

A TPTP Formalization of the Unified Foundational Ontology

Daniele Porelo, João Paulo A. Almeida, Giancarlo Guizzardi,
Claudenir M. Fonseca, Tiago Prince Sales

October 12, 2021

Abstract

This document presents a formalization of the Unified Foundation Ontology (UFO) expressed in first-order logics through the TPTP syntax. This formalization is intended to support verification of UFO's theory through automated provers and consistency checkers.

1 Introduction

This document presents a formalization of the Unified Foundation Ontology (UFO) expressed in first-order logics through the TPTP syntax. This formalization is intended to support verification of UFO's theory through automated provers and consistency checkers.

2 UFO's TPTP Specification

2.1 UFO Taxonomy

2.1.1 Partial Taxonomy of Thing

```
4 % Thing
5
6 fof(ax_thing_taxonomy, axiom, (
7   ![X]: ((type_(X) | individual(X)) <=> (thing(X)))
8 )).
9
10 fof(ax_thing_partition, axiom, (
11   ~?[X]: (type_(X) & individual(X))
12 )).
13
14 % Individual
15
16 fof(ax_individual_taxonomy, axiom, (
17   ![X]: ((concreteIndividual(X) | abstractIndividual(X)) <=> (
18     individual(X)))
```

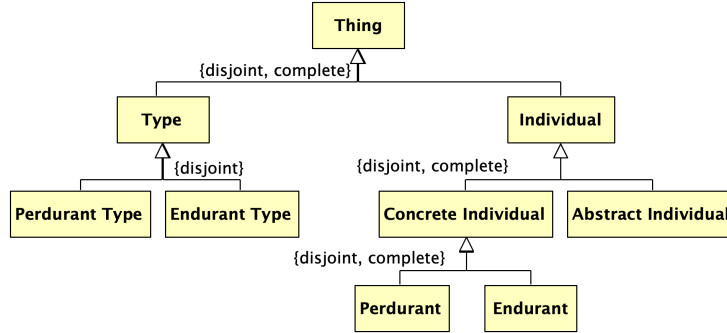


Figure 1: Partial Taxonomy of UFO – Thing.

```

18 ))).
19
20 fof(ax_individual_partition, axiom, (
21   ~?[X]: (concreteIndividual(X) & abstractIndividual(X))
22 ))).
23
24 % Concrete Individual
25
26 fof(ax_concreteIndividual_taxonomy, axiom, (
27   ![X]: ((endurant(X) | perdurant(X)) <=> (concreteIndividual(X)))
28 ))).
29
30 fof(ax_concreteIndividual_partition, axiom, (
31   ~?[X]: (endurant(X) & perdurant(X))
32 ))).
33
34 % Type
35
36 fof(ax_type_taxonomy, axiom, (
37   ![X]: ((endurantType(X) | perdurantType(X)) => (type_(X)))
38 ))).
39
40 fof(ax_type_partition, axiom, (
41   ~?[X]: (endurantType(X) & perdurantType(X))
42 ))).
43
44 % Thing partial taxonomy instances
45 % (tested to rule out trivial models)
46
47 % fof(ax_thing_instances, axiom, (
48 %   type_(type1) & individual(individual1) & concreteIndividual(
49 %     concreteIndividual1) & abstractIndividual(abstractIndividual1)
50 %     & endurant(endurant1) & perdurant(perdurant1) & endurantType(
51 %       endurantType1) & perdurantType(perdurantType1)
52 %   ))).

