Using OWL for CIM profiling

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CIM Introduction

• The Common Information Model (CIM) for power systems is described in a series of IEC specifications for different domains
  • Power Networks (both transmission and distribution) - IEC 61970
  • Utility OT processes - IEC 61968
  • Energy markets - IEC 62325

• CIM consist of three main parts
  • Canonical CIM, a common power system information model in UML
  • Profiles describing subsets of canonical CIM for dedicated data exchanges
    • CIM RDF (IEC 61970-501) describe the profile information model
    • Data exchange formats, CIMXML (IEC 61970-552) or XML Schema based
  • CIM conformity tested with models from ENTSO-E, e.g. MicroGrid
Solve Issues With CIM Profiling

• Solve current tool lock in
  • UML Editors with the XMI format
  • Profiling tools using the CIM RDF format (IEC 61960-501)
  • CIM RDF use custom extensions and is not up to date with OWL

• Enable exchange of meta data between tools
  • The XMI format for UML model exchange has poor interoperability
  • Profiling tools need a common and up to date exchange format
  • Avoid tool vendor lock in, XMI a big issue, lack of common format for profiles

• Use of the shelf ontology tools
  • Ontology editors, e.g. Protégé
  • Graph databases (triple stores)

• Enable merge of other domain ontology’s with CIM
Issues With CIM Profiling - Examples

• XMI has a large custom part, about 5/6 of all data
• XMI has an extensive duplication of data between the standardized and custom sections
• XMI is complex to search due to its mix of hierarchical (standardized section) and flat structured (custom section) data
• CIM Tool save profiles in an OWL format that no other tool can use
• Other profiling tool read and write CIM RDF format (IEC 61960-501) but CIM Tool cannot read the CIM RDF
• No support for OCL in profile data
Semantic Web Technology Introduction

- Knowledge distributed on the web
- Cooperation and integration of knowledge islands
- W3C are developing the technology supporting this
  - Resource Description Framework (RDF)
  - Resource Description Framework Schema (RDFS)
  - OWL 1 an information modeling language
  - OWL 2 that extend OWL 1 into a knowledge representation language
- RDF is a graph structure, the foundation for graph databases & SPARQL
OMG Meta Object Facility (MOF) describe a layered information architecture
1. M0 - Domain data, e.g. CIMXML data
2. M1 – Domain data model describing the M0 data, e.g. CIM
3. M2 – Meta data describing M1 domain models, e.g. UML
4. M3 – Meta meta data describing M2, not used in this work
OMG has a UML model for UML but in this work a UML model of UML has been reversed engineered from XMI, refer to slide 20.

These two ontologies has been created in this work

CIMXML has been made ontology aware
Of The Shelf Tools Used For Proof of Concept

Load OWL instances and link with OWL ontology, mismatch between ontology and instance data is easily spotted in the GUI

OWL support all least three different formats that support both ontology and instances
- RDF/XML, used for CIMXML (IEC 61970-552)
- OWL/XML
- Functional
# UML to OWL Mapping as by ODM*

<table>
<thead>
<tr>
<th>CIM UML structures</th>
<th>OWL structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>Ontology</td>
</tr>
<tr>
<td>Class</td>
<td>Class</td>
</tr>
<tr>
<td>Simple valued attribute</td>
<td>Data property</td>
</tr>
<tr>
<td>Attribute typed as a class or role</td>
<td>Object property</td>
</tr>
<tr>
<td>Association</td>
<td>Object properties with inverse relation</td>
</tr>
<tr>
<td>CIM primitive data types</td>
<td>Equivalence with XML Schema types</td>
</tr>
<tr>
<td>CIMdatatype stereotyped types</td>
<td>In profiles these types are mapped to XML Schema types and the CIMdatatype sub-structure is not used</td>
</tr>
<tr>
<td>Inheritance between classes</td>
<td>Subtypes</td>
</tr>
<tr>
<td>Enumeration member</td>
<td>An instance</td>
</tr>
<tr>
<td>Enumeration class</td>
<td>A class describing the enumeration member instances</td>
</tr>
</tbody>
</table>

