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.
- It is essentially a re-casting and extension of previous work from

Prateek Jain, Pascal Hitzler, Kunal Verma, Peter Yeh, Amit Sheth, Moving beyond sameAs with PLATO: Partonomy detection for Linked Data. In: Ethan V. Munson, Markus Strohmaier (Eds.): 23rd ACM Conference on Hypertext and Social Media, HT '12, Milwaukee, WI, USA, June 25-28, 2012. ACM, 2012, pp. 33-42.

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.

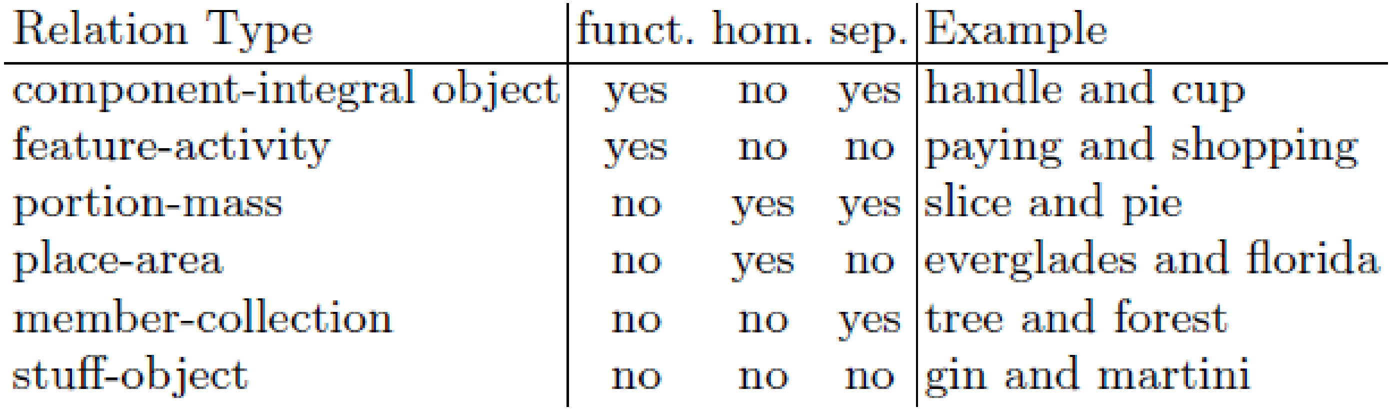
This doesn’t work.

Does this mean that part-of isn’t transitive, end of discussion?

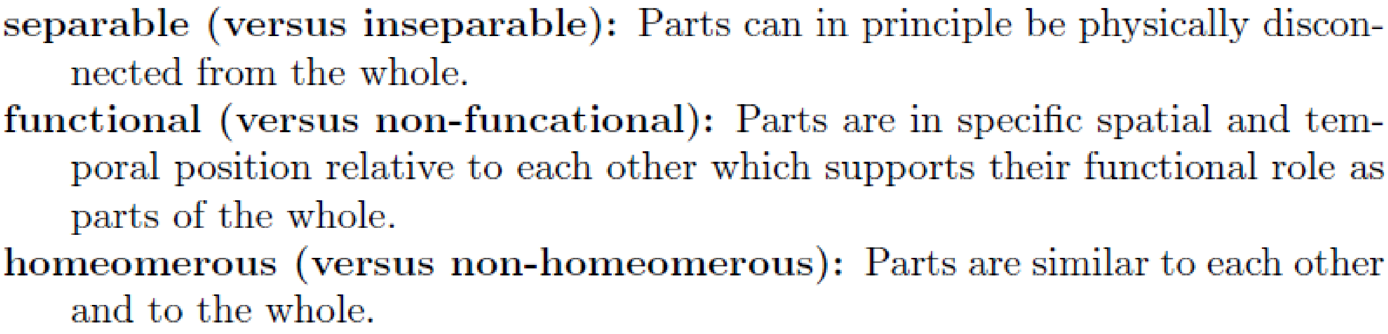
It turns out that transitivity can be partially preserved if different kinds of part-of relationships are identified.