```

2.1.2 Partial Taxonomy of Abstract Individual

```

51 % Abstract Individual
52

```

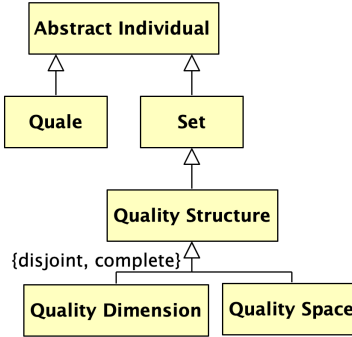


Figure 2: Partial Taxonomy of UFO – Abstract Individual.

```

53 fof(ax_abstractIndividual_taxonomy_quale, axiom, (
54   ![X]: (quale(X) => (abstractIndividual(X)))
55 )).
56
57 fof(ax_abstractIndividual_taxonomy_set, axiom, (
58   ![X]: (set_(X) => (abstractIndividual(X)))
59 )).
60
61 fof(ax_abstractIndividual_taxonomy_world, axiom, (
62   ![X]: (world(X) => (abstractIndividual(X)))
63 )).
64
65 % Set
66
67 fof(ax_set_taxonomy_qualityStructure, axiom, (
68   ![X]: (qualityStructure(X) => (set_(X)))
69 )).
70
71 % Quality Structure
72
73 fof(ax_qualityStructure_taxonomy, axiom, (
74   ![X]: ((qualityDimension(X) | qualitySpace(X)) <=> (
75     qualityStructure(X)))
76 )).
77
78 fof(ax_qualityStructure_partition, axiom, (
79   ~?[X]: (qualityDimension(X) & qualitySpace(X))
80 )).
81
82 % Abstract Individual partial taxonomy instances
83 % (tested to rule out trivial models)
84
85 fof(ax_abstractIndividual_instances, axiom, (
86   % set_(set1) & quale(quale1) & qualityStructure(qualityStructure1
87     ) & qualityDimension(qualityDimension1) & qualitySpace(
88       qualitySpace1) & world(world1)
89 % )).

```

2.1.3 Partial Taxonomy of Endurant

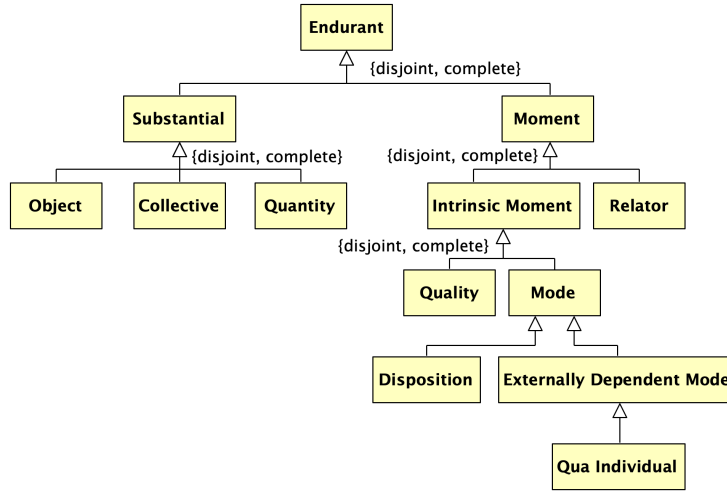


Figure 3: Partial Taxonomy of UFO – Endurant.

```

88 % Endurant
89
90 fof(ax_endurant_taxonomy, axiom, (
91   ![X]: ((substantial(X) | moment(X)) <=> (endurant(X)))
92 )).
93
94 fof(ax_endurant_partition, axiom, (
95   ~?[X]: (substantial(X) & moment(X))
96 )).
97
98 % Substantial
99
100 fof(ax_substantial_taxonomy, axiom, (
101   ![X]: ((object(X) | collective(X) | quantity(X)) <=> (substantial
102     (X)))
103 )).
104
105 fof(ax_substantial_partition, axiom, (
106   ~?[X]: ((object(X) & collective(X)) | (object(X) & quantity(X)) |
107     (collective(X) & quantity(X)))
108 )).
109
110 % Moment
111
112 fof(ax_moment_taxonomy, axiom, (
113   ![X]: ((intrinsicMoment(X) | relator(X)) <=> (moment(X)))
114 )).
115
116 fof(ax_moment_partition, axiom, (
117   ~?[X]: (intrinsicMoment(X) & relator(X))
118 )).
119
120 % Intrinsic Moment

```

```

119
120 fof(ax_intrinsicMoment_taxonomy, axiom, (
121   ![X]: ((quality(X) | mode(X)) <=> (intrinsicMoment(X)))
122 )).
123
124 fof(ax_intrinsicMoment_partition, axiom, (
125   ~?[X]: (quality(X) & mode(X))
126 )).
127
128 % Mode
129
130 fof(ax_mode_taxonomy_externallyDependentMode, axiom, (
131   ![X]: (externallyDependentMode(X) => (mode(X)))
132 )).
133
134 % Externally Dependent Mode
135
136 fof(ax_externallyDependentMode_taxonomy_quaIndividual, axiom, (
137   ![X]: (quaIndividual(X) => (externallyDependentMode(X)))
138 )).
139
140 % Endurant partial taxonomy instances
141 % (tested to rule out trivial models)
142
143 % fof(ax_endurant_instances, axiom, (
144 %   substantial(substantial1) & moment(moment1) & object(object1) &
145 %   collective(collective1) & quantity(quantity1) &
146 %   intrinsicMoment(intrinsicMoment1) & relator(relator1) & quality
147 %   (quality1) & mode(mode1) & disposition(disposition1) &
148 %   externallyDependentMode(externallyDependentMode1) &
149 %   quaIndividual(quaIndividual1)
150 % )).

