# Hybrid Modelling with ADOxx: Virtual Enterprise Interoperability Using Meta Models

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**Abstract.** This practical paper introduces hybrid modelling and its application in supporting interoperability within virtual enterprises. Based on a survey report of the FINES cluster, different dimensions of enterprise interoperability are introduced before concept modelling as an instrument and meta-modelling as the technological approach is discussed. The challenge of holistically combining different modelling approaches concerned with enterprise interoperability can be tackled via hybrid modelling. The open development platform ADOxx is introduced as a technological basis supporting realization of the hybrid modelling and the semantic lifting. Hybrid modelling applied in the project BIVEE to holistically model a Value Production Space is introduced to demonstrate a complex meta-modelling environment.

**Keywords:** Meta Models, Concept Modelling, Conceptual Integration.

## 1 Introduction

Industry 4.0 [1] describes the ongoing paradigm shift in production industry towards networked enterprises. Future Internet Enterprise Systems (FInES), virtual enterprises and networked IT-infrastructure are keywords indicating current and upcoming challenges of future enterprises facing agility, sensing, community-orientation, liquidity and globalism. Enterprise Interoperability (EI) is hence defined "as a field of activity with the aim to improve the manner in which enterprises, by means of ICT, interoperate with other enterprises..." [2]. Concept models such as business processes, value process chains or e3value models are commodity and hence a promising candidate to support EI. A well-known realization approach for modelling is the meta-model technology that is an abstraction of models enabling the domain-specific realization of modelling languages. Depending on the complexity of the requirements, most likely interplay of several meta-models focusing on different viewpoints is required. This interplay between meta-models is seen as hybrid modelling, as different viewpoints are commonly applied to create a holistic observation This short introduction is followed by a section which focuses on different levels of interoperability, starting with a state of the art survey and mapping it to the proposed approach – the concept modelling. Third section focuses on the core of the paper – the hybrid modelling approach, which is then followed by an application sample in the

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BIVEE project and concluded in section 4 with a summary and pointers toward communities related to the introduced approach. ).

## 2 Interoperability and Conceptual Background

First part of this section is based on the findings of the enterprise interoperability survey from the project ENSEMBLE [7] within the FInES cluster activities. ENSEMBLE [7] observed the different aspects of interoperability. For a detailed discussion on the different aspects we refer to the original document, but would like to highlight different layers and viewpoints of EI as relevant requirements for concept modelling. In [7] ENSEMBLE depicts four levels of interoperability. Level 1 focuses on e.g. Data, Cultural, Software, etc., interoperability. Level 2 for example considers Knowledge interoperability dealing with different semantic abstraction of content to enable human or machine based interpretation whereas Level 3 aims at Cloud interoperability and Level 4 has focus on Ecosystems interoperability in the global world. It is clearly stated that, although maturity level of aforementioned interoperability aspects have been evolved to elaborate them individually, still there are strong dependencies, overlapping and similar common issues among them. . Major requirement is therefore that different concept models may support different dimensions of EI. But different concept models for different dimensions of EI must be on a holistic platform that shares those parts that are in common and enables a specialisation of those parts that are dimension specific. The term “model” is interpreted with the meaning discussed in [8], where a model is “a representation of either reality or vision” [15], that are created “for some certain purpose” [13] “with an intended goal in mind” [27]. Hence the benefit of models can be described in four types: (1) to act as a clear specification, reduce complexity, allow a structured approach and, due to a common understanding, support a participative creation. ([9], [10]); (2) to target semi-automatic implementation of software like Model Driven Architecture; (3) to support knowledge management or (4) to evaluate current status against modelled target goals. Hence, targeting aforementioned EI with concept models, means that pre-defined diagrammatic concepts are available that have a specific meaning enabling to reconstruct relevant parts of the reality in order to either (1) specify, (2) support execution, (3) represent knowledge or (4) evaluate the different dimensions of EI. According to the framework described in [11] and [12], the building blocks of a modelling method include: (1) the modelling language that is most prominently associated with concept models, as available concepts to be used for such model are pre-defined according their semantic, their syntax and their graphical notation, (2) the modelling procedure which defines the stepwise usage of the modelling language and hence is not always available and (3) mechanisms and algorithms that enable the computer-based processing of models. So we can state that all concept model approaches can be described with the aforementioned framework and vice versa, every new concept model approach needs to reflect firstly how to realise the relevant building block. Meta-modelling can be used as a realisation approach to develop domain-specific modelling tools and hence enable IT-supported concept modelling as described previously. The modelling language is understood as the meta-model, which for example is defined in a meta model language like ALL (ADOxx Library Language [5]). The specification of the meta-model can be again defined by a model – the so called meta meta model. Meta Model approaches have been analysed in [14] and can be distinguished in (i) domain, (ii) design – macro and micro level – as well as (iii) integration.. Comparing aforementioned list of identified meta model approaches in the literature it is obvious that most of the interoperability issues raised in the beginning of this section are already covered by individual meta-model approaches. Hence, there are meta models suitable to cover certain aspects of EI dimensions, which can be specified with the generic modelling framework and derived from a meta meta model.

