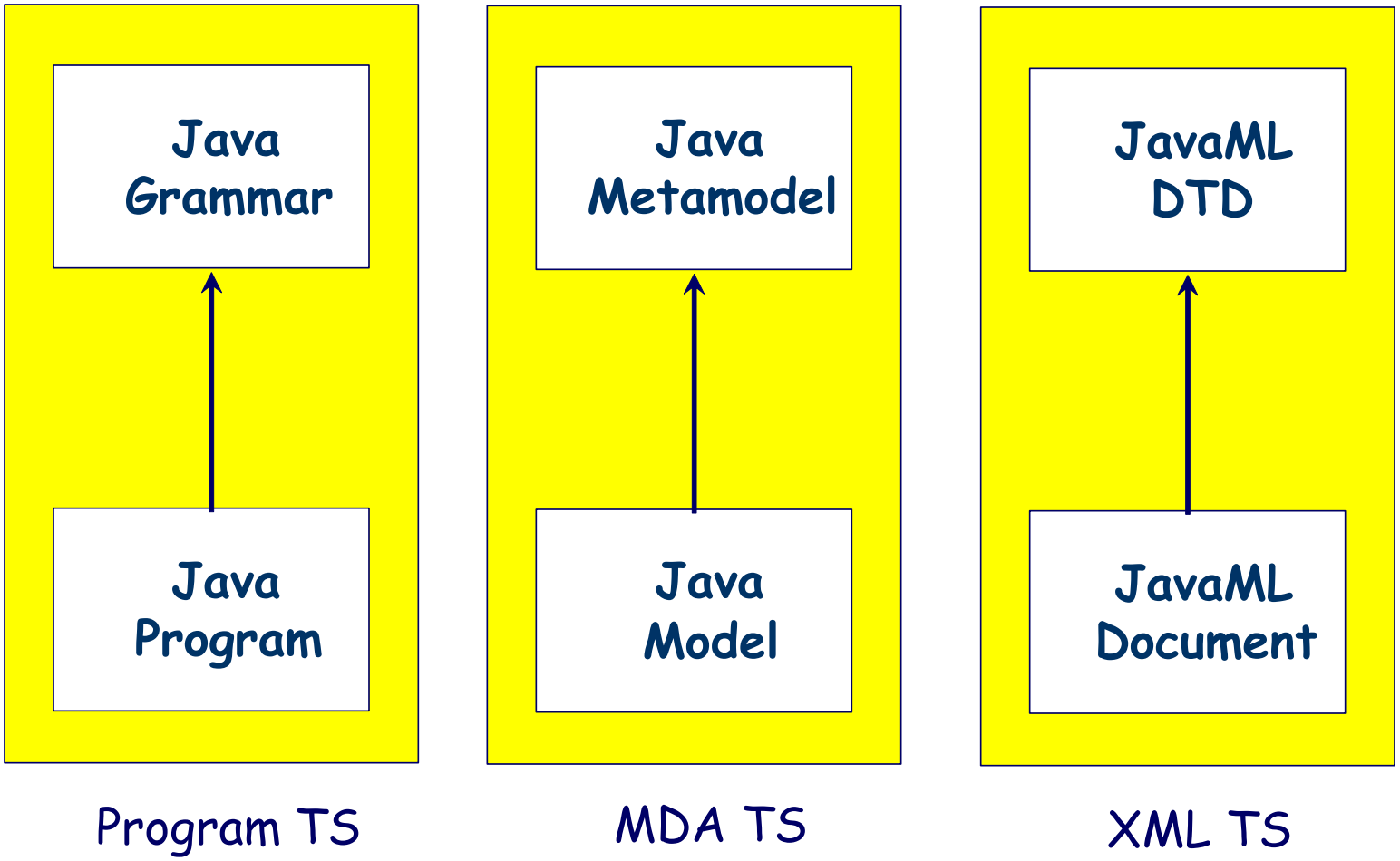








Different technical spaces for modeling



Three representations for the same program

```
1  import java.applet.*;
2  import java.awt.*;
3
4  public class FirstApplet extends Applet {
5    public void paint(Graphics g) {
6      g.drawString("FirstApplet", 25, 50);
7    }
8  }
```

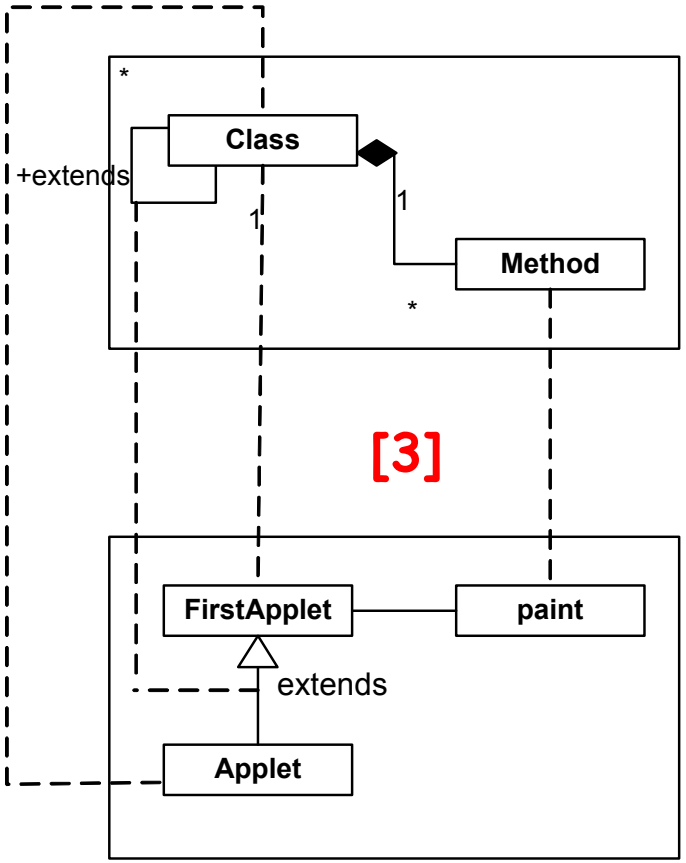
[1]

Java source code

```
1 <?xml version="1.0" encoding="UTF-8"?>
2 <!DOCTYPE java-source-program SYSTEM "java-ml.dtd">
4 <java-source-program name="FirstApplet.java">
5   <import module="java.applet.*"/>
6   <import module="java.awt.*"/>
7   <class name="FirstApplet" visibility="public">
8         <superclass class="Applet"/>
9         <method name="paint" visibility="public" id="meth-15">
10                  <type name="void" primitive="true"/>
11                  <formal-arguments>
12                        <formal-argument name="g" id="frmarg-13">
13                        <type name="Graphics"/></formal-argument>
14                  </formal-arguments> …….
```

[2]

JavaML document



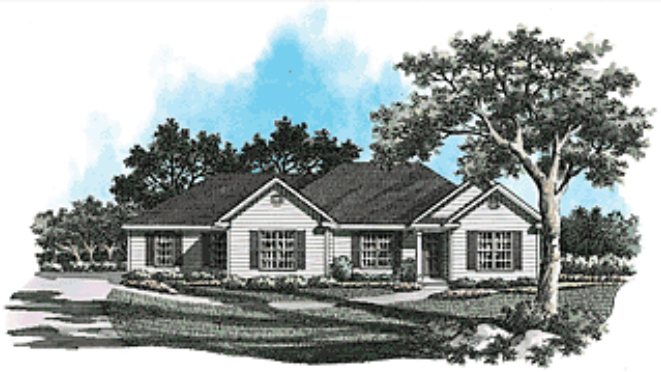
Each of these representations may be more convenient to perform some operation on the program.

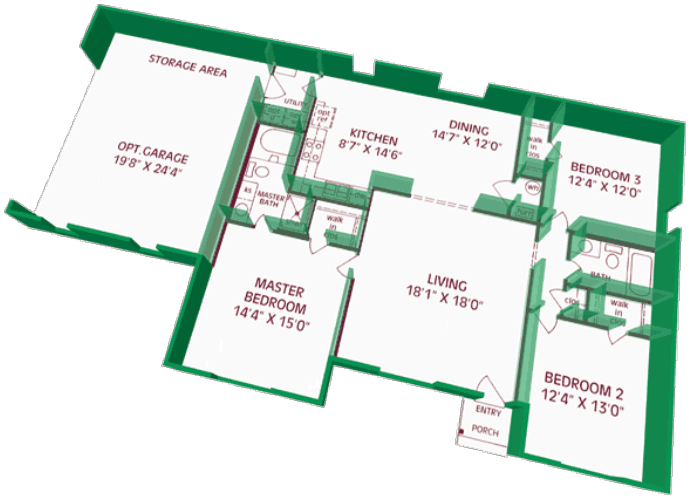
Production of a system from a model

S

M

Production of a system
from a model.
For example construction a building
from its floor plans.





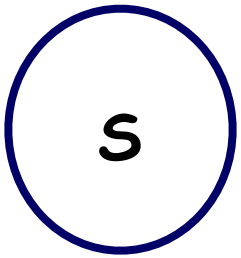
S

repOf

M

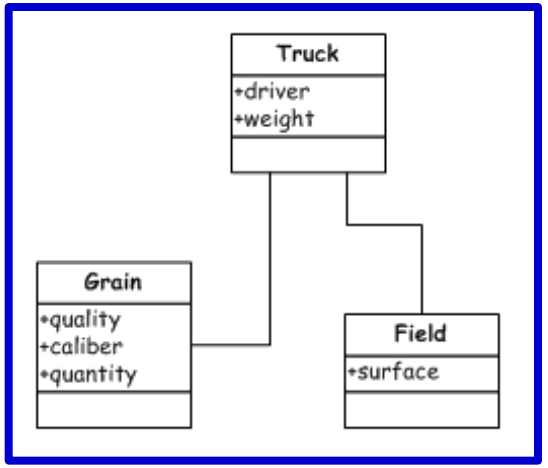
{postcondition}

Production of a model from a system



Production of a model from a system.
For example production of the business model of a bank in the UML language.

