Model driven integration architecture for IO G2 information

Reference Semantic Model alignment to ISO 15926

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Content

- **Background**
  - Owner / operator requirements

- **Reference Architecture**
  - Conceptual Reference Architecture for IO G2
  - The IBM Integrated Information Framework

- **Reference Semantic Model**
  - Integrating information model for the oil&gas industry

- **RSM alignment to ISO15926**
  - RSM as a Reference Data Library module
  - Providing ISO15926 data from the IIF/RSM
StatoilHydro TAIL-IO R&D Programme - Operational reality

- Large number of different applications. Each instance with own unique reference and data model. Example:
  - Real Time historians / IMS Systems - One for each asset
  - Hydro Carbon Accounting systems - One for each asset / license

- Complex views spanning divisions/plants/process areas requires new “one-off” application developments.

- Challenges
  - Lost volumes
  - Inefficient operation & maintenance
  - Incidents
  - Reduced IT ROI
The current situation – complexity is increasing

- Equipment Fault Detection
- Equipment Condition Monitoring
- Execute Maintenance Operations
- Production Optimization
- Drilling Program Planning
- Plan Turnaround
- INFO STRUCT
- DATAMODEL
- MEDIATION
- SECURITY
- COMMS

DCS, PLC & Historians
Rotating Equipment Monitoring
Facility Monitoring and MES
Engineering Systems
Maintenance & Asset Management
Equipment and Process Documentation

NEW APPLICATIONS

EXISTING APPLICATIONS & INFORMATION REPOSITORIES

PROCESS CONTROL DOMAIN

OFFICE DOMAIN

abela

FSi

olf
• Current EAI/ESB technologies are inadequate

*)Svein G. Johnsen (SINTEF), Einar Landre, Knut Sebastian Tungland (StatoilHydro), Frode Myren (IBM), Paul Carr (CapGemini)
The Service patterns

Integrated Operations in the High North – Joint Industry Project

Sand Detection Monitoring Services

- Model workbench
- Events
- Tasks
- KPI's
- Sand Monitoring DB

Business Processes

Service Components

Rotating Equipment Monitoring

Maintenance & Asset Management

PROCESS CONTROL DOMAIN

OFFICE DOMAIN

IEEE S3: A Service-Oriented Reference Architecture, Arsanjani et al.
The Integration pattern within the architecture

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Enterprise Services Bus

Services Integration

Communications Integration

DCS, PLC & Historians

Rotating Equipment Monitoring

Facility Monitoring and MES

Engineering Systems

Maintenance & Asset Management

Equipment and Process Documentation

Enterprise Services Bus

Mediations

Orchestration Process Svcs

REST Services

Web Services

Information As a Service

OPC Client+Server

Publish Subscribe

Event processing

Direct connection Router Broker

NEW COMPOSITE APPLICATIONS

EXISTING APPLICATIONS & INFORMATION REPOSITORIES

PROCESS CONTROL DOMAIN

OFFICE DOMAIN
The Role of the Semantic Model within the integration architecture

Integrated Operations in the High North – Joint Industry Project

DRILLING PROGRAM PLANNING
PRODUCTION OPTIMIZATION
EQUIPMENT FAULT DETECTION
MONITOR EQUIPMENT CONDITION
EXECUTE MAINTENANCE OPERATIONS
PLAN TURNAROUND

NEW COMPOSITE APPLICATIONS

Semantic Pattern
Integration Pattern

Enterprise
Area
Asset
Production
Work
Environment
Measurement
Value

ISA 95
ISA 88
MIMOSA
OAGIS
ISO 15926

DCS, PLC & Historians
Rotating Equipment Monitoring
Facility Monitoring and MES
Engineering Systems
Maintenance & Asset Management
Equipment and Process Documentation

EXISTING APPLICATIONS & INFORMATION REPOSITORIES

PROCESS CONTROL DOMAIN
OFFICE DOMAIN

RSM: Part of real time transactional integration platform
ISO15926: Master data definitions and structures
The Purdue Reference Model – Enterprise – Operation – Control
Applicable standards for integration

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OAGIS (Supply chain)

ISA S95 Parts 1, 2, and 5 and B2MML

ISA S95 Parts 3 and 4

OPC UA, MIMOSA and IEC and ISO standards

ISA S88, BatchML, IEC and ISO standards

Business Logistics
Plant Production Scheduling, Shipping, Receiving, Inventory, etc

Manufacturing
Operations Management
Dispatching, Detailed Production Scheduling, Production Tracking, ...