```

2.1.4 Partial Taxonomy of Endurant Type (on ontological natures)

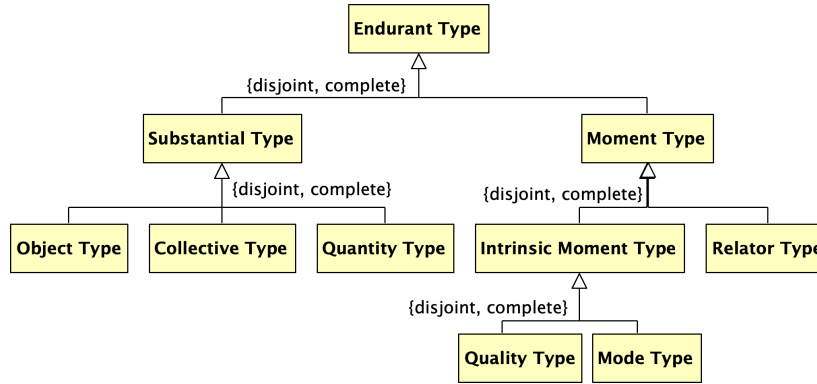


Figure 4: Partial Taxonomy of UFO – Endurant Types (by ontological nature).

```

147 % Endurant Type (by ontological nature)
148

```

```

149 fof(ax_endurantType_taxonomy_nature, axiom, (
150   ![X]: ((substantialType(X) | momentType(X)) <=> (endurantType(X))
151   )
152 )).
153 fof(ax_endurantType_partition_nature, axiom, (
154   ~?[X]: (substantialType(X) & momentType(X))
155 )).
156
157 % Substantial Type
158
159 fof(ax_substantialType_taxonomy, axiom, (
160   ![X]: ((objectType(X) | collectiveType(X) | quantityType(X)) <=>
161     (substantialType(X)))
162 )).
163 fof(ax_substantialType_partition, axiom, (
164   ~?[X]: ((objectType(X) & collectiveType(X)) | (objectType(X) &
165     quantityType(X)) | (collectiveType(X) & quantityType(X)))
166 )).
167 % Moment Type
168
169 fof(ax_momentType_taxonomy, axiom, (
170   ![X]: ((intrinsicMomentType(X) | relatorType(X)) <=> (momentType(
171     X)))
172 )).
173 fof(ax_momentType_partition, axiom, (
174   ~?[X]: (intrinsicMomentType(X) & relatorType(X))
175 )).
176
177 % Intrinsic Moment Type
178
179 fof(ax_intrinsicMomentType_taxonomy, axiom, (
180   ![X]: ((qualityType(X) | modeType(X)) <=> (intrinsicMomentType(X)
181     ))
182 )).
183 fof(ax_intrinsicMomentType_partition, axiom, (
184   ~?[X]: (qualityType(X) & modeType(X))
185 )).
186
187 % Endurant Type (by ontological nature) partial taxonomy instances
188 % (tested to rule out trivial models)
189
190 % fof(ax_endurantType_instances_natures, axiom, (
191 %   substantialType(substantialType1) & momentType(momentType1) &
192 %   objectType(objectType1) & collectiveType(collectiveType1) &
193 %   quantityType(quantityType1) & intrinsicMomentType(
194 %     intrinsicMomentType1) & relatorType(relatorType1) & qualityType
195 %     (qualityType1) & modeType(modeType1)
196 % )).