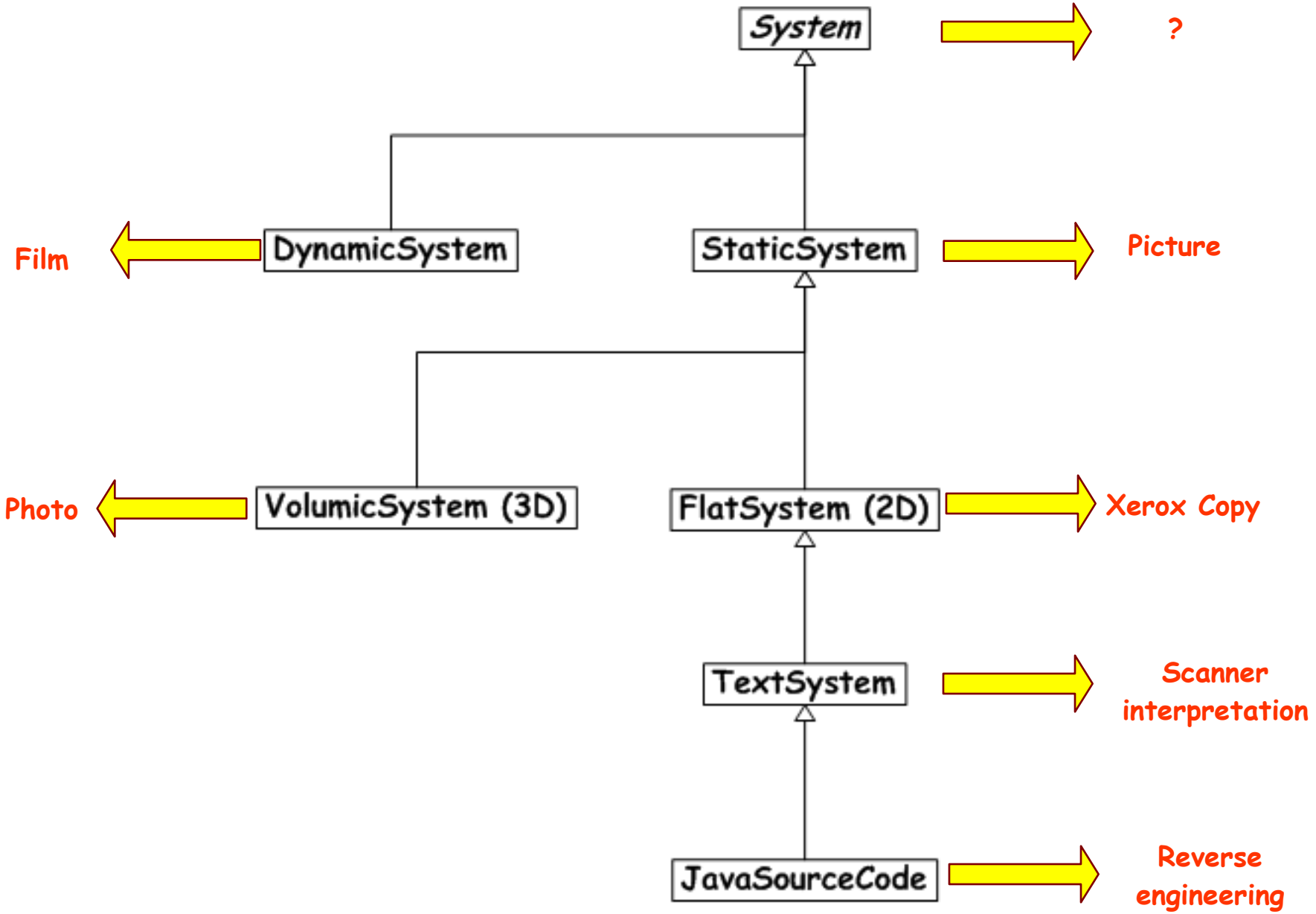
a system S
e.g. agricultural enterprise



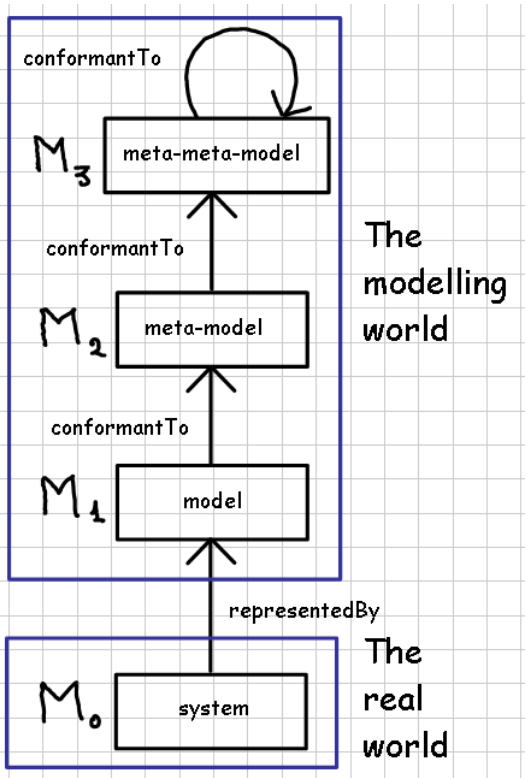
a business model M
of the agricultural enterprise

{postcondition}

Model extraction techniques depend on the nature of the system



A generic DSL to specify metamodels



metametamodel MMM

c2

metamodel MM

c2

terminal model M

repOf

representation of

system S

What is a model?

- A model is a representation of a system
- A model is written in the language of its unique metamodel
- A metamodel is written in the language of its unique metametamodel
  - The unique MMM of the MDA is the MOF
- A model is a constrained directed labeled graph
- A model may have a visual graphical representation (sometimes)

Conclusion of the first part

- Building models as a help to understanding or to building systems is an old activity, still very useful.
- Models are constrained by the language in which they are written; Metamodels are the central tool to define these languages.
- Advanced modeling frameworks also provide specific languages to write metamodels (like MOF) and specific languages to write transformations between models.

Presentation Schedule

- Part 1 : Ubiquitous Models
  - What is a model?
  - What is a metamodel?
  - What is a metametamodel?
  - What is the purpose of a model?
- Part 2 : MDA™ vs. MDE
  - Glossary of acronyms
  - The three-level OMG stack
  - Automating model management

Agenda

Acronyms & Definitions

Working Definitions:

- Model
- Metamodel
- Metametamodel
- DSL
- TS

Double definition for a model

Acronyms

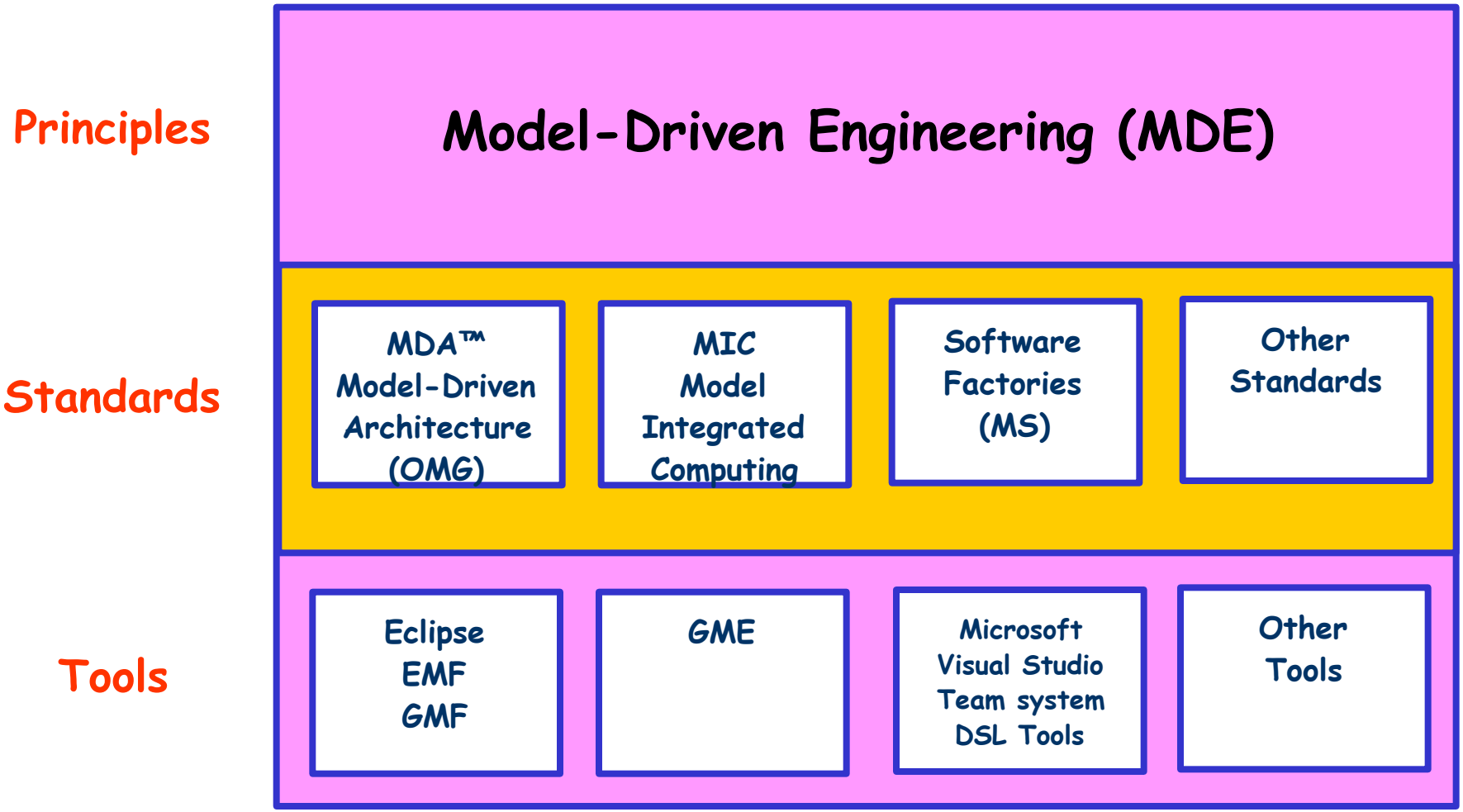
- MDE Model Driven Engineering
- ME Model Engineering
- MDA Model Driven Architecture
- MDD Model Driven Development
- MDSD Model Driven Software Development
- MDSE Model Driven Software Engineering
- MM Model Management
- MDDE Model Driven Data Engineering
- ADM Architecture Driven Modernization
- MDRE Model Driven Reverse Engineering
- DSL Domain Specific Language
- DSM Domain Specific Modeling

- MDE is a generic term; ME ~ MDE
- MDA™ and MDD™ are OMG trademarks; MDD is a protection trademark (no use as of today/just reserved by OMG for future use)
- MDSD like MDSE is sometimes used instead of MDD when one does not wish to be associated to OMG-only technology, vocabulary and vision.
- ADM is another standard intended to be the reverse of MDA: MDA covering forward engineering while ADM covers backward engineering. ADM ~ MDRE
- MM ~ MDDE
- DSM is more Microsoft marked but of increasing use by the academic and research community