## 3 Hybrid Modelling as Solution

Hybrid modelling is a concept that merges several meta models and hence applies a similar approach in meta modelling that service orientation applies in software engineering. In the first step the different meta models are classified according (a) their domain, (b) the level of technical granularity, (c) the degree of formalisation and finally (d) the cultural dependency of the applying community. Second, the so called meta model merging is applied. It is seen as the composition of such meta models, and distinguishes in (a) loose integration of meta models, (b) strong integration and (c) hybrid integration. In the PhD thesis of Kühn [12], meta model merging patterns ranging from loosely coupled to tightly coupled meta models are introduced. Loose coupling is very flexible, whereas tight coupling enables the realisation of additional functionality. Meta modelling merging patterns can be, based on [16], summarised as: (1) *Reference pattern*, where two meta-models are complementary and should not or cannot be changed. (2) *Transformation pattern*, where two meta-models are in principle complementary but part of one meta model correspond or can be created out of parts from the target meta model. (3) *Use or aggregation pattern* uses part of the meta model in another meta model or aggregate them into a new meta model, (4) *Merge and extension patterns* of meta models are applied if meta models are closely related and cover similar issues. The challenge is to develop a new or extended meta-model that still keeps the same concepts of the original meta model. (5) *Semantic Lifting* of meta-models is a special way of meta model merging, where a domain specific meta model is merged with the semantic meta model – in most cases an ontology. Research in semantic lifting in the domain of EI is one of the activites within the BIVEE [3] project as outlined in section 3.3.

### 3.1 ADOxx Technology for Hybrid Modelling Solutions

This section provides an overview on the key points of the ADOxx.org [5] development platform, to enable the discussion how hybrid modelling can be realised. Hence this section refers to the public tutorials on ADOxx.org, where the development platform and the corresponding tutorials can be downloaded. ADOxx® platform provides two pre-defined meta-models that can be used to build domain-specific meta-models. The first one depicts the operative semantic of directed graphs to represent dynamic aspects, and the second focuses on the operative semantic of tree-like structures in the organizational context to represent static aspects. Hence, the dynamic meta-model provides start, activity, decision, parallelity, merging and the end concept. Additionally there are two classes with container semantic, the aggregation and the swim-lane that automatically groups the elements drawn inside them. The static meta-model realizes an organisational structure with persons, resources as well as with above mentioned containers. A new meta-model is developed, through inheriting from aforementioned pre-defined and defining new classes. ADOxx® platform provides further functionality to realize individual mechanisms or algorithms. Generic functionality is provided on root classes of the meta-model for (a) modelling, (b) querying, (c) transformation and (d) simulation. Generic functionality can be extended by a script language called AdoScript that provide more than 400 APIs to interact with the platform. Functionality can be added either by implementing it within the tool or from outside the application using batch files or Web Service access to invoke AdoScripts.

