Hybrid Modelling

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Research Group Knowledge Engineering

Wrocław
June 28th, 2012
The University of Vienna ...

Was founded by Duke Rudolph IV in 1365. It is the oldest University in the German-speaking cultural area and one of the largest in Central Europe.

The University of Vienna is the largest teaching and Research institution in Austria, with ca. 6,200 persons academic staff. It aims to sustain a wide range of studies as well as to promote new and innovative fields of research.

Currently, about 72,000 students are enrolled in more than 130 courses, of which 34 are Diploma Programmes, 26 Bachelor Programmes and 46 Master Programmes.
Business Informatics at the University of Vienna

- Business Informatics research supposed to be beneficial for society and business, based primarily on:
  - Behavioristic research
  - Design-oriented research

- Most prominent objective:
  - To position design-oriented IS research in the international research community.
  - To produce practically beneficial, business relevant results.

Memorandum on Design-Oriented Information System Research:
www.dke.univie.ac.at

Hubert Österle, Jörg Becker, Ulrich Frank, Thomas Hess, Dimitris Karagiannis, Helmut Krcmar, Peter Loos, Peter Mertens, Andreas Oberweis and Elmar J. Sinz

O.Univ.-Prof.Dr. Dimitris Karagiannis
Agenda

- Motivation
- Conceptual Foundations
- The EU-Project ComVantage
- Evaluation
- Conclusion
Why Model ?!

REVEAL THE APPARENTLY SIMPLE (COMPLEX) TO BE COMPLEX (SIMPLE)

DESIGN AND REDESIGN SUGGEST EFFICIENCIES

DISCOVER NEW QUESTIONS ANALYZE AND SIMULATE

DEMONSTRATE TRADEOFFS PREDICTION

DOCUMENTATION OPTIMIZE

ILLUMINATE UNCERTAINTIES

EXECUTION

DATA COLLECTION

EXPLAIN

Modelling as Horizontal Function!
- Covering all domains of Computer Science

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Apply a Modelling Method: Examples

Petri Nets

Integrated Circuit

Computer Hardware Engineer

Material

UML

Computer Software Engineer

Software

Immaterial

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BP Modelling Languages: A Selection

Integrated Definition Methods IDEF3

Petrinets

Event Driven Process Chains (EPC)

Business Process Modelling Notation (BPMN)

Role Activity Diagrams (RAD)

UML Activity Diagram

LOVEM

ADONIS BPMS

Source: UML AD [OM10], LOVEM [IB95], ADONIS BPMS (sample models ADONIS), remaining [MT10]
## BP Modelling Languages - Types

<table>
<thead>
<tr>
<th>Graph-based Languages</th>
<th>Rule-based Languages</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph-based Diagram" /></td>
<td><img src="image2" alt="Rule-based Diagram" /></td>
</tr>
</tbody>
</table>

- **Graph-based Languages**
  - Activity of ?Current.Process is ?Send.product.to.customer

- **Rule-based Languages**
  - THEN (a.Subsequent.Activity of ?Send.product.to.customer is ?Check.customer.creditability)

<table>
<thead>
<tr>
<th>Speech-act based Languages</th>
<th>System-dynamic based Languages</th>
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<tbody>
<tr>
<td><img src="image3" alt="Speech-act Diagram" /></td>
<td><img src="image4" alt="System-dynamic Diagram" /></td>
</tr>
</tbody>
</table>

*Source: adapted after [Ju00]*
Apply different Modelling Methods

Source: adapted after [KJ96]
Macroflow
"To-Be"

Microflow
Technical Details, e.g. UML Sequence Diagr
A ComVantage Vision Scenario

- sofa via online furniture shop
- unique Italian fabrics store
- delay notification
- feedback to product design
- remote maintenance
- specific information

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Enterprise Modelling: The ComVantage Project

• Aims at providing a product centric information space for cross-organizational information that is shared during production time and beyond.

http://www.comvantage.eu

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Challenge

What is the most appropriate approach to cover all of the FInEIS modelling aspects?

