From Model Transformations to Model Driven Interoperability

Oslo | Apr, 21st 2008

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"Please allow me to introduce myself, I'm…"*

- Jean-Pierre Bourey (jean-pierre.bourey@ec-lille.fr)
- Teaching domains
  - Software Engineering
  - Object-Oriented Modelling (UML)
  - Enterprise Modelling
  - Information Systems (Oracle)
  - Programming Language (Ada)
- Research domains
  - Petri Nets for Automated Systems
  - Modelling, Model Transformations,
  - Model Driven Interoperability

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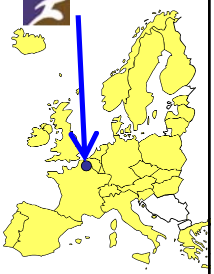

*[Rolling Stones, Sympathy for the Devil, Beggars Banquet, 1968]

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- Teaching domains
  - Software Engineering
  - Object-Oriented Modelling (UML)
  - Enterprise Modelling
  - Information Systems
  - ERP
- Research domains
  - Model Driven Interoperability
  - Knowledge Management

Objectives and Prerequisites

- Objectives
  - To give an overview on Models, Modelling and Model Transformations
  - To present an example of the use of a transformation language
  - To explain the OMG's Model Driven Architecture®
  - To present the current works on Model Driven Interoperability
  - To illustrate pragmatically all these points on concrete tested examples
- Prerequisites (but not strict)
  - To be able to read UML class diagrams
- OMG, Object Management Group, MDA, Model Driven Architecture, Model Driven Development, XMI, UML, Unified Modeling Language are either registered trademarks or trademarks of Object Management Group,Inc. in the United States and/or other countries.

Outline

- Part I: Models and Model Transformations
  - 1.1) Definitions: Model, Metamodel
  - 1.2) Transformations and Mappings
  - 1.3) Basic Examples
- Part II: Transformation Techniques
  - 2.1) From Programming Languages to Model Transformation Languages
  - 2.2) Applications
- Part III: Model Driven Architecture
- Part IV: Model Driven Interoperability

Part 1: Models and Model Transformations

1.1) Definitions: Model, Metamodel
1.2) Transformations and Mappings
1.3) Basic Examples

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First Word about Models

"Essentially, all models are wrong, …

but some are useful "
Box, George E. P.; Norman R. Draper (1987)
Empirical Model-Building and Response Surfaces

Basic Concepts: formalism

- Language or formalism
- Set of constructs
  - Providing a **syntax** and a **semantics**
  - Put together according **precise grammatical rules**
  - **To represent an artefact** (object, message, knowledge, …)
- Syntax and Semantics
  - A language is needed to express/communicate the syntax and the semantics

Semantics

- Types of semantics
  - **Real World Semantics**: meaning refers to the real world which is modelled
  - **Formal Semantics**: based on mathematics, to validate, to transform, … …models
- Semantics required
  - To compare languages (used to represent the same thing)
  - To compare models (representing the same thing)
  - To validate models
- But problem of Semantics!
- "Semantics: this does not mean anything!" [Favre 2004]

Formalisms

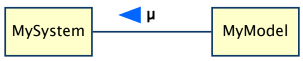
- Examples
  - Petri Nets (places, transitions,…)
  - Grafcet (steps, transitions,…)
  - UML Class Diagram (classes, associations, attributes, …)
  - Differential equations
  - etc

Model

- A **model** is a **consensus** about an **abstraction** of phenomena of the real world: a **representation** of an **aspect** of the world for a specific **purpose**
- Model = Representation
- Types:
  - informal (texts in natural language)
  - semi-formal (descriptive models, graphical notations)
  - formal (mathematical notations, First Order Logic)

Model

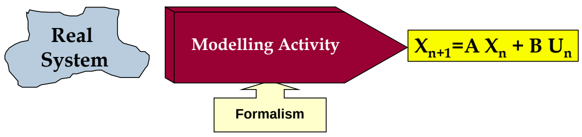
μ = represents



[Favre 2004]

Modelling

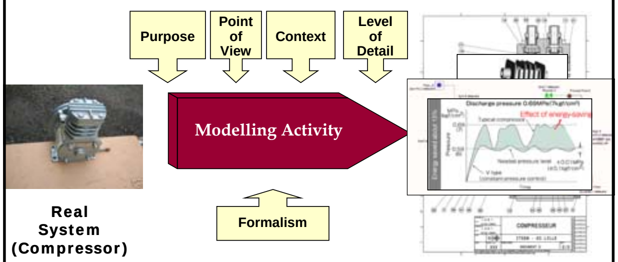
- Modelling
  - Activity of creating models
  - …using a formalism



Fundamental questions

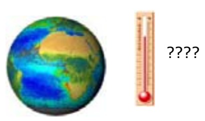
- Fundamental questions about a model :
  - Purpose : to do what ?
  - Scope of the model : context?
  - Point of View : aspects taken into account?
  - Level of detail : precision level?
- Always start with the purpose!

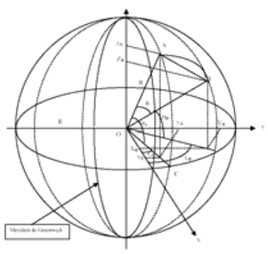
Model, Modelling



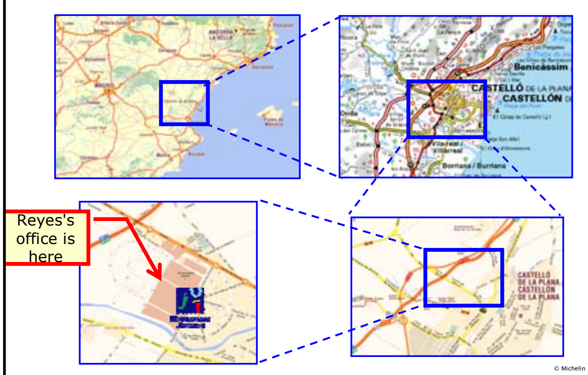
What is a good model ?

- "M is a good model of S if M makes it possible to answer predefined questions about S in a satisfactory way" (Ross)
  - Right level of detail
  - Right point of view

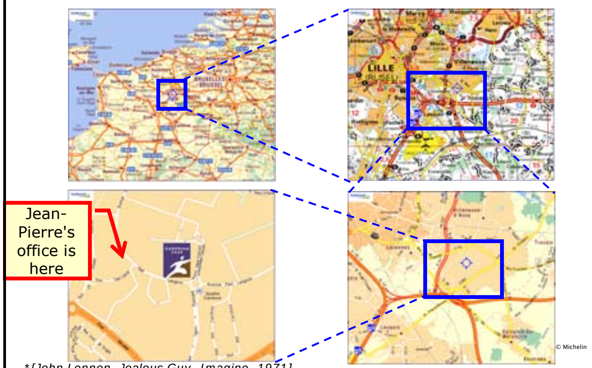




Model and Level of details

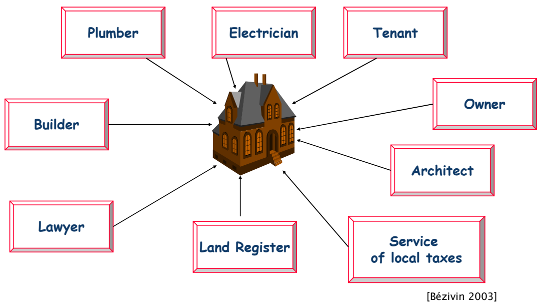


Model and Level of details (since "I'm just a jealous guy"*)

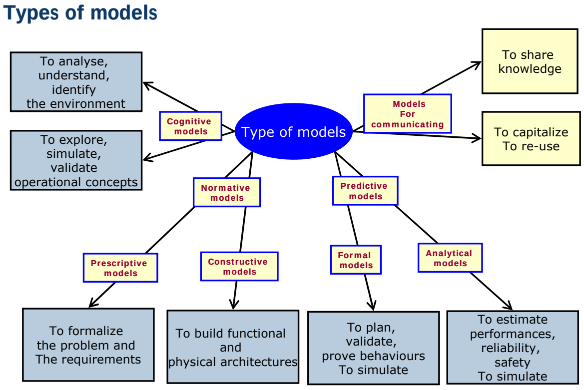


*[John Lennon, Jealous Guy, Imagine, 1971]

Points of view



Types of models



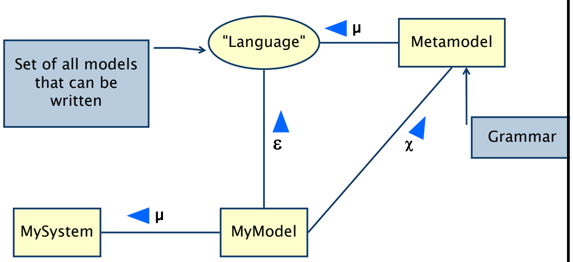
From [http://www.afis.fr]

From Model to Metamodel

- A **metamodel** is yet another abstraction, **highlighting properties of the model itself**.
- This model is said to **be conformed to** its metamodel
  - like a program corresponds to the grammar of the programming language used to write it
- A metamodel can be considered as an **explicit description** (constructs and rules) of **the way to build a domain-specific model**
- What is the exact nature of the relations between system, model, metamodel,... ?

