Megamodelling and Etymology

A story of Words:
from MED to MDE via MODEL in five millenniums

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Abstract. Is a model of a model, a metamodel? Is the relational model a metamodel? Is it a model? What is a component metamodel? Is it a model of a component model? The word MODEL is subject to a lot of debates in Model Driven Engineering. Add the notion of metamodel on top of it and you will just enter what some people call the Meta-muddle. Recently megamodels have been proposed to avoid the meta-muddle. This approach is very promising but it does not solve however the primary problem. That is, even a simple use of the word Model could lead to misunderstanding and confusion. This paper tackles this problem from its very source: the polysemic nature of the word MODEL. The evolution and semantic variations of the word MODEL are modelled from many different perspectives. This papers tells how the prefix MED in indo-european has lead, five millenniums after, to the acronym MDE, and this via the word MODEL. Based on an extensive study of encyclopedias, dictionaries, thesauri, and etymological sources, it is shown that the many senses of the word MODEL can be clustered into four groups, namely model-as-representation, model-as-example, model-as-type, and model-as-mold. All these groups are fundamental to understand the real nature of Model Driven Engineering. Megamodels and Etymology are indeed keys to avoid the Meta-muddle.

1 Introduction

MDA, MDD, MDE, MOF, UML, XMI,... Programmers like TLA, Three Letter Acronyms. Programmers like coding. They don't like words. Words are for plain people. Codes are for machines. Programmers love machines. Theoretical Computer scientists love formulas. They don't like codes. But they don't like words either: "Semantics must be defined through formulas". Words are indeed quite bad to express Semantics, at least the semantics of programs as defined by computer scientists. But what about the semantics of words? In Software Engineering very little attention is paid to words, even though words and word semantics are one of most powerful inventions of mankind.

Currently the focus in Software Engineering is rather on Model Driven Engineering (MDE) [2]. Models and model transformations are at the centre of this approach. The strong interest in models relies in the hope of being able to bridge the gap between words and codes: the client uses words to expresse requirements while the computer executes only codes. The role of the Software Engineers is "just" to transform words into codes. Models and model transformations are the solutions in the between. That's at least the research hypothesis of Model Driven Engineering.

This is an episode of the series "From Ancient Egypt to Model Driven Engineering" [1]

Understanding the real nature of models is therefore of paramount importance. While Model Driven Engineering takes its roots in the MDA industrial standard from the OMG [3][4], leaders like Microsoft and IBM develop their own technologies. In fact, MDE is mostly driven by the development of new tools and technologies. Research is also quite active. At the time of writing this paper, PlanetMDE references about 20 books related to this topic. More than 50 conferences or workshops will be held in the year 2005 [2].

A lot is said and written about Model Driven Engineering. All that using plain words. While the notion of model is the very core of the approach, this notion is still a source of lot of debates and sometimes disputes. While disputes stay at the level of words, which is a good thing, these disputes are mostly due to the usage of words, and this is too bad. Words is the only way to communicate effectively among humans. Polysemic words like Model, are responsible to a lot of confusion and misunderstanding. For instance would you say that a component model is a metamodel? Is the metamodel of a transformation model, a model of that transformation? What does a metamodel of a model of transformation of models mean?

Got lost? Well your are entering into what is sometimes called the *meta-muddle*. This term refers to confusing world populated by meta concepts that are (1) explained through imprecise words and (2) implemented through difficult-to-explain (and often not-fully-understood) technologies [6]. The large amount of standards from the OMG and their incremental development contribute to the meta-muddle, even though the OMG' meta-pyramid architecture was an attempt to structure the space of models, metamodels, meta-metamodels and so on [9].

Clarifying the fundamental concepts of MDE is indeed a necessity [5][8][10][11][13], especially since this approach addresses not only the MDA technologies, but also other technical spaces [18] such as Grammarware, Dataware, Graphware, XMLware; Ontologyware, etc. [22][24]. Megamodelling aims at establishing foundations for MDE [7][8][9], but before going into further details let consider the following questions as a good illustration of the meta-muddle:

(Q1) ***Is a model of a model, a metamodel?***

According to some tutorials and FAQ available on internet the answer is YES. The next figure presents an excerpt of the book on EMF [6], the MDE technology developed by IBM in the context of Eclipse.

> People often get confused when talking about meta-metamodels (metamodels in general, for that matter), but the concept is actually quite simple. **A metamodel is simply the model of a model**, and if that model is itself a metamodel, then the metamodel is in fact a meta-metamodel. Got it? If not, I wouldn't worry about it, since it's really just an academic issue anyway.

Figure 1 Excerpt of "Eclipse Modelling Framework", page 13.

According to this book the answer is therefore YES [5]. Some experts argue on the contrary that the answer is NO (e.g. [5]). In this paper will take an intermediate position: the answer is in the middle, or better said one can say either YES or NO, depending on the interpretation of the word model.

Thanks to an in-depth study of the etymology or the word model, this paper shows that they are four groups of meanings for this word: model-as-representation, model-as-example, model-as-type, and model-as-mold. Removing the prefix invariably leads to ambiguity and therefore confusion. This is especially true when different meanings are used in the same sentence! To cope with these kinds of problems, this paper combines our previous work in attempting to establish a basic theory for MDE [5], with the results of an extensive work on the etymology of the word model.

The rest of the paper studied the notion of model from many different perspectives. Section 2 presents the notion of models in the context of megamodelling. The four next sections review the notion of model as represented in Encyclopedias (Section 3), in Dictionaries (Section 4), in Thesauri (Section 5) and in Etymology (Section 6). Finaly all these points of view are integrated in Section 7.

2 Models in Megamodelling

Before anything else, let us just give a few working definitions that will be used, unless explicitly stated, as the standard meaning in this paper.

2.1 Basic working definitions

Below is our working definition of the word model. As it will be shown in Section 7, this meaning can be qualified as model-as-representation. The spirit of this definition is relatively consensual [8], so we expect the reader to understand something close enough to what we mean (this is not granted because most words in the definition are themselves polysemic). A detailed discussion about definitions of model in the context of MDE can be found in [8]. The rest of this paper will discussed other senses of Model as defined by dictionaries, thesauri, etc.

(D1) ***A model is 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*** *[12].*

Note that a map of the world is a typical example of model since it helps to answer questions about the geography of Earth. We will also assume in this paper the following working definition of the term Metamodel. Again, at this level of abstraction, there is a growing consensus about what is a metamodel. Definitions about metamodels are discussed in further details in [9].

(D2) ***A metamodel is a model of a modelling language.***

The last part of this definition can be rewritten as a "language of models", so that the only word that remains to defined is Language. Here, for the sake of simplicity, Language will be taken in the sense of formal language theory, that is a set of sentences. For instance the set {"", "o","oo","ooo","oooo" ... } is a (formal) language. If each symbol o represents the presence of an animal in a zoo, then we have a language of models (i.e. a modelling language) for Zoos. For instance, the model "oo" represents the fact that they are two animals in the zoo being modelled.

It is very important to stress that the definitions above do NOT refer to any technical space [18]. This is a distinctive feature of Model Driven Engineering [2][24]. For instance one can use the regular expression "o*" to model the set described above. That means that "o*" is a metamodel with respect to "oo", which is a model of the Zoo. Got it? If not, don't worry. Understanding is actually a quite important issue, and megamodels have been designed for that. So just read on.

2.2 Megamodel (models)

Megamodels aims at providing structures to avoid the meta-muddle. In [6], Bézivin defines a *megamodel* as "*a model which elements represent models, metamodels and other global entities*". While Modelling-in-the-small is the activity that consider the details of models, metamodels, etc., Modelling-in-the-large, or *Megamodelling* consider the global relationships between these artefacts, without considering their content. In fact any software produced by a Model Driven Engineering process is made of a complex structure of models, metamodels but also artefacts such as interpreters, transformation models, transformation engines, and so on. For instance for a model to be useful, one needs a metamodel but also transformations that operates on it, and then transformation engines to interpret the transformation models, interpreters to interpret the language in which the transformation engines are written in, and so on. A megamodel is a model that represents this kind of complex arrangements without entering into the details of each artefact.

As an illustration, let us consider the very simple megamodel represented in Figure 2. Let assume that it represents a small subset of a huge megamodel describing the whole legacy software developed an astronomy research institute. The focus of interest is on a simulation software that represents the solar system according to Ptolemy’ Geocentric vision.