Hybrid Modelling!

focus

Conceptual Foundations of Modelling Methods
Hybrid Modelling

- Fundamental *integration problem* among metamodels (modelling languages):
  - *Vertically different* (they vary in the level of details they describe);
  - *Horizontally different* (concepts on the same abstraction level describe different aspects);
  - Both vertically and horizontally different metamodels.

- There is a need to overcome *syntactical*, *structural* and *semantic* discrepancy of metamodels, in order to join their concepts together.
Hybrid Modelling: Heterogeneity

- **Syntactical heterogeneity**
  - Represents the difference in formats intended for the serialization of metamodels.

- **Structural heterogeneity**
  - **Representational heterogeneity**: metamodels are represented using different metamodelling languages, each of them showing difference in its expressive power of available modelling primitives (classes, attributes, ...);
  - **Schematic heterogeneity**: equal concepts are modelled either with different modelling primitives or with different number of primitives.

- **Semantic heterogeneity**
  - Difference in the meaning of the considered metamodel concepts.
Hybrid Modelling: Platform Support

- Metamodelling platforms should be realized on a component-based, distributable, and scalable architecture.

- The meta-metamodel, most important element of the platform, needs to define all the necessary concepts.

- The model repository needs to be designed to accommodate the reuse of already developed modelling method constructs.

- Hybrid modelling methods can be developed using chunks and pieces from the repository by binding them together using appropriate mapping and integration rules.
Agenda

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- Conceptual Foundations
- The EU-Project ComVantage
- Evaluation
- Conclusion
Conceptual Foundations

How do we like to do that?

Proposed Approach: “Meta-modelling” as a concept

A “Meta-modelling” as an idea is introduced to rise the level of abstraction and to simplify the development of modelling languages, modelling methods, and finally, modelling tools.
Why Metamodel !?

- Understand and describe the problem domain
- Define a vocabulary for the elements in this domain
- Help other understand the problem domain by using the same language
- Manage complexity by raising the level of abstraction at which we think and design

- **Additional functionality** for a specific domain of application should be engineered upon the meta-metamodel of the metamodelling platforms. That way a new generation of *more specialized* platforms will emerge

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**Conceptual model**, also known as domain model, represents concepts (entities) and relations between them, and is independent of design or implementation concerns.

Expresses the meaning of terms and concepts used by domain experts to discuss the problem, and to find the correct relationships between different concepts.

Robinson, S.: Designing Simulations that are better than the Rest: Conceptual Modelling for Simulation. In Proceedings: YoungOR 17, 5 - 7 April 2011
Focus on the Metamodel-Level

Level 0
System (Original, Reality...)

Level 1
Model(s) described in Modelling language

Level 2
Metamodel(s) described in Metamodelling language

Level 3
Meta-Metamodel described in Meta-metamodelling language

Meta²-Model

BPMN Metamodel

Reviewing Process

Meta-Metamodel

Meta-Metamodelling language

Meta-metamodelling language

Modelling language

Metamodelling language

represented by

conforms to

model of

conforms to

conforms to

Reviewing
Process

BPMN
Metamodel

Review Paper
Notify acceptance

Flow
Graphical Object
Task
Start
End
Sequence flow

Review Paper
Notify acceptance

...
Aspects of Meta-Modelling

Formalisation Approach

Meta\(^2\) Model

- Philosophical Level, Basic Elements

Meta Model

- Enabling Multiple Instantiation on Model Level

Model

- Conceptual Representation of Instances

Instance

- Implementation Level

Conceptualisation Approach

BP Model

- Flow Object Programming Language C++
FDMM: A Formalisation Approach

Generic Modelling Method Framework
Describes modelling methods on three major parts

- the **modelling language** that describes the syntax, semantics and notation

- **notation**
  - visualizes
  - considers

- **syntax**
  - defines grammar
  - connects
  - describes meaning of

- **semantics**
  - defines visualization
  - defines way of language application
  - defines way of language application
  - semantic mapping
  - semantic domain