CIM Modeling With OWL Starting From XMI

XMI IM data is translated into OWL instances described by the UML IM ontology. CIM XMI data is translated into CIM OWL instances that are described by the UML IM ontology. The UML IM ontology is derived from the UML IM OWL instances. The CIM ontology is derived from the CIM OWL instances that describe CIMXML instance data. Benefits doing this:

- All information maintained by UML tools (schema, diagrams, actions, OCL ...) described by a common UML information model.
- The corresponding UML Ontology is standardized and independent of UML tool specifics.
- By this the derivation rules can be standardized given that all used UML stereotypes has been defined for a specific domain information model.
- The UML tool specifics is managed in the translation step.
Profile Modelling With OWL From XMI

Basically the same as with the canonical UML but with smaller profile information models, red items in the diagram indicate new data or processes.

A profile information model at level M2 is created in UML that is exported as XMI and translated to OWL instances. A profile information model is derived from the profile information model OWL instances.

CIMTool provide a CIM profile information model in CIM RDF that is translated into CIM profile OWL Instances. The CIM profile OWL instances are used to create a reduced set (profiled) of CIM OWL instances from which a profile CIM ontology is derived in the same way as for the full canonical UML.
Add ontology header to CIMXML document, e.g. in Microgrid EQ-BE and EQ-BD

```xml
<rdf:RDF ... xmlns:owl=http://www.w3.org/2002/07/owl#...>
  <owl:Ontology rdf:about="urn:uuid:34e5b362-7771-4a8f-a5a8-571f76de9f41">
  </owl:Ontology>
</rdf:RDF>
```

Make IDs valid RDF, i.e. prefix with "urn:uuid:"
UML Packages As Ontology

<rdf:RDF ...
<owl:Ontology rdf:about="http://iec.ch/TC57/2013/CIM-schema-cim16/EQCore/IEC61970">
  <rdfs:label>IEC61970</rdfs:label>
  <rdfs:comment>Top package for IEC 61970.</rdfs:comment>
</owl:Ontology>
<owl:Class rdf:about="#IEC61970CIMVersion">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  <rdfs:label>IEC61970CIMVersion</rdfs:label>
  <rdfs:comment>This is the IEC 61970 CIM version number assigned to this UML model.</rdfs:comment>
</owl:Class>

Load sub-ontology's representing UML sub-packages. The red IRI is ID of this ontology.
Protégé Screen Shot MicroGrid T1
SPARQL, Known CIM Classes

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX cim: <http://iec.ch/TC57/2013/CIM-schema-cim16#>

select * where {
  graph <http://entsoe.eu/Microgrid-T1> {
    ?cimsub rdf:type ?cimtype
  } graph <http://iec.ch/TC57/2013/CIM-schema-cim16/EO/IEC61970> {
    ?cimtype rdf:type ?ontype
  }
} order by ?cimtype
limit 100
```

Table | Raw Response | Pivot Table | Google Chart | Graph (beta) | Download as

| Filter query results |

<table>
<thead>
<tr>
<th>cimsubm</th>
<th>cimtype</th>
<th>ontype</th>
</tr>
</thead>
<tbody>
<tr>
<td>urn:uuid:170b64a87-5b8a-4979-b8de-0b4025e8b4da</td>
<td>cim:ACLLineSegment</td>
<td>owl:Class</td>
</tr>
<tr>
<td>urn:uuid:797363c7-9c0-4b32-b3fe-808165e6ce6</td>
<td>cim:ACLLineSegment</td>
<td>owl:Class</td>
</tr>
<tr>
<td>urn:uuid:7f435006-2430-4b4d-9146-0a40d66c5e40</td>
<td>cim:ACLLineSegment</td>
<td>owl:Class</td>
</tr>
<tr>
<td>urn:uuid:7f435006-2430-4b4d-9146-0a40d66c5e40</td>
<td>cim:ACLLineSegment</td>
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<td>cim:ACLLineSegment</td>
<td>owl:Class</td>
</tr>
</tbody>
</table>

Showing results from 1 to 572 of 572. Query took 0.889 s.
SPARQL, Unknown CIM Classes

