Towards an upper ontology for representing oil & gas enterprises

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1 Introduction

Many operations systems used by oil & gas companies originate from the time when the oil-platforms or refineries they are controlling have been constructed, which means they have been implemented roughly 20+ years ago. At that time, concepts of semantic modeling and representation of the structure of oil platforms were hardly in use. Respective modeling techniques had evolved in the areas of knowledge representation (see [1]) and object-orientation (see [2] and [3]); but neither software engineers nor knowledge engineers had considered operations control for highly complex equipment infrastructures like oil-platforms or refineries as an application area for the modeling techniques they had invented. It is probably fair to say that, on the other side, companies implementing the operations control systems for such highly complex technical infrastructures were not really aware of the capabilities that semantic-oriented modeling can provide.

In the meantime, the situation tends to change. The complexity of the technical infrastructure continues to grow, operating the technical equipment becomes more complex and the need for semantically richer information on 'what goes on' on a platform or in a refinery is being recognized by many oil & gas producing enterprises.

Since the early 1990's, the idea of modeling the structure of manufacturing enterprises in general has led to the definition of various industry standards like ISA88 ([8]) , ISA95 ([9]), or MIMOSA ([10], or ISO 15926 ([10])) where object-oriented modeling techniques have been used to formalize the concepts identified by the different standards bodies. The initial purpose of such standards was 'to get the terminology right' and thus to create a commonly accepted nomenclature for representing structural and operational aspects of (oil and gas) enterprises. Once these standards had been accepted by a large enough community, industry solutions exploiting them have been implemented closing the loop to allow enterprises using standards based operations control or manufacturing execution systems.

The Reference Semantic Model (RSM), see [6] for further reference on its use, whose 'upper ontology' shall be described in this article has been developed to address two major concerns:

- Pull together concepts from various standards with the objective to fill gaps and build 'bridges' between them;
- Use it as the base for implementing a modern operations control and event processing system for oil & gas producers

From an abstract point of view, RSM based applications typically look as follows.

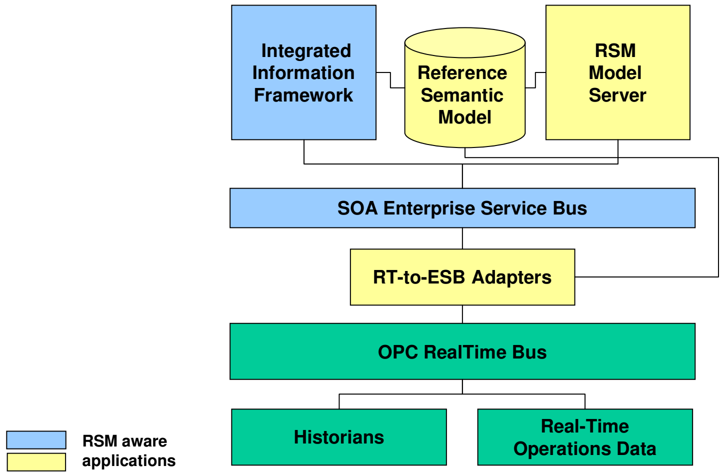

Figure 1: Schematic view of RSM based applications

The bottom of the diagram shows the real-time device world controlling the equipment on an oil-platform; applications deliver real-time operations data and/or store it in historians. This is typically an 'OPC world' since Open Process Control has established a de facto standard for this layer of the architecture, c.f. [5]. The connectivity among OPC enabled applications can be considered as an OPC Real-Time Bus. In order to have modern J2EE (c.f. [12]) or SOA (c.f. [13]) applications interface with this 'OPC World', respective adapters connect the Real-Time Bus and the Enterprise Service Bus. The RSM can be exploited by respective adapters linking the two buses and converting the 'semantically poor' data traveling on the OPC Real-Time bus to more 'semantically rich' information handled in the Enterprise Service Bus.

The RSM Model Server is based on the Utility Integration Bus (UIB) product from SISCO Inc., see ([14]); it exploits RSM capabilities in order to interpret OPC data on the background of the semantic information represented in RSM. The Integrated Information Framework (IIF) from IBM (see [6]) is a modern Web 2.0 application which allows for graphical modeling and monitoring of oil & gas manufacturers' technical equipment and assets. Both SISCO UIB and IBM IIF make detailed use of semantically rich representations of oil platforms or refineries as expressed in RSM.

2 The upper ontology of RSM

In order to improve the understanding of the structure of an oil & gas enterprise, principles of semantic modeling are an adequate means to represent the portion of the real world made up by an oil producer.

The model is based on various other industry standards to represent different aspects of manufacturing enterprises:

- The enterprise structure view has been adopted from ISA95 and ISA88 standards.
- Concepts of asset management have been developed originally by the MIMOSA organization.
- A rich reference library of terms and notions about technical equipment and their connectivity has been developed in the ISO 15926 standard.

All of these standards represent valuable sources of information by which the model sketched here has been inspired with the objective to implement enterprise operations systems for the oil and gas industry.