Batch Production Control
Continuous Production Control
Discrete Production Control

The production processes
StatoilHydro TAIL-IO R&D Programme

F0B GODI Full Scale Pilot project context

5 use cases

2 use cases

2 use cases

1 use case

F0B Build Services

F0B Condition Monitoring Services

F0B Operations and Production Collaboration Svcs

F0B Real Time Visualization Production Optimization Services

Manage Services

Systems & Infrastr

Model Mgmt

Integration Patterns

Services Patterns

Semantic Models

Global Operations Data Integration

In a total of 61 test cases completed

• Verification of flexibility & scalability wrt work processes and data access
• Verification of performance, availability, security, usability
IBM C&P Integrated Information Framework, extending IBM WebSphere

Users and applications
- Maintenance Supervisor/Engineer
- Platform Engineer
- Production Supervisor
- Operator
- HSE Engineer
- Field, Asset Owner

Built in IIF Extensions
- Production and performance reporting
- Condition based monitoring
- Intelligent alerts & event management
- KPIs and production calculations
- Collaboration for decision making

IIF (Middleware)
- Reference semantic model
- Global standards
- Smart SOA with collaboration
- Configurable event rules engine
- Visualization in context of process

Accessed via Model aware adapters
- Facility monitoring, HSE apps. & legacy appl.
- Rotating equipment monitoring
- DCS, PLC, & historians
- Drilling & Production Acc. systems
- Maintenance & Asset mgt
- Equipment & process documentation

Integration with other systems (ERP, EAM, Oil accounting)
IIF Solution Studio
Facilitates exchange of measurements, equipment, planning information, federated across applications, across facilities.
IOHN Activity 2 has the architecture focus
To establish a digital platform infrastructure across domains

**Digital platform**

**Business processes**
- Drilling and completion
- Production, reservoir mgmt
- Operations & Maintenance

- Risk management for reliable information and IT (Activity 4)
- Semantic oil and gas platform and information assurance (Activity 3)
- Networks, infrastructure and web services (Activity 2)
- Robust subsea sensor network and control systems

Activity 1 Activity 2 Activity 3 Activity 4
IOHN Activity 3 focus for this effort
To establish a semantic platform

**Business processes**
- Drilling and completion
- Production, reservoir mgmt
- Operations & Maintenance

**Digital platform**
- Risk management for reliable information and IT
- Semantic oil and gas platform and information assurance
- Networks, infrastructure and web services
- Robust subsea sensor network and control systems

"Home" of this effort
Mission and scope

Represent the Reference Semantic Model (RSM) in ISO15926

This scope: Represent in ISO15926 the scope of the Reference Semantic Model (RSM) currently exploited by the F0B/GODI (TAIL) project
Examples of challenges targeted by the RSM and the IIF framework

- Part of real time transactional integration platform
- Access to information concerning the same object(s) even if the information is dispersed across many facilities and many applications
- An instance model providing a naming context for measurements across facilities
Reference Semantic Model
- An integrating information model for the oil & gas industry

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Overview

• Why the Reference Semantic Model
• Main elements of Reference Semantic Model
• Summary
Main aspects of the Reference Semantic Model

• Uniform representation of data/information flowing through the IIF

• Supports information needs of different applications

• Is a blend of different information model standards like ISA S88, S95, MIMOSA, ISO 15926