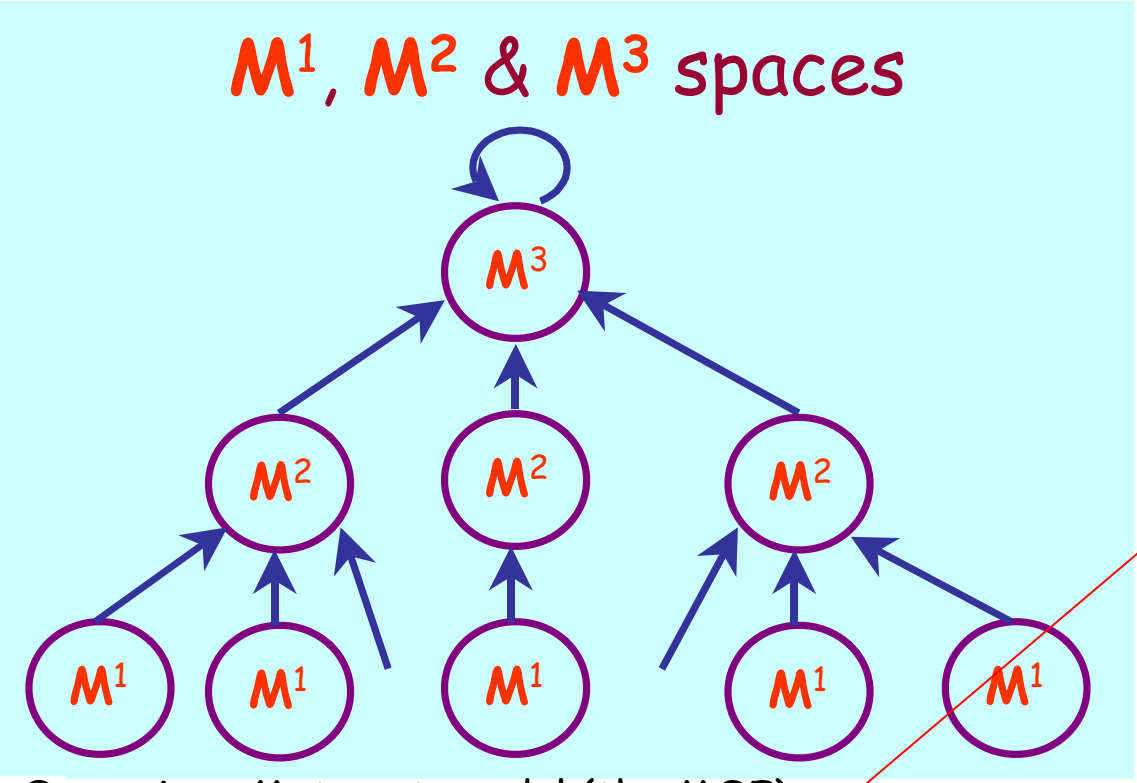
Some OMG Trademarks (http://www.omg.org/legal/tm_list.htm)

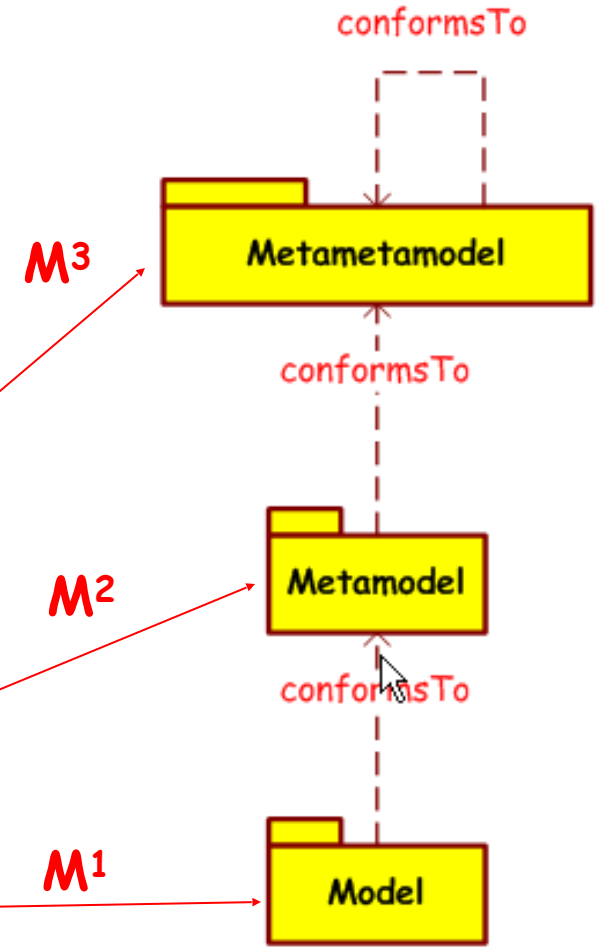
- OMG's Registered Trademarks Include:
  - MDA®
  - Model Driven Architecture®
  - UML®
  - CORBA®
  - CORBA Academy®
  - XMI®
- OMG's Trademarks Include:
  - CWM™
  - Model Based Application Development™
  - MDD™
  - Model Based Development™
    Model Based Management™
  - Model Based Programming™
  - Model Driven Application Development™
  - Model Driven Development™
  - Model Driven Programming™
  - Model Driven Systems™
  - OMG Interface Definition Language (IDL)™
  - Unified Modeling Language™
  - <<UML>>™