The RSM is originally defined in the Unified Modeling Language (UML) and there is a derived OWL (Web Ontology Language) version of it available as well.

2.1 Inheritance hierarchy among upper ontology classes

The first diagram represents the main classes of the RSM upper ontology and the inheritance relationships among them.

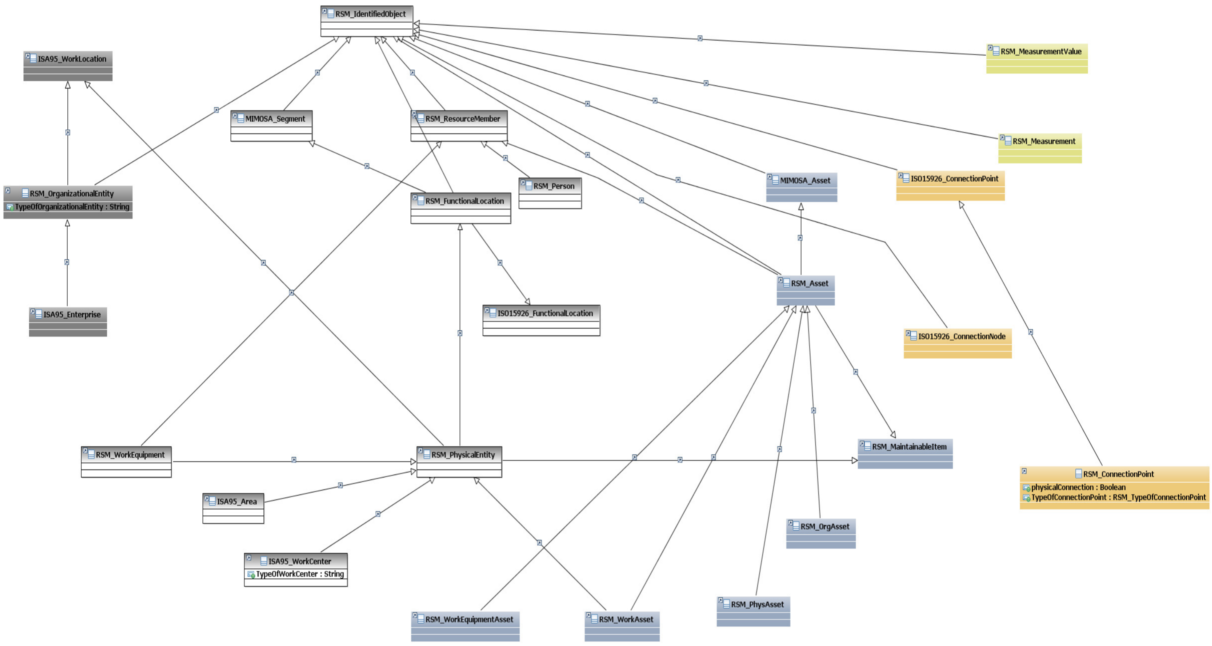

Figure 2: Inheritance hierarchy of upper level classes

The upper level classes of RSM address the following concepts for representing and monitoring an oil and gas company.

Organizational structure of an enterprise

- key class is *RSM_OrganizationalEntity*, which allows for representing organizational structures in an abstract manner. Enterprises are typical organizational entities from an RSM perspective, but also departments or functional units like development, manufacturing or sales can be seen as organizational entities. Organizational entities can be structured hierarchically.

Physical Structure of an enterprise

- key class is *RSM_PhysicalEntity* which allows for representing physical elements of interest for an enterprise. As can be seen from the inheritance hierarchy diagram, a couple of other terms and notions have become sub-classes of *RSM_PhysicalEntity*, including *ISA95_Area*, *ISA95_WorkCenter*, *RSM_WorkEquipment*, or *RSM_WorkAsset*. The class hierarchy also shows how concepts from other standards have been absorbed into RSM. Physical entities can contain other physical entities to form hierarchic structures.
- Connectivity between physical equipment within an enterprise is another central aspect of representing the physical structure. The classes *ISO15926_FunctionalLocation*, *ISO15926_ConnectionNode* and *ISO15026_ConnectionPoint* are essential elements for describing connections between equipment as typically illustrated in P&ID diagrams. See more on connectivity in Section 2.2 below. which describes the non-inheritance relationships between the upper ontology classes.

Assets within an enterprise

- assets are considered as all the property owned by an enterprise, where the focus of RSM is more on physical assets and maintainable items, as represented by the class *RSM_MaintainableItem* and its ‘asset neighborhood’.

Measurements and measured values

- In order to asses the state of an enterprise, *RSM_Measurements* can be taken at various places in the enterprise. Each measurement represents a key performance indicator being relevant for the enterprise’s business. Measurements consist of series of measured values captured at ‘point of interest’ within the enterprise.

2.2 Major associations between upper ontology classes

The following diagram illustrates the main associations with the upper ontology of RSM.