```

2.1.5 Partial Taxonomy of Endurant Type (on modal properties of types)

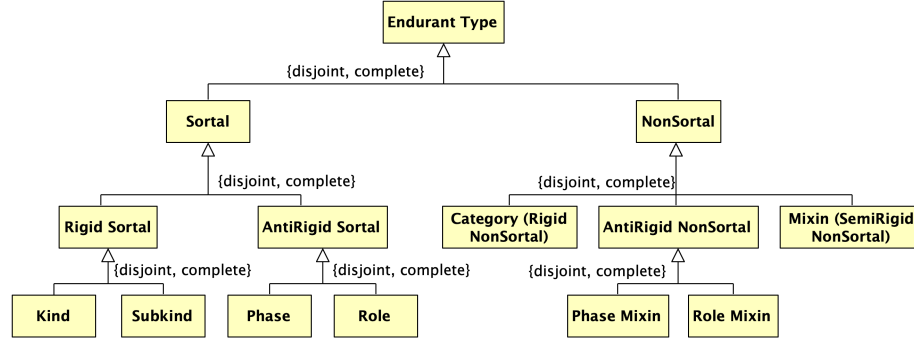


Figure 5: Partial Taxonomy of UFO – Endurant Types (by modal properties of types).

```

194 % Endurant Type (by modal properties of types)
195
196 fof(ax_endurantType_taxonomy_properties, axiom, (
197   ![X]: ((sortal(X) | nonSortal(X)) <=> (endurantType(X)))
198 )).
199
200 fof(ax_endurantType_partition_properties, axiom, (
201   ~?[X]: (sortal(X) & nonSortal(X))
202 )).
203
204 % Sortal
205
206 fof(ax_sortal_taxonomy, axiom, (
207   ![X]: ((rigidSortal(X) | antiRigidSortal(X)) <=> (sortal(X)))
208 )).
209
210 fof(ax_sortal_partition, axiom, (
211   ~?[X]: (rigidSortal(X) & antiRigidSortal(X))
212 )).
213
214 % Rigid Sortal
215
216 fof(ax_rigidSortal_taxonomy, axiom, (
217   ![X]: ((kind(X) | subkind(X)) <=> (rigidSortal(X)))
218 )).
219
220 fof(ax_rigidSortal_partition, axiom, (
221   ~?[X]: (kind(X) & subkind(X))
222 )).
223
224 % Anti-Rigid Sortal
225
226 fof(ax_antiRigidSortal_taxonomy, axiom, (
227   ![X]: ((phase(X) | role(X)) <=> (antiRigidSortal(X)))

```

```

228 ))).
229
230 fof(ax_antiRigidSortal_partition, axiom, (
231   ~?[X]: (phase(X) & role(X))
232 ))).
233
234 % Non-Sortal
235
236 fof(ax_nonSortal_taxonomy, axiom, (
237   ![X]: ((rigidNonSortal(X) | semiRigidNonSortal(X) |
238     antiRigidNonSortal(X)) <=> (nonSortal(X)))
239 ))).
240
241 fof(ax_nonSortal_partition, axiom, (
242   ~?[X]: ((rigidNonSortal(X) & semiRigidNonSortal(X)) | (
243     rigidNonSortal(X) & antiRigidNonSortal(X)) | (
244     semiRigidNonSortal(X) & antiRigidNonSortal(X)))
245 ))).
246
247 % Category
248
249 fof(ax_rigidNonSortal_taxonomy, axiom, (
250   ![X]: (rigidNonSortal(X) <=> (category(X)))
251 ))).
252
253 % Mixin
254
255 fof(ax_semiRigidNonSortal_taxonomy, axiom, (
256   ![X]: (semiRigidNonSortal(X) <=> (mixin(X)))
257 ))).
258
259 % Anti-Rigid Non-Sortal
260
261 fof(ax_antiRigidNonSortal_taxonomy, axiom, (
262   ![X]: ((phaseMixin(X) | roleMixin(X)) <=> (antiRigidNonSortal(X))
263     )
264 ))).
265
266 fof(ax_antiRigidNonSortal_partition, axiom, (
267   ~?[X]: (phaseMixin(X) & roleMixin(X))
268 ))).
269
270 % Endurant Type (by modal properties of types) partial taxonomy
271 instances
272 % (tested to rule out trivial models)
273
274 % fof(ax_endurantType_instances_properties, axiom, (
275 %   sortal(sortal1) & nonSortal(nonSortal1) & rigidSortal(
276 %     rigidSortal1) & antiRigidSortal(antiRigidSortal1) & kind(kind1)
277 %     & subkind(subkind1) & phase(phase1) & role(role1) & category(
278 %     category1) & mixin(mixin1) & antiRigidNonSortal(
279 %     antiRigidNonSortal1) & phaseMixin(phaseMixin1) & roleMixin(
280 %     roleMixin1)
281 % )).