### 3.2 Technical Solution for Hybrid Modelling on ADOxx

Strong and intermediate integration of meta-models is performed before the modeling tools are deployed, whereas loose integration enables deployment of modelling tools before actual integration is carried out. *Strong and intermediate Integration of Meta Models* is realized by merging two meta models, extending one meta model with another meta model, using part of one meta model in another meta model or aggregating concepts from two meta model into one new concept of the new meta model. It is supported by using text editors with syntax highlighting using the meta model language ALL, where parts of or the whole meta model can be merged, extended, used or aggregated into another meta model. The user should not be aware of the fact that actually two meta models are used. The separation of concern is realized by model types. The graphical notation of meta models enable different views, so the user is guided by the tool menu. This enables to share objects or reference objects with so-called "interref" (a functionality to point to another object), hence the user may access features of any modelling tool. *Loose Integration of Meta Models* such as semantic lifting is a special form of referenced meta model merging. Depending on the level of the user friendliness and applicability, there are different ways to achieve the loose integration. Strict loose integration has no changes in the meta model at all, but it lacks of user friendliness. User friendly solutions require adaptations in the meta model. There are different implementation variants available such as: (1) *Non supported direct linkage* requires no changes in the meta models, the user needs to manually enter the linkage in an existing suitable attribute; (2) *Supported direct linkage*, can be realized by an AdoScript that accesses the other modelling tool and enables the selection of an object; (3) *Indirect linkage* can be realized using a so-called transit model type where concepts of the corresponding other meta model are included. Hence user friendly mechanisms to reference a model objects (e.g. an interref) can be used. This results in redundant data storage; hence the redundancy must be managed. (4) *Loose coupling* is a special form of indirect linkage, as the concepts that are referenced too are not the target concepts but a reference ontology, which is referenced by both the source and the target concept; *(5) Direct and indirect linkage* is a combination of supported and non-supported linkage, by supporting a fixed core set of concepts but permit the flexibility to also allow agile evolving concepts. All aforementioned solutions have their advantages and disadvantages when supporting the end user – easier one may be too error prone (e.g. free text linkage), and other may involve more resources to be implemented or be too strict (e.g. fixed set of concepts).

### 3.3 Hybrid Modelling in BIVEE

Hybrid modelling approach has been realized in the BIVEE project. The setting was concerned with the improvement of the Innovation processes in Virtual Enterprises. It was applied to integrate the meta models of the Virtual Innovation Space (VIS) and the traditional Value Production Spaces (VPS) of a Virtual Enterprise (see [17] for details). The selected approach was the realization scenario of the semantic lifting with the semantic meta model of the Production and Innovation Knowledge Repository (PIKR) [18]. VPS meta model itself is deducted based on different aspects including: (a) The Supply Chain Operations Reference [19]. (b) The Value Reference Model [20], (c) SixSigma [24], (d) e3value Model [22], (e) CIMOSA [23], Zachmann [25] and TOGAF [21]. Additionally to these publicly available aspects, a survey on meta-models for production and logistics has been reported and taken into account for VPS within ComVantage research project [26]. These aspects have been reflected in the so-called modelling stack of the VPS meta model comprised of the Value Production Space Chart, Product, Process, Network, KPI, IT-System Pool, and the Artifact Pool. These models, due to necessity to enhance the user friendliness have been integrated following the Strong integration pattern. The dynamic part was achieved by adding the Semantic Transit Model (STM) to the VPS meta model and enabling the semantic lifting based integration with the VIS. The semantic lifting of the VPS meta-model, applies a loose coupling through a transit model (STM) with the PIKR and enables application of the VIS concepts in the model and vice versa.

## 4 Conclusion and Outlook

The paper started with the observation on EI, their dimensions and their corresponding requirements on model-based approaches. Concept modelling has been introduces as a mature field of knowledge representation that is most commonly realized using meta-model as technology. Hybrid modelling as an instrument has been introduced to show how complex systems can be described. The application of the ADOxx® as an open use meta-modelling platform has been described in order to explain how hybrid modelling approaches from theory, can be implemented into a software platform. The EU-project BIVEE was used to demonstrate how hybrid modelling has been realized in the so-called Value Production Space. An approach presented in the paper is a research topic at the laboratory of the Open Model Initiative [4] and technology to implement the hybrid modelling is provided through the open development platform ADOxx.org [5].

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