Winston’s approach

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



Relation Type	funct.	hom.	sep.	Example
component-integral object	yes	no	yes	handle and cup
feature-activity	yes	no	no	paying and shopping
portion-mass	no	yes	yes	slice and pie
place-area	no	yes	no	everglades and florida
member-collection	no	no	yes	tree and forest
stuff-object	no	no	no	gin and martini

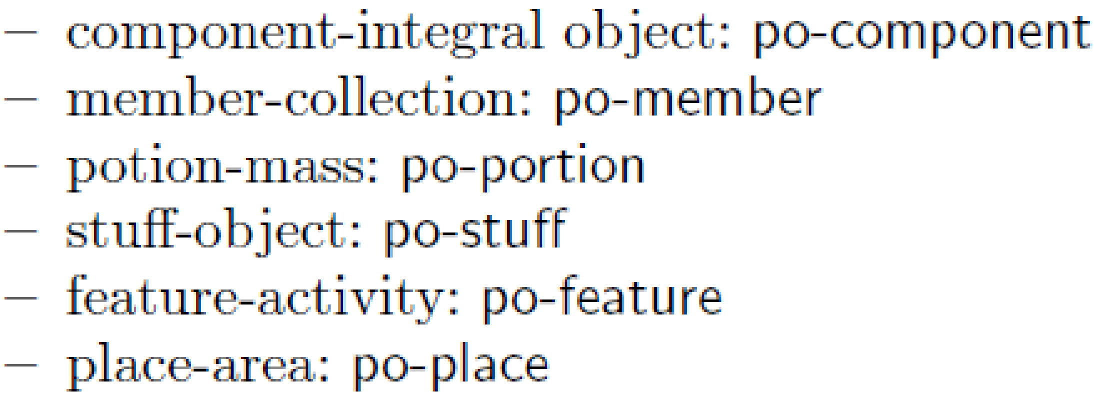


separable (versus inseparable): Parts can in principle be physically disconnected from the whole.

functional (versus non-funcational): 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.

Ontologizing



- 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

$$\textsf{po-component} \circ \textsf{po-component} \sqsubseteq \textsf{po-component} \tag{1}$$

$$\textsf{po-member} \circ \textsf{po-member} \sqsubseteq \textsf{po-member} \tag{2}$$

$$\textsf{po-portion} \circ \textsf{po-portion} \sqsubseteq \textsf{po-portion} \tag{3}$$

$$\textsf{po-stuff} \circ \textsf{po-stuff} \sqsubseteq \textsf{po-stuff} \tag{4}$$

$$\textsf{po-feature} \circ \textsf{po-feature} \sqsubseteq \textsf{po-feature} \tag{5}$$

$$\textsf{po-place} \circ \textsf{po-place} \sqsubseteq \textsf{po-place} \tag{6}$$

$$\mathrm{AsymmetricObjectProperty}(\textsf{po-component}) \tag{7}$$

$$\mathrm{AsymmetricObjectProperty}(\textsf{po-member}) \tag{8}$$

$$\mathrm{AsymmetricObjectProperty}(\textsf{po-portion}) \tag{9}$$

$$\mathrm{AsymmetricObjectProperty}(\textsf{po-stuff}) \tag{10}$$

$$\mathrm{AsymmetricObjectProperty}(\textsf{po-feature}) \tag{11}$$

$$\mathrm{AsymmetricObjectProperty}(\textsf{po-place}) \tag{12}$$

$$\textsf{po-component} \sqsubseteq \textsf{part-of} \tag{13}$$

$$\textsf{po-member} \sqsubseteq \textsf{part-of} \tag{14}$$

$$\textsf{po-portion} \sqsubseteq \textsf{part-of} \tag{15}$$

$$\textsf{po-stuff} \sqsubseteq \textsf{part-of} \tag{16}$$

$$\textsf{po-feature} \sqsubseteq \textsf{part-of} \tag{17}$$

$$\textsf{po-place} \sqsubseteq \textsf{part-of} \tag{18}$$

Ontologizing

$$\textsf{spatially-located-in} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{19}$$

$$\mathrm{ReflexiveObjectProperty}(\textsf{spatially-located-in}) \tag{20}$$

$$\textsf{po-component} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{21}$$

$$\textsf{spatially-located-in} \circ \textsf{po-component} \sqsubseteq \textsf{spatially-located-in} \tag{22}$$

$$\textsf{po-member} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{23}$$

$$\textsf{spatially-located-in} \circ \textsf{po-member} \sqsubseteq \textsf{spatially-located-in} \tag{24}$$