From Model to Metamodel

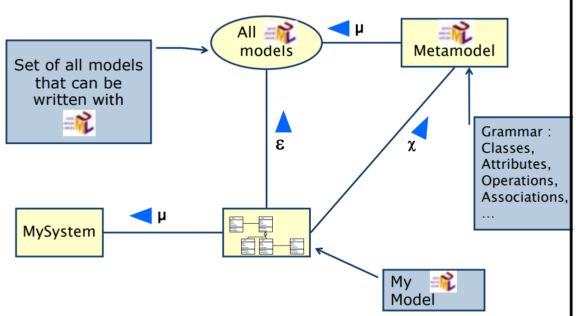
μ = represents
χ = conforms to
ε = belongs to

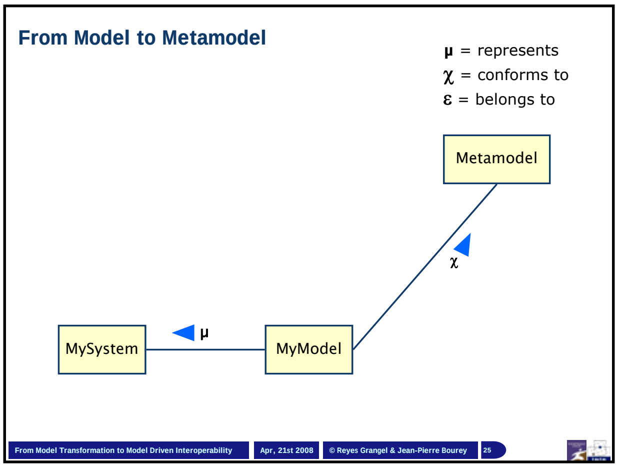


[Favre 2004]