- **modeling language**
  - modeling technique

- **modeling procedure**
  - steps
  - results
  - used in
  - delivers

- **mechanisms & algorithms**
  - generic mechanisms & algorithms
  - specific mechanisms & algorithms
  - hybrid mechanisms & algorithms

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Modelling Language: Semantics for Syntactic Elements

- Aspects of a modelling language that cannot be described with mechanisms for syntax definitions are pushed into the semantics area\(^1\)

- Operational Semantics
  - The basic interest is on the “execution” of models based on an abstract machine, e.g. Interpreter for Petri-Nets or Statecharts

- Denotational Semantics
  - The denotation is expressed through a mapping of syntactic constructs to constructs of a commonly accepted domain that is assumed to be well understood, e.g. Control-Flow of BPEL denoted in terms of Petri-Nets

Generic Modelling Method Specification Framework

Describes modelling methods on three major parts:

- **modeling language**
  - defines visualization
  - defines grammar

- **syntax**
  - visualizes
  - connects

- **semantics**
  - describes meaning of
  - arranges according to

- **modeling procedure**
  - steps
  - results

- modeling technique
  - defines meaning of
  - defines way of language application

- **notation**
  - considers

- semantic mapping
  - connects

- semantic domain

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Generic Modelling Method Specification Framework

Describes modelling methods on three major parts:

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algorithms and mechanisms that provide “functionality to use and evaluate” models described by a modelling language

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Metamodel of a Metamodelling Language

Erweiterung von: Kühn et al. (1999a), S. 79
Metamodel Element: Relation Class

- Relations in ADOxx® are customized – by the use of the Meta² Construct “Relation Class”
- A Relation Class
  - describes relationship between two or more classes or modeltypes;
  - has endpoints defining which classes a relation class can connect.
- An “InterRef” is a special configuration of a relation class.
Metamodell einer Prozedurdefinitionssprache
Semantic Object Model on ADOxx®
Metamodel Integration: An Example
Metamodel of a M&A Definition

Mechanisms & Algorithms: A Process-based Compliance Scenario

- **Frequency of Occurrence**  
  *e.g. How many regulations show the different paths in contrast to the total fitting of the business process?*

- **Average Regulation Fitting for the Business Process**  
  *e.g. What is the average fitting with regulations for the entire business process?*

- **Probability of Regulation Fitting (Weighted)**  
  *e.g. How likely is it that a path result regarding the regulation fitting occur?*

- **Probable Average Occurrence of a Regulation (Weighted)**  
  *e.g. What is the average probability of a specific regulation within the business process?*

Mechanisms & Algorithms: A Process-based Compliance Scenario

Algorithm: Frequency of Occurrence

\[
rf = \frac{\sum_{j=1}^{l} |cnrs_j|}{|RS|}
\]

rf = Regulation Fitting (Indicator)
RS = Regulation Set
 cnrs = compliance node regulation set

\[
rf_{path_1} = \frac{\sum_{j=1}^{l} |cnrs_j|}{|RS|} = \frac{cnrs_4 + cnrs_{11} + cnrs_{12} + cnrs_{14}}{|RS|} = \frac{5}{9} = 0.55\bar{5}
\]

\[\sum|cnrs_j| = 5\]
\[x\] is kept constant \(\bar{x}\)
RS: \(\bar{x} = 9\)
\[rf_{path_1} = ?\]

\[path_1 = \{n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_9, n_{10}, n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, n_{17}, n_{18}\}\]

Assumption:
A typical business process model shows several different paths.