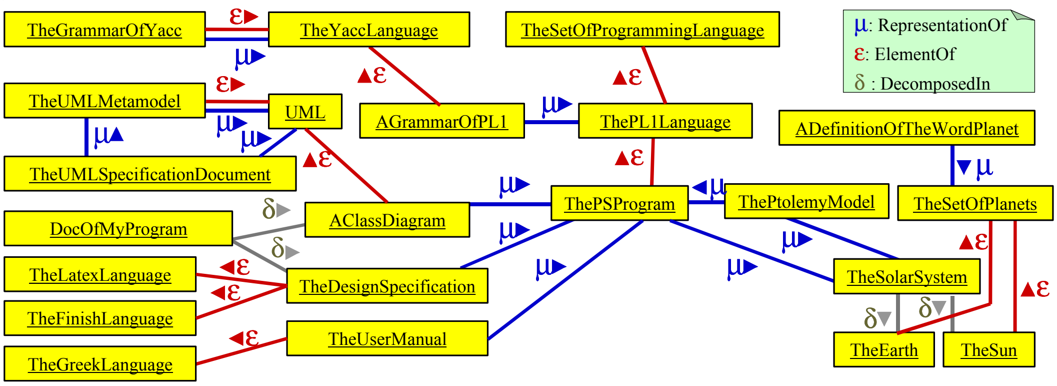


Figure 2 Example of (a Model of) a Megamodel (expressed as an UML instance diagram)

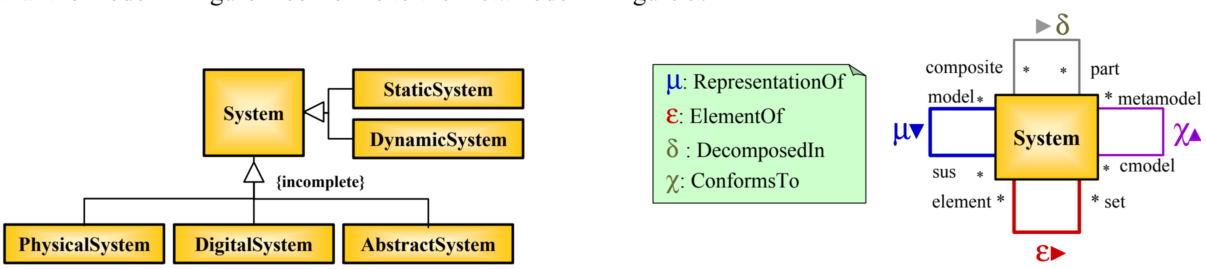
This figure fits in the definition of model (D1). From it, one can learn for instance, that the Ptolemy Simulator (PS) program has been written in the PL1 programming language; that many different languages have been used either to document or to implement the software, etc.

Formally, the model is a μεδ-graph, that is a graph with edges decorated by μ, ε, or δ labels. μ-graphs have been introduced in [8], ε-graph and μεχ-graphs in [9]. No χ edges are represented in this example but, as explained later, these edges can derived automatically. Attention should be paid however to the fact that the power of megamodels do not come from their concrete representation, but on the contrary on the information they convey. For instance, converting this model to a set of english-like statements is easy thanks to the key provided in the figure. One would write "PtolemyModel is a RepresentationOf TheSolarSystem", "TheUserManual is ElementOf TheGreekLanguage". Similarly, this graph can be transformed in a set of prolog facts "representationOf(tychoBraeModel,theSolarSystem). elementOf(theUserManual,theGreekLanguage)". It can be stored in a relational database, etc. The key in megamodelling is the information modelled, not the way it is represented.

Though the information displayed in Figure 2 is a model, this term do not give any clue about its content. This is definitely not a metamodel (D2), because it does not describe a language. We call it a megamodel because these kind of views enable to describe models, metamodels and other MDE artefacts, from a modelling-in-the-large perspective.

2.3 Megamodel (metamodels)

While Figure 2 describes a particular example, the interesting aspect from a research point of view is the identification of the structure of megamodels, that is the essential concepts to model MDE itself. This leads to the notion of megamodel metamodel. The qualification metamodel is often omitted to simply the discourse, in particular because the difference between a megamodel metamodel and metamodel model is usually easy to get from the context. Basically, a megamodel (metamodel) is just a model that describes the fundamental MDE concepts. A zone for megamodels will be open in Zooomm [17]. Let’s concentrate here on the megamodel we developed in previous work (e.g. [8][9][22]). A subset of it is presented below in the form of two standard UML class diagrams. Note that the model in Figure 2 conforms to the metamodel in Figure 3.



(a) Basic classification of systems

(b) Basic relations among systems

Figure 3 The Megamodel Metamodel

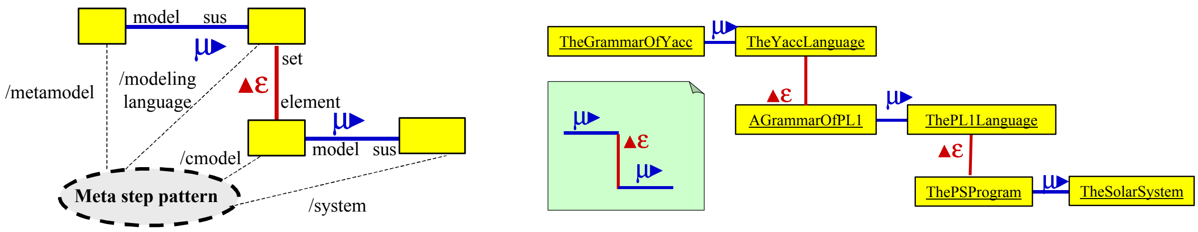
The core hypothesis is that "everything is a system" (Figure 3.a). All the objects in Figure 2 are instances of the class System. The classification as physical system, digital system, abstract system, etc. is here just to put the emphasis that the megamodel aims at representing many different kinds of artefacts. For instance, the solar system is a physical system, the PSProgram is a digital system, Ptolemy's geocentric view is an abstract system, etc. The fact that a system is static or dynamic is an orthogonal dimension. The solar system is dynamic. A map of a world is static. As shown in Figure 3.b, we consider four relations about systems, each one being represented as an UML association, with named roles.

- δ **- DecomposedIn, composite/part**. A *system* is very often defined as a complex set of more elementary parts. This relation represents the decomposition of systems in subsystems, and so on. For instance the planet Earth is a *part* of the solar system (see the corresponding δ link in Figure 2).
- μ **- RepresentationOf, model/sus**. A *model* is a representation of a *system under study* (sus for short). This relation is the key of modelling (e.g. [5][10]). Sometimes the distinction is made [10] between specification models, which represent a system to be build (e.g. the design specification of the PS program in Figure 2), and descriptive models that describe an existing system (e.g. Ptolemy's model). These associations could be introduced as specialization of μ if required. The μ relation is extensively described in [8].
- ε **- ElementOf, element/set**. This relation corresponds to the notion of set in the Set Theory [22]. For instance Earth is an element of the set of all planets; the PS program is a element of the PL1 language (remember that languages are sets, and should not be confused with models of these sets).
- χ **- ConformsTo, metamodel/cmodel**. This relation defines the notion of metamodel with respect to a model. A model must conforms to its metamodel [6]. In fact, χ is derived from the μ and ε as shown in [9].

Our metamodel includes a few other relations such as τ to model transformations, and σ to model semantics, but this is out of the scope of this paper. The important fact here is that these elementary relations allow to model very complex MDE megamodel.

2.4 Megamodel patterns

In the last years, the megamodel described above have been used to describe a lot of different kinds of artefacts, ranging from software to linguistic and conceptual arts [1][22]. This enables not only to validate the metamodel on concrete examples, but also to identify recurrent megamodel patterns, also called mega-patterns. Some very simple mega-patterns are described in [26]. The "Interpreter" and "Transformation" mega-patterns are described in [22], the "Meta-step" mega-pattern in [9]. This last one is of fundamental importance for MDE since it defines indeed the notion of metamodel (see Figure 4.a). This mega-pattern will also be referred as the "Z" pattern for its shape. Episode II of the series "From Ancient Egypt to Model Driven Engineering" explains the relation with this shape and the meta-pyramid [9].



(a) Definition of the mega-pattern with associated roles

(b) A model with two occurrences of the meta-step pattern

Figure 4 The "Meta step" or "Z" mega-pattern [9]

A mega-pattern just defines a collaboration between some systems in a megamodel. Each system plays a different role in the collaboration. For instance in Figure 4.b two occurrences of the pattern can be recognized. One where modellingLanguage is bound to TheYaccLanguage, and the other were modellingLanguage is bound to ThePL1Language.

Note that this pattern matching does not rely on intuition but only on the shape of the graph. The use of words is just here to give an idea of what this means. While qualifying Yacc and PL1 as modelling language could seem quite strange, this is however very consistent to the definition of model (D1). The PS program is clearly a model of the solar system since it enables to answer questions about the solar system (D1).

Note that the role metamodel is attributed to the model of a modelling language (D2). The PL1 and Yacc grammars play this the role of metamodel (MDE cross the boundaries of technical spaces and associated specific terminologies). The role "cmodel" here stands for "conformant model", which is not exactly the same role as being a model with respect to a system (μ). It will be shown in the rest of this paper that these kinds of subtle matters played indeed an essential role in the etymology of the word model, which is for a great part responsible of the meta-muddle.