• The RSM is
  ▪ defined as a UML meta-model
  ▪ implemented as a relational database for storing model instance data
Clarifying terms and how they are used in RSM and ISO 15926

**Ontology**

- **C** = class
- **R** = relation
- **A** = axiom
- **CI** = class instance
- **RI** = relation instance

**Language**

**RSM**

- UML+SQL

**ISO 15926**

- OWL

**Meta-Model**

**Model-Instance(s)**

C = class, R = relation, A = axiom, CI = class instance, RI = relation instance
Semantics for RSM: by translation into ISO 15926

- O&G industry domain content
- m-m mapping
- m-i transformation

FOL Semantic Space

- RSM meta-model
- RSM model-instance
- UML+SQL
- tr(RSM)
- tr(RSM m-m)
- tr(RSM m-i)
- ISO 15926
- OWL

semantics (tr(RSM))
Why the term ‘Reference Semantic Model’?

- Reference Semantic Model aims at
  - richer content quantity \(\neq\) higher content quality through
    - expanding the industry domain modeling scope
    - unification of relevant information models like S95, S88, MIMOSA
  - richer content quantity \(\neq\) **higher content quality** through
    - Reviews of UML master model
    - (semantics-defining) transformation to ISO 15926
    - exploiting semantics of OWL used as modeling language for ISO 15926
Overview

• Why a Reference Model

• **Main elements of Reference Semantic Model**

• Summary
Standards around RSM and IIF

- Asset Management
- EngineeringSystem
- EquipmentMonitoring

- MIMOSA
- ISO 15926
- S95

- RSM AwareAdapter
- RSM AwareAdapter
- RSM AwareAdapter

- RSM Model Server
- RSM Model DB

- OPC

- Realtime&History
Standards around RSM and IIF

Integrated Operations in the High North – Joint Industry Project

- Asset Management
- Engineering System
- Equipment Monitoring

RSM AwareAdapter

pump0815:MaintainableItem

mo0815.3:MaintenanceOrder

flow100cm3/sec:Measurement

RSM Model Server

RSM Model DB

Realtime & History

opcTag4711, 100
<table>
<thead>
<tr>
<th></th>
<th>Classes</th>
<th>Enumerations</th>
<th>Literals</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSM</td>
<td>182</td>
<td>19</td>
<td>~ 100</td>
</tr>
<tr>
<td>ISA S88</td>
<td>30</td>
<td>5</td>
<td>~ 100</td>
</tr>
<tr>
<td>ISA S95</td>
<td>89</td>
<td>15</td>
<td>~ 100</td>
</tr>
<tr>
<td>ISO 15926</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MIMOSA</td>
<td>20</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>OPENGIS</td>
<td>38</td>
<td>6</td>
<td>~ 50</td>
</tr>
<tr>
<td>UNCEFACT</td>
<td>2</td>
<td>3</td>
<td>~ 800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>365</strong></td>
<td><strong>49</strong></td>
<td><strong>1208</strong></td>
</tr>
</tbody>
</table>
Key aspects of O&M for oil & gas enterprises in RSM

• Currently most exploited parts of RSM
• Main areas of RSM subject for ISO 15926 alignment
• Alignment means
  ▪ Position RSM more precisely in the ISO 15926 ontology
    ➔ RSM classes as subclasses of ISO 15926 classes
  ▪ Import equipment classifications from ISO 15926 into RSM
    ➔ ISO 15926 classes as subclasses of RSM classes
    ➔ ISO 15926 classes as instances of RSM classes
Functional enterprise structure

Objectives of the RSM and ISO 15926 alignment effort

1. The intended representation aimed at capturing
   - the functional entities in an enterprise
   - the accountable assets – including a view of the physical specimen

2. Unify RSM, ISA, ISO 15926, and MIMOSA terminology

3. Capture a notion of connectivity between functional entities

4. Simplify RSM modeling to eliminate redundancies

5. Adapt the 'TypeOf...' representations for better alignment with ISO 15926
Functional enterprise structure

Hierarchy of RSM FunctionalEntity merging
- MIMOSA_Segment
- RSM_PhysicalEntity
- RSM_FunctionalLocation
- ISO15926 FunctionalLocation
Both models have detailed model elements for functional structure ➔ close links are possible ➔ better mechanical translations
The 'TypeOf...' construction - I

- In the RSM there are many different types of
  - OrganizationalEntity
  - FunctionalEntity
  - Asset
  - ...

