Ontology Design Patterns for Winston’s Taxonomy of Part-Whole Relationships

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Rationale

- Continuing our quest of producing a set of useful but not overly complicated ontology design patterns for modular ontology modeling.

- In this particular case, we were prompted by application concerns from Material Science.

Part-Whole Relationships

Derek’s nose is part of Derek.
Derek is part of the Department faculty.

Hence: Derek’s nose is part of the Department faculty.

This doesn’t work.
Does this mean that part-of isn’t transitive, end of discussion?

It turns out that transitivity can be partially preserved if different kinds of part-of relationships are identified.
Winston’s approach

Part-whole relationships come in different kinds. Transitivity holds if you stay within one type

<table>
<thead>
<tr>
<th>Relation Type</th>
<th>funct. hom. sep.</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>component-integral object</td>
<td>yes</td>
<td>handle and cup</td>
</tr>
<tr>
<td>feature-activity</td>
<td>yes</td>
<td>paying and shopping</td>
</tr>
<tr>
<td>portion-mass</td>
<td>no</td>
<td>slice and pie</td>
</tr>
<tr>
<td>place-area</td>
<td>no</td>
<td>everglades and florida</td>
</tr>
<tr>
<td>member-collection</td>
<td>no</td>
<td>tree and forest</td>
</tr>
<tr>
<td>stuff-object</td>
<td>no</td>
<td>gin and martini</td>
</tr>
</tbody>
</table>

separable (versus inseparable): Parts can in principle be physically disconnected from the whole.

functional (versus non-functional): Parts are in specific spatial and temporal position relative to each other which supports their functional role as parts of the whole.

homeomerous (versus non-homeomerous): Parts are similar to each other and to the whole.
- component-integral object: po-component
- member-collection: po-member
- potion-mass: po-portion
- stuff-object: po-stuff
- feature-activity: po-feature
- place-area: po-place

Axioms on next page. No schema diagram.
Ontologizing

\[ \text{po-component } \circ \text{po-component } \sqsubseteq \text{po-component} \]
\[ \text{po-member } \circ \text{po-member } \sqsubseteq \text{po-member} \]
\[ \text{po-portion } \circ \text{po-portion } \sqsubseteq \text{po-portion} \]
\[ \text{po-stuff } \circ \text{po-stuff } \sqsubseteq \text{po-stuff} \]
\[ \text{po-feature } \circ \text{po-feature } \sqsubseteq \text{po-feature} \]
\[ \text{po-place } \circ \text{po-place } \sqsubseteq \text{po-place} \]
\[ \text{AsymmetricObjectProperty(po-component)} \]
\[ \text{AsymmetricObjectProperty(po-member)} \]
\[ \text{AsymmetricObjectProperty(po-portion)} \]
\[ \text{AsymmetricObjectProperty(po-stuff)} \]
\[ \text{AsymmetricObjectProperty(po-feature)} \]
\[ \text{AsymmetricObjectProperty(po-place)} \]
\[ \text{po-component } \sqsubseteq \text{part-of} \]
\[ \text{po-member } \sqsubseteq \text{part-of} \]
\[ \text{po-portion } \sqsubseteq \text{part-of} \]
\[ \text{po-stuff } \sqsubseteq \text{part-of} \]
\[ \text{po-feature } \sqsubseteq \text{part-of} \]
\[ \text{po-place } \sqsubseteq \text{part-of} \]
Ontologizing

\[
\text{spatially-located-in} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

ReflexiveObjectProperty(\text{spatially-located-in})

\[
\text{po-component} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{spatially-located-in} \circ \text{po-component} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{po-member} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{spatially-located-in} \circ \text{po-member} \sqsubseteq \text{spatially-located-in}
\]

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\text{po-portion} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

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\text{spatially-located-in} \circ \text{po-portion} \sqsubseteq \text{spatially-located-in}
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\[
\text{po-stuff} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

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\text{spatially-located-in} \circ \text{po-stuff} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{po-feature} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{spatially-located-in} \circ \text{po-feature} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{po-place} \circ \text{spatially-located-in} \sqsubseteq \text{spatially-located-in}
\]

\[
\text{spatially-located-in} \circ \text{po-place} \sqsubseteq \text{spatially-located-in}
\]
We would also like to declare irreflexivity axioms, but we’re not allowed to do so in OWL 2 DL.

We could instead drop the transitivity axioms, but that seems less appealing.

We could also use nominal schemas to approximate in terms of weaker axioms.

Winston lists some additional axioms, but they are in fact tautologies.
A contextualized version

For recording context, e.g., provenance information.

Instead of

:everglades po:po-place :florida .

We now have

:everglades cpo:po-place :florida ;
  cpo:isPartOf :everglades-po-place-florida .
:everglades-po-place-florida rdf:type cpo:PO-Place-Type ;
  cpo:hasWhole :florida .
E.g. Provenance as Context

This is, essentially, from PROV-O.
Ontologizing

Adopt all previous axioms.

\[
\begin{align*}
\text{Po-Component-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Po-Member-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Po-Portion-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Po-Stuff-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Po-Feature-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Po-Place-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Po-Part-Of-Type} & \sqsubseteq \text{RelationInstance} \\
\text{Spatially-Located-In-Type} & \sqsubseteq \text{RelationInstance}
\end{align*}
\]

Add

\[
\text{isPartOf}(x, y) \land C_R(y) \land \text{hasWhole}(y, z) \rightarrow R(x, z)
\]

(R is any of the part-of relationships, \(C_R\) is any of the corresponding classes)

as

\[
\begin{align*}
C_R & \equiv \exists c_R. \text{Self} \\
\text{isPartOf} \circ c_R \circ \text{hasWhole} & \sqsubseteq R
\end{align*}
\]
Ontologizing

We would have preferred to have

\[ \text{isPartOf} \circ c_R \circ \text{hasWhole} \equiv R, \]

but this cannot be expressed in OWL 2 DL.

Further add

\[ R \subseteq \text{part-of}, \]

as well as

\[ \top \subseteq \forall \text{isPartOf.RelationInstance} \quad (43) \]
\[ \forall \text{hasWhole.RelationInstance} \subseteq \top \quad (44) \]

The rest, i.e., asymmetry and reflexivity axioms, is (as far as we know) not expressible in OWL 2 DL.
Thanks!