```


2.1.6 Defining Types, Individuals, and Specialization

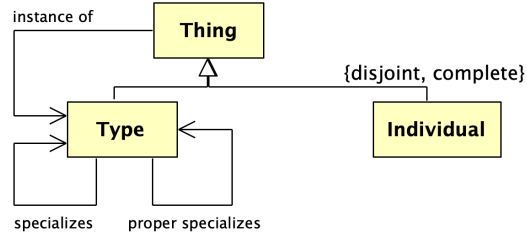


Figure 6: Types, individuals, instantiation, and specialization.

```

273 %%%%%%%%% Instance of, Types, and Individuals %%%%%%%%%
274
275 fof(ax_dIof, axiom, (
276   ![X,Y,W]: (iof(X,Y,W) => (type_(Y) & world(W)))
277 )).
278
279 fof(ax_dType_a1, axiom, (
280   ![X]: (type_(X) <=> (?[Y,W]: iof(Y,X,W)))
281 )).
282
283 fof(ax_dIndividual_a2, axiom, (
284   ![X]: (individual(X) <=> (~?[Y,W]: iof(Y,X,W)))
285 )).
286
287 % TODO: confirm whether we are including second-order types in this
      formalization
288
289 fof(ax_multiLevel_a3, axiom, (
290   ![X,Y,W]: (iof(X,Y,W) => (type_(X) | individual(X)))
291 )).
292
293 fof(ax_twoLevelConstrained_a4, axiom, (
294   ~?[X,Y,Z,W]: (type_(X) & iof(X,Y,W) & iof(Y,Z,W))
295 )).
296
297 % Instantiation relations
298 % (tested to rule out trivial models)
299
300 % fof(ax_iofInUse, axiom, (
301 %   type_(t2) & individual(i2) & world(w2) & iof(i2,t2,w2)
302 % )).
303
304 % Ax |= "th_everythingIsAThing_t1"; conjecture commented for
      convenience
305
306 % fof(th_everythingIsAThing_t1, conjecture, (
307 %   ![X]: (type_(X) | individual(X))
308 % )).
309
310 % Ax |= "th_thingPartition_t2"; conjecture commented for
      convenience

```

```

311
312 % fof(th_thingPartition_t2, conjecture, (
313 %   ~?[X]: (type_(X) & individual(X))
314 % )).
315
316 %%%%%%%%% Specialization and Proper Specialization %%%%%%%%%
317
318 fof(ax_dSpecializes, axiom, (
319   ![X,Y]: (specializes(X,Y) => (type_(X) & type_(Y)))
320 )).
321
322 fof(ax_specialization_a5, axiom, (
323   ![T1,T2]: (specializes(T1,T2) <=> (
324     type_(T1) & type_(T2) & ![W]: (world(W) => ![E]: (iof(E,T1,W)
325       => iof(E,T2,W)))
326   ))
327 )).
328
329 fof(ax_properSpecializes_d1, axiom, (
330   ![X,Y]: (properSpecializes(X,Y) <=> (specializes(X,Y) & ~
331     specializes(Y,X)))
332 )).
333
334 % Ax |= "th_cyclicSpecializations_t3"; conjecture commented for
335 %   convenience
336
337 fof(th_cyclicSpecializations_t3, conjecture, (
338 %   ![X,Y]: (specializes(X,Y) => (specializes(X,X) & specializes(Y,
339 %     Y)))
340 % )).
341
342 % Ax |= "th_transitiveSpecializations_t4"; conjecture commented for
343 %   convenience
344
345 fof(th_transitiveSpecializations_t4, conjecture, (
346 %   ![X,Y,Z]: ((specializes(X,Y) & specializes(Y,Z)) => (
347 %     specializes(X,Z)))
348 % )).
349
350 fof(ax_sharedSpecializations_a6, axiom, (
351   ![T1,T2]: (?[X,W]: ((iof(X,T1,W) & iof(X,T2,W) & ~specializes(T1,
352     T2) & ~specializes(T2,T1)) => (
353     (?[T3]: (specializes(T1,T3) & specializes(T2,T3) & iof(X,T3,W)
354       ))|
355     (?[T3]: (specializes(T3,T1) & specializes(T3,T2) & iof(X,T3,W)
356       )))
357 )).
358
359 % Specialization relations
360 % (tested to rule out trivial models)
361
362 fof(ax_specializesInUse, axiom, (
363   %   endurantType(t3_1) & endurantType(t3_2) & specializes(t3_1,t3_2
364   %     ) & properSpecializes(t3_1,t3_2) & specializes(t3_1,t3_1) &
365   %     endurant(e3) & world(w3) & iof(e3,t3_1,w3)
366 % )).