- In ISO 15926 those types of ... are represented as classes in the meta-model

- Adopting this approach for RSM
  - is highly interesting, since it allows for exploiting ISO 15926 equipment classification
  - has to be done with care, because, e.g.,
    - ISO 15926 has 10.000+ equipment types represented as OWL classes
    - Representing each such OWL class per equipment type as a UML class in RSM would lead to 10.000+ sparsely populated DB tables
Equipment type modeling:
- instances vs subclasses – original RSM approach

**Meta-model**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>TypeOfEquipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>tOE : TypeOfEquipment</td>
<td>rdlURL : String</td>
</tr>
</tbody>
</table>

- `motor:TypeOfEquipment`
- `pump:TypeOfEquipment`
- `valve:TypeOfEquipment`

**Database**

<table>
<thead>
<tr>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>motor1</td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>m10000</td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>pump1</td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>p10000</td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>valve1</td>
<td></td>
<td>valve</td>
</tr>
</tbody>
</table>

One big table: many queries run against large amounts of data

original RSM
Equipment type modeling:
- instances vs subclasses – original ISO 15926 approach

### Meta-model

| Equipment | rdIURL : String |

### Database

**Valve**

<table>
<thead>
<tr>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>valve1</td>
<td></td>
<td>valve</td>
</tr>
</tbody>
</table>

**Motor**

<table>
<thead>
<tr>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>m10000</td>
<td></td>
<td>motor</td>
</tr>
</tbody>
</table>

**Pump**

<table>
<thead>
<tr>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>p1</td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>p10000</td>
<td></td>
<td>pump</td>
</tr>
</tbody>
</table>

Dedicated tables: down at the equipment hierarchy many tables are sparsely populated.

original ISO 15926
Equipment type modeling:
- instances vs subclasses recommendation

ISO 15926 and RSM alignment allows for a combined 'TypeOf...' modeling approach
- subclasses for equipment types with high population
- just type instances for equipment types with low population
Equipment type modeling:
- instances vs subclasses as recommended

Database

<table>
<thead>
<tr>
<th>Equipment</th>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>valve1</td>
<td></td>
<td></td>
<td>valve</td>
</tr>
</tbody>
</table>

Meta-model

- Equipment
  - tOE : TypeOfEquipment

- TypeOfEquipment
  - rdlURL : String
  - motor:TypeOfEquipment
  - pump:TypeOfEquipment
  - valve:TypeOfEquipment

instances

<table>
<thead>
<tr>
<th>Motor</th>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td></td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td>motor</td>
</tr>
<tr>
<td>m10000</td>
<td></td>
<td></td>
<td>motor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pump</th>
<th>name</th>
<th>desc</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>p1</td>
<td></td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td>pump</td>
</tr>
<tr>
<td>p10000</td>
<td></td>
<td></td>
<td>pump</td>
</tr>
</tbody>
</table>
The 'TypeOf...' construction - II

- Adopting the ISO 15926 modeling approach strictly for RSM, the equipment types are sub-classes of RSM_WorkEquipment

- The chosen approach for RSM 2.0 is more flexible in the sense of
  - Modeling the ISO 15926 equipment type hierarchy through RSM classes 'down to a reasonable' level of detail
    - if large numbers of certain equipments suggest separate tables per equipment type
  - Modeling ISO 15926 equipment types as instances of class RSM_TypeOfWorkEquipment
    - if small numbers of certain equipment types suggest a single table for equipment of different types
Overview