From Model to Metamodel: Example

μ = represents
χ = conforms to
ε = belongs to




From Model to Metamodel
μ = represents
χ = conforms to
ε = belongs to
Metamodel
χ
μ
MySystem
MyModel
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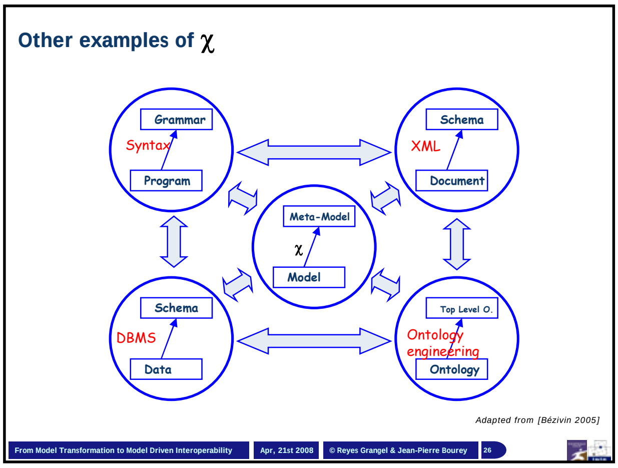
Other examples of χ
Grammar
Syntax
Program
Schema
XML
Document
Meta-Model
χ
Model
Schema
DBMS
Data
Top Level O.
Ontology engineering
Ontology
Adapted from [Bézivin 2005]
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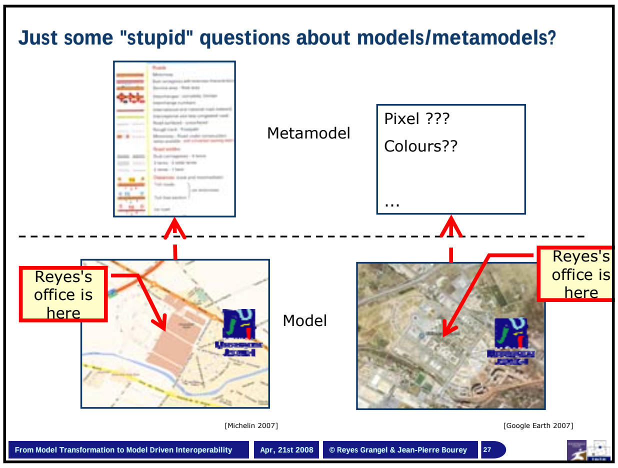
Just some "stupid" questions about models/metamodels?
Metamodel
Pixel ???
Colours??
...
Reyes's office is here
Model
Reyes's office is here
[Michelin 2007]
[Google Earth 2007]
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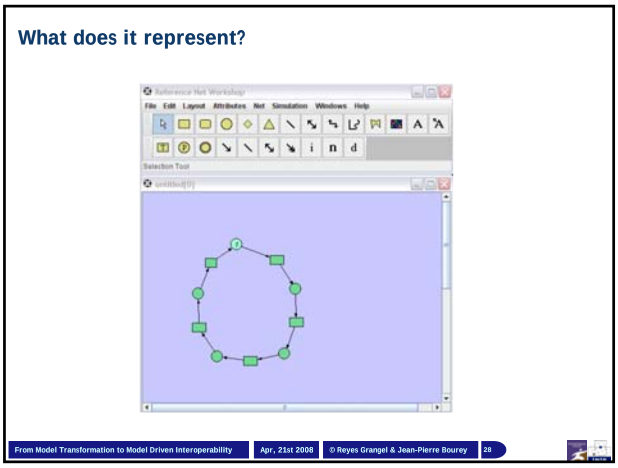
What does it represent?
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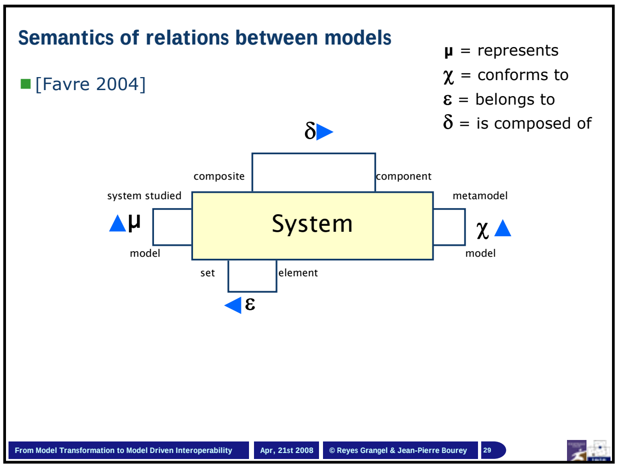
Semantics of relations between models
[Favre 2004]
μ = represents
χ = conforms to
ε = belongs to
δ = is composed of
δ
composite
component
system studied
metamodel
μ
System
χ
model
model
set
element
ε
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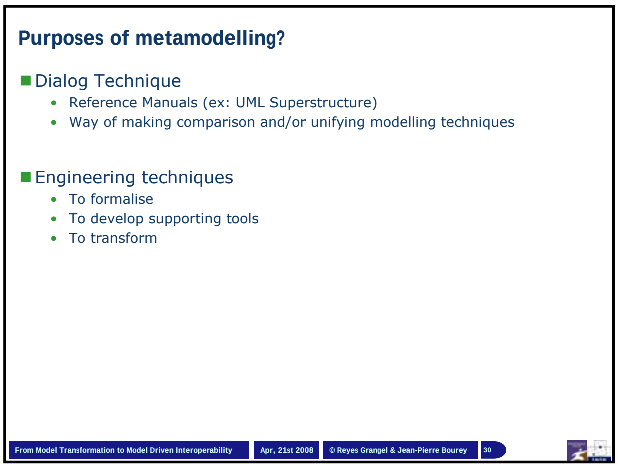
Purposes of metamodelling?
Dialog Technique
Reference Manuals (ex: UML Superstructure)
Way of making comparison and/or unifying modelling techniques
Engineering techniques
To formalise
To develop supporting tools
To transform
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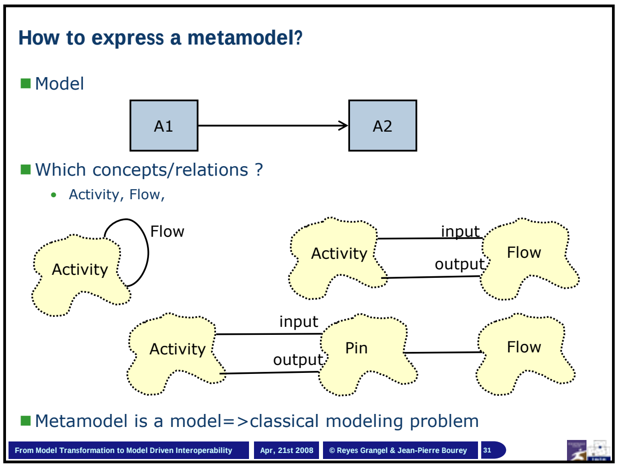
How to express a metamodel?
Model
A1
A2
Which concepts/relations ?
Activity, Flow,
Flow
Activity
Activity
input
output
Flow
Activity
input
output
Pin
Flow
Metamodel is a model=>classical modeling problem
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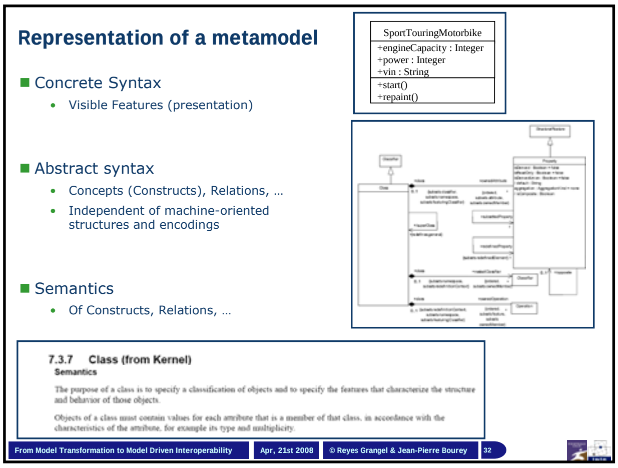
Representation of a metamodel
Concrete Syntax
Visible Features (presentation)
Abstract syntax
Concepts (Constructs), Relations, ...
Independent of machine-oriented structures and encodings
Semantics
Of Constructs, Relations, ...
SportTouringMotorbike
+engineCapacity : Integer
+power : Integer
+vin : String
+start()
+repaint()
7.3.7 Class (from Kernel)
Semantics
The purpose of a class is to specify a classification of objects and to specify the features that characterize the structure and behavior of those objects.
Objects of a class must contain values for each attribute that is a member of that class, in accordance with the characteristics of the attribute, for example its type and multiplicity.
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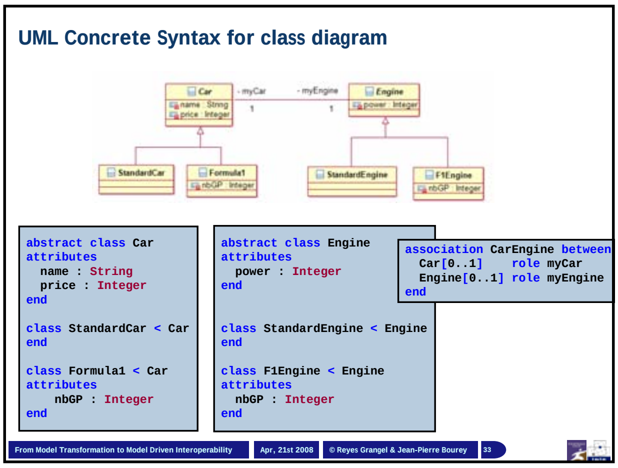
UML Concrete Syntax for class diagram
Car
name : String
price : Integer
- myCar
- myEngine
1
1
Engine
power : Integer
StandardCar
Formula1
nbGP : Integer
StandardEngine
F1Engine
nbGP : Integer
abstract class Car
attributes
name : String
price : Integer
end
class StandardCar < Car
end
class Formula1 < Car
attributes
nbGP : Integer
end
abstract class Engine
attributes
power : Integer
end
class StandardEngine < Engine
end
class F1Engine < Engine
attributes
nbGP : Integer
end
association CarEngine between
Car[0..1] role myCar
Engine[0..1] role myEngine
end
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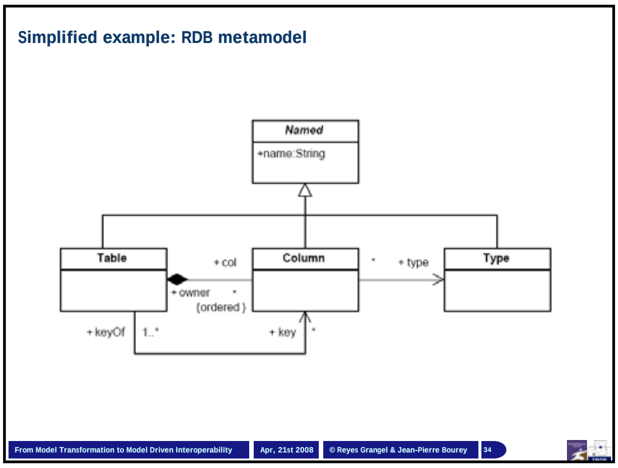
Simplified example: RDB metamodel
Named
+name:String
Table
+ col
Column
*
+ type
Type
+ owner
{ordered }
+ keyOf
1..*
+ key
*
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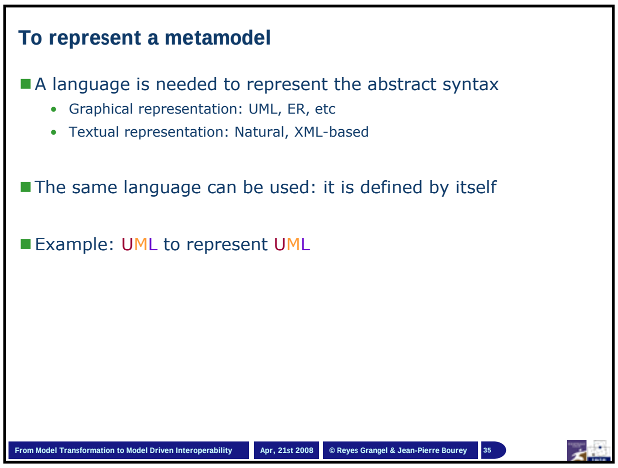
To represent a metamodel
A language is needed to represent the abstract syntax
Graphical representation: UML, ER, etc
Textual representation: Natural, XML-based
The same language can be used: it is defined by itself
Example: UML to represent UML
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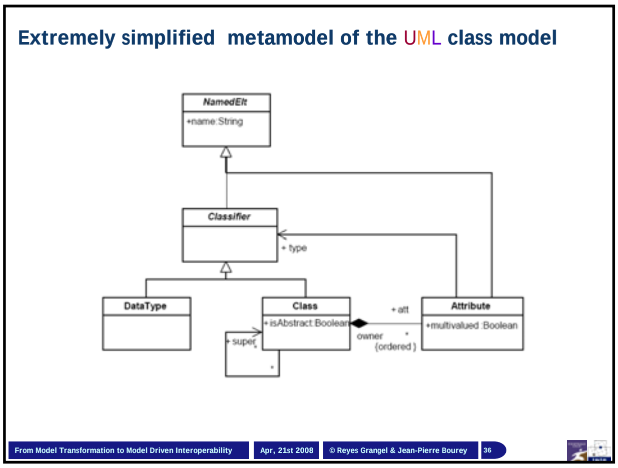
Extremely simplified metamodel of the UML class model
NamedElt
+name:String
Classifier
+ type
DataType
Class
+isAbstract:Boolean
+ super
+ att
Attribute
+multivalued:Boolean
owner
{ordered }
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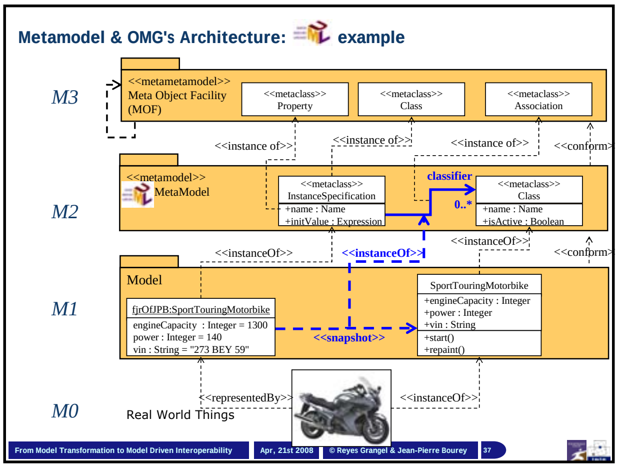

