Transforming XML Schema to OWL Using Patterns

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AGENDA

1. B2B Use Case
2. XML Semantics
3. Transformation Patterns and Rules
4. System Evaluation
5. Conclusion
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B2B Standards

- **40+ B2B standards** have been analyzed
- Most of them specify:
  - Data Dictionaries, Messages, WSDL, Business Processes, Code Lists and EDIFACT messages
- Formats:
  - EDIFACT, less and less provided
  - DTD, very few
  - Ontologies, mostly research work yet, but showing growing interest
  - JSON, no one
  - XML Schema (XS), **everyone**
B2B Use Case Scenario
XML Documents and XML Schemas

Different semantics m:n matching

Code vs. string

Structural

Mandatory without match

Code vs. string

PapNet

OAGIS
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XML Semantics: Names’ Derivation for OWL Entities

• Having proper entity names improves the transformation process
  - providing a meaningful ontology
  - improving the integration of multiple sources
  - simplifying the matching operations with other resources
XML Semantics: Names’ Derivation for OWL Entities

- XML Schema design have a lot of different practices on naming elements that not always are of direct understanding
  - Normal words using *Camel Case* convention, like *OfficeLocation*
  - Abbreviations, like *amt_ccy* (= *amount currency*)
  - Acronyms, like PO (*Post Office* or *Purchase Order*)
  - Compound words, like *cash-flow*, but sometime not separated, like *foodservice*
  - Misspelled words
  - Specific terms
  - Prefix or a suffix, like *_type*, *TYPE*, *_tp*, *_t*, *_T*, *type_*
  - Unrelated words with the meaning of the element, like *UnitOfMeasure, BBIECommonData*
XML Mining: Some Figures

- Statistics based on 25 B2B standards
  - 3432 XSD Files, +586,000 XML Components, +170,000 named
  - 145,540 XML tags are composed by +3000 recognized terms
  - 85% of tags use real terms (based on WordNet and specific abbr. dict.)
  - 15% results to be difficult to get the semantic meaning,

- Improving the semantic recognition means:
  - more complex management of abbreviations
  - implementing NLP techniques
  - improving the external dictionaries capabilities
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XML Schema Components

• There are several XS components BUT!
  - 17 ways to declare elements (e.g. global/local element, references to a global element, a global/local element which defines a simple/complex type inline declaration, …)
  - 20 different ways to declare attributes.

• Components are divided in groups as follow:
  - **Named components (Nc):** establishing the ontology entities (Classes (C), Datatypes (D))
    - simple type (St) definitions, complex type (Ct) definitions, attribute (A) declarations and element (E) declarations, attribute group (AG) definitions, model group (G) definitions, SubstitutionGroup (S).
  - **Relational XS constructs (R):** defining ontology properties (P) (OWL datatype and object properties)
    - sequence, all, choice, ref, simpleContent, complexContent, restriction, extension, SubstitutionGroup, union, any, min/max occurs.
  - **Helper components (H),** which provide small parts of other components and are dependent on their context, mainly annotations.

• We define \( X = \langle Nc, R.Nc \rangle, \) where \( Nc = U(A, E, G, AG, St, Ct, S) \)
Ontologies and XML schemata serve very different purposes
- Ontology languages are a means to specify domain theories based on logical representation
- XML schemata are a means to provide syntactic and integrity constraints for information sources

But have one main goal in common: both provide information about data vocabulary and “structure”

The derivation methodology to permit the provision of not only basic information for a target ontology is a mix of rules and patterns
- Capturing the most natural derivations
- Interpret logical construct from some XML Schema

We define the domain conceptualization $T$ as the set of derived logical assertions from $X'$, the sub-set of $X$, having a corresponding element in $T$, through the surjection $m$.

$$m : X' \rightarrow T$$

$$X' = \{ \forall x \in X \mid m(x, t), t \in T \} \subseteq X$$

$$T = \{ U(C, D), P \cdot T \}$$
Simple and Complex Types Patterns: Example

<table>
<thead>
<tr>
<th>#</th>
<th>XS</th>
<th>OWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;simpleType name=&quot;st_name&quot;/&gt;</td>
<td>:st_name rdf:type rdfs:Datatype .</td>
</tr>
<tr>
<td>2</td>
<td>&lt;union memberTypes=&quot;st_name1 xsd:nativDataType ...&quot;/&gt;</td>
<td>:st_name owl:equivalentClass :st_name1 ;</td>
</tr>
<tr>
<td></td>
<td>&lt;simpleType name=&quot;st_name&quot;/&gt;</td>
<td>owl:equivalentClass xsd:nativeDataType;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>owl:equivalentClass .</td>
</tr>
<tr>
<td>3</td>
<td>&lt;complexType name=&quot;ct_name&quot;/&gt;</td>
<td>:Ct_name rdf:type owl:Class .</td>
</tr>
</tbody>
</table>