Principles, standards and tools



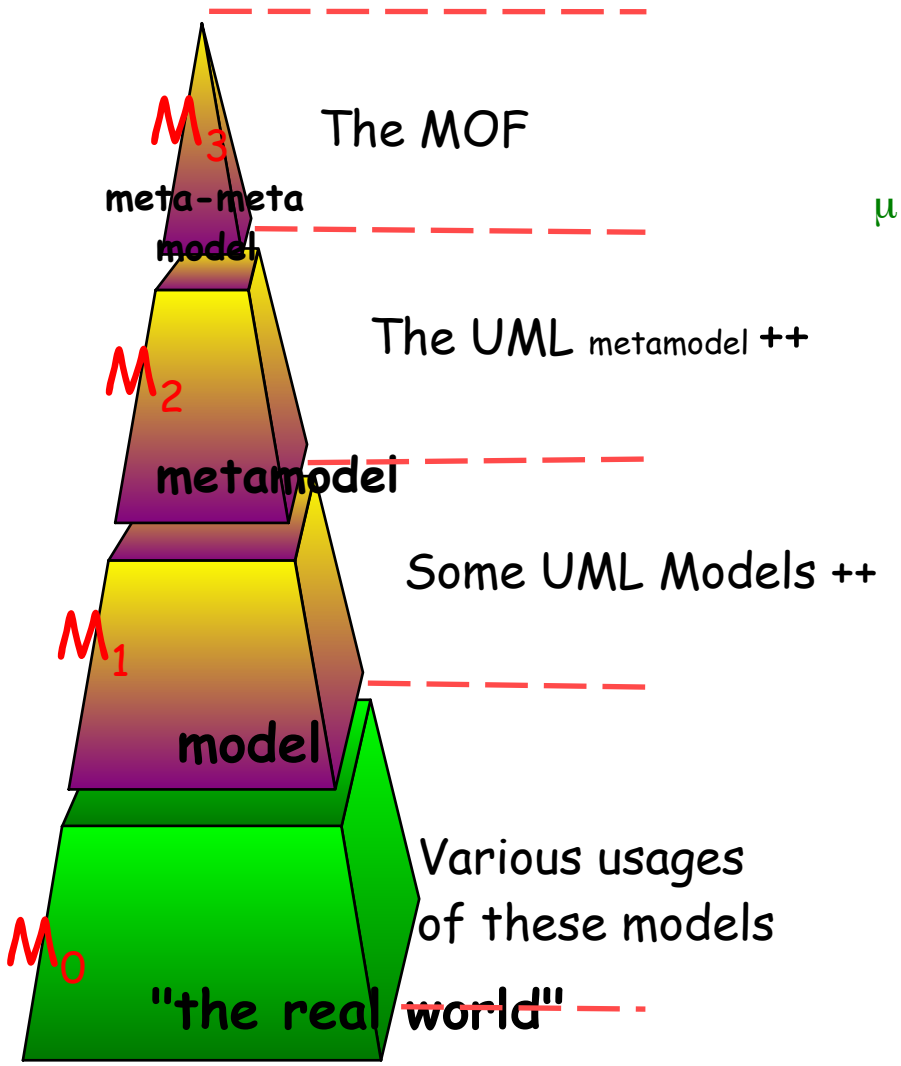
MDA in a nutshell

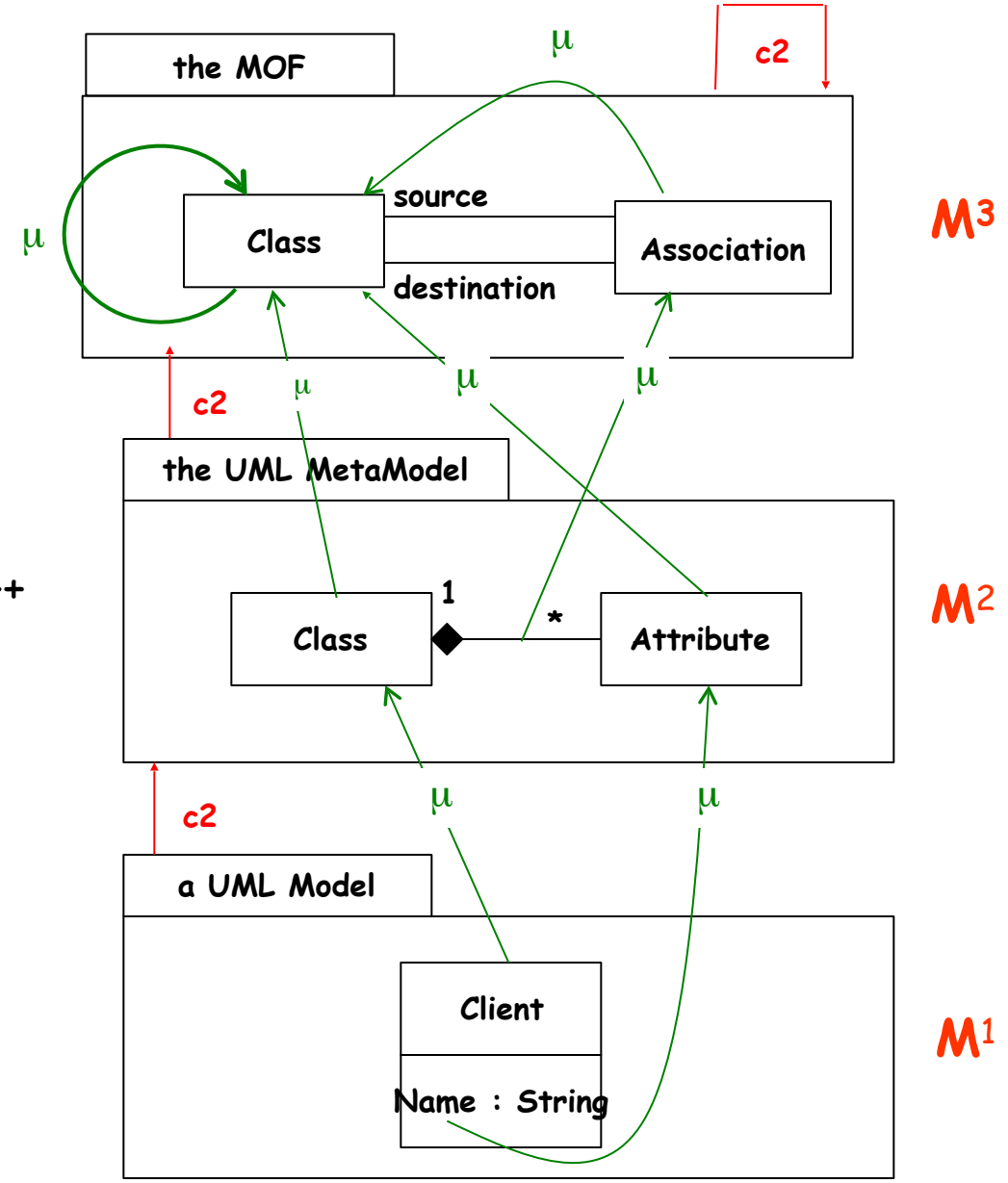




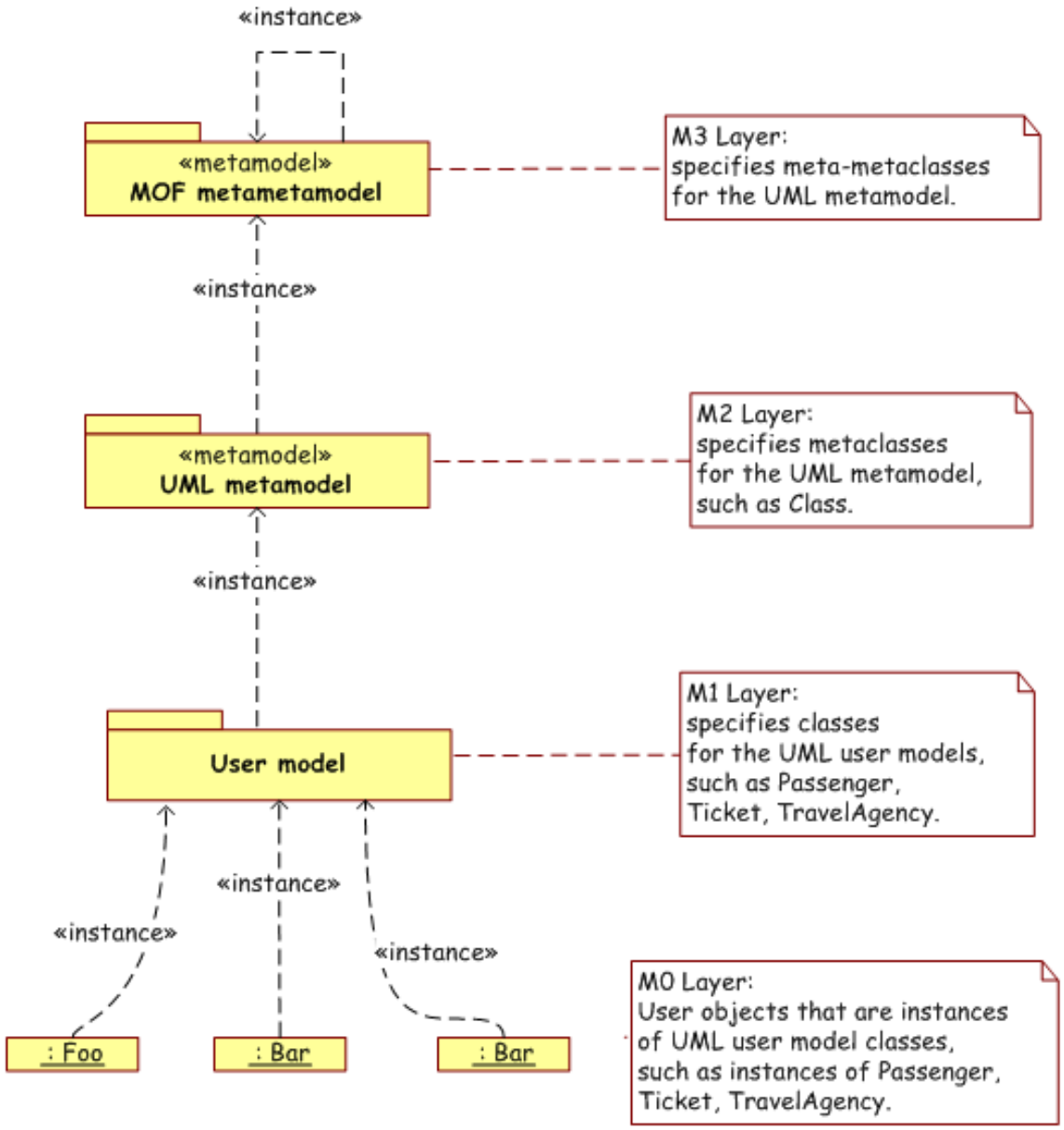
- One unique Metametamodel (the MOF)
- An important library of compatible Metamodels, each defining a DSL
- Each of the models is defined in the language of its unique metamodel

The OMG/MDA Stack





One OMG "official" interpretation



UML centric

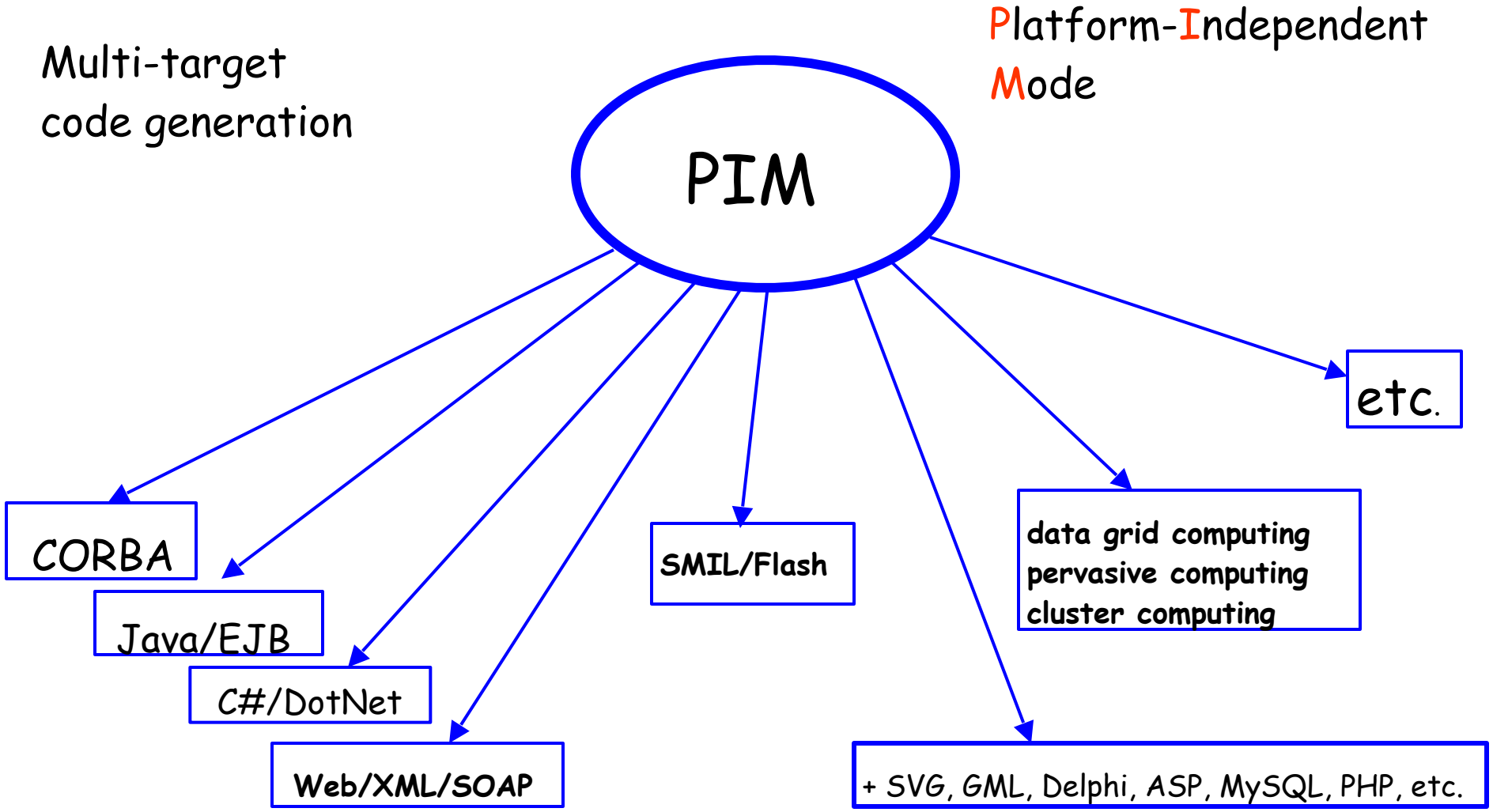
Separating the platform dependent and independent parts of systems

We don't want anymore to pay such a high price for simply moving our information system to a new middleware platform (COM, CORBA, Java, HTML, XML, DotNet, etc.) when our business system stays stable.
We are prepared to pay a last price for building the abstract models of our business and services that will guarantee us against technological obsolescence.
From there, any platform provider will also have to provide the mapping solutions from standard business models before we buy.