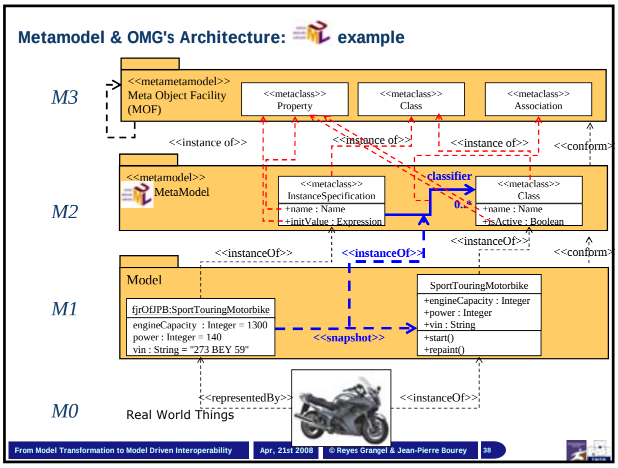

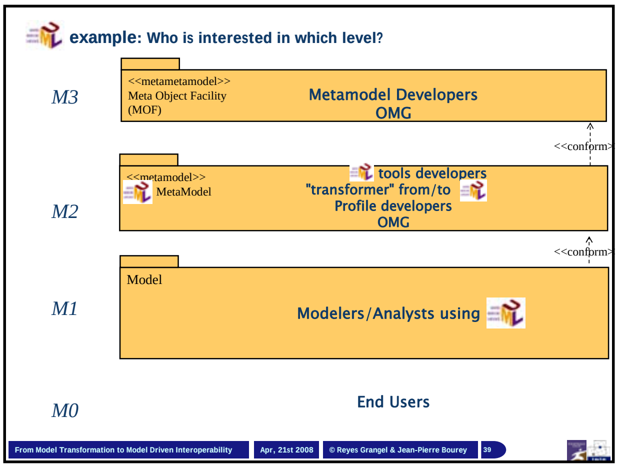

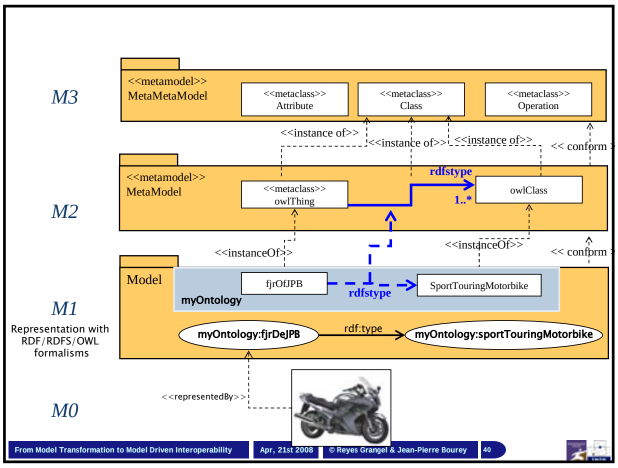

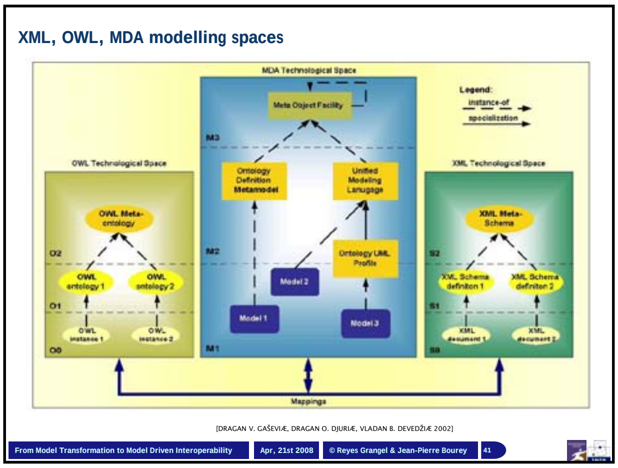

Model, MetaModels & Model Driven Engineering

- **Model-Driven Engineering** (or **MDE**)
  - systematic use of **models** as **primary engineering artefacts** throughout the engineering lifecycle
- In MDE
  - Models are considered as first class citizen
  - Everything is model
- MDE can be applied to
  - software,
  - system,
  - data engineering,
  - …
- OMG's **Model Driven Architecture (MDA)** is one MDE initiative
- MDE is based on **Model** and **Model Transformations**

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Last words about Models

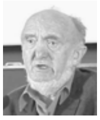
"We don't see the world with our eyes,...

We see it with our concepts"

From "Petite philosophie à l'usage des non philosophes" 1997

Albert Jacquart (1925-)

Genetician, Writer



Part 1: Model Transformations

1.1) Definitions: Model, Metamodel

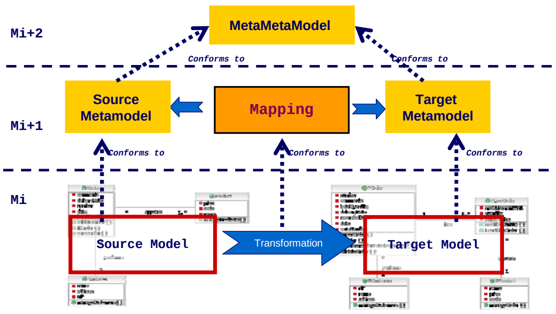
1.2) Transformation and Mappings

1.3) Basic Examples

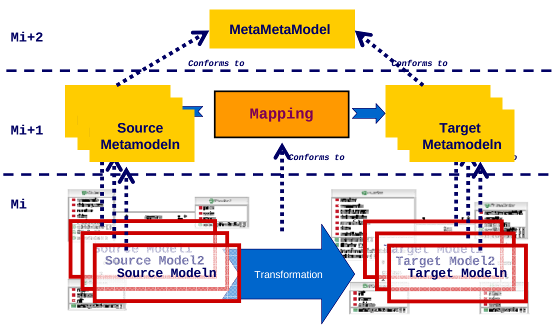
Model Transformation

- A Model Transformation takes a model and produce another model
- Model Transformations are …
- …..Models

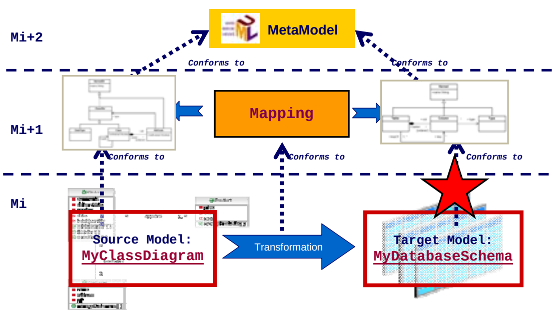
Transformation Architecture



Model Weaving



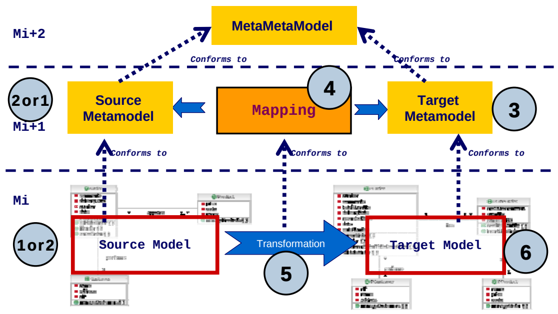
Transformation: UML2RDBMS



Mapping

- A specification for a Transformation [MDA 2003]
- Synonym: Model Morphism [MoMo 2006]
  - a **morphism** is an abstraction of a structure-preserving process between two mathematical structures
- To establish correspondences between
  - one or more constructs of the source language
  - and 0 or more constructs of the target language.

Transformation Architecture

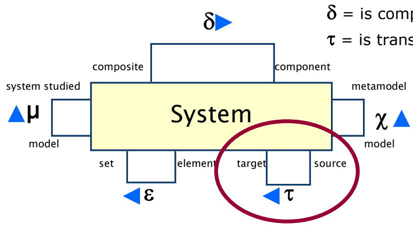


Transformation

- Takes input(s) and produces output(s)
  - One way process
- Composable
- Specialisable
- Classification of transformations
  - "Manual" / Tool Supported
  - Vertical (Example: code generation) / Horizontal (Example: UML2ER)
  - Reversible / Not Reversible
  - Endogenous / Exogenous

Semantics of relations between models

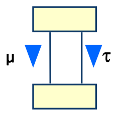
μ = represents
χ = conforms to
ε = belongs to
δ = is composed of
τ = is transformed into



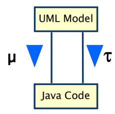
Vertical transformation

μ = represents
χ = conforms to
ε = belongs to
δ = is composed of
τ = is transformed into

- Forward engineering transformation



- Example

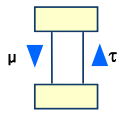


[Favre 2004]

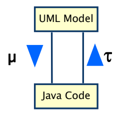
Vertical transformation

μ = represents
χ = conforms to
ε = belongs to
δ = is composed of
τ = is transformed into