$$\textsf{po-portion} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{25}$$

$$\textsf{spatially-located-in} \circ \textsf{po-portion} \sqsubseteq \textsf{spatially-located-in} \tag{26}$$

$$\textsf{po-stuff} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{27}$$

$$\textsf{spatially-located-in} \circ \textsf{po-stuff} \sqsubseteq \textsf{spatially-located-in} \tag{28}$$

$$\textsf{po-feature} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{29}$$

$$\textsf{spatially-located-in} \circ \textsf{po-feature} \sqsubseteq \textsf{spatially-located-in} \tag{30}$$

$$\textsf{po-place} \circ \textsf{spatially-located-in} \sqsubseteq \textsf{spatially-located-in} \tag{31}$$

$$\textsf{spatially-located-in} \circ \textsf{po-place} \sqsubseteq \textsf{spatially-located-in} \tag{32}$$

Ontologizing

We would also like to declare irreflexivity axioms, but we’re not allowed to do so in OWL 2 DL.

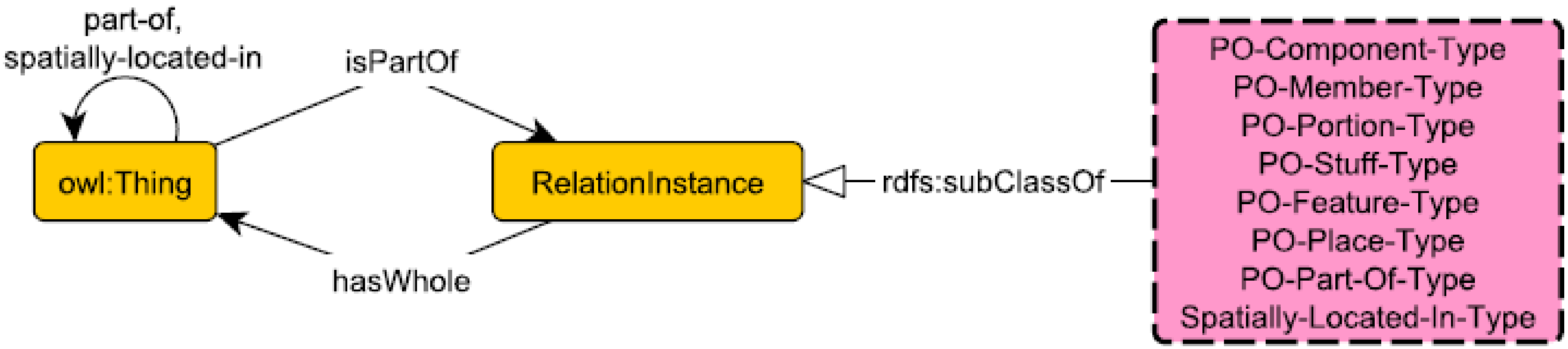
We could instead drop the transitividty axioms, but that seems less appealing.

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.