• Why a Reference Model
• Background Reference Semantic Model
• Main elements of the Reference Semantic Model

• Summary
Two interesting threads to bring RSM forward

• Gain acceptance for RSM through established standardization bodies
  ▪ The standards integration approach of RSM considered meaningful

• Expand the scope of RSM to provide improved integration support through IIF
  ▪ Understand integration and information model alignment needs along the processing chain
RSM and its parent standards

- Parent standards are established as industry standards
- RSM is not yet standardized
- Its nature as a mesh-model combining other standards implies
  - Portions of RSM ‘close enough’ to parent standard could be standardized by the organization owning the parent standard
  - Standardizing RSM may also trigger parent organizations cross-accepting other standard’s models

Standardize RSM

- to obtain acceptance of RSM based applications by POSC Caesar and ISO
- to assure better interoperability with systems based on RSM parent standards
Number of existing standards prohibitively high to incorporate all of them into RSM

ISO Standards for use in the oil & gas industry
Standards around RSM and IIF

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ISO 13628-1 Subsea production systems

IIF Standards around RSM and IIF

S95 MIMOSA

OPC

WITSML

Drilling Device Control

RSM AwareAdapter

RSM AwareAdapter

RSM AwareAdapter

RSM Model Server

RSM Model DB

EqtState2EqtMon

CreateMntOrd

WITSML-to-RSM Adapter

ISO13628-to-RSM Adapter

ModelTransformation

ISO 13628-1 Subsea production systems

Non-absorbed standards

Absorbed standards

Asset Management

EngineeringSystem

EquipmentMonitoring

Asset Management

EngineeringSystem

EquipmentMonitoring

FormatTransformation

Realtime&History

ProductionControl

ISO 15926

Non-absorbed standards

ISO 13628-1 Subsea production systems
'To absorb' or 'Not to absorb'?

• (Partially) absorbed parent standards
  - Allow for simpler transformation between IIF and applications relying on parent standard
    ➔ format transformation in adapters
  - 'Absorption' means static model alignment

• Non-absorbed (further) parent standards
  - Require more complex transformations
    ➔ model transformation inside adapters
  - 'Non-absorption' requires dynamic model transformation

• Expand parents standard integration for applications that exchange information with IIF at the bottom of the event processing pyramid
  - good candidates are PRODML/WITSML
Exploitation and evolution of RSM

- StatoilHydro TAIL project
  - Gain practical experience and prove applicability

- Streamline RSM content and align with ISO 15926
  - Gain acceptance through established standardization bodies

- Absorb elements from further standards
  - Assure wider scope of usage
Alignment to ISO 15926

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DNV
IOHN Activity 3 overall objective

Based on requirements from the pilot projects and project participants:

- Extend and improve the content and quality of the ISO 15926 Reference Data Library (RDL)
- Develop a prototype information validation service

ISO 15926 – Integration of life-cycle data for process plants including oil and gas production facilities.
Domain specific reference data

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Domain specific nomenclatures

Drilling

Production and Reservoir

Operations and Maintenance

ISO 15926*

Structure and add to ISO 15926 Reference Data Library (RDL)

Oil and gas ontology (Reference Data)
‘RSM in ISO 15926’ means two things

• The RSM UML model in ISO 15926 Reference Data Library
  - Represented as an ISO 15926 ontology
  - RSM classes are mainly specializations of O&M, P&R classes

• Export/import data between IIF/RSM systems and ISO 15926 format
  - RSM content provided with RDL classification
  - On demand production of exchange-friendly instance data
RSM model in the ISO 15926 RDL hierarchy

- Domain-specific parts of the PCA RDL depend on generic parts
- RSM classes specialize RDL classes from the IOHN Activity 3 information scope
- The RSM model representation effort introduced new classes to the RDL
Work carried out in IOHN Activity 3

- Modelling using Protégé OWL workbench and Rational Software Architect
- RSM UML model entities represented as RDL classes and relations
- Complex mappings expressed in ISO 15926-7 templates
- Mappings tested using Template Expander tool
- The RSM classes uploaded to the RDL
Three generic levels of *data* alignment

- **Dictionary**: Explanation
  - apply reference definition to things
- **Taxonomy**: Aggregation
  - generic/specific categories of things
- **Ontology**: Relation
  - identify things that are related in various ways
Current classification isn’t uniform

RSM table
Site 1

'Separator vann'

'Separator vann'

Water separator'

Gas turbine'

RSM table
Site 2

#.. 