- Reverse engineering transformation



- Example

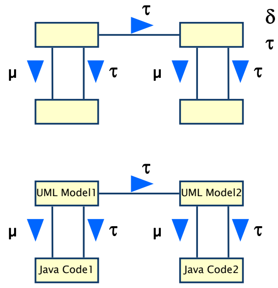


[Favre 2004]

Combination

- Model Driven Evolution

μ = represents
χ = conforms to
ε = belongs to
δ = is composed of
τ = is transformed into



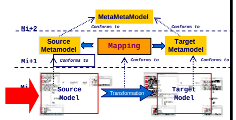
- Example

[Favre 2004]

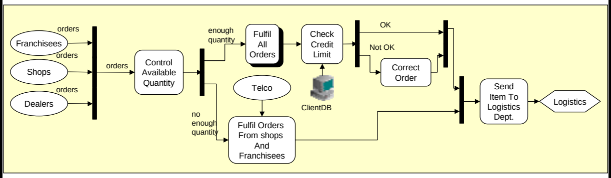
Part 1: Model Transformations

1.1) Definitions: Model, Metamodel
1.2) Transformations and Mappings
1.3) Basic Examples

Objective

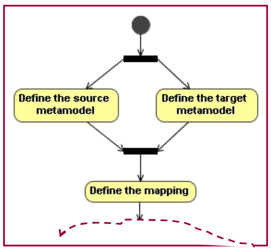


- To build a simple mapping
- From GRAI Extended Actigram to UML Activity Diagram



Method

- First steps



- Overview of the GRAI Extended Actigrams
- GRAI Extended Actigram Metamodel
- UML Activity Diagram Metamodel
- Mapping Proposal

GRAI Methodology

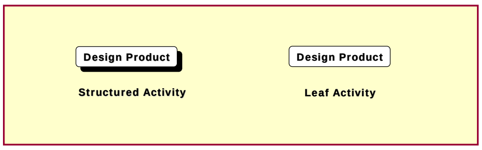
- It is an Enterprise Modelling Methodology
  - Under development since 1980 by the LAP Research Laboratory
- Developed using
  - A set of basic notions of the GRAI conceptual reference model
  - Graphical notations to describe models
- Takes several aspects into account
  - Decision-making
  - Functions/Processes
  - Information

GRAI Methodology: Extended Actigram

- Derived from IDEF0 (**I**CAM **DEF**inition) /SADT
- Built on
  - 3 primary concepts
    - Process
    - Activities
    - Flows
  - 3 secondary concepts
    - Connectors
    - Logical operators
    - Resources

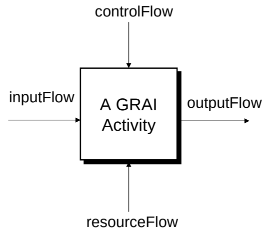
GRAI Process and Activity

- Process
  - Set of logically sequenced activities
- Activity
  - Transformation, production
  - Can be broken down: Structured Activity



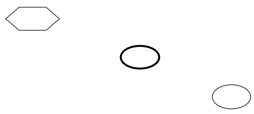
GRAI Flows and Resources

- Different flow types
  - Input
  - Output
  - Control
  - Resource
- Resource
  - Material/Human
- Flow
  - Information/Product

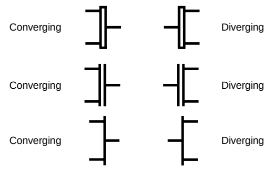


GRAI Connectors and Logical Operators

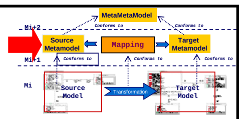
- Connectors
  - Process
  - Internal
  - External

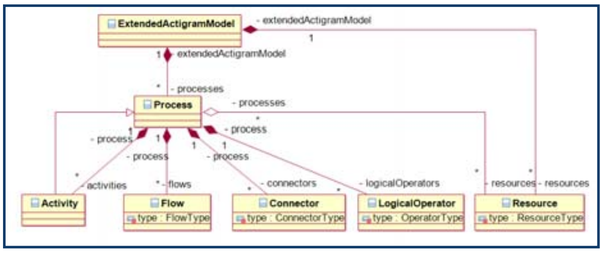


- Logical Operators
  - Synchronous And
  - Asynchronous And
  - OR

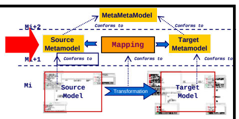


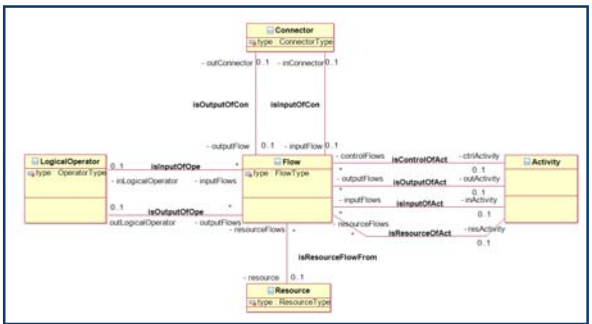
GRAI EA Metamodel: Structure





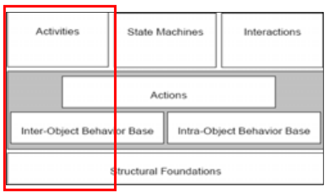
GRAI EA Metamodel: Flow Connections



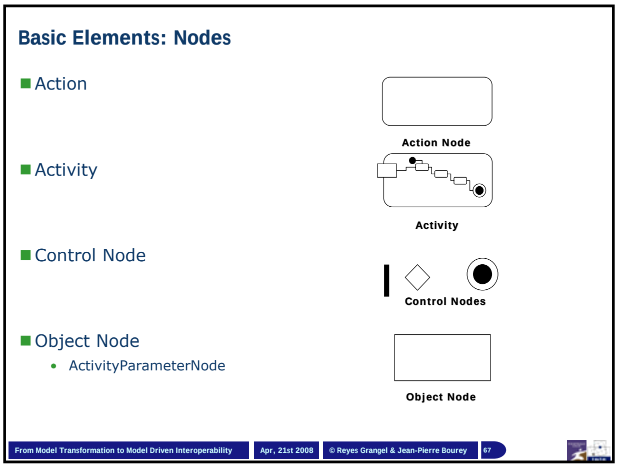


UML Activity Diagram

- Used to describe
  - Inter-object behaviour
  - Actions
  - Process



Source : [UML Superstructure 2.0]