1. <xs:simpleType name="DispositionType">                      1. :disposition a rdfs:Datatype .
2. <xs:simpleType name="DispositionType">                      2. :disposition owl:equivalentClass
   <xs:union memberTypes=""                                       :criminalDisposition , xs:string .
   CriminalDispositionTypes xs:string"/>                        3. :Coordinate a owl:Class .
   </xs:simpleType>                                             

Example 2

15  <element name="elt_name" type="xsd:nativeDataType">

18  <complexType name="ct_name">
    <sequence>
      <element ref="elt_name"/>
    </sequence>
  </complexType>

21  <element name="Elt_name">
    <complexType>
      <sequence>
        <element name="elt_name" type="xsd:nativeDataType"/>
      </sequence>
    </complexType>

22  <element name="Elt_name">
    <complexType>
      <sequence>
        <element name="elt_name" type="xsd:nativeDataType"/>
      </sequence>
    </complexType>

---

15  <xs:element name="NationalNumber" type="xs:string"/>

21  <xs:element name="InternationalNumber">

22  <xs:complexType>
  <xs:sequence>
    <xs:element name="InternationalCode" type="xs:string"/>
    <xs:element ref="NationalNumber"/>
  </xs:sequence>
  <xs:complexType/>
  <xs:element/>

---

:elt_name rdf:type rdfs:Datatype ; owl:subClassOf xsd:nativeDataType .

:has_elt_name ct_name a rdfs:Datatype;
  rdfs:domain :ct_name ; rdfs:range :elt_name .

:Elt_name rdf:type owl:Class .

:has_elt_name a owl:DatatypeProperty ;
  rdfs:domain :Elt_name ; rdfs:range :xsd:nativeDataType.

:nationalNUmber a xs:Datatype ;
  owl:subClassOf xs:string .

:InternationalNumber a owl:Class .

:has_international_code a owl:DatatypeProperty ;
  rdfs:domain :InternationalNumber ;
  rdfs:range :internationalCode .

:has_nationalNumber a owl:DatatypeProperty ;
  rdfs:domain :InternationalNumber ;
  rdfs:range xs:string .
### Derived Types

<table>
<thead>
<tr>
<th>#</th>
<th>XS</th>
<th>OWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>[rdf:type owl:Class; rdfs:subClassOf :Ct_name2]</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;complexContent&gt;</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>&lt;restriction base=&quot;ct_name2&quot;&gt;</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; owl:oneOf (&quot;value1&quot;^^xsd:nativDataType ...)]</code></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>[rdf:type owl:Class; rdfs:subClassOf :Ct_name2]</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;complexContent&gt;</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>&lt;extension base=&quot;ct_name2&quot;&gt;</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; owl:onDatatype :basedDT; owl:withRestrictions ([xsd:minInclusive &quot;value1&quot;^^:basedDT] [xsd:maxExclusive &quot;value2&quot;^^:basedDT])]</code></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
</tr>
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<td></td>
<td><code>&lt;simpleContent&gt;</code></td>
<td><code>:has_ct_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;extension base=&quot;xsd:nativDataType&quot;&gt;...</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; owl:onDatatype :basedDT; owl:withRestrictions ([xsd:minInclusive &quot;value1&quot;^^:basedDT] [xsd:maxExclusive &quot;value2&quot;^^:basedDT])]</code></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
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</tr>
<tr>
<td>8</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;simpleContent&gt;</code></td>
<td><code>:has_ct_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;extension base=&quot;ct_name2&quot;&gt;</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td>(see #26, 27, 28)...</td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; owl:oneOf (&quot;value1&quot;^^xsd:nativDataType ...)]</code></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
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<tr>
<td></td>
<td><code>&lt;simpleContent&gt;</code></td>
<td><code>:has_ct_name rdf:type owl:DatatypeProperty</code></td>
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<tr>
<td></td>
<td><code>&lt;extension base=&quot;ct_name2&quot;&gt;</code></td>
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<td>(see #26, 27, 28)...</td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; ((#4,5,6))...</code></td>
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<tr>
<td>10</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
</tr>
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<td><code>&lt;simpleContent&gt;</code></td>
<td><code>:ct_name_dt rdf:type owl:Class</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;restriction base=&quot;xsd:nativDataType&quot;&gt;</code></td>
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<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
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<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; (cf/#4,5,6)]</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
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<td>11</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
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<td><code>&lt;simpleContent&gt;</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
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<td></td>
<td><code>&lt;restriction base=&quot;ct_name2&quot;&gt;</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; rdfs:subPropertyOf :has_st_name]</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td>12</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
<td><code>:Ct_name rdf:type owl:Class</code></td>
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<td><code>&lt;simpleContent&gt;</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
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<td><code>&lt;restriction base=&quot;ct_name2&quot;&gt;</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
<tr>
<td></td>
<td><code>[rdf:type rdfs:Datatype; rdfs:subPropertyOf :has_st_name]</code></td>
<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
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<td>13</td>
<td><code>&lt;complexType name=&quot;ct_name&quot;&gt;</code></td>
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<td><code>:has_st_name rdf:type owl:DatatypeProperty</code></td>
</tr>
</tbody>
</table>
Pattern Recognition Limitations

• OWL is more generally expressive than XML Schema, it is not possible to derive a direct transformation pattern for each OWL logical construct.