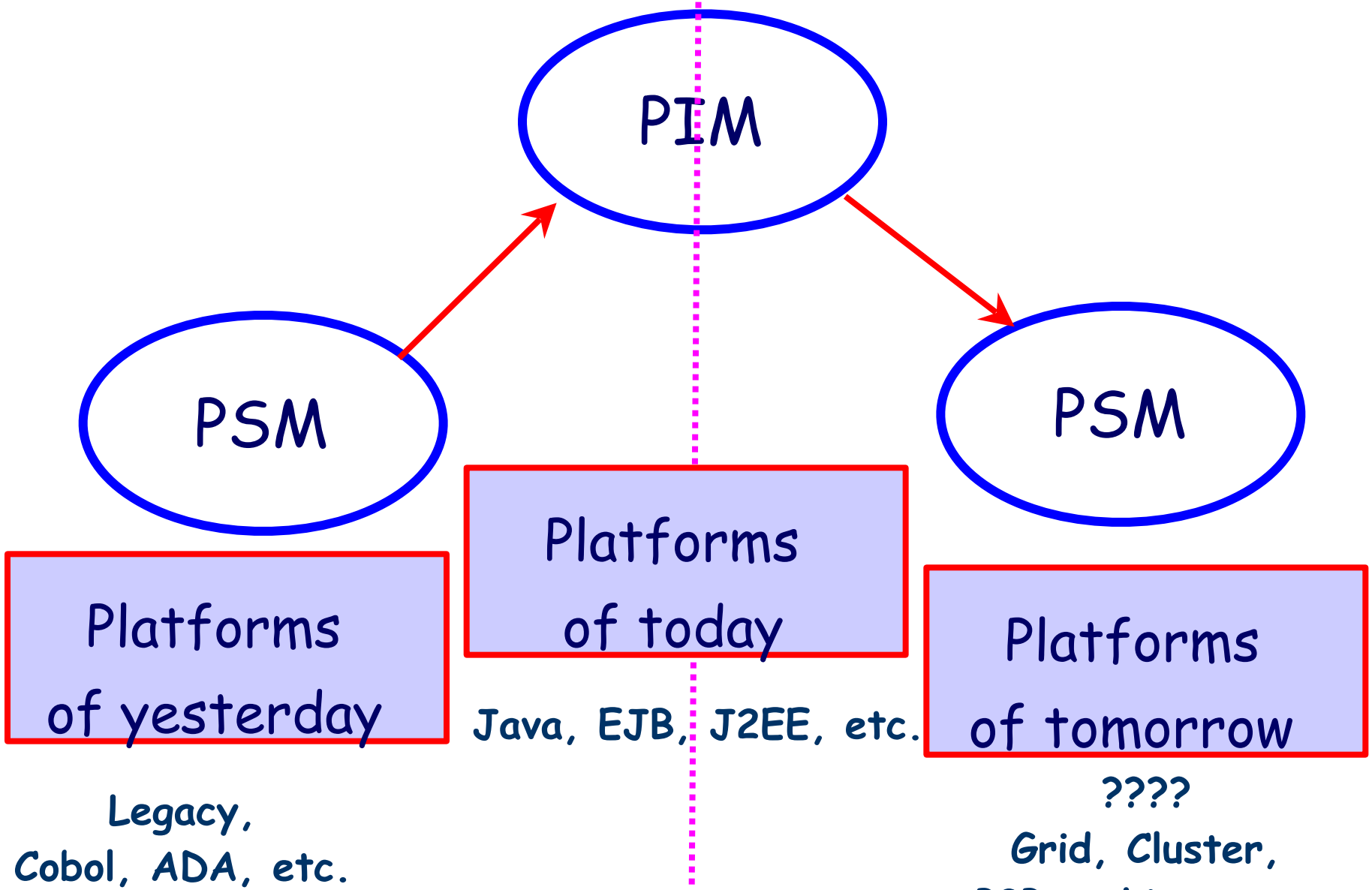
The origins of MDA

~~Write Once, Run Anywhere~~

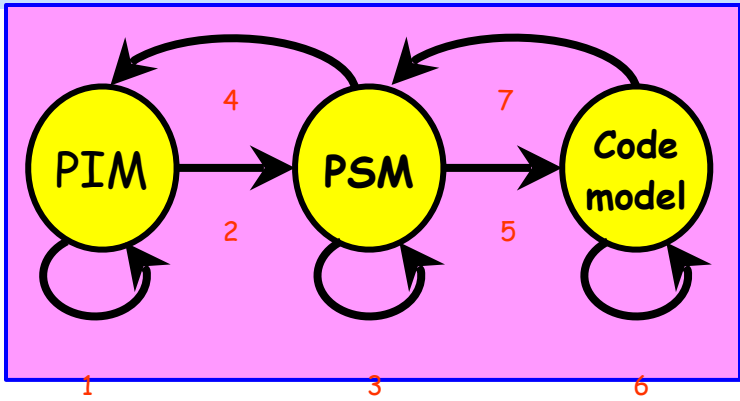
Model Once, Generate Anywhere

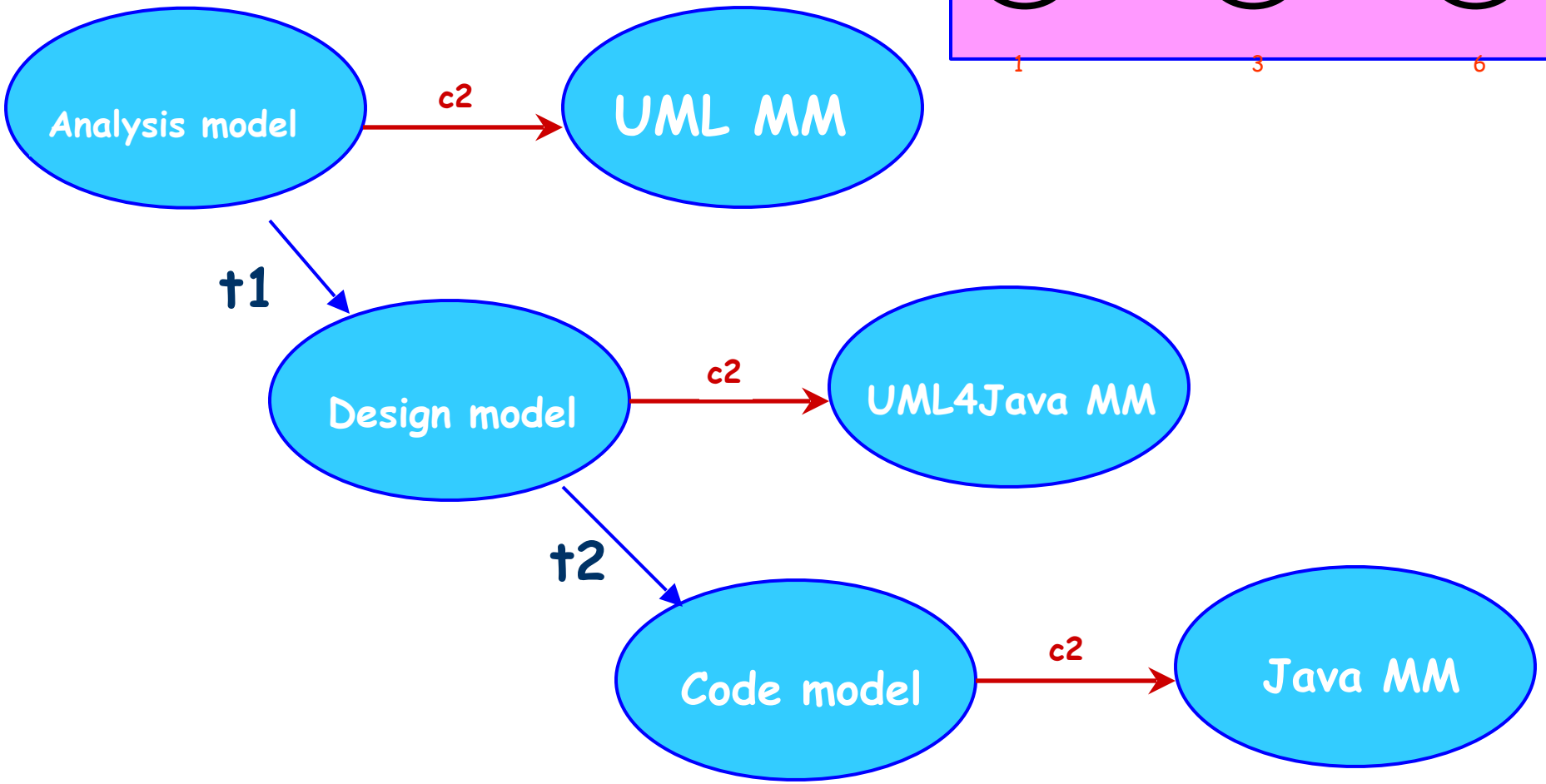


Forward and reverse engineering

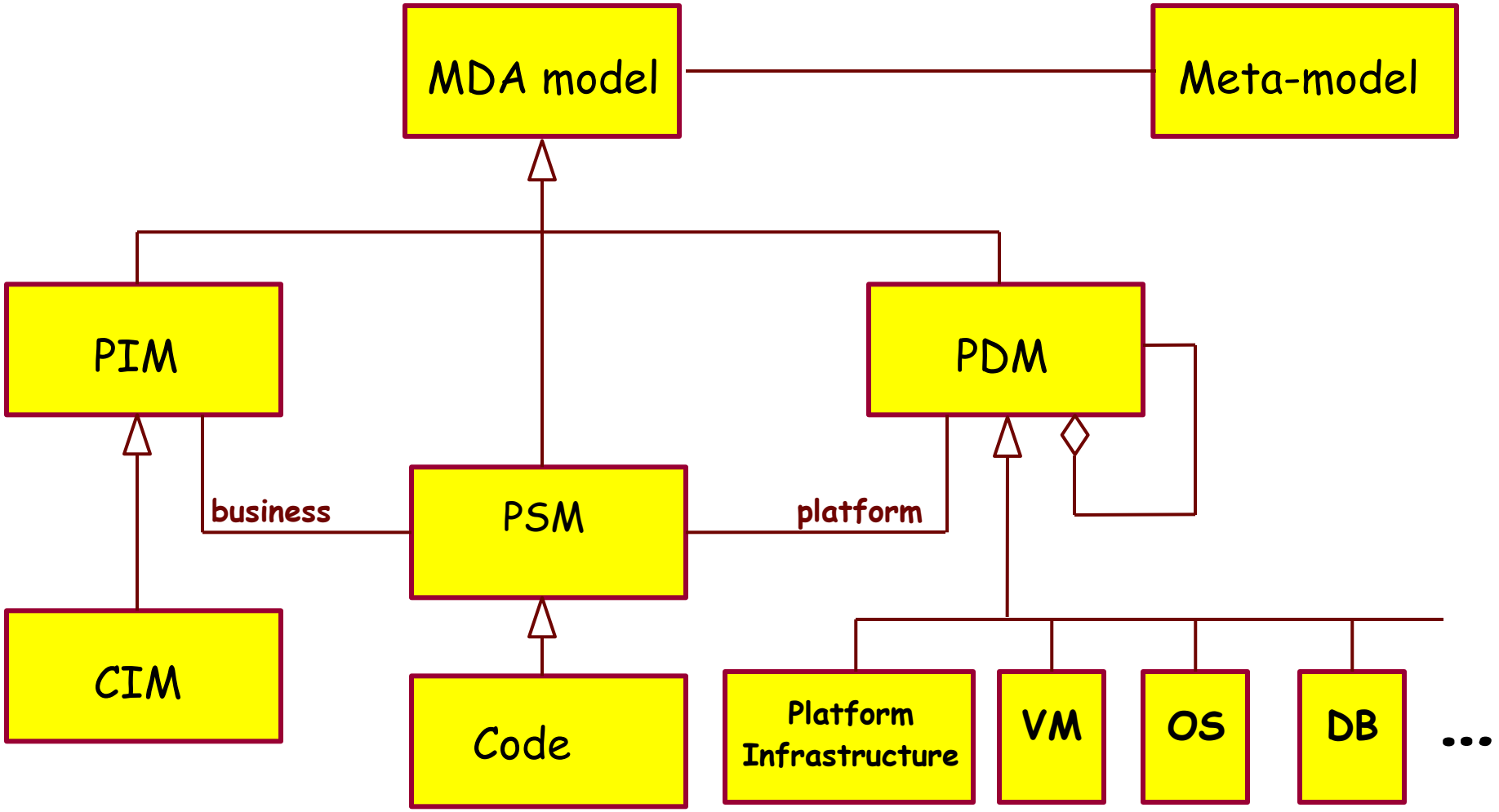


General MDA organization

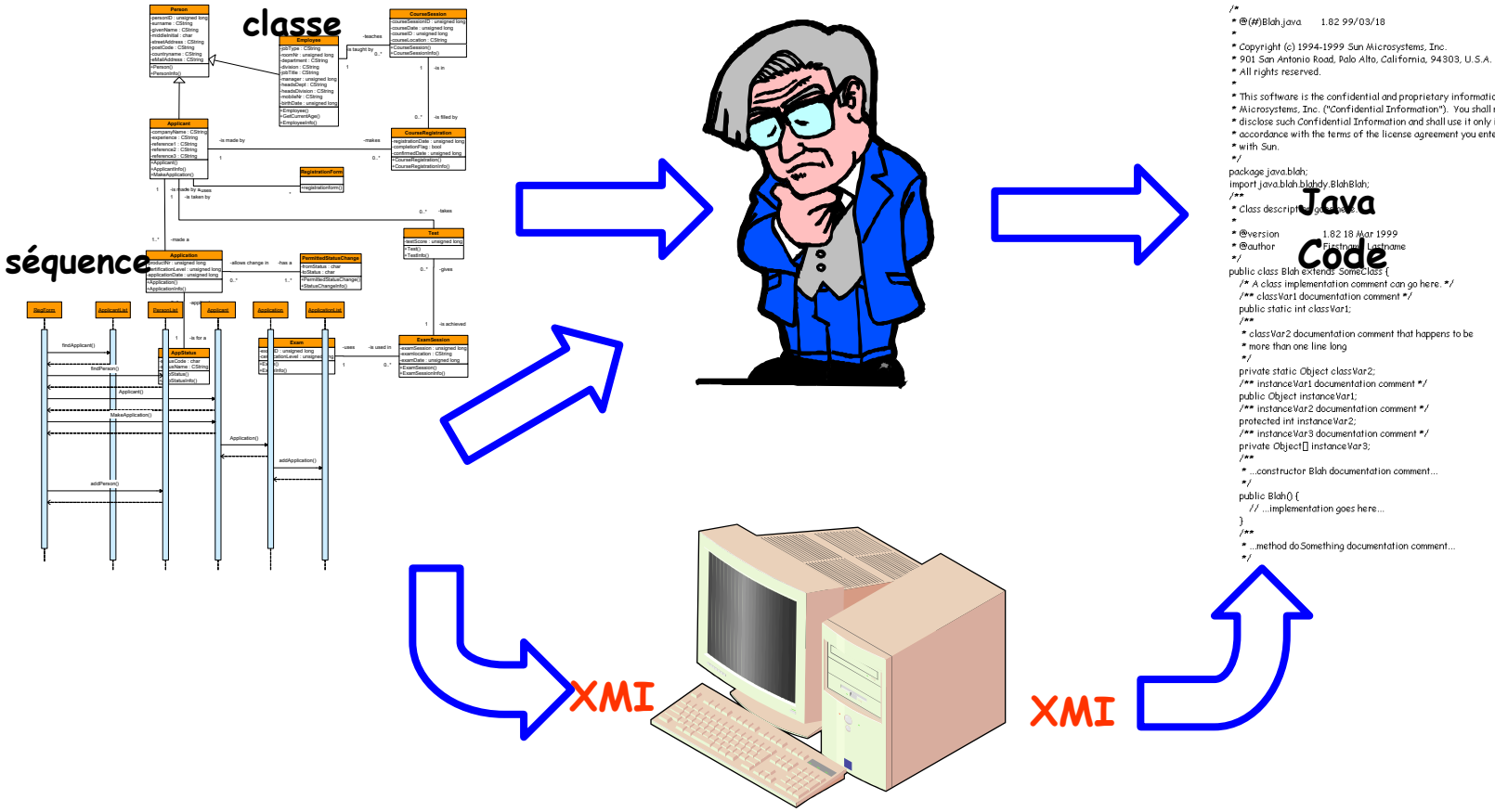




A sample classification of models

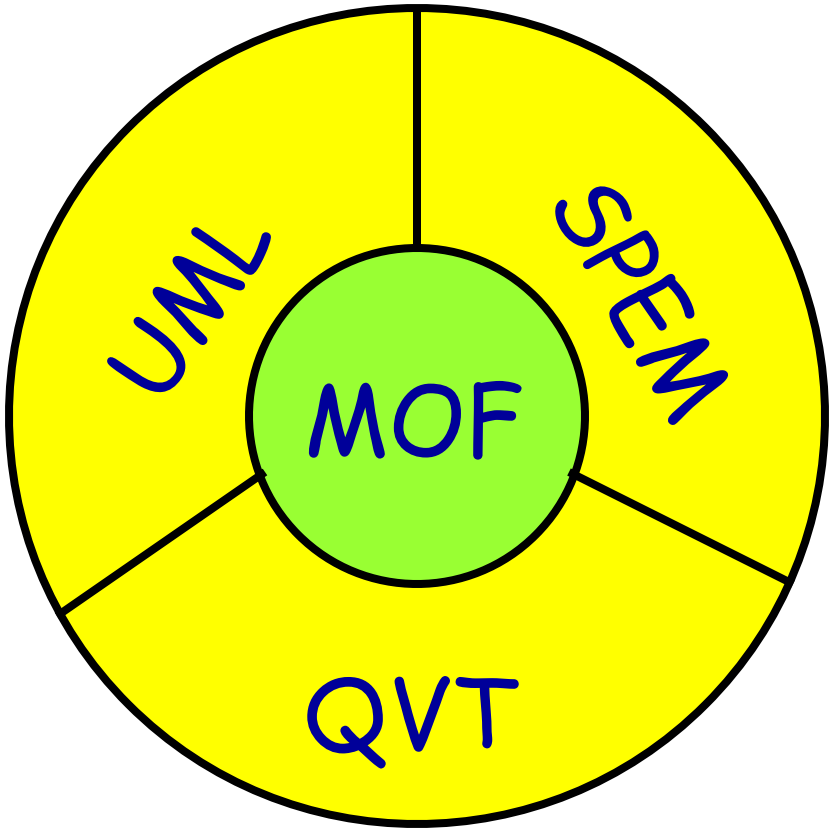


From contemplative to productive approaches



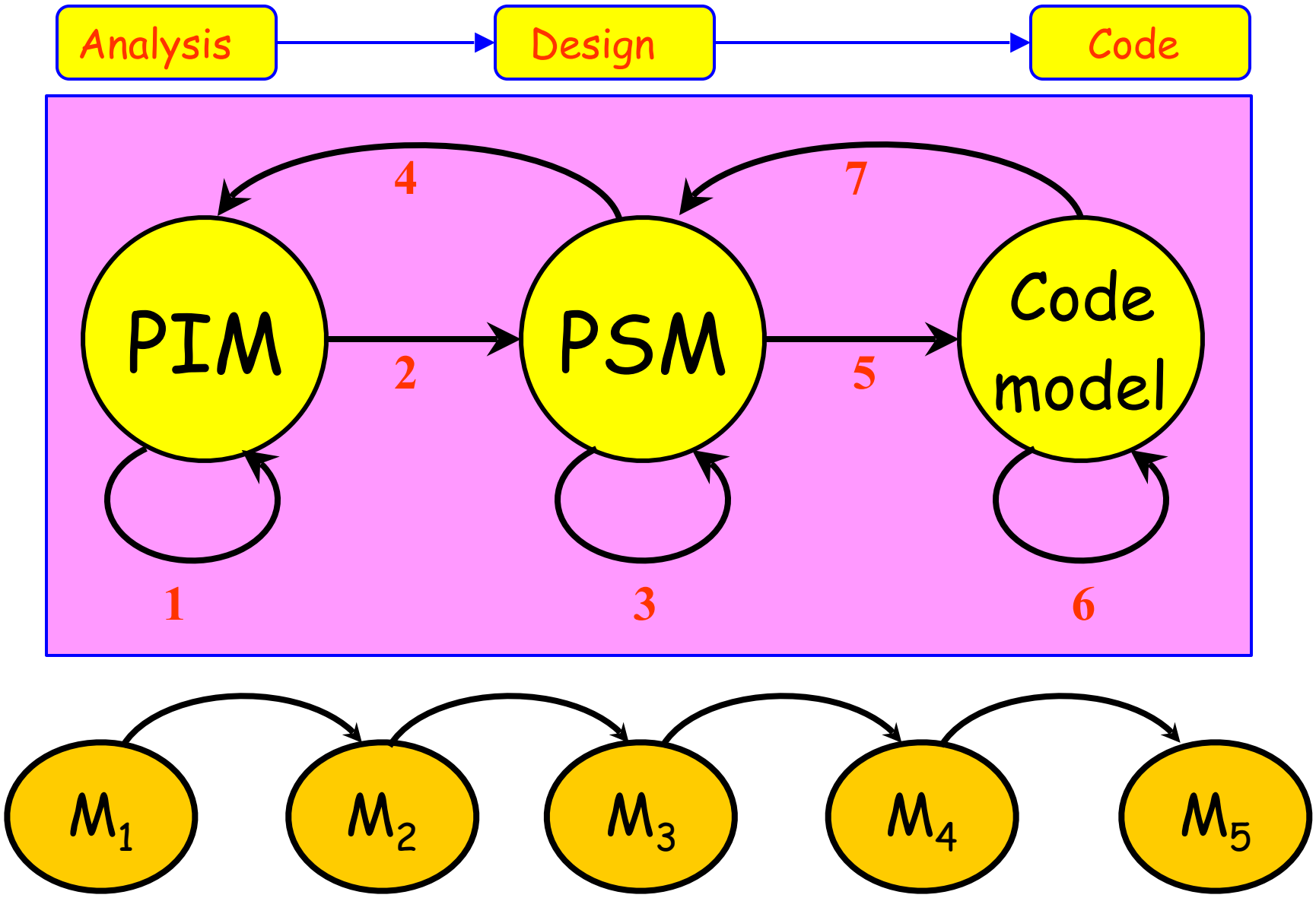
From human-readable to computer-understandable.
From hand-crafting (e.g. Design Patterns)
to full automation (e.g. Model transformation)

Some MDA Standards



UML MM : description of OO software artifacts
SPEM MM: how to use and produce them
QVT MM: how to generate models from other models

Software development considered as a chain of model transformations



Some loose definitions of what is a model

- Phil Bernstein, "A Vision for Management of Complex Systems".
  A model is a complex structure that represents a design artifact such as a relational schema, an interface definition (API), an XML schema, a semantic network, a UML model or a hypermedia document.
- OMG, "UML Superstructure".
  A model captures a view of a physical system. It is an abstraction of the physical system, with a certain purpose. This purpose determines what is included in the model and what is relevant. Thus the model completely describes those aspects of the physical system that are relevant to the purpose of the model, at the appropriate level of detail.
- OMG, "MDA Guide".
  A formal specification of the function, structure and/or behavior of an application or system.
- Steve Mellor, et al., "UML Distilled"
  A model is a simplification of something so we can view, manipulate, and reason about it, and so help us understand the complexity inherent in the subject under study.
- Anneke Kleppe, et. al. "MDA Explained"
  A model is a description of (part of) a system written in a well-defined language. A well-defined language is a language with well-defined form (syntax), and meaning (semantics), which is suitable for automated interpretation by a computer.
- Chris Raistrick et al., "Model Driven Architecture with Executable UML"
  A formal representation of the function, behavior, and structure of the system we are considering, expressed in an unambiguous language.
- J. Bézivin & O. Gerbé, "Towards a Precise Definition of the OMG/MDA Framework"
  A simplification of a system built with an intended goal in mind; The model should be able to answer questions in place of the actual system.