Application Scenario: Process-based Compliance

Margit Schwab, “Process-based Compliance: Probabilities”
### Mechanisms & Algorithms: A Process-based Compliance Scenario

**Algorithm:** Average Regulation Fitting for the Business Process

<table>
<thead>
<tr>
<th>No.</th>
<th>Path Description</th>
<th>Excluded Nodes</th>
<th>Absolute Number of Regulations</th>
<th>Regulation Fitting, $rf$</th>
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<tr>
<td>1</td>
<td>$n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_9, n_{10}, n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, n_{16}$</td>
<td>$n_8, n_{16}$</td>
<td>9</td>
<td>1</td>
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<tr>
<td>2</td>
<td>$n_1, n_2, n_3, n_4, n_7, n_9, n_{10}, n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, n_{16}$</td>
<td>$n_8, n_9, n_{10}, n_7, n_8, n_9, n_{10}, n_{16}$</td>
<td>4</td>
<td>0.444</td>
</tr>
<tr>
<td>3</td>
<td>$n_1, n_2, n_3, n_4, n_5, n_6, n_9, n_{10}, n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, n_{16}$</td>
<td>$n_7, n_8, n_{12}, n_{13}, n_{14}, n_{16}$</td>
<td>5</td>
<td>0.555</td>
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<tr>
<td>4</td>
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<td>5</td>
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<tr>
<td>15</td>
<td>$n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_9, n_{10}, n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, n_{16}$</td>
<td>$n_{13}, n_{15}$</td>
<td>9</td>
<td>1</td>
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<tr>
<td>16</td>
<td>$n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_9, n_{10}, n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, n_{16}$</td>
<td>$n_{15}$</td>
<td>5</td>
<td>0.555</td>
</tr>
</tbody>
</table>

\[
rf_{\text{avg}} = \frac{\sum_{n=1}^{k} rf_{\text{path}_n}}{n} = \frac{9.328}{16} = 0.583
\]

\[
rf_{\text{avg}} = \text{Average Regulation Fitting (Indicator)}
\]

\[
\sum = 9.328
\]
Metamodelling Platforms: Some Features

- Extensible, repository-based metamodelling platform
- Three-step modelling hierarchy with a rich meta-metamodel
- Can be customized using metamodelling techniques
- Extendable with custom specific components
- Platform kernel provides basic modules for managing models and metamodels
- Graphical and tabular model editing
- Scripting language for defining mechanisms and algorithms
In general, metamodelling environments can also be used to specify and implement “domain-specific” modelling tools.

**Metamodelling Platforms**
- ADOxx
- MetaEdit+
- Obeo Designer
- GME
- ConceptBase
- ...

**Metamodelling Frameworks**
- Eclipse: EMF (GEF, GMF), and others
- Visual Studio: Visualization & modeling SDK
- ...

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Agenda

- Why Hybrid Modelling
- Conceptual Foundations
- The EU-Project ComVantage
- Evaluation
- Conclusion
Modelling Method Specification

Context

1. App design support
2. Linked Data
3. Access Control Models
4. Framework
5. Specification

ComVantage: Collaborative Manufacturing Network for Competitive Advantage

www.comvantage.eu

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Theoretical Research Focus

Modelling Framework

1. What **formalism** is needed to describe a metamodelling framework?
2. What are the **atomic elements** on which a modelling method can be built?

Modelling Stack

1. What are the **explicit model types (and their concepts)** that are relevant to ComVantage requirements?
2. What are the **implicit model types (and their concepts)** that should be derived through mechanisms?
3. What is the integration model for ComVantage?
Hybrid Modelling

Formal Concepts on Domain Layer

Semantic Mediation

Reference Alignment

Similarity Discovery

Underlying Graph or Query Rewriting Rules

Metamodel A

Metamodel B

Mediating superconcept

Mediating subconcept

Concept from A

Concept from B

Reference ontology
Integration model

Similarity metrics:
- Taxonomical level
- Relational level
- Syntactical level

Mapping

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**ComVantage: Graph Rewriting**

**Definition:** Transformation of one graph into another by means of graph grammars.

A graph grammar provides rules for transforming occurrences of certain graph patterns (subgraphs) into new patterns, thus generating a new graph.