#Cs1

#..
Dictionary alignment:
*Apply common terminology*

ISO 15926 RDL (dictionary)

- **SEPARATOR**
- **WATER SEPARATOR**
- **TEST SEPARATOR**
- **GAS TURBINE**

RSM table
Site 1

#Sv1
#Ws2
#..
#Gt1

RSM table
Site 2

#..
#Cs1
#..
#..
Taxonomy alignment:
Discover additional knowledge

ISO 15926 RDL (taxonomy)

RSM table
Plant 1

#Sv1
#Ws2
#..
#Gt1

RSM table
Plant 2

#..
#Cs1
#..
#..

GAS TURBINE

SEPARATOR

TEST SEPARATOR

WATER SEPARATOR
Ontology alignment

*Knowledge discovery along arbitrary dimensions*

ISO 15926 RDL (ontology)

RSM table Plant 1
- #Sv1
- #Ws2
- #..
- #Gt1

RSM table Plant 2
- #..
- #Cs1
- #..
- #..
Mapping complex patterns

- Several constructions in the RSM scope require information assemblies of more than one element
  - *E.g. Connections, measurements, properties*
  - For a meaningful interpretation, several pieces of information have to be considered together.
  - The *dictionary, taxonomy, ontology* alignment levels apply also to patterns of information

- RSM and ISO 15926 represent things differently
ISO 15926 Templates

- *Part 7* is a new addition to ISO 15926
- A template captures a pattern for stating facts
- Signature – Rule (Axiom):
  - The template signature specifies the input arguments
  - The template rule specifies what statement is made, expanding to explicit ISO 15926 format
  - Template rules allow for interpretation as first-order logic axioms
Example: Connections

• Typical information in an RSM database: A generator is connected to power a fan.
• The general case is: Pieces of equipment are connected.
• We want to present such connection information in the ISO 15926 space as well.
Connections in RSM

We need to consider the RSM classes

- Functional Entity
- Connection Point
- Connection Node

and relations between them.
Connections in ISO 15926

We need to consider the ISO 15926 entity types

- ArrangedIndividual
- FeatureWholePart
- ConnectionOfIndividual

and relations.
Alignment: Connections

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RSM

RSM_FunctionalEntity_2.0

RSM_ConnectionPoint

RSM_ConnectionPoint.belongsTo_PhysicalEntity

ISO15926_ConnectionPoint.toConnectionNode

RSM_ConnectionNode

ISO15926_ConnectionPoint.toConnectionNode

RSM_ConnectionPoint

Generator

ArrangedIndividual

hasWhole

hasPart

Socket

ArrangedIndividual

hasSide1

hasSide2

Plug

ArrangedIndividual

FeatureWholePart

ConnectionOfIndividual
Connections: RSM representation

- There are two pieces of equipment, A and B.
- There is a connection N between A and B.
- Connection points CA, CB represent equipment parts that participate in the connection.
- N is the connection itself.
This signature defines a table for recording RSM connections.