Before presenting the concept of megamodel transformation, just let us introduce, for the sake of this paper, the "S" pattern (see Figure 5). The shape of the S pattern has been chosen to directly mimic the layout of the piece of art "One and Three Chairs" from Kozuth. This story will be described in a subsequent episode [37]. In this episode the reader will learn how Kosuth has created one of the most famous pieces of conceptual art of the XXth century thanks to a photo of a chair, a chair, some space, and the definition of the word chair.

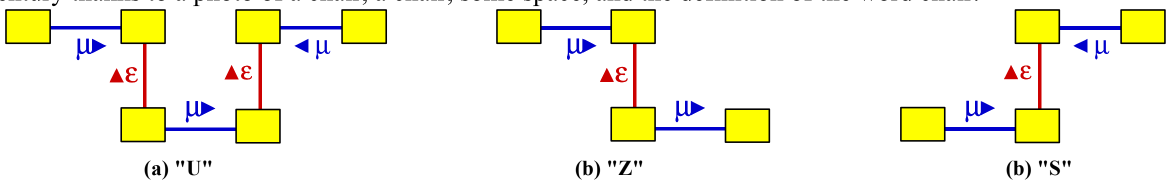


Figure 5 The "U","Z" and "S" mega-patterns

2.5 Megamodel transformations

Recognizing an occurrence of a mega-pattern in a complex megamodel greatly helps in the comprehension process because one can put a word on a sometimes quite complex arrangements of systems. Patterns can be used to define megamodel (model) transformations (see Figure 6). The transformation presented is the one which derive the relation ConformsTo (χ) from με graph. It helps in structuring complex megamodel by using the notion of metamodel. For instance, Figure 6.b shows an example of application of this transformation. The original graph represents the meta-pyramid of the OMG referred as the four-layer metamodelling architecture [3]. The results is the μχ graph proposed by Bézivin to explain this architecture, the layers M3, M2, M1, M0 being assigned from left to right [5].

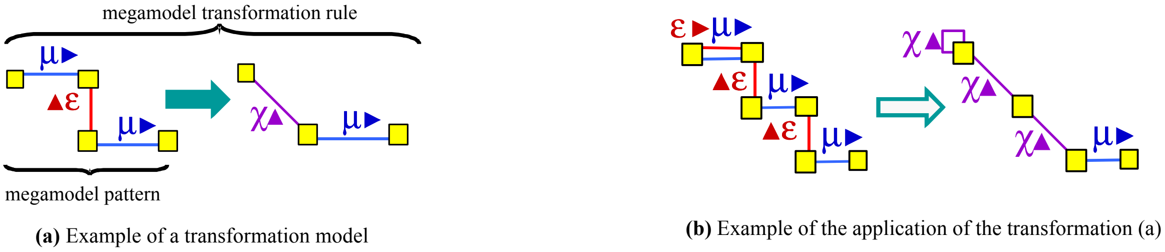


Figure 6 Example of a Megamodel Transformation

2.6 Discussion

This ends the presentation of megamodelling in this paper, the rest being devoted to the study of the word model. A few observation can be made however:

- The megamodel is not tied to any particular technical space.
- There is no restriction on the "formality" of the models. Our megamodel does not assume that an explicit and well-defined metamodel is attached to each model. Our goal is to describe the whole range of actual MDE situations, not only ideal ones.

- Most of the time, confusions arise from terminological issues and misinterpretations of polysemic words. For instance *element* and *part* are synonyms, thus the reader might be confused by the co-existence of the relation δ and ε (Section 2.3). However the relation δ and ε are different. For instance the class diagram in the PS program is a *part* of the documentation, but an *element* of the UML language.
- Similarly the confusion is often made between the relation ConformsTo (χ) and ElementOf (ε). Both relations are often called InstanceOf. This term which is largely overloaded, is in a great part responsible for the current meta-muddle [5]. The use of greek letters just help to reason formally on megamodels without being confused by misleading names. Section 7 summarizes the many different names used by different authors to name the relations identified in our megamodel.
- Another important source of confusion in MDE comes from considering the notion of model as intrinsic property of a system. Our megamodel put a very strong emphasis on the fact being a model is just a role. In other words our motto could be "Nothing is a Model, but Everything could serve as a Model". For instance, a map is not a model per se. A dog will just consider it as a regular system and play with it. The other way around, every object can serve as a model. For instance Ptolemy could have used an apple and some nuts to model the solar system and explain its behaviour to others. Everything is relative.

Now that the notion of model have been modelled through a megamodel, let's consider a much broader perspective. In the remainder of this paper the notion of model is studied through encyclopedias, dictionaries, thesauri and etymology.

3 Models in Encyclopedias

Each study of a concept could start by having a look at an encyclopedia since an *encyclopedia* is *"a comprehensive reference work containing articles on a wide range of subjects or on numerous aspects of a particular field, usually arranged alphabetically*" [27]. The first encyclopedia, "L'encyclopédie de Diderot et d'Alembert", was on of the major achievement of the French Enlightenment. It results, over more than 20 years, of the collaborative work of more than 140 people (1751-1777). In the "Encyclopédie" entry Diderot said "*Indeed, the purpose of an encyclopedia is to collect knowledge disseminated around the globe; to set forth its general system to the men with whom we live, and transmit it to those who will come after us, so that the work of preceding centuries will not become useless to the centuries to come*". In other words, the idea of Diderot was to build a model of the knowledge accumulated by mankind. This results in 20,8 millions of words, structured in 70 000 articles gathered in 32 volumes. This is one of the first extensive model of human knowledge.

3.1 The notion of Model in encyclopedias.

Nowadays, encyclopedias are available in different languages. The table below represents how the concept of Model is represented in 11 encyclopedias edited in 4 different countries.

Ref	Name	# volumes	Country	Edition	# pages on "model"
E1	Encyclopédie Diderot et d'Alembert	32	FR	1751	-
E2	Academic American Encyclopedia	20	US	1994	-
E3	Collier's Encyclopedia	22	US	1992	-
E4	**Encyclopedia Americana**	29	US	1994	**5**
E5	World Book	21	US	2001	-
E6	The Canadian Encyclopedia	1	CA	2000	-
E7	Encyclopedia Britanica	41	UK	2002	-
E8	The cambridge Encyclopedia	1	UK	2001	-
E9	World Encyclopedia	1	UK	2001	-
E10	**Encyclopedia Universalis**	23	FR	1989	**21**
E11	**La Grande Encyclopedie Larousse**	20	FR	1975	**3**

Figure 7 A Model of the coverage of the concept of Model in Encyclopedias

The most comprehensive survey of the notion of Model can be found in the [E10] with 21 pages dedicated to this concept. This survey models the notion of Model from many different perspectives: "Model in Mathematics", "Model in Physics", "Model in Earth Sciences", "Model in Biology", "Model in Psychology", "Model in Linguistic", "Model in Arts", "Model and Epistemology". Various pages are also dedicated to the mathematical "Theory of Models". As the reader can see, no reference is made to the notion of Model in Computer Science. The is the same in the multi-disciplinary collaborative book "Investigation around the notion of Model" [34]. It considers models as used in Physics, Mathematics, Biology, Meteorology, Environment, Economy, Politics and Philosophy. The absence of Computer Science might be explained by the fact that this discipline is very young with respect to others. Moreover, the systematic use of models is still in its infancy in this domain. At least in has not been recognized as such. This contrast with other disciplines which already agreed on the fact that models are at the "confluent of sciences" [35].

Instead of modelling the notion of models in other sciences, let’s consider the historical perspective as provided by the Encyclopedia Americana [E4]. In this encyclopedia the history of models is modelled via two parts (1) a short summary of the use of models in Ancient Egypt and (2) the use of early models in ship building.

A this point, it is important to note however that the entry "Model" starts by the following statement "*MODEL, a three-dimensional, typically small construction intended to illustrate, explain, or discover certain properties of its prototype, the subject that it represents*". Note, that apart from the 3D and physical restriction this characterisation is compatible with the definition provided in this paper. Here prototype stands for system-under-study.

3.2 Models in Ancient Egypt

The earliest-known models for which definite records exist are those that were made by the Ancient Egyptians about 4000 B.C. [E4]. These miniatures represented scenes of everyday life. At that time, the difference between the models and the subjects under study was not always clear cut. Models were placed in the tombs of deceased nobbles and kings so that the deceased would have their aid, comfort, and use in the spirit world, awaiting the day when the ka (the spirit gone from the body) would return [E4]. As shown in Figure 8, models were physical systems in the form of carved of wood. This is one of the first technical space used for modelling.

(a) Model of a granary **(b)** Models of soldiers of Mesehti **(c)** Models of household activities

Figure 8 Models from Ancient Egypt representing Everyday Life

Ancient Egyptians used the systems depicted above as specification models for creature in the spirit world. Nevertheless, these systems play nowadays a quite different role. Egyptologists still use these systems, but as representations of egyptian life. These "models" were constructed with such precision that it is possible to see how ancient egyptians rigged their ships, harnessed their horses, and fastened their clothing. Models has played a very important role for our current knowledge about life in Ancient Egypt.