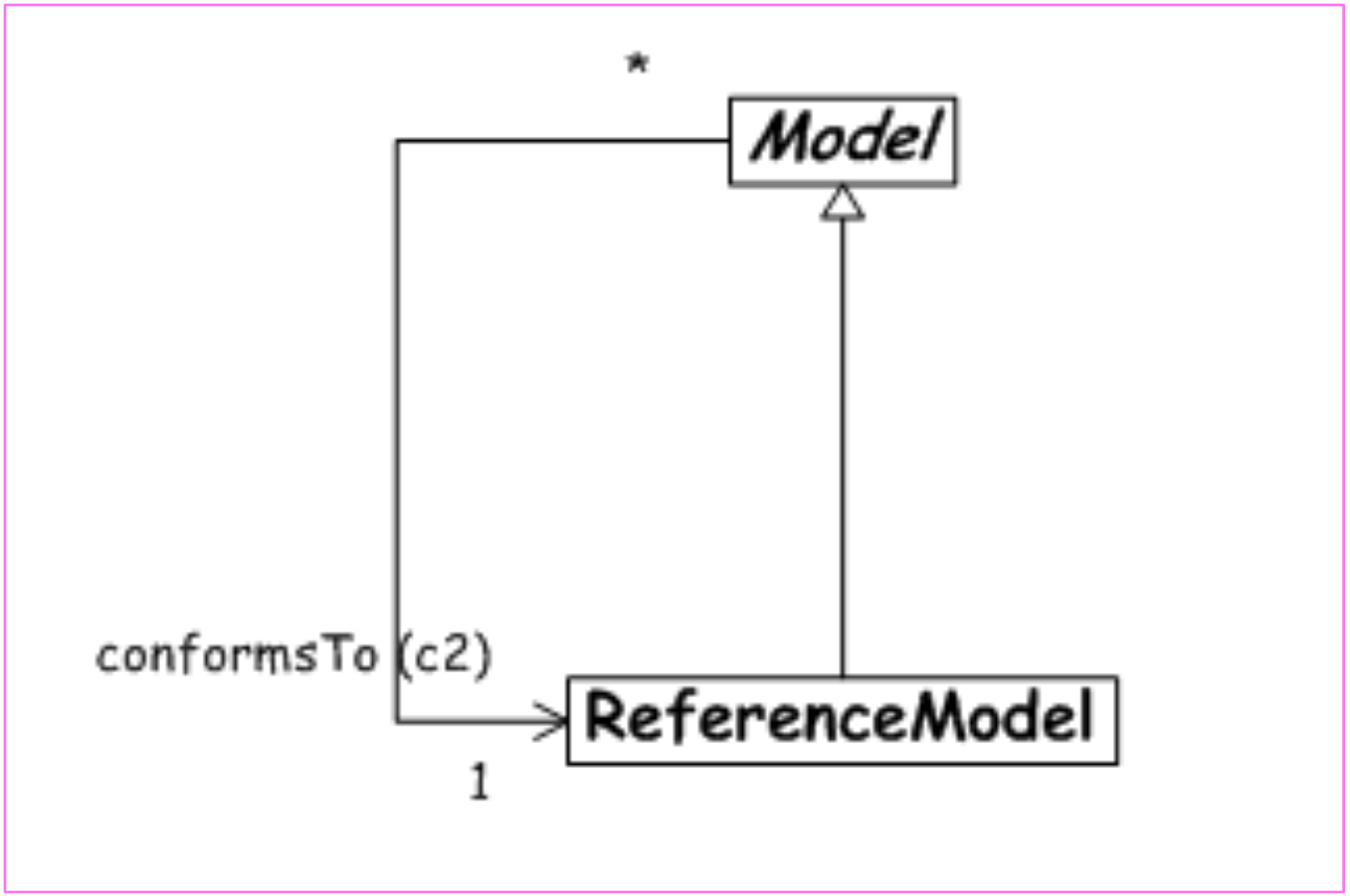
✓All of these definitions are partially correct
✓None is complete
✓None is really useful for the real engineer
✓We need a workable definition for "model"

Structural definition of a model

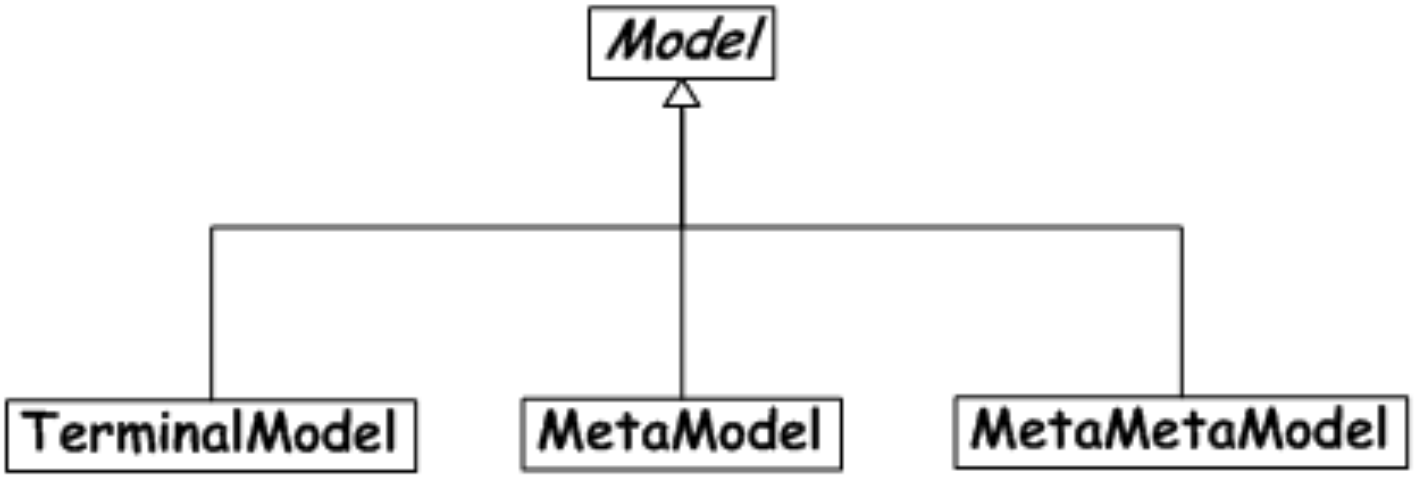
- **Definition 1**. A directed multigraph $G = (N_G, E_G, \Gamma_G)$ consists of a finite set of distinct nodes N_G, a finite set of edges E_G and a mapping function $\Gamma_G : E_G \rightarrow N_G \times N_G$

- **Definition 2**. A model $M = (G, \omega, \mu)$ is a triple where:
  - $G = (N_G, E_G, \Gamma_G)$ is a directed multigraph
  - ω is itself a model, called the reference model of M, associated to a graph $G_\omega = (N_\omega, E_\omega, \Gamma_\omega)$
  - μ: $N_G \cup E_G \rightarrow N_\omega$ is a function associating elements (nodes and edges) of G to nodes of G_ω (metaElements)

Each model conforms to its reference model



There are several kinds of models



Definitions

- **Definition 3**. A metametamodel is a model that is its own reference model (i.e. it conforms to itself).

- **Definition 4**. A metamodel is a model such that its reference model is a metametamodel.

- **Definition 5**. A terminal model is a model such that its reference model is a metamodel.

This definition is compatible with OMG view

A Proposal for an MDA Foundation Model

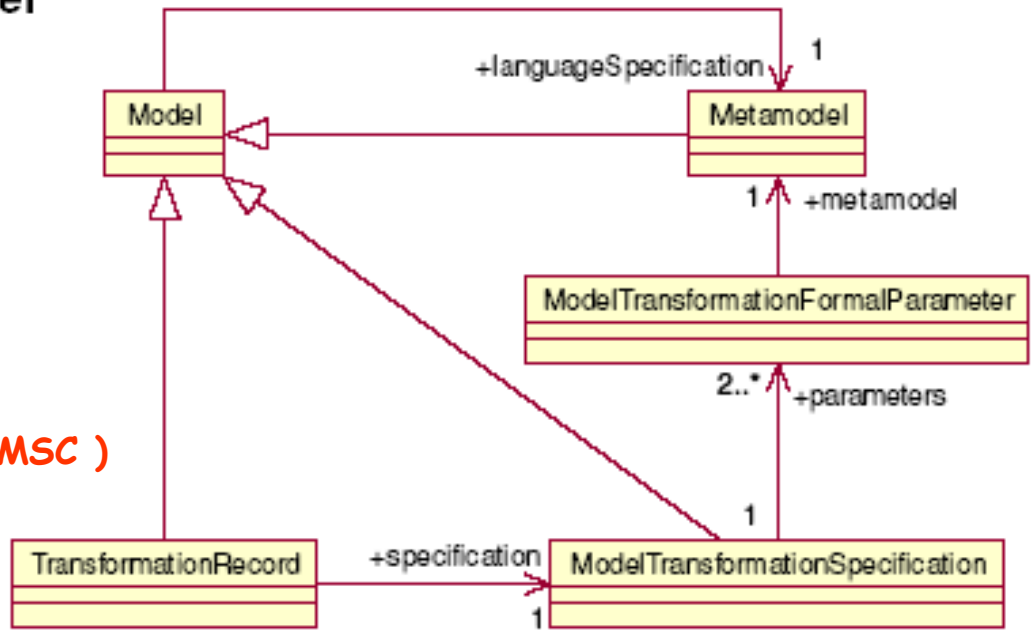
An ORMSC White Paper

V00-02

ormsc/05-04-11

Object Reference Model SubCommittee (ORMSC)

"The MDA guide"



"MDA is an approach to system development…[that]… provides a means for using models to direct the course of understanding, design, construction, deployment, operation, maintenance and modification." [MDA Guide omg/03-06-01]

At the core of MDA are the concepts of models, of metamodels defining the abstract languages in which the models are captured, and of transformations that take one or more models and produce one or more other models from them. Figure 1 shows the relationships between these major concepts.

Utilization definition

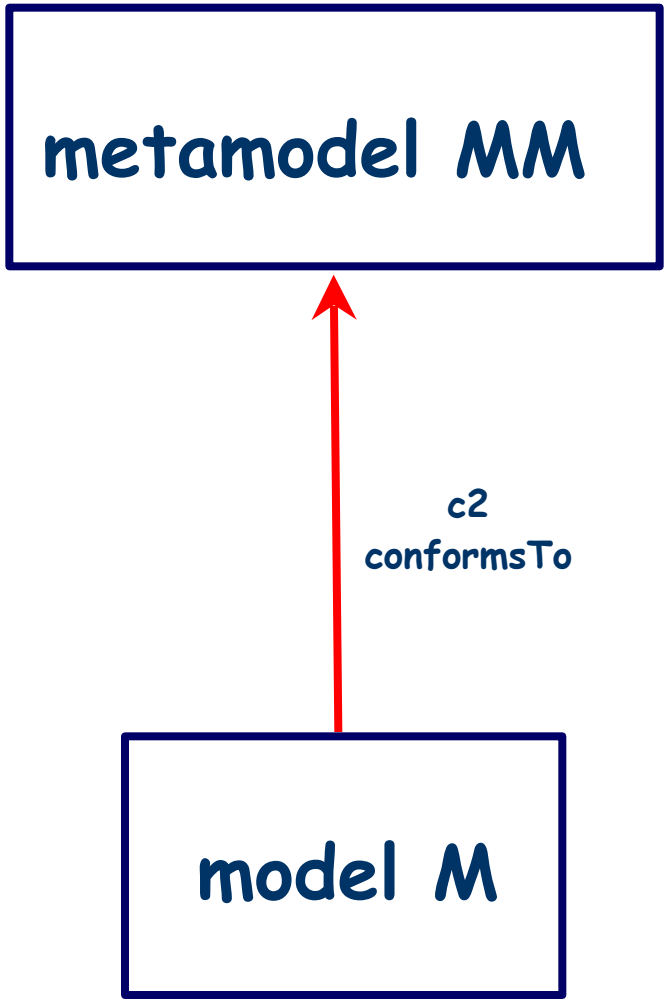
The objective here is to define the possible usages of a model. Consequently model will mean here "terminal model".