  - E.g. inverse, transitive and symmetric properties (\textit{owl:differentFrom}, \textit{owl:NegativePropertyAssertion} and \textit{owl:PropertyChainAxiom})

<table>
<thead>
<tr>
<th>DL Expressivity</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>F - Functional properties.</td>
<td>✓</td>
</tr>
<tr>
<td>E - Full existential qualification (Existential restrictions that have fillers other than \textit{owl:Thing}).</td>
<td>✓</td>
</tr>
<tr>
<td>U - Concept union.</td>
<td>-</td>
</tr>
<tr>
<td>C - Complex concept negation.</td>
<td>-</td>
</tr>
<tr>
<td>S - An abbreviation for ALC with transitive roles.</td>
<td>~</td>
</tr>
<tr>
<td>H - Role hierarchy (subproperties - rdfs:subPropertyOf).</td>
<td>✓</td>
</tr>
<tr>
<td>R - Limited complex role inclusion axioms; reflexivity and irreflexivity; role disjointness.</td>
<td>-</td>
</tr>
<tr>
<td>O - Nominals. (Enumerated classes of object value restrictions - \textit{owl:oneOf, owl:hasValue}).</td>
<td>✓</td>
</tr>
<tr>
<td>I - Inverse properties.</td>
<td>-</td>
</tr>
<tr>
<td>N - Cardinality restrictions (\textit{owl:cardinality, owl:maxCardinality}).</td>
<td>✓</td>
</tr>
<tr>
<td>Q - Qualified cardinality restrictions (available in OWL 2, cardinality restrictions that have fillers other than \textit{owl:Thing}).</td>
<td>✓</td>
</tr>
<tr>
<td>(D) - Use of datatype properties, data values or data types.</td>
<td>✓</td>
</tr>
</tbody>
</table>

• Conversely, not all XML Schema integrity constraints are convertible into OWL

  - E.g. pattern and length constraints on data values (<\textit{pattern value}="[a-z] [a-z] [0-9]"/>, <\textit{xs:length value}="8"/>,)
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System Implementation

- First step **parses** XSD sources and recognise selected **patterns** and stores candidate ontology entities in an organized internal data model based on multiple hash-tables.
- Second step **normalizes** extracted labels and produces real semantics, using:
  - WordNet version 3.0 using JWNL as English dictionary Other dictionaries are s
  - Specific lists of abbreviations, acronyms, stop-words, *compound words* and “*useless words*” (tailored for the specific domain but simply replaceable and adaptable)
- The following **filtering** step identifies more abbreviations eventually not detected previously and purges sources that do not produce a semantically well structured output,
- The last step simply **translates** the normalised internal data model to OWL

- Implementation
  - Java as programming language
  - SAX as XSD parser
  - OWL-API to generate OWL ontologies
Transformation Comparison

- Number of XSD constructs, appreciate the completeness of the map
- XML instances, produces OWL individuals
- Extensibility of the system
- Exception management, not a simple direct mapping
- Semantic normalisation
- Concept structures, to resolve hierarchical, properties and datatype relations
- Concept relations to get the richness of semantic relations
- OWL expressivity

<table>
<thead>
<tr>
<th></th>
<th>XML2OWL</th>
<th>OWLMAP</th>
<th>LDM</th>
<th>Janus</th>
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<tbody>
<tr>
<td>N. of XS construct</td>
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<td>9</td>
<td>18</td>
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<tr>
<td>XML instances</td>
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<td>Extensible</td>
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<td>✓</td>
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<tr>
<td>Exception management</td>
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<td>limited</td>
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<td>✓</td>
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<td>Semantic normalisation</td>
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<td>✓</td>
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<td>Concept structures</td>
<td>limited</td>
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<td>✓</td>
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<td>Concept relations</td>
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<td>OWL expressivity</td>
<td>ALUHN</td>
<td>tbd</td>
<td>tbd</td>
<td>ALHONQF(D)</td>
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</table>
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Conclusion

**Semantics**
*To obtain meaningful ontology*
Early topic to be further investigated

**Rules**
*To realize basic conversions*
Highly adopted already

**Patterns**
*To unveil logical assertions*
High extensible contribution provided with this work
Thank you!

www.alcatel-lucent.com