The metamodels of these models remain however mostly implict. While many model elements have a natural and direct interpretation, some are not. Like most egyptian arts, models followed quite precise conventions for representation. For instance one leg in front of the other (see Figure 8.b) does not mean that the person represented was walking, but just that he or she was alive. Two joined legs means a death body [1].

Note that boats (see Figure 9) constitute one of the largest surviving collections of egyptian models. They have been very common, and are found throughout Egyptian history. At least two boats were usually placed in tombs, consisting of one rigged for sailing south, and one rigged for rowing north with the Nile current [33]. Summing up, models in Ancient Egypt were primarily used as specification of elements necessary in the spirit world and were religious items.

(a) Model of a kitchen boat **(b)** One of the model funerary boots from Tutankhamun's tomb **(c)** Model of a traditional boat

Figure 9 Boat models used in Ancient Egypt Beliefs

3.3 Model Driven Ship-Engineering

The second topic in the history section of the Encyclopedia Americana [27] is also dedicated to ships models. It relates however the beginning of what could be called today "Model Driven Engineering". This was indeed the first systematic use of models to move from craft to industrial production, and this at the nation-wide scale [27][32] (see Figure 10).

In the early days of shipbuilding, designs for ships were planned by master shipbuilders, and new ideas were incorporated by improvisations. In France in 1679, Jean-Baptiste Colbert, Louis XVI's minister of marine, ordered the superintendents of all royal navy yards to make a scale model of every ship they built. The idea was to constuct a set of models that would serve as precise standards for any ships built in the future. Thousands of exquisite scale models were built, and early in the 19th century the French government established a maritime museum, Musée de la Marine, in which many of these models were displayed.

Figure 10 A model of the history of models (from [E4]).

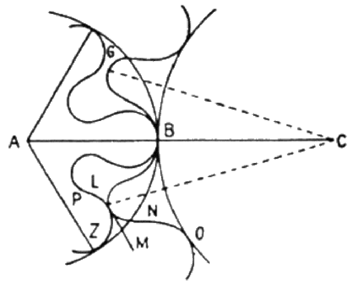
These models were so precise, so that in principle, by studying them in great details anybody could build a ship. In fact, these models acted both as specification model for new ships and as descriptive models of existing ships. They constitute as the same time reusable pieces of knowledge that can be repeatedly used in ships construction. That is, even when a boat was not to be build following a given model, particular designs or standard designs were still reused. As it will be explain later in this paper these many different kinds of usage of models explain in part the confusion that exist currently in Model Driven Engineering. Note also that here the distinction can be clearly made between :

- *Model Driven Engineering* which refers to the construction of ships based knowledge from models, and,
- *Model Engineering* which refers to the construction of the models themselves.

Model Engineering was far more complex that one could imagine at the first place and some workshops with highly skilled people were dedicated to the construction of such models. For instance the model depicted in Figure 11.a was built in the model workshop of the shipyard of Brest in France. Two models of this boat were built during the construction of the boat itself. It took five years to a team of six highly-skilled people to build these two models. As it can be seen in the photo, the hull is open in order to show the detail of the inside and make visible its design.

When Colbert ordered the systematic construction of ship models, his goal was clearly to rationalize the construction of ships in an industrial mode. This gives raises to Ship Engineering. From then all new machines and inventions were "modelled" either in 3D or 2D. This leads to the publication between 1735 and 1756 of the "compendium of machines and inventions approved by the Academy of Sciences". A new edition with 76-volumes was then published between 1761 and 1789. In fact, many of the 2D models from this series were later use by Diderot and Alembert for their encyclopedia. 2D models, just like the one presented in Figure 11.b, were used along

(a) A 3D Model of the Valmy. 190 x 55 x 45 cm



(b) A 2D Model of Hull to study Mechanical Property

Figure 11 Early Models in Ship Engineering

with plain texts to model scientific and engineering knowledge. In simple words, the Musée de la Marine was the first extensive 3D Model repository used for Engineering and the Encyclopedia from Diderot and d'Alembert the most extensive Model repository about current knowledge at that time. 11 volumes were dedicated to drawings and graphical representations.

Note that although these last artefacts have almost the same usage of wood models, there pertain to different technical spaces (wood construction vs. ink drawings). Models like the one in Figure 11.b do not fit within the "3D" model definition from the Encyclopedia Americana [E4]. In fact, one of the core difference between encyclopedias and dictionaries is that dictionaries attempt to define all senses of a word, here the word Model, while encyclopedias usually focus on only one sense: model-as-3D-representation for [E4] and models-as-simulation in [E11].

4 Models in Dictionary

The next step in the investigation about Model is then to look at the Model entry of dictionaries. One of these dictionaries defines a *dictionary* as "*a book that lists (usually in alphabetical order) and explains the words of a language or gives equivalent words in another language*". Dictionaries are models of a language (usually expressed in that language): dictionaries define which words can be used in a given language. Given an occurrence of a word in a text, the dictionary can be used to check if the word is conforms to that language. The dictionary plays the role of metamodel with respect to the text (if the text is considered as a model of something which is usually the case). Grammar books constitute other examples of models of the language, but here let us concentrate on the model of the Word model as given in "The Free English Dictionary" [27]. The following excerpt give 8 senses for the word Model when considered as a noun (see Figure 11). Sentences in italics are examples that conform to the given sense.

1. A small object, usually built to scale, that represents in detail another, often larger object.
2. a. A preliminary work or construction that serves as a plan from which a final product is to be made: *a clay model ready for casting*.
b. Such a work or construction used in testing or perfecting a final product: *a test model of a solar-powered vehicle*.
3. A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics: *a model of generative grammar; a model of an atom; an economic model*.
4. A style or design of an item: *My car is last year's model*.
5. One serving as an example to be imitated or compared: *a model of decorum.* See Synonyms at ideal.
6. One that serves as the subject for an artist, especially a person employed to pose for a painter, sculptor, or photographer.
7. A person employed to display merchandise, such as clothing or cosmetics.
8. *Zoology* An animal whose appearance is copied by a mimic.

Figure 12 A Textual Model of the Word Model (from The Free English Dictionary [27])

Note that #2.a corresponds to the notion of specification model as shortly described in the megamodel, while #2.b and #3 are closer to descriptive models. A closer look at the others senses show that they are different (yet sometimes not so far) from the notion of model as defined in the begining of this paper. Looking at other dictionaries will just reveal that the many senses of the word Model can be represented by many different sentences. Getting a structured mental model about the senses of the word model is therefore quite difficult with dictionaries.

5 Models in Thesauri

Fortunately, thesauri can provide more structured models. A *thesaurus* is "*a book that lists words in groups of synonyms and related concepts*". While thesauri were traditionally developed as sequential textual models, nowadays they can be explored interactively and visually thanks to computer models. For instance Figure 13 displays a graphical model centred around the word Model. The left pane displays as a graph the relationships existing between words and senses. While each sense is just represented as a circle in the graph pane, moving the cursor on it display the textual representation of this sense in a tooltip and highlight it in the right pane. Note that in the coloured version of the image, colours represents the word categories: Noun, Adjectives, Verbs, and Adverbs (to save space only senses of nouns are shown in the left pane).