<table>
<thead>
<tr>
<th>#</th>
<th>Role</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Entity 1</td>
<td>ArrangedIndividual</td>
</tr>
<tr>
<td>2</td>
<td>Entity 2</td>
<td>ArrangedIndividual</td>
</tr>
<tr>
<td>3</td>
<td>Conn. pt. 1</td>
<td>ArrangedIndividual</td>
</tr>
<tr>
<td>4</td>
<td>Conn. pt. 2</td>
<td>ArrangedIndividual</td>
</tr>
<tr>
<td>5</td>
<td>Connection</td>
<td>ConnectionOfIndividual</td>
</tr>
</tbody>
</table>
Rule: The ISO 15926 representation pattern

ISO 15926-7 template signature:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Entity 1</td>
</tr>
<tr>
<td>2</td>
<td>Entity 2</td>
</tr>
<tr>
<td>3</td>
<td>Conn. pt. 1</td>
</tr>
<tr>
<td>4</td>
<td>Conn. pt. 2</td>
</tr>
<tr>
<td>5</td>
<td>Connection</td>
</tr>
</tbody>
</table>

ISO 15926-7 template rule:

\[
\text{RSMFunctionalEntityConnection} (x_1, x_2, x_3, x_4, x_5) \leftrightarrow \\
\text{ArrangedIndividual}(x_1) \& \\
\text{ArrangedIndividual}(x_2) \& \\
\text{ArrangedIndividual}(x_3) \& \\
\text{ArrangedIndividual}(x_4) \& \\
\text{ConnectionOfIndividual}(x_5) \& \\
\text{FeatureWholePartTemplate}(x_3, x_1) \& \\
\text{FeatureWholePartTemplate}(x_4, x_2) \& \\
\text{DirectConnectionTriple}(x_5, x_3, x_4) . \\
\]
Template expansion

ISO 15926-7 template instance

<table>
<thead>
<tr>
<th>RSMFunctionalEntityConnection</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Entity 1</td>
<td>Equipment A</td>
</tr>
<tr>
<td>2 Entity 2</td>
<td>Equipment B</td>
</tr>
<tr>
<td>3 Conn. pt. 1</td>
<td>Conn point_1</td>
</tr>
<tr>
<td>4 Conn. pt. 2</td>
<td>Conn point_2</td>
</tr>
<tr>
<td>5 Connection</td>
<td>Conn node N</td>
</tr>
</tbody>
</table>

Expanded to explicit ISO 15926-2

ArrangedIndividual(A) & ArrangedIndividual(B) & ArrangedIndividual(CA) & ArrangedIndividual(CB) & ConnectionOfIndividual(N)

This illustrates RSM to ISO 15926 model interchange for equipment connectivity.
The connection in ISO 15926-2

OWL representation
Translation in two directions

ISO 15926 data set

- Generator
- Fan
- Socket
- Plug
- S-P_Connect

RSM data set

- Generator
- Socket
- Plug
- Fan

Expand
Query
Another complex mapping: Measurements

ISO15926/PCA RDL

1. arranged_individual (functional)
   - enumerated_property_set
     - classification
     - property
       - classification
       - hasMeasurementquantification
         - arithmetic number
           - classification
           - number space

RSM

1. RSM_FunctionalEntity_2.0
   - RSM_Measurement.associatedTo_PhysicalEntity
     - RSM_Measurement
       - RSM_MeasurementValue.IsA_Measurement
         - RSM_MeasurementValue.UOM
           - Validation?
             - *RSM_MeasurementValue.UOM
               - UOM
                 - RSM_MeasurementValue.Source
                   - RSM_MeasurementValue.Source.
                     - sourceOf_MeasurementValue

2. RSM_MeasurementValue.associatedTo_PhysicalEntity

3. RSM_MeasurementValue

4. RSM_Measurement

5. RSM_Measurement.associatedTo_PhysicalEntity
RSM model in RDL: Advantages

• We obtain a standardized representation of the model
• Documentation of the system structure is openly available
• Users and independent software vendors can investigate the model for alignment and integration
RSM data in ISO 15926: Advantages

- Dictionary alignment. *Apply common terminology*
- Taxonomy/ontology alignment. *Discover additional knowledge*

- Data quality. Content from various OPC sources is given a standard classification
- Integration. ISO 15926/reference data content is suitable for exchange
- Applications. The OWL/RDF format makes content available for semantic tools
Thank you!

Questions?