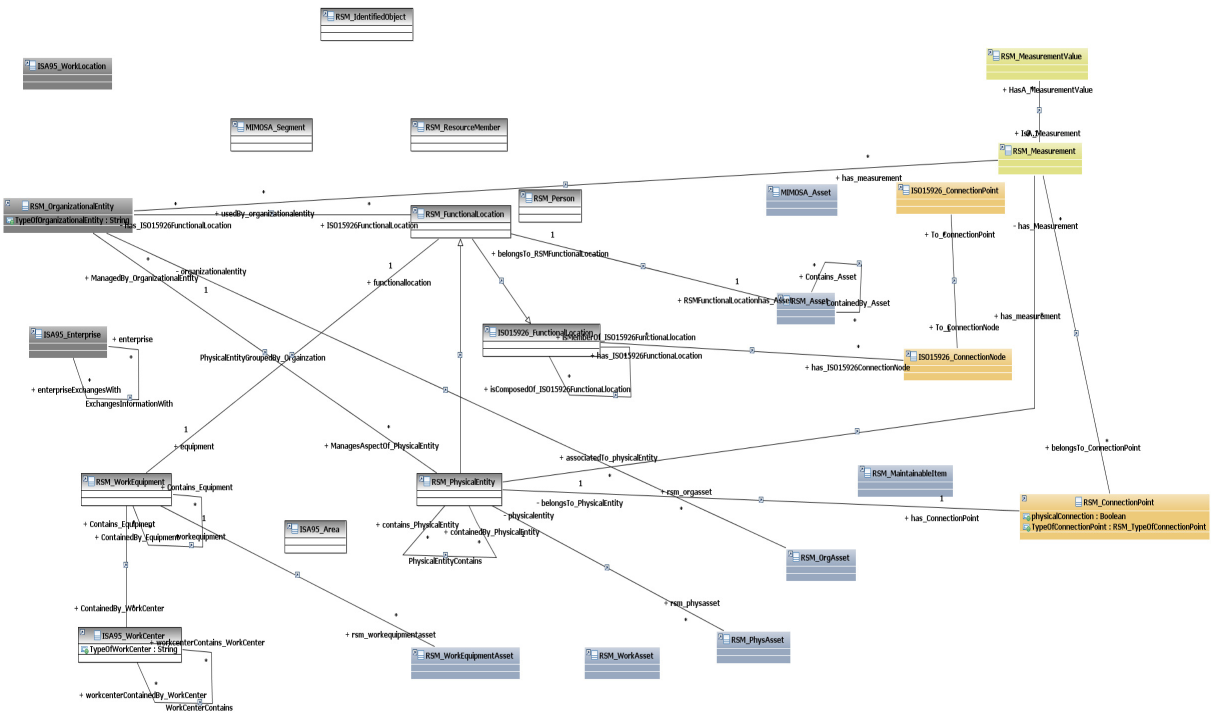

Figure 3: Associations between upper ontology classes

Organizational structure of an enterprise

- *RSM_OrganizationalEntities* can be structured hierarchically, and *ISA95_Enterprises* can exchange information with other enterprises.

Linking the organizational structure to the physical structure

- *RSM_OrganizationalEntities* and *RSM_PhysicalEntities* can be related in an abstract manner; this association can be interpreted as ‘*RSM_OrganizationalEntity isReponsibleFor RSM_PhysicalEntity*’ so that ownership of physical inventory by organizational units within the enterprise can be expressed. Similarly, organizational entities can be linked to functional locations.

Relationships between the classes representing physical inventory

- First of all, *RSM_PhysicalEntities* can be structured hierarchically to express that one physical entity can contain another one.
- Since *ISA95_Areas* are *RSM_PhysicalEntities*, they can be structured hierarchically as well; the same applies to *ISA95_WorkEquipment* and *ISA95_WorkCenter*.
- *ISA95_WorkCenter* can contain *ISA95_WorkEquipment*.

Assets

- *RSM_Assets* can be structured hierarchically and the *RSM_PhysicalAssets* are linked to the *RSM_PhysicalEntities* and to the *RSM_FunctionalLocations*. This allows to express which physical assets are installed at a functional location, which represents the design side descriptions of the installed parts of an oil-rig or a refinery.

Connectivity among physical entities

- the classes *ISO15926_ConnectionNode*, *ISO15926_ConnectionPoint*, *ISO15926_FunctionalLocation* and their relationships to *RSM_FunctionalLocation* *RSM_PhysicalEntity*, *RSM_WorkEquipment*, and *RSM_Asset* allows for expressing how different physical equipment is connected in an industry installation.

Measurements and measured values

- data can be collected for many entities in the enterprise including *RSM_PhysicalEntities*, *RSM_OrganizationalEntities*, and *RSM_ConnectionPoints*. This enables performance and condition analysis of both technical equipment and organizational units of an enterprise.

The model and the system architecture sketched above are used in concrete projects as described in [7] and [15].

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