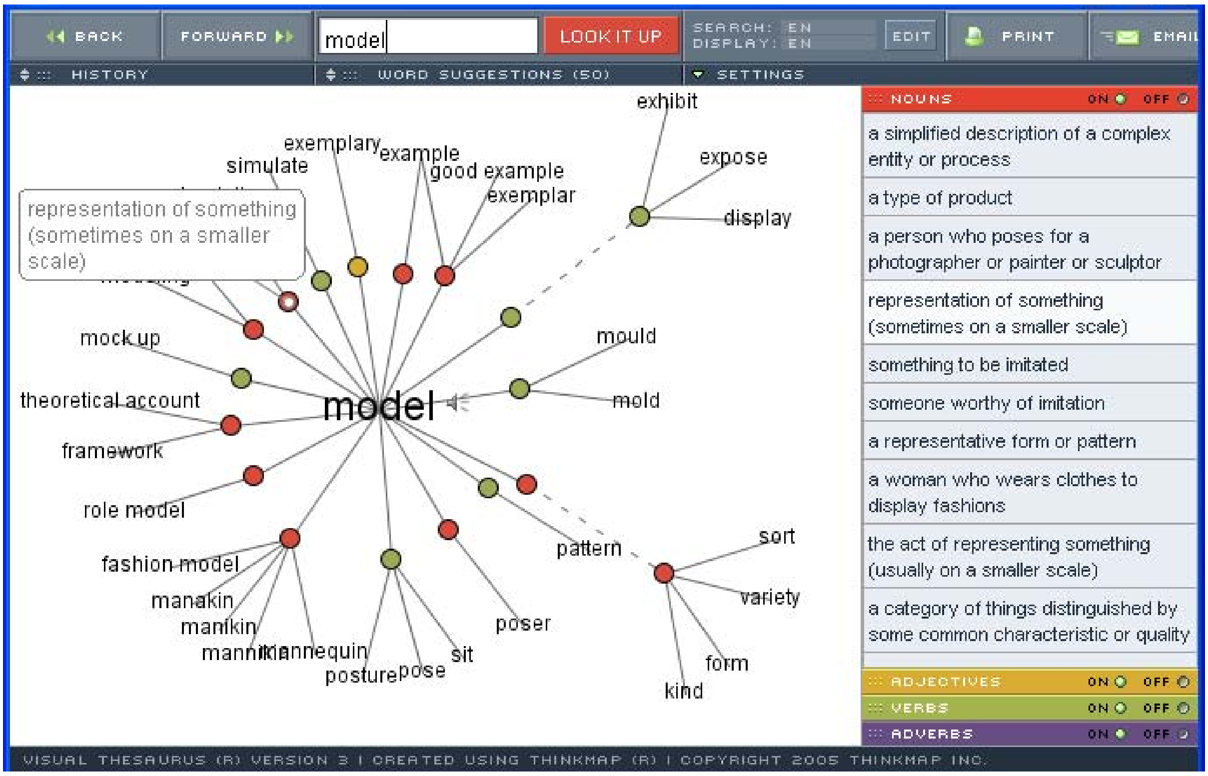


Figure 13 A Visual Model of the Word Model (from the VisualThesaurus [27])

Understanding a model implies understanding the language it is written it, in this case the language of thesauri. Since a "natural" language is not used here, the thesauri language should be explained and modelled. Two models of this language are given in this paper. The first one is a textual model expressed in English (see Figure 14) while the second is a visual model expressed in UML and OCL (see Figure 15). Both are metamodels of the model of the Word model presented in Figure 13. Note that both metamodels express more or less the same information.

> A sense has a category (noun, adjective, etc.). Each sense is described by a textual definition. Some examples are given when available. The relation "Means" between words and senses is the core of a thesaurus. A word can have various senses. Conversly various words can share the same sense. In these case there are said to be synonymous. A sense can be also a specilizations of another one.

Figure 14 A Simple Textual Metamodel Representing the language of Thesauri

These metamodels give no hints about the concrete syntax of the visual models produced by the VisualThesaurus software. While words are represented through their textual representations, senses are represented by circles, the category of senses by colours. The definition of a sense appears on the right panel as well as some examples when available (not shown in the figure). The relationship "Means" between words and senses are represented as plain edges between text labels and circles, while isTypeOf relationships between senses are represented as dotted lines between circles (other relations such as isAntonymOf have been omitted for the sake of simplicity).

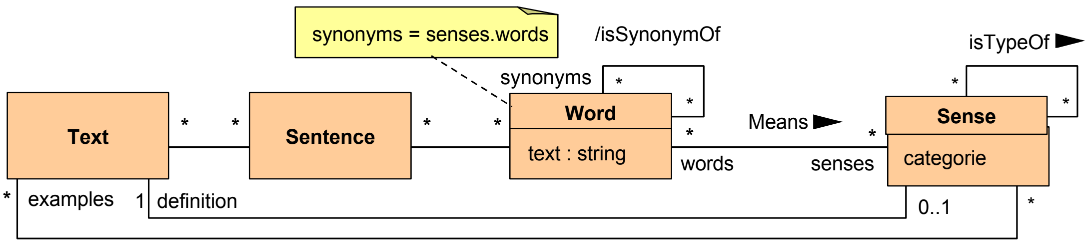
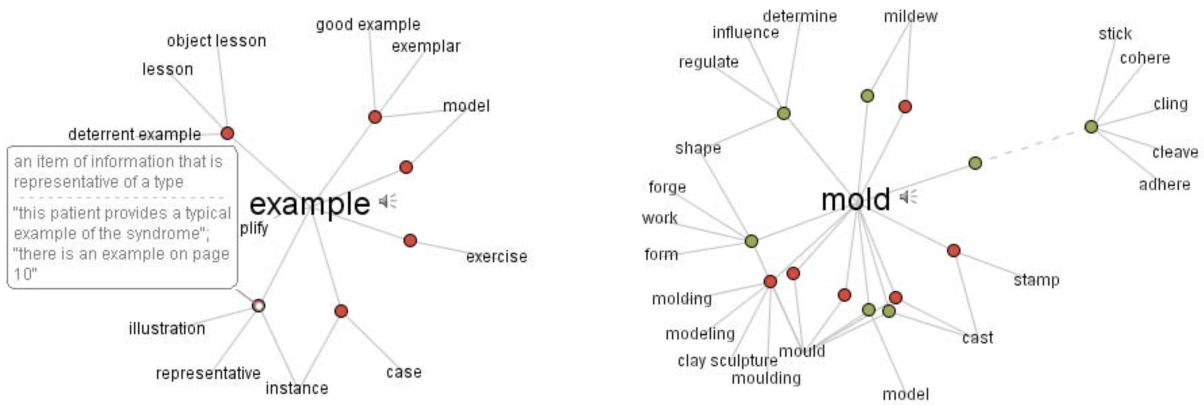


Figure 15 A simple visual metamodel representing the language of thesauri

Note finally that both metamodels introduce the concept of synonym, allowing to derive new information from models. While this concept is not explicitly shown in the visual model it can be derived through (1) the OCL expressions in the metamodel expressed UML, (2) the textual definition of the notion of synonyms in the textual metamodel, (3) a graphical interpretation of the textual language since two words are synonymous if their labels are connected trough a circle. For instance, from the visual model in Figure 13 we can learn that the word Model is a synonym of the word Mold, of the word Example, and so on. In fact synonyms provide a very good mean to disambiguate particular occurrences of words in a text or speech. When required, a good practice is to postfix the word to be disambiguated with the appropriate synonym. This leads for example to model-as-example, model-as-mold, model-as-representation, and so on. This techniques will be extensively used in the rest of this paper.

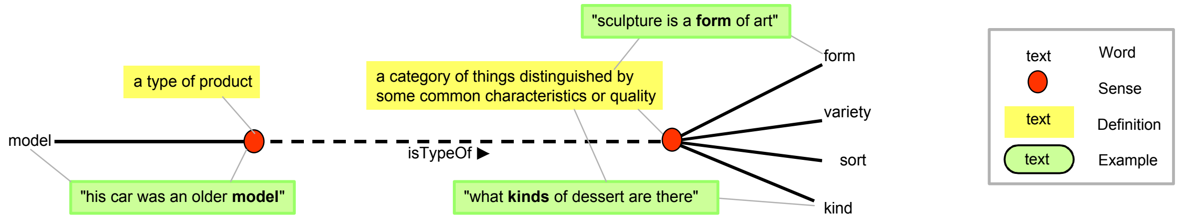
Note that while most of the time a pair of synonyms has one single sense, this is not always the case (thus an associative class could not be used for the class Sense in the UML class diagram). Figure 13 shows for instance that model-as-example leads to two senses. The definition of the first sense is "A representative form or pattern", while the second one shared with the word Exemplar is "Something to be imitated". Further exploration shows that Example is in fact synonym of Instance (see Figure 16.a), while exemplar and exemplary are close to Type.



(a) Synonyms of the word Example (including Model) [27] **(b)** Synonyms of the word Mold (including Model) [27]

Figure 16 Model, Example and Mold

Synonyms could also be derived following isTypeOf relationships. Figure 17 gives a visual model of the relation between the notion of model and the notion of type. Though the model below is static, it can be dynamically obtained by the VisualThesaurus software by moving the cursor on the corresponding sense.



(a) A "thesaurus" model of the relation between the notion of model and the notion of type **(b)** One of its metamodel

Figure 17 Model and Type

6 Models in Etymology

Though quite complex, a thesaurus is a huge simplification of a language, in particular because it considers only a static snapshot of this language at a given point in time. However natural languages, like programming languages evolve too! [21]. Language are dynamic systems. While a thesaurus can take either the form of a static system (e.g. a book) or of a dynamic system (e.g. VisualThesaurus), a book on Etymology is a (static) model of the language dynamics. While a dictionary defines the word *Etymology* as the "*historically verifiable sources of the formation of a word and the development of its meaning*", a book about etymology defines etymology as following: "*ETYMOLOGY: from Old French* ethimologie*, from the Latin* etymologia*, from Greek* etymologia*, as* etymon*,* -logy*)*.". As it can be observed, the story of words crosses the millenniums as well as boundaries of cultures, countries and languages.