```sparql
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX cim: <http://iec.ch/TC57/2013/CIM-schema-cim16#>

select * where {
  graph <http://entsoe.eu/Microgrid-T1> {
    ?cimsubj rdf:type ?cimtype
    graph <http://iec.ch/TC57/2013/CIM-schema-cim16/FO/IEC61970> {
      filter not exists {?cimtype rdf:type ?ontype}
    }
  }
}
order by ?cimtype
limit 10000
```
SPARQL, Known CIM Properties

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX cim: <http://iec.ch/TC57/2013/CIM-schema-cim16#>

SELECT * WHERE {
  graph <http://entsoe.eu/Microgrid-T1> {
    ?cimSubj ?cim ?cimType .
  } minus {?cimSubj rdf:type ?cimType}
  graph <http://iec.ch/TC57/2013/CIM-schema-cim16/IEC61970> {
    ?cim rdf:type ?o .
  } limit 10000
}
```

Filter query results

<table>
<thead>
<tr>
<th>cimsubj</th>
<th>cimp</th>
<th>cimtype</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>urm:uuid:00210a40-3857-46dc-b84a-30420083558f</td>
<td>cim:Equipment:aggregate</td>
</tr>
<tr>
<td>3</td>
<td>urm:uuid:00210a40-3857-46dc-b84a-30420083558f</td>
<td>cim:IdentifiedObject:object</td>
</tr>
<tr>
<td>4</td>
<td>urm:uuid:00210a40-3857-46dc-b84a-30420083558f</td>
<td>cim:IdentifiedObject:name</td>
</tr>
<tr>
<td>5</td>
<td>urm:uuid:00210a40-3857-46dc-b84a-30420083558f</td>
<td>cim:LinearShuntCompensator:barPerSection</td>
</tr>
</tbody>
</table>
SPARQL, Unknown CIM Properties

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX cim: <http://iec.ch/Tc57/2013/CIM-schema-cim16#>

select * where { 
    graph <http://entsoe.eu/Microgrid-T1> { 
        ?climsub ?cimtype . 
        filter not exists (?climsub rdf:type ?cimtype) 
    }
    graph <http://iec.ch/Tc57/2013/CIM-schema-cim16/IEC61970> { 
        ?clim rdf:type ?cimtype 
        filter not exists (?clim rdf:type ?cimtype) 
    }
}
order by ?cimtype ?climsub ?cim 
limit 10000
```

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Differences CIM RDF (IEC 61970-501) and OWL

• RDF and RDFS is a subset of OWL*

• New definitions in OWL replacing the CIM RDF extensions
  • owl:Ontology, owl:imports, owl:ObjectProperty, owl:DatatypeProperty,
    owl:equivalentClass, owl:oneOf, owl:maxQualifiedCardinality,
    owl:minQualifiedCardinality, owl:inverseOf, owl:Restriction, owl:onProperty,
    owl:onClass, owl:NamedIndividual, ...

• RDF/RDFS definitions still used
  • rdfs:Datatype, rdfs:subClassOf, rdfs:domain, rdfs:range, rdf:type, rdfs:label,
    rdfs:comment, rdf:Description, ...

• RDFS definitions no longer used
  • rdfs:class replaced by owl:class, ...

*) Refer to OWL2 Web Ontology Language Primer, http://www.w3.org/TR/owl-primer
The diagram show the information model for UML itself used in this work.

The corresponding UML information model from OMG has not been used.
The diagram shows the profile data information model used in this work. This information model is linked with the information model for UML.
Conclusions

• Proved that OWL can replace XMI and CIM RDF
• Explicit information models for UML and profiles enables validation and verification of any information model and profile data.
• Yet to do
  • Extend the information model to cover the full UML
  • Evaluate use of OMG version instead
  • After this OWL can fully describe the UML information model
  • Develop a new IEC 61970 specification for profile data replacing CIM RDF
  • Reconsider use of one OWL ontology per UML package
  • Evaluate SPARQL for derivation of ontologies from OWL instances
• The future
  • Use a profile information model in addition to the UML information model
  • Use OWL instead of CIM RDF and XMI, tool vendors need to support this
  • Retire CIM RDF and XMI