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# Q2 A conceptual framework for large-scale ecosystem Q3 interoperability and industrial product lifecycles

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A B S T R A C T

One of the most significant challenges in information system design is the constant and increasing need to establish interoperability between heterogeneous software systems at increasing scale. The automated translation of data between the data models and languages used by information ecosystems built around official or de facto standards is best addressed using model-driven engineering techniques, but requires handling both data and multiple levels of metadata within a single model. Standard modelling approaches are generally not built for this, compromising modelling outcomes. We establish the SLICER conceptual framework built on multilevel modelling principles and the differentiation of basic semantic relations (such as specialisation, instantiation, specification and categorisation) that dynamically structure the model. Moreover, it provides a natural propagation of constraints over multiple levels of instantiation. The presented framework is novel in its flexibility towards identifying the multilevel structure, the differentiation of relations often combined in other frameworks, and a natural propagation of constraints over multiple levels of instantiation.



## 1. Introduction

Lack of interoperability between computer systems remains one of the largest challenges of computer science and costs industry tens of billions of dollars each year [1,2]. Standards for data exchange have, in general, not solved the problem: standards are not universal nor universally applied (even within a given industry) leading to *heterogeneous ecosystems*. These ecosystems comprise large groups of software systems built around different standards that must interact to support the entire system lifecycle. We are currently engaged in the “Oil and Gas Interoperability Pilot” (or simply OGI Pilot), an instance of the Open Industry Interoperability Ecosystem (OIIE) initiative that aims for the automated, model-driven transformation of data during the asset lifecycle between two of the major data standards in the Oil & Gas industry ecosystem. The main standards considered by the project are the ISO15926 suite of standards [3] and the MIMOSA OSA-EAI specification [4]. These standards and their corporate use[1] are representative of the interoperability problems faced in many

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[1] Industrial participants in past demonstrations included: Bentley, AVEVA, Worley-Parsons, for ISO15926; IBM, Rockwell Automation, Assetricity for MIMOSA; various Oil & Gas or power companies as potential end users.

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industries today.To enable sensor-to-boardroom reporting, the effort to establish and maintain interoperability solutions must be drastically reduced. This is achieved by developing model transformations based on high level conceptual models.

In our previous work [5] we presented three core contributions: (1) we compared the suitability of different multi-level modelling approaches for the integration of ecosystems in the Oil & Gas industry, (2) introduced the core SLICER (Specification with Levels based on Instantiation, Categorisation, Extension and Refinement) relationship framework to overcome limitations of existing approaches with respect to the definition of object/concept hierarchies, and (3) evaluated the framework on an extended version of the comparison criteria from [6].

The current work extends these contributions by: (1) expanding on the explicit handling of descriptions in the SLICER framework, (2) extending the core SLICER relationships with a complete treatment of attributes, relationships, and their integrity constraints, (3) presenting the formalisation of SLICER core and the treatment of attributes, and (4) illustrating mappings between a SLICER model and alternatives making use of SLICER's finer semantic distinctions to identify patterns of meaning in the original models.

## 2. Ecosystem interoperability

The suite of standard use cases defined by the Open O&M Foundation covers the progress of an engineering part (or plant) through the Oil & Gas information ecosystem from initial specification through design, production, sales, deployment, and maintenance including round-trip information exchange. The data transformations needed for interoperability require complex mappings between models covering different lifecycle phases, at different levels of granularity, and incorporating data and (possibly multiple levels of) metadata within one model.

Notably, different concepts are considered primitive objects at different stages of the lifecycle. For example, during design, the specification for a (type of) pump is considered an object that must be manipulated with its own lifecycle (e.g. creation, revision, obsolescence), while during operations the same object is considered a type with respect to the physical pumps that conform to it and have their own lifecycle (e.g. manufacturing, operation, end-of-life). Furthermore, at the business/organisational level, other concepts represent categories that perform cross-classifications of objects at other levels. This leads to an apparent three levels of (application) data: business level, specification level, and physical entity level. To describe these different levels multi-level modelling (MLM) approaches to model-driven engineering seem a natural fit. Ideally, a flexible conceptual framework should represent the entire system lifecycle, in a way that simplifies the creation of mappings between disparate models by the interoperability designer.

The ecosystem transformations use a joint metamodel that serves as the common representation of the information transferred across the ecosystem (cf. Fig. 1) and must be able to handle the MLM aspects. As pointed out in [7], such complex domains generally are not dealt with using the classical GAV or LAV (Global/Local As View) querying approach, but require a more general form of mapping describing complex data transformations. Notably, the data integration systems surveyed in [7] generally use languages that do not have MLM or even metamodelling capabilities, and the automated matching capability of the systems listed (e.g., MOMIS, CLIO) is probabilistic. As transformations in the engineering domain must guarantee correctness (e.g., an incorrectly identified part or part type can result in plant failures), probabilistic matching cannot

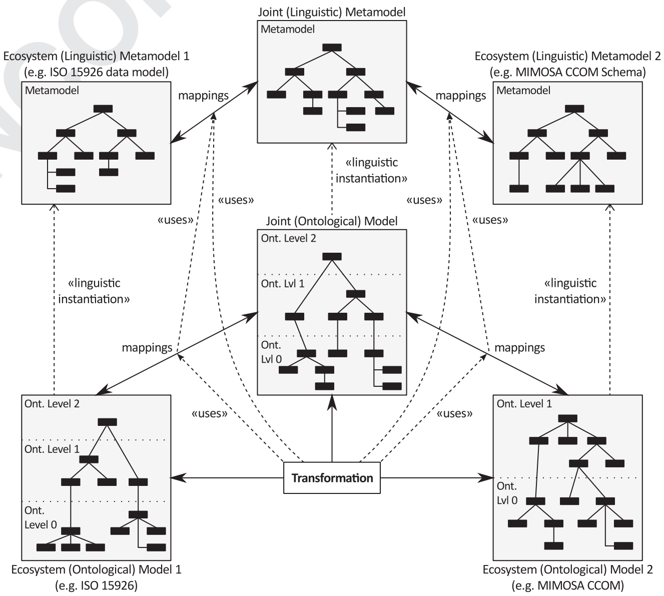


**Fig. 1.** Ecosystem interoperability through a joint metamodel.



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