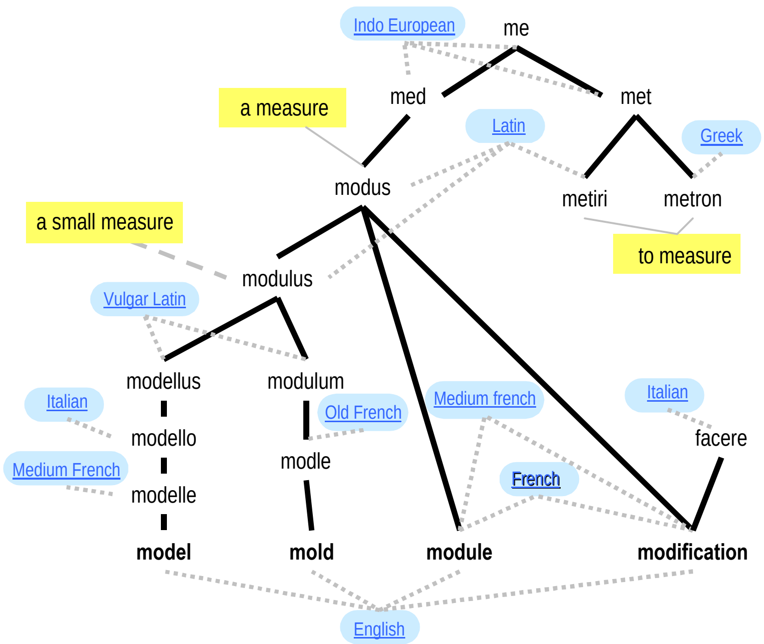
Textual etymological models are often difficult to use and compare. To facilitates the understanding of the history of the word Model, we derived a visual model (see Figure 18.a) from the study of four etymological sources [28][29][30][31]. To ease the interpretation of this model, a corresponding metamodel is given in Figure 18.b. Etymology mainly focus on the derivesFrom relation (which would be refined in practice). While many words are derived from a single root, others like Modification, have more that one roots. Note that various languages can share the same word, just like Module. From the derivation of words, the derivation of languages can be tracked, though these relations are not shown in the model. The vertical axis is mostly[1] used to represent time precedence without any attempt to use a proportional scale. The whole story depicted in this visual model might covers about five millenniums, although this is just a raw estimation [31].

As shown in the figure, the four english words Model, Mold, Module, and Modification are all derived from the Indo-European root MED, which led to the Latin word Modus, that is Measure as a noun. The descendants of the MET prefix, which means measure in the verb sense, are not shown. This includes among others to the words Meter, and Measure [28][29][30]. An interesting observation can be made at this point: while the notion of measure is one of the roots of all scientific sciences, in particular of so-called exact sciences, this notion leads also to the notion of Model which, as pointed out before, is considered to be the "confluent of sciences" [35].

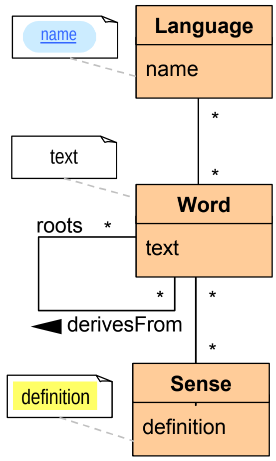
Amazingly, as it will be shown later in this paper, all four words derived from the branch Modus (measure) correspond to one of the core concepts in the megamodel. But let’s first review how each of these word relate to the notion of measure.

- *Model and Measure*. This relation is quite obvious, especially when considering that the first sense associated to Modelle in Medium French was "scale models". For engineering models, such as those presented in Section 3.3, a scientific treatment of measures is fundamental.

1. In fact some "derivation" links are not temporal, but correspond for instance to grammatical derivation. For instance Modulus is the diminutive in Latin of Modus. The nature of the links can be quite complex and have not been shown detailed for the sake of simplicity.



(a) Model of the Etymology of the word Model and associated words



(b) A metamodel for (a)

Figure 18 From MED to Model...

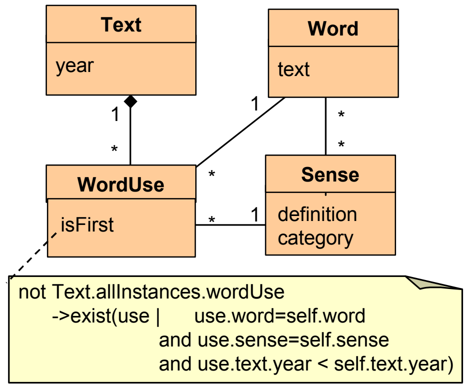
- *Mold and Measure*. This relation is not surprising since Mold and Model are synonyms. The expression "to fit in the mold" is also directly related to the compatibility of measures. Model and Mold just represent indeed two faces of the same coin (in the proper and figurative senses of the expression). A closer look at the history of bronze molding perfectly explains this duality. When a statue of bronze had to be build, the artist first realized a clay model of the statue. Then this model was used to build a mold around the model. After removing the model from the mold, the mold could be used to generate exemplars of the statue.
- *Modification and Measure*. This relation is best exemplified by the following sense of the word modification: "the act of changing the shape or dimensions of something but not its nature", "a small alteration, adjustment or limitation" [27].
- *Module and Measure*. While the formal derivation between the words Module and Modus (measure) is absolutely clear, the connection between the corresponding senses might not be clear on the first sight. In fact, this is only because the current sense associated to the word Module does not correspond to its etymology (the etymology of etymology is "true meaning" [28]). The original sense of Module, that is "a standard or unit size of measurement" still appear in some dictionaries (e.g. [27]). However, most of them retain mostly the module-as-component sense. This is especially true in the field of architecture, and in particular in the last decades in Hardware and then Software Architectures. In fact, module-as-measure also comes from the field of architecture, but it is necessary to go back to Ancient Greece. Module was the size of a the diameter of a column, all the proportions of temples being defined in proportion to that measure. A modular architecture is therefore an architecture which dimensions respect proportions to a standard size. The modern expression "modular" kitchen provides a good example: the dimensions of all (modular) components should be proportional to a given size in order to be composed easily. Summing up, the current use of module in (Software) Architecture is the result of the shift from measure to module-as-measure to module-as-modular-component and then to module-as component.

Global etymological models are very useful to get an overview of the history of words. Figure 18.a clearly shows that Model, Mold, Module and Modification all comes from Modus (measure). Sometimes more detailed model are required however. In fact, the global views are derived from detailed yet extensive studies of huge corpus of texts written in different languages. Thanks to these systematic studies, the history of words can be tracked along with their sense. Figure 19.a shows two detailed etymological models representing the history of the english meaning of the word Model and of the word Module. These models are static yet they represent the dynamics of word meanings by mean of explicit dates. These dates correspond to the first known use of a given sense for a given word. This is what is expressed by the OCL constraint in the metamodel Figure 19.b.

MODEL
1575 Noun sense: "architect's set of design"
1639 Noun sense: "thing or person to be imitated"
1665 Verb sense : "fashion in clay or wax"
1691 Noun sense: "artist's model"
1900 Noun sense: "vehicle of a particular design" (e.g. "Model T", 1909)
1904 Noun sense: "fashion model"
1915 Verb sense : "to act as a model, to display (clothes)"

MODULE
1566 Noun Sense: "Alloted measure"
1955 Noun Sense: "Interchangeable part"
1961 Noun Sense: "Separate section of spacecraft"

(a) Detailed historical models of word usages of Model and Module in English



(b) A metamodel for (a)

Figure 19 Examples of detailed etymological (meta)models

7 Putting all together

In this paper many models of the notion of model have been presented, but all perspectives have their limitations:.

- Megamodels are often considered as too abstract and they don't explain what is a model in practice.
- Encyclopedias provide in-depth coverage of given topic, but they focus only on one sense of models.
- Dictionaries describe all senses of models but their lack of structure hinder any useful synthesis.
- Thesauri are well structured but one can still rapidly get lost with the large number of senses of Model.
- Etymology brings an historical dimension but focusing on the evolution of the word rather than its senses.

This section briefly presents the integration of these multiple points of view in some synthetic model.

7.1 The many senses of the word Model in the "S" mega-pattern

What has been missing is the a way to form consistent groups of senses. As shown in Figure 20, the "S" mega-pattern actually provides an excellent means, not only to form groups, but also to determinate their relative positions according to μ and ε and relations. All the senses given in the VisualThesaurus model (Section 5) have been classified leaving aside "somebody who wears clothes to display fashion", which is anyway a sense that occurs after many derivation. The various synonyms of the word model has been classified as well. As it can be seen, all positions in the "S" mega-pattern can receive the designation Model! It should not be surprising in that condition that speeches and texts about modelling could be confusing. To give a precise name to each position, we select a synonym:

- **model-as-representation.** This role corresponds to the working definition used in this paper (Section 1, D1). Models are simplified representations of a system under study. This explains the choice of the name RepresentationOf for the relation μ. The typical example of such model is a map, but the egyptian models and models of ships presented in Section 3 can fit in that category.
- **model-as-example**. This is the counter-part of model-as-representation following the μ link, since it denotes the system under study. A typical example is the model represented by the painter. In the MDE terminology, the model is the system under study, the painter the modeller, and the painting, the model. In fact, in some occasion it quite difficult to determine which is the model and which is the system under study. We believe that this difference, that appear with the distinction between specification model and descriptive model, is mostly driven by the process used. More research is needed on this aspect.