Basic Elements: Nodes
Action
Activity
Control Node
Object Node
ActivityParameterNode
Action Node
Activity
Control Nodes
Object Node
From Model Transformation to Model Driven Interoperability
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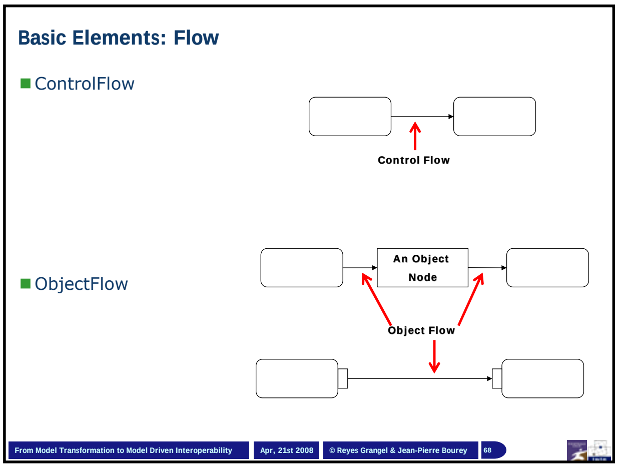
Basic Elements: Flow
ControlFlow
ObjectFlow
Control Flow
An Object Node
Object Flow
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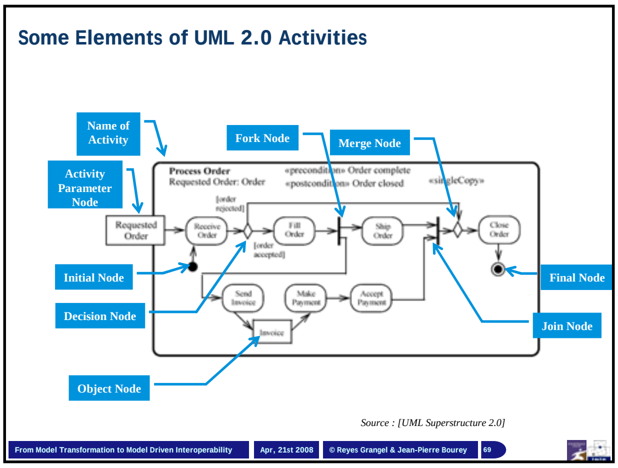
Some Elements of UML 2.0 Activities
Name of Activity
Activity Parameter Node
Fork Node
Merge Node
Initial Node
Decision Node
Object Node
Final Node
Join Node
Process Order
Requested Order: Order
Source : [UML Superstructure 2.0]
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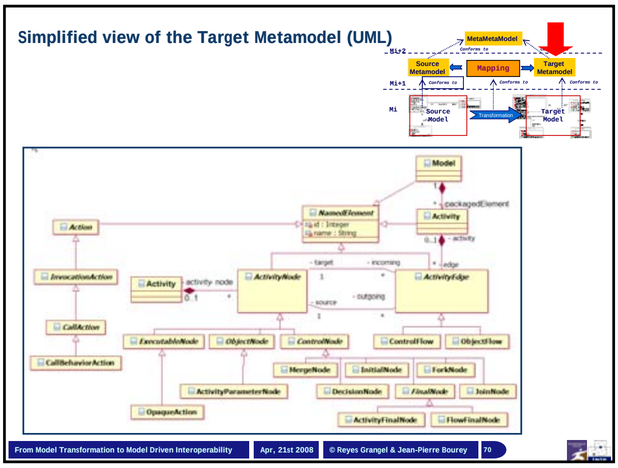
Simplified view of the Target Metamodel (UML)
From Model Transformation to Model Driven Interoperability
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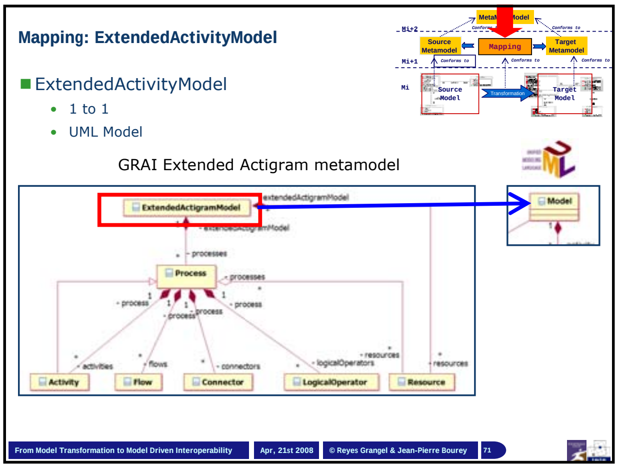
Mapping: ExtendedActivityModel
ExtendedActivityModel
1 to 1
UML Model
GRAI Extended Actigram metamodel
From Model Transformation to Model Driven Interoperability
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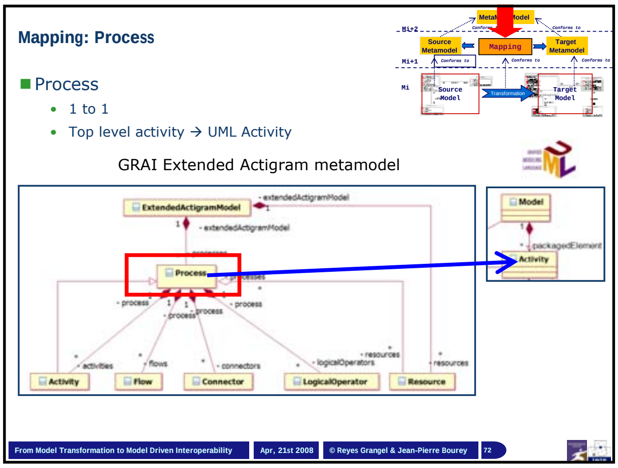
Mapping: Process
Process
1 to 1
Top level activity → UML Activity
GRAI Extended Actigram metamodel
From Model Transformation to Model Driven Interoperability
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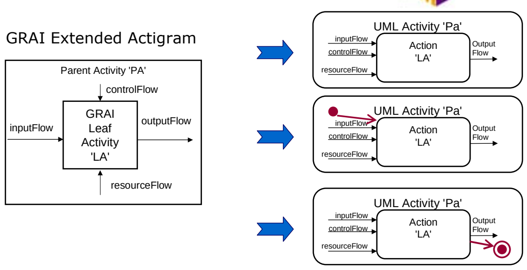
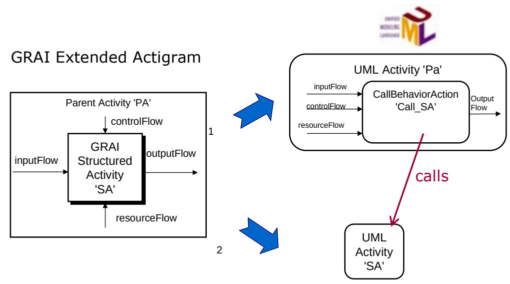
Mapping: Leaf Activities

- Conditional 1 to n
- Leaf Activity
  - UML Action (UML2.0) or OpaqueAction (UML2.1)
  - with optional initial/final elements



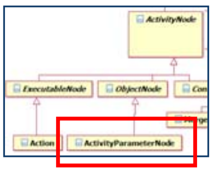
Mapping: Structured Activities

- Structured Activity: several UML candidates
  - UML Structured Activity
  - UML CallBehaviorAction + UML Activity (splitting)



Mapping: Connector, Resource

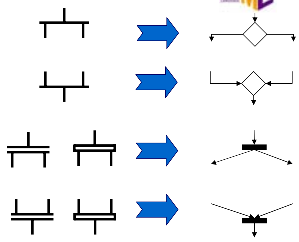
- Connectors and Resources can be considered as "External" from Activity viewpoint
- **Activity Parameter Nodes**
  - Object Node for Inputs and Outputs to Activities
- Connector
  - Many to one:
  - Process, Internal, External connectors => **Activity Parameter Node**
- Resource
  - One to one
  - Resource => **Activity Parameter Node**



Mapping: Logical Operators

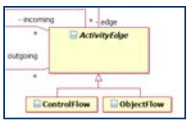
GRAI Extended Actigram

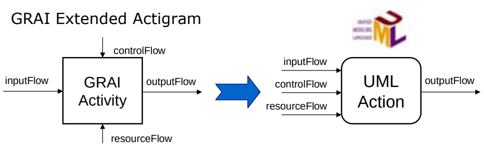
- Diverging OR
  - Decision Node
- Converging OR
  - Merge Node
- Diverging AND
  - Fork Node
- Converging AND
  - Join Node



Mapping: Flows

- Connected to a Resource or Connector
  - ObjectFlow
- Otherwise
  - ControlFlow
- Merge of Input, Resource and Control flows
  - UML input Flow





Mapping Summary

GRAI Extended Actigram	*Condition*	*UML Activity Diagram*
Extended Actigram Model		Model
Process		Activity
Activity	it is a structured Activity	Activity + CallBehaviourAction
	it is a **non** structured Activity	Action
Connector		ActivityParameterNode
LogicalOperator	Converging OR	MergeNode
	Converging AND	JoinNode
	Diverging OR	DecisionNode
	Diverging AND	ForkNode
Resource		ActivityParameterNode
Flow	not connected to a Resource or to a connector	ControlFlow
	connected to a Resource or to a connector	ObjectFlow

Conclusion on the mapping definition

- Detailed knowledge on both metamodels
  - Semantics
    - To find the best appropriated correspondence(s)
  - Syntactic
    - Ensure consistency
    - Ex: mapping of flows
- GRAI EA to UML AD
  - Illustration of different mapping cases
  - Semantic losses
  - Specifies irreversible transformation

Part 2: Transformation Techniques

2.1) From Programming Languages to Model Transformation Languages

2.2) Applications

Transformation Techniques

- Mapping=specifications of transformations
- How to implement these specifications?
- Four main implementation categories

Four categories of model transformation techniques

- General purpose programming languages
  - Java, C++, C#...
- Generic transformation tools
  - Graph transformations, XSLT
- CASE tools scripting languages
  - Objecteering, Rose ...
- Dedicated model transformation tools
  - OMG QVT style , ATL, MTL, MTF...

