Table 1: Concise infix notation used in this paper with equivalents in OWL and standard DL notation

Abbreviated Informal	OWL Abstract Syntax	DL German Syntax
A AND B	intersectionOf(A B)	$A \sqcap B$
A OR B	unionOf(A B)	$A \sqcup B$
NOT A	complementOf(A)	$\neg A$
has_property SOME C	restriction(has_property someValuesFrom(C))	$\exists$ has_property . C
has_property ONLY C	restriction(has_property allValuesFrom(C))	$\forall$ has_property . C
has_property EXACTLY-n C	restriction(has_property cardinality(1, C)[27]	$\exists!1$ has_property . C
B → A	subclassOf(B A)	$B \sqsubseteq A$
A — B — — C	subclassOf(B A) subclassOf(C B)	$B \sqsubseteq A$ $C \sqsubseteq B$
$A \cong B$	equivalentClass(A B)	$A \cong B$
P_1 propagates_via P_2	not applicable	$P_1 \circ P_2 \rightarrow P_2$

[27] Not supported in the current OWL standard although proposed for extensions

Table 2a: The property hierarchy for the OWL implementation

Property	Transitive	Domain/ Range	Comments
is_part_of / has_part	Y	Physical_entity / Physical_entity	The generic part-whole relation Reflexive & antisymmetric properties not captured directly in OWL.
— is_gross_part_of/ has_gross_part	Y	Physical_entity / Physical_entity	The common parent (in effect the disjunction) of measurable portions and determinate parts and other properties indicated by the ellipsis ("…")
— — is_determinate_part_of / has_determinate_part	Y	Physical_entity / Physical_entity	The relation between determinate parts and wholes, *e.g.* fingers and hands.
— — is_portion_of/ has_portion	Y	Amount_of_matter/ Amount_of_matter	The relation between the water in the bay and the water in the lake. See 2.4.3
— — is_ingredient_of / has_ingredient	Y	Amount_of_matter/ Amount_of_matter	The relation between plasma and blood. See 2.4.3
— — — …			See Section 2.4.4 and Table 3
— is_grain_of / has_grain	N	Physical_object / Collective	The relation between a grain and the collective. Represented as a subproperty of is_part_of in OWL as an approximation of propagates_via see 2.2 item 3 and 2.3.

Table 2b: The high level entity hierarchy for the OWL implementation

Class	Use in this paper	Comments
Physical_entity	Domain/range of is_part_of and is_determinate_part_of	Common ancestor of all physical entities
— Physical_object	Domain for is_grain_of	Material physical entities
— Non_material_object	Excluded from domain for is_grain_of	Non-material physical entities, *e.g.* holes, lines, etc.
— Amount_of_matter	range for is_ingredient_of	Amounts of "stuff", roughly corresponding to mass nouns. (NB the Relation between Physical_object and Amount_of_matter depends on the debate between the cognitivist & realist stance and is not directly relevant to this paper. See 4.3)
— — Mixture	domain for is_ingredient_of	Abstract including solutions, suspensions etc.
Collective	Range of is_grain_of	Whether or not Collectives are considered physical and whether or not they are to be disjoint from Physical_object, is deferred. See 4.3 and 4.4.3.

Table 3: Property hierarchy reconciling ingredients and proportions.

Property	Transitive	Domain/ Range	Comments
is_ingredient_of / **has_ingredient**	Y	Amount_of_matter / Amount_of_matter OR Proportion_of_matter	Ingredients of ingredients are ingredients of the whole
— of_mixture / **has_proportion**	N	Proportion / Amount_of_matter	Proportions of proportions are not proportions of the whole.
— is_proportion / **is_of_ingredient**	N	Amount_of_matter/ Proportion	

Note that the relevant properties are the inverses (given in bold) to remain consistent with Table 2a.

Table 4: Johansson's list of cases for non-transitivity of part-whole relations

1.	A handle, x, can be part of a door, y, and a door can be part of a house, z, but yet the handle need not be (is not) a part of the house. That is, 'x < y' and 'y < z' but '¬(x < z)'. (Of course, 'part' cannot here and elsewhere in the list be synonymous with 'spatial part'.)	*Not accounted for*: confusion of direct and indirect partonomy.
2.	A platoon is part of a company, and a company is part of a battalion, but yet a platoon is not part of a battalion.	*Possibly accounted for*: Is a platoon a grain or a part of a company?
3.	A cell's nucleus is part of a cell, and a cell is part of an organ, but yet the nucleus is not part of an organ.	*Accounted for*. Cells are granular parts of the organ, not gross parts.
4.	Heart cells are parts of the heart, and the heart is part of the circulatory system, but yet the cells are not parts of the circulatory system.	*Accounted for*. Cells are granular parts of the Heart, not gross parts.
5.	Person P is part (member) of the football club FC, and FC is part (member) of the National Association of Football Clubs, NAFC, but yet P is not a part (member) of NAFC.	*Accounted for*. The person is a grain (member) of the football club, not a part of it and, similarly, the football club is a grain (member) of the association.
6.	Simpson's finger is part of Simpson, and Simpson is part of the Philosophy Department, but yet Simpson's finger is not part of the Philosophy Department.	*Accounted for*. Simpson is a member (grain) of the philosophy department (or possibly in some other relation to it), but not "part" of it in the sense used here.
7.	Hydrogen is part of water, and water is part of our cooling system, but yet hydrogen is not part of our cooling system.	*Accounted for* and a false example. Hydrogen is not part of water. Hydrogen atoms are part of water molecules, collectives of which constitute water used in the cooling system
8.	Cellulose is part of trees, and trees are parts of forests, but yet cellulose is not part of forests.	*Accounted for*. Trees are grains for forests.
9.	A handle is part of a spoon, and a spoon is part of eating soup, but yet a handle is not part of eating soup.	*Not accounted for*; A different issue. Continuants and occurrents cannot be parts of each other for reasons not discussed in this paper.
10.	This shard was part of a plate, and the plate was part of a dinner service, but yet the shard was not part of the dinner service.	*Odd case not accounted for*. An adequate discussion requires consideration of time. It is unclear whether or not the shards existed prior to the shattering of the plate. .
11.	This tree is part of the Black forest, and the Black forest is part of Germany, but yet this tree is not part of Germany.	*Accounted f*or. Trees are grains of forests. (Also the notion of geographical parthood might be treated differently by some authors)
12.	These grains of sand are part of the beach, and the beach is part of the island, but yet these grains of	*Accounted for*. The grains of sand are grains of the beach.

sand are not part of the island	