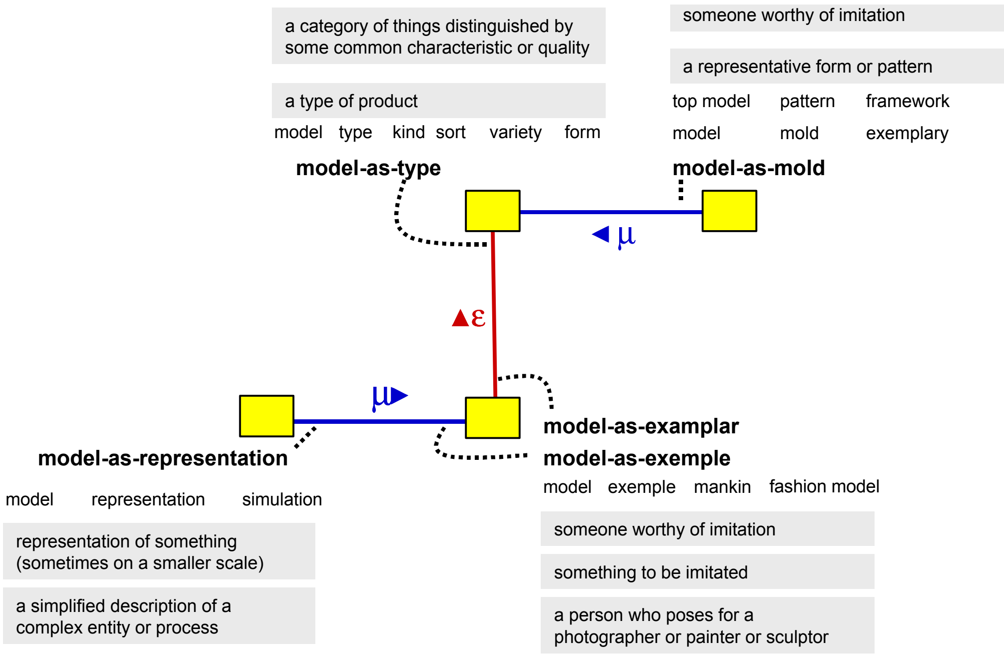


Figure 20 The many senses of "model" in the "S" mega-pattern

- **model-as-type**. A typical example of this sense it the Model-T, type of car. In this case, the term just designates a set of systems, "*a category of things distinguished by some common characteristic or quality*". Obviously confusing model-as-type and model-as-representation leads to great confusion. Our experience shows that this happens very often in informal discussions. Another synonym is be model-as-class.
- **model-as-exemplar.** This is the counter-part of model-as-type following the ε dimension. As shown in Section 5, Figure 16.a Exemplar and Instance are synonyms as example and they fit really in this position since the sense associated to this pair of synonym is "*An item of information that is representative of a type*". Obviously it is tempting to use the name InstanceOf for the ε relation. Following to Bézivin recommendation [5], we prefer to avoid this name because it is overloaded and widely used in the object-oriented technical space. Moreover, as explained below this name would also fit in the relation between as model-as-mold and model-as-exemplar...
- **model-as-mold**. To understand the position of top models in the "S" mega pattern, just consider the following statement "*Claudia Shiffer represents the type of women that men love*". The last part of the sentence is not relevant here, but the first part clearly shows that top models are linked to Type by a μ relation. Note that this is not the type of relation men would like to have with top models. The position of the term pattern, which is a synonym of model, can be justified by the fact that a pattern is a concrete mean to represent a set of similar objects (horizontal μ relation to model-as-type) and generates exemplars of this pattern (the relation on the diagonal is not represented in the figure). This leads to the name of the whole class, model-as-mold. As shown in Section 6 the etymology of the words Model and Mold are very close. The process of bronze molding also shows that these two words are the "two faces of the same coins". The idea of a mold is to generate many exemplars. The expression "to fit on the mold" corresponds to the other way around. Note that this is diagonal is quite close to the relation ConformsTo (μ).

Summing up, the term model can be used to refers to all the positions in the "S" mega-pattern, though these positions are different with respect to the μ and ε links. It is very important to understand that these positions are roles, and that they are relatives to other systems. In particular that means that a system can play various roles at the same time and therefore occupy different positions. For instance, the ship model presented in the Section 3 plays at the same time the role of model-as-representation w.r.t. the actual ship it describes, but also the role model-as-model w.r.t. the various ships it can describe. This ambivalence is also true for the prototypes of car for instance. A car of a model-T could at the same time play the role model-as-exemplar and model-as-mold.

7.2 Megamodelling and Etymology

The next figure shows another interesting findings. Surprisingly, all concepts in the megamodel correspond to a word that derive from the notion of measure (which is said to be the root of all sciences):

- **Model and μ**. This relation is obvious. This is the starting point of all this study. The link with the notion of measure comes from scale models. Models were already used in Ancient Egypt.
- **Module and δ**. The decomposition of systems and subsystems is obviously linked to what we call today the notion of architecture. The relation with the word module is direct. The connections with the notion of measure comes from the construction of temples in Ancient Greece.
- **Mold and χ**. A mold can be seen either as a way to generate systems, or in the other way around as a way to check if a given system conforms to the mold, hence the expression "to fit in the mold". The relation between mold and measure is obvious. The relation between mold and model comes from the early day of bronze moulding. Note that a metamodel is not a mold, but a mold of models (see the "meta-step" pattern).
- **Modification and dynamic systems**. Modification comes from changing the measure without changing the nature. A dynamic system is a system that supports modification.

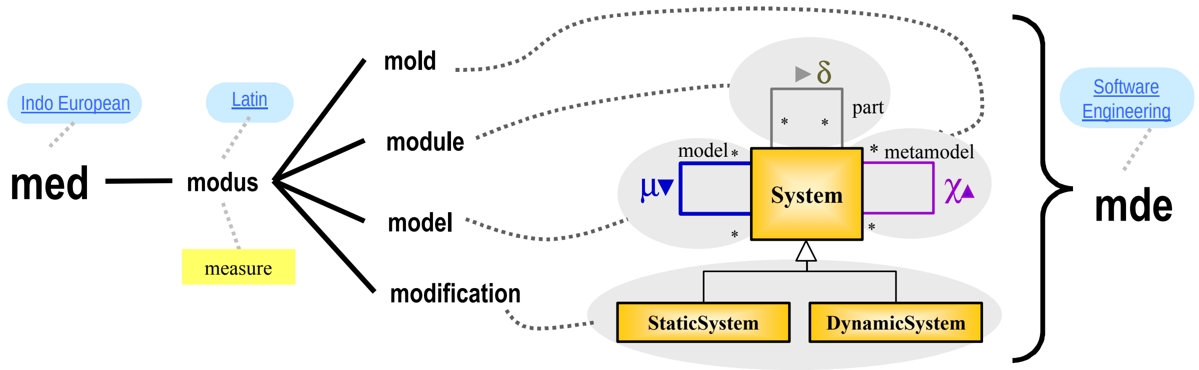


Figure 21 Relating Etymology to Megamodelling : from med to mde

Interestingly we found a similar mapping between etymology, metamodelling and arts, but this will be the subject of a subsequent episode [27].

7.3 Is a metamodel a model of a model?

As said in this introduction the answer to this question is a source of debate. Here is a rational explanation based on the disambiguation of the term model. Since this question is often asked without any previous agreement on the sense used for the term model, it simply can't be answered. Let us consider various combinations (see Figure 22). For the sake of simplicity only the senses model-as-representation and model-as-mold are combined.

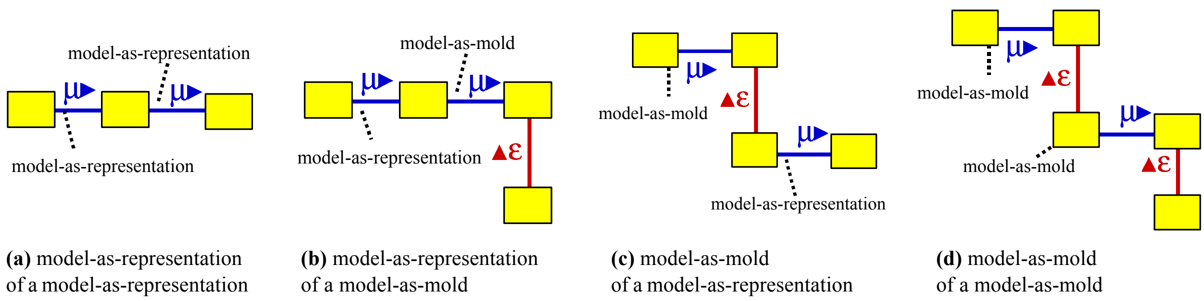


Figure 22 Four interpretations of "a model of a model"

Answering to the question without using the graph is difficult. With the graph it is enough to determine if the first model on the left is playing the role of metamodel, in other words if there is an occurrence of the a "meta-step" or "Z" pattern. The answers are therefore:

- (a) NO. Being a model-as-representation of a model-as-representation does NOT imply being a metamodel. This is the answer given by Bézivin [6]. This should be the answer if one agree with the definition D1. As an example a drawing of a map of the world does not play the role of metamodel with respect to the map.
- (b) NO. Being a model-as-representation of a model-as-mold does NOT imply being a metamodel.
- (c) YES. Being a model-as-mold of a model-as-representation is equivalent to being a metamodel.
- (d) YES. Being a model-as-mold of a model-as-mold implies being a metamodel, but the inverse is false: some metamodels are not model-as-mold of a model-as-mold.