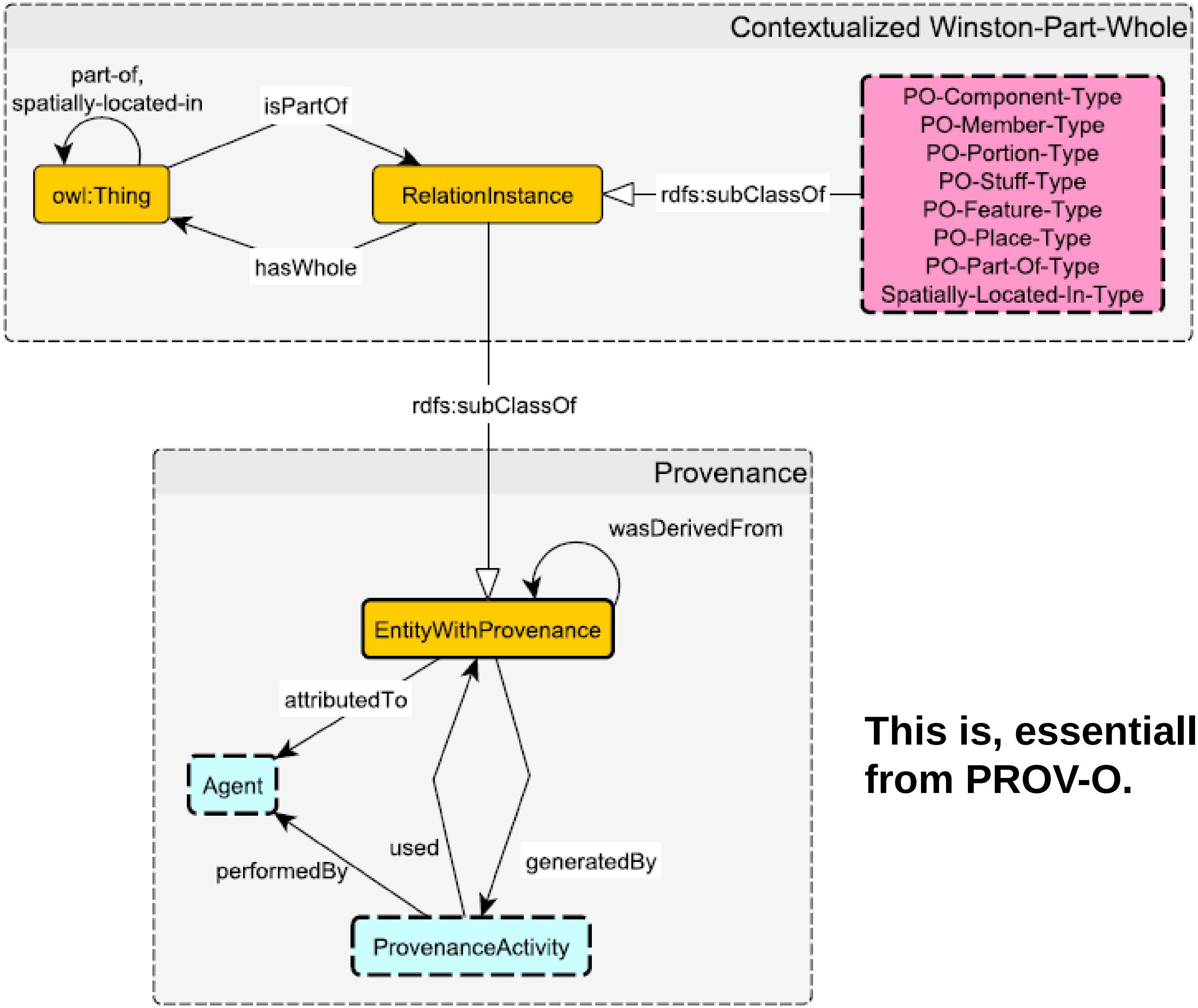
instead of

```
: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.

$$\text{Po-Component-Type} \sqsubseteq \text{RelationInstance} \quad (33)$$

$$\text{Po-Member-Type} \sqsubseteq \text{RelationInstance} \quad (34)$$

$$\text{Po-Portion-Type} \sqsubseteq \text{RelationInstance} \quad (35)$$

$$\text{Po-Stuff-Type} \sqsubseteq \text{RelationInstance} \quad (36)$$

$$\text{Po-Feature-Type} \sqsubseteq \text{RelationInstance} \quad (37)$$

$$\text{Po-Place-Type} \sqsubseteq \text{RelationInstance} \quad (38)$$

$$\text{Po-Part-Of-Type} \sqsubseteq \text{RelationInstance} \quad (39)$$

$$\text{Spatially-Located-In-Type} \sqsubseteq \text{RelationInstance} \quad (40)$$

Add $\text{isPartOf}(x,y) \wedge C_R(y) \wedge \text{hasWhole}(y,z) \to R(x,z)$

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

as

$$C_R \equiv \exists c_R.\text{Self} \quad (41)$$

$$\text{isPartOf} \circ c_R \circ \text{hasWhole} \sqsubseteq R \quad (42)$$

Ontologizing

We would have preferred to have

$$\text{isPartOf} \circ c_R \circ \text{hasWhole} \equiv R,$$

but this cannot be expressedin OWL 2 DL.

Further add $$R \sqsubseteq \text{part-of},$$

as well as

$$\top \sqsubseteq \forall \text{isPartOf}.\text{RelationInstance} \qquad (43)$$
$$\forall \text{hasWhole}.\text{RelationInstance} \sqsubseteq \top \qquad (44)$$

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

Thanks!