**Main Applications:**
- Image processing (transformations)
- Model driven software engineering
- Artificial intelligence (inference engines)

**References:**
*Handbook of Graph Grammars and Computing by Graph Transformations*. Volume 1-3. World Scientific Publishing

*Design and implementation of a graph grammar based language for functional-structural plant modeling*


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ComVantage: Apps Model

Mobile Mockup Model
- Classes are GUI elements
- Supports Mobile feature design

Business Process Model
- Classes are activities, decisions, hubs, mobile support
- Supports design for business processes with mobile support

App Orchestration Model:
Reflects precedence of feature accesses derived from business processes.
The ComVantage Method: Current State

Product Design:
- Product structure models

Strategic Design:
- Business model
- Supply chains
- Supply network
- Market structure models

Operational Design:
- Organisational structure
- Business processes
- Causality models

Mobile Support Design:
- Mobile app orchestration models
- Mobile mockup models

Design, Analyse, Optimise

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The ComVantage Method
Conceptualisation Process

Theoretical Method Development

Conceptualisation of the Method

Method Implementation Environment

e.g. ADOxx

ComVantage
What is ADOxx®?

ADOxx® is a metamodeling development and configuration platform for design/implement modelling methods.
Agenda

- Motivation
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Evaluation

A) Scientific: The Open models initiative

www.openmodels.at

B) Business: The BOC-Management Office

www.adonis-community.com

A Spin-off from the University of Vienna
# Evaluation: Selected Methods

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<tr>
<th>Name</th>
<th>Members</th>
<th>University / Institute</th>
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<td>University of Klagenfurt</td>
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## OMI Platform Users

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<th>All</th>
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</thead>
<tbody>
<tr>
<td>182</td>
<td>311</td>
</tr>
</tbody>
</table>
Evaluation: Method Building

Blocks

Classes = Abstract + Normal
Relations = Relational Classes
Events = On Event Calls
Modeltypes do not include View-Modes

EKD Modeltypes are:
1. Goal
2. Actor-Role
3. Role-Activity
4. Class Association
5. Event Trace
6. State Transition
7. Rules

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Evaluation: openmodels.at


Visits: 4,459
Unique Visitors: 2,187
Pageviews: 24,384
Pages/Visit: 5.47
Avg. Visit Duration: 00:04:39
Bounce Rate: 43.49%
% New Visits: 47.12%

- 52.86% Returning Visitor
  2,357 Visits
- 47.14% New Visitor
  2,102 Visits

- 27.54% Search Traffic
  1,228 Visits
- 31.37% Referral Traffic
  1,399 Visits
- 41.09% Direct Traffic
  1,832 Visits
Agenda

• Motivation
• Conceptual Foundations
• The EU-Project ComVantage
• Evaluation
• Conclusion
Key Messages

1) **Observation that one Modelling Method** – e.g. UML, BPMN, BPEL - **is not enough** to cover all Modelling Aspects of Next Generation Enterprise Systems

2) **Hybrid Modelling** as **Solution** Approach

3) **Best Practice Samples** of FInES Cluster Projects / EU FP7 Projects: ComVantage (www.comvantage.eu) and BIVEE (bivee.eu/)

4) **Outlook towards Open Models Initiative** as Collaboration Platform
Some Research Issues (I)

- **Alignment of business process and security** (prevention strategies against social engineering attacks, addressing security risks in business process modelling, security threats identification, etc.).

- **Optimizing information flow and efficient reuse of existing knowledge** as part of the business strategy of viable enterprises (approaches and solutions for active, viable, and agile information systems, information logistics and knowledge supply, etc.).

- **Intelligent educational systems** (collaborative learning environments, virtual and distant education, internet based tutoring systems, etc.).
Some Research Issues (II)

• *Information integration* (event based data integration, user centric data integration, streaming data integration; solving information overflow problem for the users, etc.).

• *Interoperability* (completely understandable interfaces to share data between different systems, people, and businesses, etc.).

• New *architectures for information systems* (enterprise architecture frameworks, ERP development approaches, etc.).

• New *modelling methods, modelling* and *metamodelling tools*. 
Selected Actual Related Work by DKE


Conclusion

There are no bad modelling methods, but only not appropriate ones!

For Enterprise Information Systems one modelling method is not sufficient!

Hybrid modelling methods are required.

O.Univ.-Prof.Dr. Dimitris Karagiannis
Thank You For Your Attention!

Any Questions?

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