While the book on EMF answers YES to this question, it does not provided any definition of what is a model. In any case, this could not be the definition (D1). Other solutions are quite weird, especially (c) since this would mean that two different senses of the same word would be used in the same sentence. Here is what is called the meta-muddle.

7.4 Terminology in Model Driven Engineering

The polysemy of the word Model is indeed omnipresent in Software Engineering and more generally in Computer Science. Let consider the field of databases, which is a particular technical space with respect with Model Driven Engineering. Just like other technical spaces, a jargon is used to communicate among this community. In this field the term model is used at three different levels and with different senses (see Figure 23).

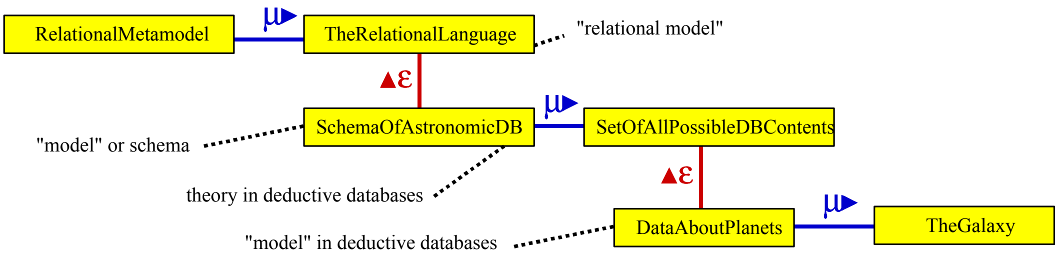


Figure 23 Example of a megamodel from the dataware technical space

First the expression "relational model" is an expression that should be understood as "relational language" or "relational model-as-type" or even better "relational modelling language" (note that the term model in "component model" is similar). It makes sense speaking of the metamodel of the relational model, but this just means the model that represents the relational language, in other words the metamodel used to expressed relational schemas. It is called "relational metamodel" in the Figure 23.

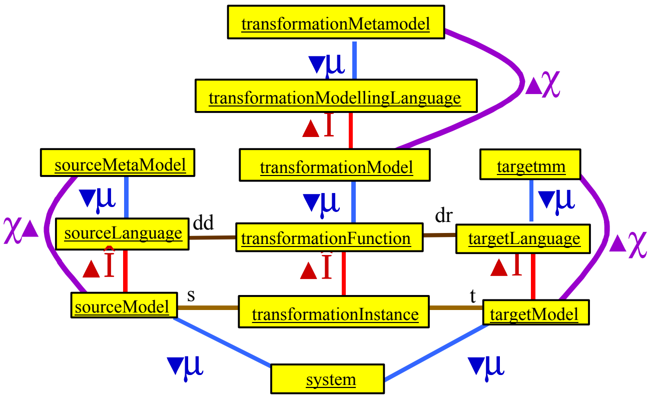
Relational schemas are also called "model" in the database community, though they are elements of the "relational model". Here we can either use the sense model-as-mold or model-as-representation. As shown in Figure 23 a relation schema also play the role of metamodel, the model being the content of the database labelled "DataAboutPlanets".

Finally in the community of deductive databases the content of the database is called a "model". The content of the Astronomic database obviously plays the role of model(-as-representation) with respect to the system under study, here the galaxy. But this not however the sense used. This terminology comes instead from the field of logics and in particular from the theory of models. In this theory, Model refers to the term model-as-exemplar with respect to what is called theory which play the role model-as-mold. In simple words, a model in this theory is a positive example that validate a theory, here the schema of the database.

People in the dataware community get used to these terms, but obviously the term model just raises a lot of discussions and debate when communicating with people from the Model Driven Engineering community. Again, we think that one of the most common mistakes is to believe that being a "model" is an intrinsic property of a system, while it is instead a role that a system can play. In fact, the concept of megamodel proved very useful to solve terminological issues. For instance Figure 24.a shows how different sources in the MDE literature use different names to refer to the relation presented in our megamodel. Mega-pattern are also very effective to compare termi-

	μ	ε	χ
MDA Guide 1.0			instanceOf
MDA Distilled	"abstract"	"classify"	isCapturedIn applicationOf instanceOf
MDA Explained	describes isDefinedBy	isWrit-tenIn	
QVT DSTC			< instance
QVT Partners			
A			instance "conforms"
B	models	lies upon	
C			instanceOf
D			instanceOf describedBy
E			< instance

(a) comparing megamodel relation names



(b) The "Transformation" mega-pattern with possible role names [

Figure 24 Frameworks to compare terminologies

nology. The "Transformation" mega-pattern introduced in [22], has been used to compare the terminology used in different sources of information. As the reader can see, there is absolutely no consensus on what is a transformation, and the debate on the word model is likely to reproduce with transformations, mappings, and so on. This will lead to the transfo-muddle.

	Transfo. Instance	**Transfo. function**	**Transfo. model**	**Transfo. program**	**Transfo. progr. lang.**	**Transfo. meta-model**	**Transfo. interpreter**
MDA Guide 1.0	Transfo.		Mapping		Mapping language		
MDA Distilled	Mapping		Mapping function				
MDA Explained	Transfo., Mapping		Transfo. definition				Transfo. tool
QVT DSTC	"Tracking"		Transfo.			Transfo. model	Transfo. engine
QVT Partners			Transfo. Relation	Mapping Relation			
F	Transfo.		Transfo pattern				
G		Mapping	Model of mapping		Mapping formalism		
H				Transfo spec.			Transformer
I	Transfo. process		Transfo descr.				
Model Reuse				Mapping			Generator

7.5 From MED to MDE : the full picture

This last model represent the etymology of MDE.

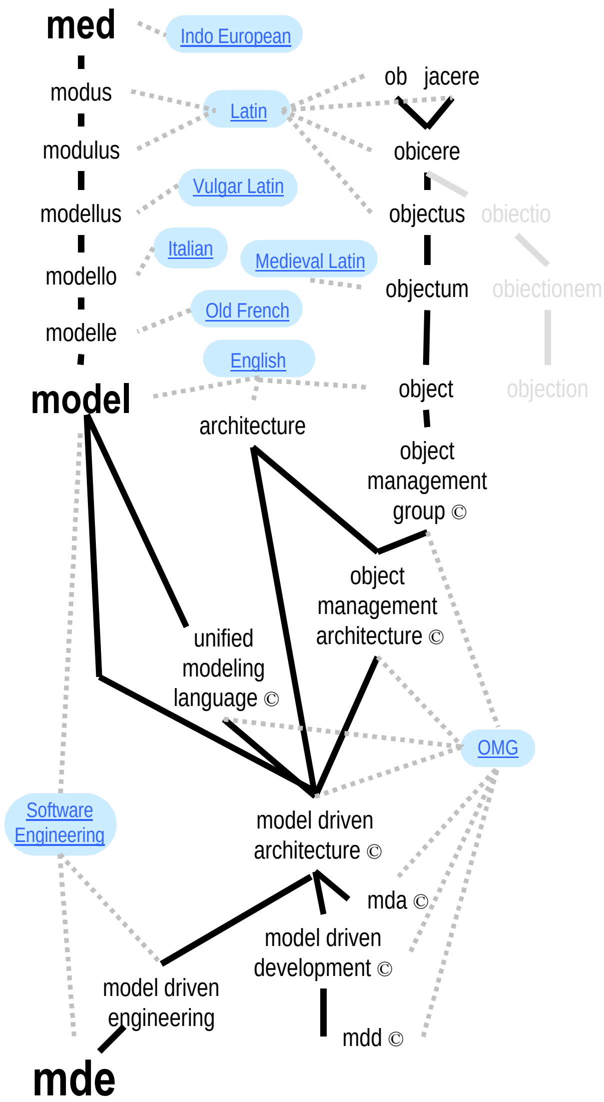


Figure 25 The Etymology of Model Driven Engineering : from med to mde in 5 millenniums

8 Acknowledgments

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9 Photographic credits

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