- **Definition 6**. A system S is a delimited part of the world considered as a set of elements in interaction.
- **Definition 7**. A model M is a representation of a given system S, satisfying the substitutability principle (see below).
- **Definition 8**. (Principle of limited substitutability). A model M is said to be a representation of a system S for a given set of questions Q if, for each question of this set Q, the model M will provide exactly the same answer that the system S would have provided in answering the same question.

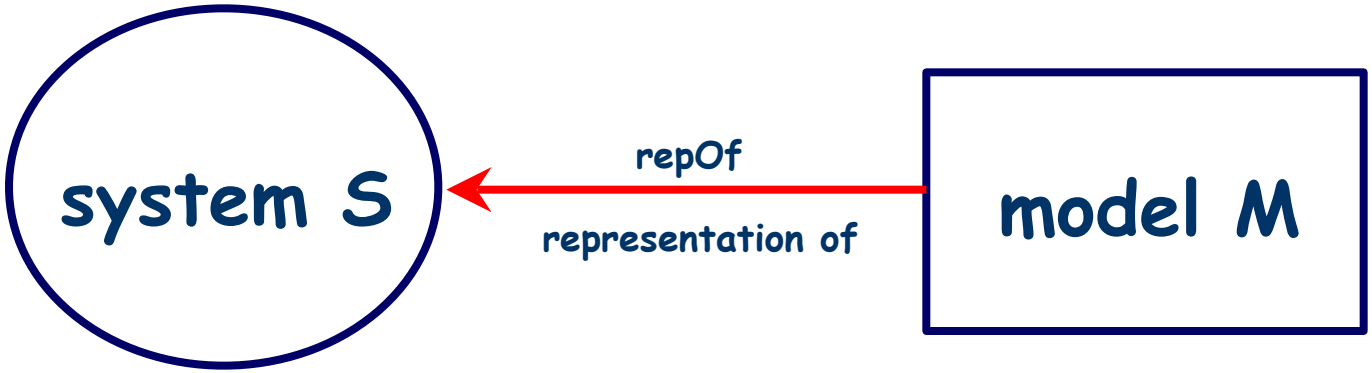
Agenda

Summary

Structural definition



Utilization definition

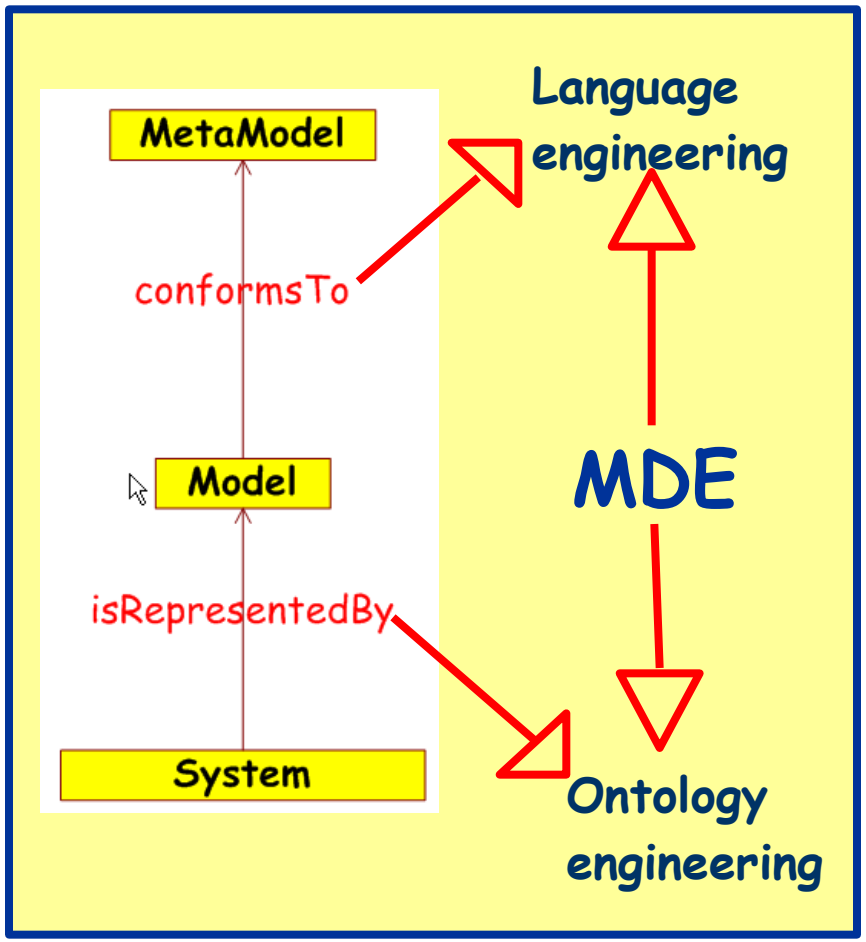


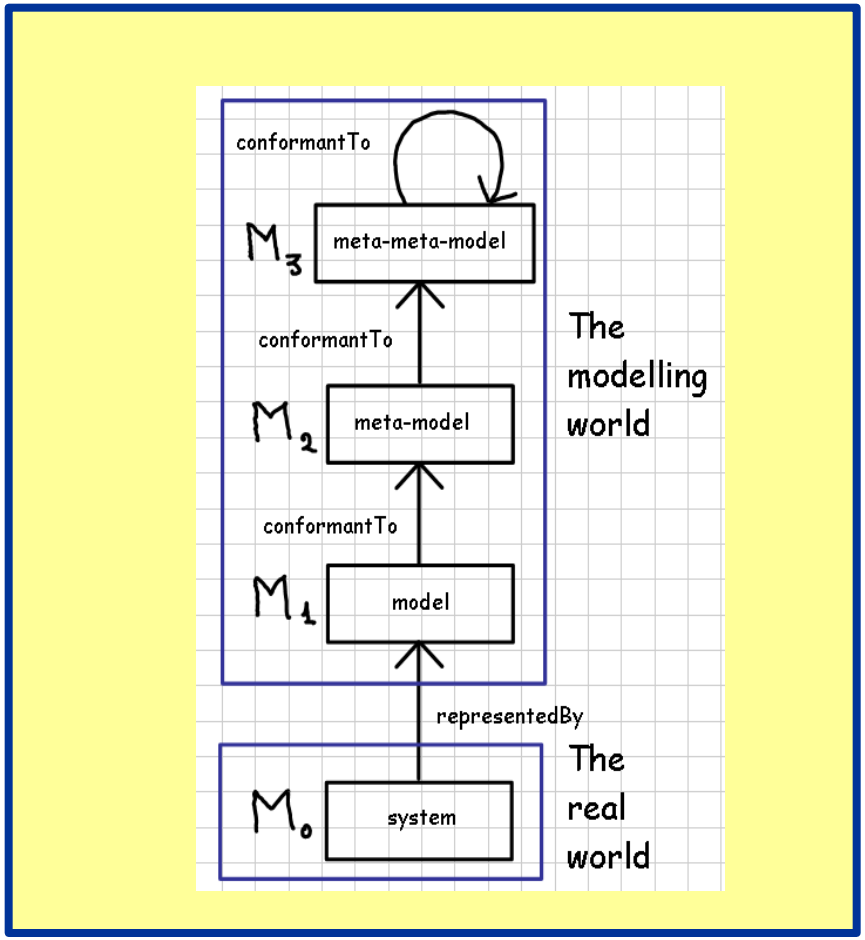
On the representation relation

"What about the [relationship between model and real-world]? The answer, and one of the main points I hope you will take away from this discussion, is that, at this point in intellectual history, we have no theory of this [...] relationship."

Cantwell Smith, B. Limits of Correctness in Computers, Report CSLI-85-36, Center for the Study of Language and Information, Stanford University, California, October 1985.

Credits and MDA compliance

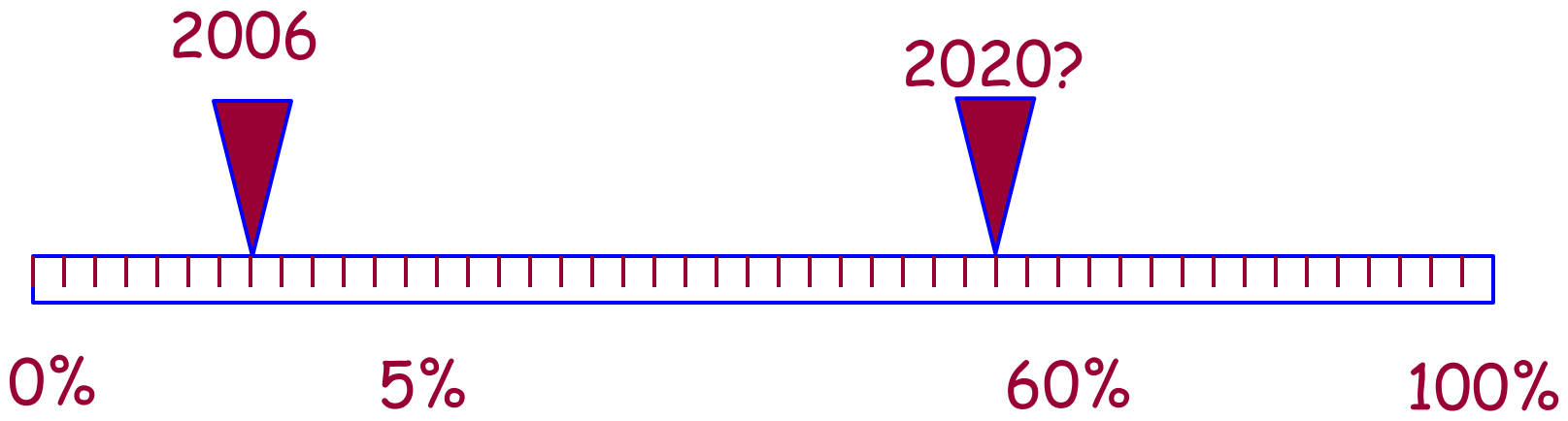




Models revisited

- Everything is a model
  - A λ-model
  - λ meaning the specific TS
  - An XML document is an XML-model
  - A Java source program is a Java-model
  - An UML model is a MDA-model
  - EMF and MS models should also be exchangeable
  - etc.
- Each TS is rooted in a metametamodel defining its representation scheme (representation ontology)

MDE: fulfilling the promises



◊It has taken OMG more than 12 years to achieve CORBA 3 interoperability standards.

◊It is very likely that MDE/MDA will take much more time to achieve a reasonable level of automatic code generation.

◊However, in some particular contexts, some specific solutions are already available today.

Thanks

- Questions?
- Comments?

http://www.sciences.univ-nantes.fr/lina/atl/

Jean Bézivin

Jean.Bezivin{noSpamAt}univ-nantes.fr

Equipe ATLAS, INRIA & LINA, Nantes, France