[Jézéquel 2005]

General purpose programming languages

- Java, VB, C++, C#,... Or your favorite language!
- Currently available in the tools via APIs
- Rules and scheduling implemented from scratch
- Advantages
  - No overhead to learn a new language
  - Tool support to write code (powerful IDE)
- Drawbacks
  - Programming effort
  - Maintenance

Generic Transformation Tools

- awk-like (awk, sed, ...)
  - Limited to 100 LOC
- XSLT to transform XML trees into other (XML) (trees)
  - More batch than interactive
  - Parameters are passed by values
  - More focus on syntax than semantics
  - XSLT transformations are not really easy to maintain (<1000 LOC)
- Graph Transformation Based
  - Declarative, based on theory of graph transformation/rewriting
  - Require careful consideration of termination of the transformation process and the rule application ordering
  - Examples
    - VIATRA2 [VIATRA2 2006],
    - GReAT(Graph Rewriting And Transfomation) [GreAT 2003]

CASE tool scripting languages

- Dedicated to a specific tool
- Example: **Objecteering** (Softeam)
  - J language
- Advanta
  - Comp
  - "Powe
- Drawbac
  - Comp
  - Often
  - Often

```
Package:listClasses ()
{
    OwnedElementClass
// Going through the Package classes
   {
      StdOut.write(NL, "CLASS:", Name);
      PartOperation.<select (Visibility == Public)
      // Going through the method's public classes
      {
         StdOut.write(NL, " Public method:", Name);
      }
   }
} // End of "listClasses
```


Tools dedicated to model transformation

- Declarative, Imperative, Hybrid,
  - **Declarative**: Declarative language describes relationships between variables in terms of functions or inference rules and the language executor (interpreter or compiler) applies some fixed algorithm to these relations to produce a result
  - **Imperative**: Any programming language that specifies explicit manipulation of the state of the computer system
  - **Hybrid**: combination of both
- Rule based
  - Invocation of the transformation rules
    - **Explicit**, via invocation operations (Java like)
    - **Implicit**, based on context and rules signature (Prolog like)

Tools dedicated to model transformation

- Example
  - OMG QVT RFP
  - ATL, MTF, MTL, ...
- Advantages
  - Openness
  - Separation Rule/Engine
- Drawbacks
  - New languages
  - "Prolog" Style
  - "Immaturity"

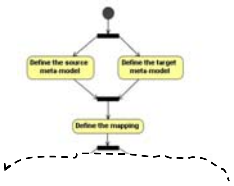
Part 2: Transformation Techniques

2.1) From Programming Languages to Model Transformation Languages

2.2) **Applications**

Application

- Back to the Transformation of GRAI Extended Actigram to UML Activity diagram
- Last steps of the proposed method



Reminder on the mapping

GRAI Extended Actigram	*Condition*	*UML Activity Diagram*
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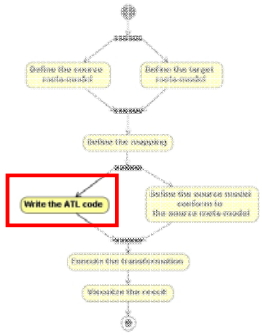
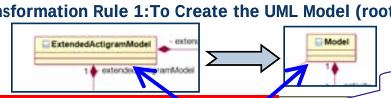
	it is a **non** structured Activity	Action
Connector		ActivityParameterNode
LogicalOperator	Converging OR	MergeNode
	Converging AND	JoinNode
	Diverging OR	DecisionNode
	Diverging AND	ForkNode
Resource		ActivityParameterNode
Flow	not connected to a Resource or to a connector	ControlFlow
	connected to a Resource or to a connector	ObjectFlow

Write the ATL Code

- Presentation of one simple rule



Transformation Rule 1:To Create the UML Model (root of the model)




```
rule GraiExtendedActigram2UmlModel{

from
source :
  GraiExtendedActigramMetaModel!ExtendedActigramModel

to
target : UML2!Model (
  name    <- source.name
)-- end of 'to' section

do {
  --Store the Model node in a global variable
  thisModule.Global_UmlModel <- target ;
}-- end of rule 'GraiExtendedActigram2UmlModel'
```

Rule to create the UML model

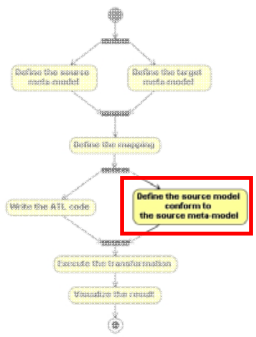
Input of the rule

Output of the rule with attribute setting

Additional Action

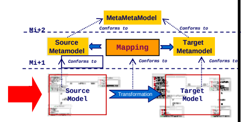
Define the Source Model

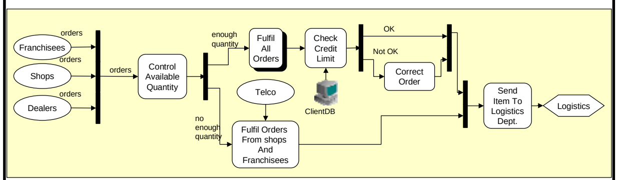
- Presentation of the source GRAI Extended Actigram



The Sales Process Model

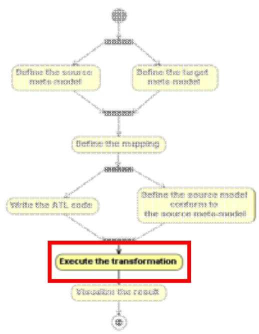
- Model "coding"





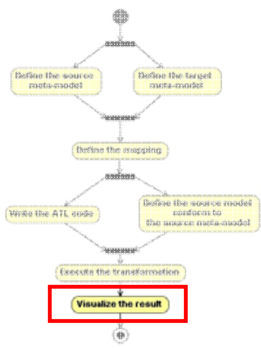
Execute the Transformation

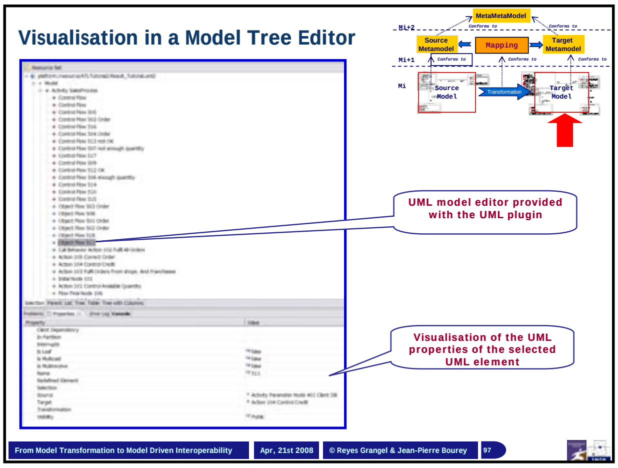
- Within a tool

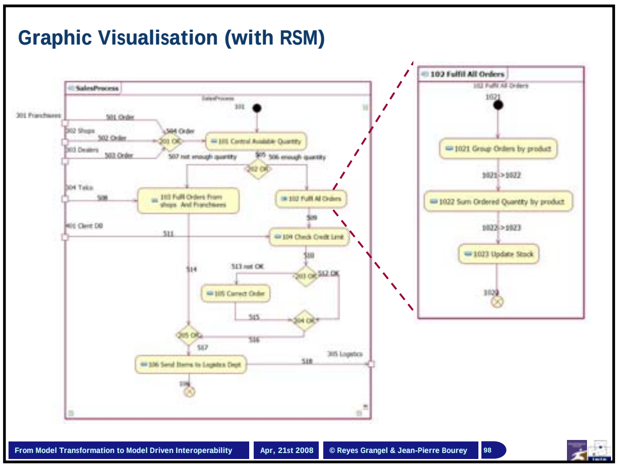


Visualise the Transformation

- "Rough" Visualisation
- Tree Editor Visualisation
- Graphic Visualisation







Part2: Conclusion

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Conclusion and some issues

- Technical/practical presentation of Model Transformation
- Essential to understand the Model Driven approaches issues
- But important problems still remain:
- How to define a metamodel
  - Which level of details?
  - Which point of view?
  - What are the constructs ?
  - What is the semantics?
  - …
- How to define a mapping (Mapping discovery)?
  - How to choose the "good" matching between constructs?
  - How to formalize it?

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Part 3: Model Driven Architecture

3.1) Inside Model Driven Architecture
3.2) Abstraction Levels: CIM, PIM, PSM

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Model Driven Architecture

- Initiative from the software engineering community called "Model Driven Development" (MDD)
- Principle: First develop models, and then transform
- Model Driven Architecture has been developed in this context by the OMG

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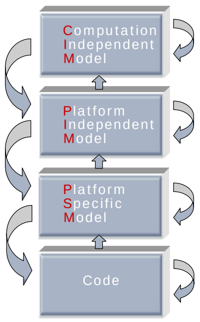
MDA's Main Components

- MDA specifies 3 viewpoints
  - Computation independent
  - Platform independent
  - Platform specific
- Platform
  - Generic
    - Object, Batch, Dataflow
  - Technology Specific
    - CORBA, Java2Component
  - Vendor Specific
    - .NET, IBM Websphere,...
- =>Separation of concerns
- Model Transformations



Computation Independent Model (CIM)

- Specify business processes, stakeholders, departments, dependencies between processes, and so on
- Represents the system requirements
- Does not show details of the structure of systems
- Domain specific model specified by domain experts
- Is made-up two subdivisions:
  - Business Model
  - Business Requirements for Systems

Platform Independent Model (PIM)

- Shows a high level of abstraction
- Independent of any specific implementation technology= assumed to be executed on technologically independent virtual machine
- Describes the requirements of the software system

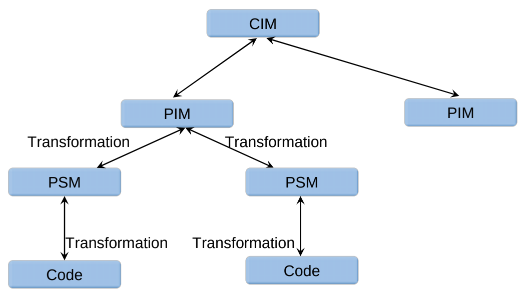
Platform Specific Model (PSM)

- Describes the system in one specific implementation technology
- A PIM is transformed into one or more PSMs
- A separate PSM is generated for each specific technology platform
- Example:
  - PSM for Relational Database (column, foreign key, etc.)
  - PSM for Enterprise Java Beans (entity bean, home interface, session bean, etc.)

Code

- Represents the final step in development
- Generated automatically

The MDA Transformation Steps

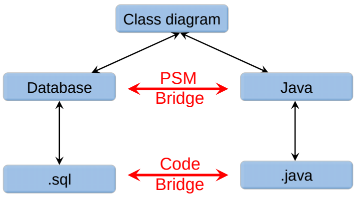


MDA Benefits

- Productivity Gain
  - Minimises the development time
  - More focused on PIM development
  - Better functionality in less time
- Portability Benefits
  - A PIM can be transformed into multiple PSMs
  - The PIM describes a portable specification

MDA Benefits

- Interoperability Benefits

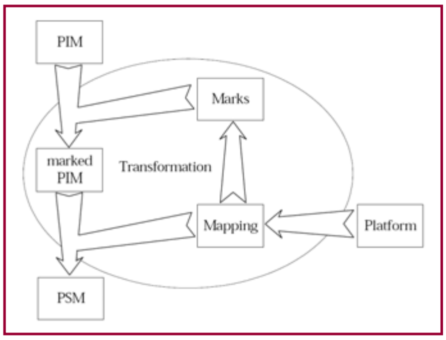


- Documentation Benefits
  - The documentation is kept up to date
  - The PIM represents the high level documentation
  - Consistency between high level of documentation and code is maintained

Some Model Transformation Approaches

- Marking and pattern
  - Mark=a concept of the PSM applied to a PIM element to indicate how to transform it
  - The marked elements of the source are transformed according to the pattern to produce the target.
- Automatic transformation
  - no need of additional information to produce the target
- Metamodel transformation

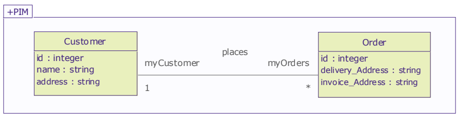
Marking



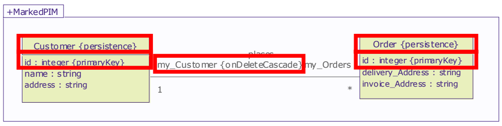
[MDA 2003]

Marking: Example (Objecteering 6.0)

- PIM Model

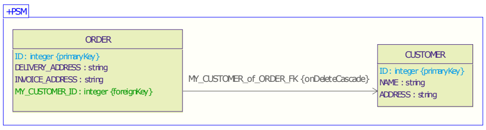


- Marked Model



Marking: Example

- PSM

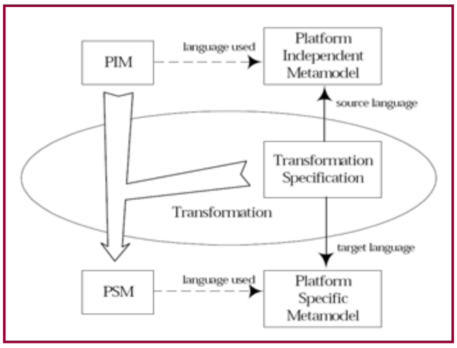


- Code

```
CREATE TABLE ORDER(
   ID                INTEGER  NOT NULL ,
   DELIVERY_ADDRESS VARCHAR2(100) ,
   INVOICE_ADDRESS  VARCHAR2(50) ,
   MY_CUSTOMER_ID   INTEGER  NOT NULL );

ALTER TABLE ORDER ADD (
   CONSTRAINT ORDER_PK PRIMARY KEY (ID)
);
ALTER TABLE ORDER ADD (
   CONSTRAINT MY_CUSTOMER_of_ORDER_FK FOREIGN KEY (MY_CUSTOMER_ID)
      REFERENCES CUSTOMER(ID)
   ON DELETE CASCADE);
```

Metamodel Transformation



[MDA 2003]

The MDA Paradigm Shift

- Main goal
  - To perpetuate the development efforts concerning rapidly changing technologies
- A real shift of focus from code to models where code will be generated automatically
- Consequences on:
  - Software development roles (PIM analyst, …)
  - Programming competencies->Modelling competencies
  - Tools (new IDE, model compiler)
- **A**rchitecture **D**riven **M**odernization (ADM) [Van Den Heuvel 2006]
  - Reverse Engineering
- **Are we at the beginning of a new era in software development??**

Last Words on MDA

"**Prediction** is very difficult, …

…especially about the **future**".

Niels Henrik David Bohr

(October, 7th, 1885 – November, 18th, 1962).

Danish physicist

Nobel Prize in 1922 in physics

"for his services in the investigation of the structure of atoms and of the radiation emanating from them"

Part 4: Model Driven Interoperability

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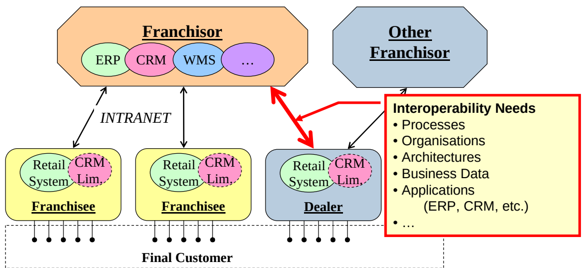
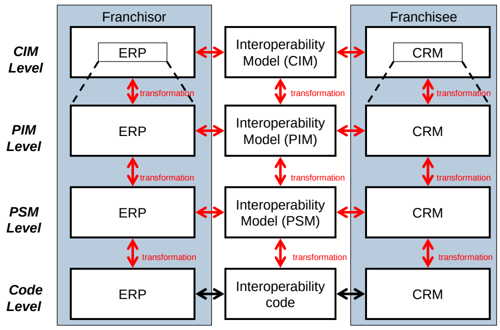
Interoperability concept

- **IEEE**
  - Ability of two or more systems or components to exchange information and to use the information that has been exchanged
- **IDEAS**
  - Ability of Enterprise Software Applications (ESA) to interact with each other
- **INTEROP NoE**
  - Is achieved if the interaction takes place on all layers of enterprises, that is the **business**, **knowledge**, and **ICT** levels, and **semantics** can also be used to accomplish a common understanding among collaborative enterprises
- **Task Group 2 (TG2)**
  - Focused on interoperability problems that enterprises face when it comes to generating ESA from enterprise Models

Case Study Description



MDI Framework and Transformations



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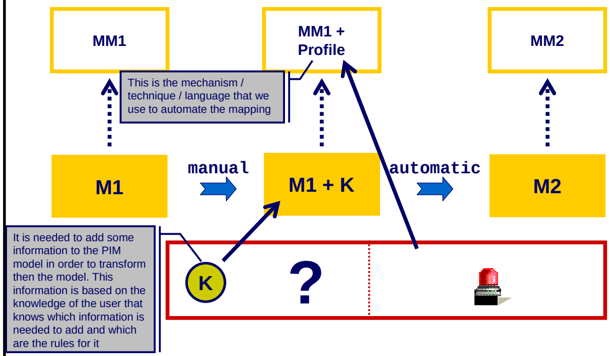
General Approach to Transform Models



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Conclusion

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Conclusion

- Model transformations are technologically feasible
- Model transformations can help to solve interoperability problems
- **Main problem** is how to add the required knowledge to perform transformations
- Adding semantic support is technologically feasible
- **Main future researches**: how to combine model transformation and semantic support from both methodological and technological viewpoints?
- MDI Method is a first step from methodological viewpoint

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Very Last Word

"Nothing is created or lost. Everything is transformed, including ideas"

Antoine-Laurent de Lavoisier (August 26, 1743 – May 8, 1794)

alias "the father of modern chemistry"
Chemist, Philosopher, Biologist, Economist
Stated the first version of the Law of conservation of mass
Named oxygen and hydrogen
Introduced Metric system
Invented the first periodic table including 33 elements

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