```

2.1.7 Defining Rigidity and Sortality

```

360 % Rigidity
361
362 % TODO: I don't find we need to attach the "rigid(T)" predicate to
      the "endurant(T)" predicate like the paper does, so let's
      review this idea.
363 % TODO: verify whether it is a problem not to introduce predicates
      "world(W1) &" and "world(W2) &" before each instantiation
364
365 fof(ax_dRigid_a18, axiom, (
366   ![T]: (rigid(T) <=> (endurantType(T) & (
367     ![X]: ((?[W1]: (world(W1) & iof(X,T,W1))) => (![W2]: (world(W2)
368       => iof(X,T,W2))))
369   )))
370
371 fof(ax_dAntiRigid_a19, axiom, (
372   ![T]: (antiRigid(T) <=> (endurantType(T) & (
373     ![X]: ((?[W1]: (world(W1) & iof(X,T,W1))) => (?[W2]: (world(W2)
374       & ~iof(X,T,W2))))
375   )))
376
377 fof(ax_dSemiRigid_a20, axiom, (
378   ![T]: (semiRigid(T) <=> (endurantType(T) & ~rigid(T) & ~antiRigid
379     (T)))
380
381 % Ax |= "th_thEndurantTypeHaveRigidity_t5"; conjecture commented
      for convenience
382
383 % fof(th_thEndurantTypeHaveRigidity_t5, conjecture, (
384 %   ![T]: (endurantType(T) <=> (rigid(T) | semiRigid(T) | antiRigid
385 %     (T)))
386 % ))).
387
388 % Ax |= "th_pairwiseDisjointRigidities_t6"; conjecture commented
      for convenience
389
390 % fof(th_pairwiseDisjointRigidities_t6, conjecture, (
391 %   ~![T]: ((rigid(T) & semiRigid(T)) | (semiRigid(T) & antiRigid(T)
392 %     )) | (rigid(T) & antiRigid(T)))
393 % ))).
394
395 % Ax |= "th_rigidAntiRigidSpecializationConstraint_t7"; conjecture
      commented for convenience
396
397 % fof(th_rigidAntiRigidSpecializationConstraint_t7, conjecture, (
398 %   ~![T1,T2]: (rigid(T1) & antiRigid(T2) & specializes(T1,T2))
399 % ))).
400
401 % Ax |= "th_semiRigidAntiRigidSpecializationConstraint_t8";
      conjecture commented for convenience
402
403 % fof(th_semiRigidAntiRigidSpecializationConstraint_t8, conjecture, (

```

```

402 % ~![T1,T2]: (semiRigid(T1) & antiRigid(T2) & specializes(T1,T2))
403 % )).
404
405 % Rigidity properties
406 % (tested to rule out trivial models)
407
408 % fof(ax_rigidityInUse, axiom, (
409 %   endurantType(t4_1) & endurantType(t4_2) & endurantType(t4_3) &
410 %   rigid(t4_1) & semiRigid(t4_2) & antiRigid(t4_3) &
411 %   properSpecializes(t4_1,t4_2) & properSpecializes(t4_3,t4_1)
412 % )).
413
414 % Sortality
415 fof(ax_endurantsKind_a21, axiom, (
416   ![E]: (endurant(E) => (
417     ?[U]: (kind(U) & (![W]: (world(W) => iof(E,U,W))))
418   ))
419 ))
420
421 fof(ax_uniqueKind_a22, axiom, (
422   ![E,U,W]: ((world(W) & kind(U) & iof(E,U,W)) => (
423     ~?[U2,W2]: (kind(U2) & iof(E,U2,W2) & ~(U = U2))
424   ))
425 ))
426
427 % Changing "ax_dSortal_a23" from the form it was defined in the
428 % paper to "sortals are endurant types that specialize some
429 % ultimate sortal" seem to express the same concept while
430 % speeding up the execution of SPASS considerably
431
432 % fof(ax_dSortal_a23, axiom, (
433 %   ![S]: (sortal(S) <=> (endurantType(S) & (?[U]: (kind(U) & (![E,
434 %     W]: (iof(E,S,W) => iof(E,U,W))))))
435 % )).
436
437 fof(ax_dSortal_a23, axiom, (
438   ![S]: ((sortal(S)) <=> (endurantType(S) & (?[U]: (kind(U) &
439     specializes(S,U))))
440 ))
441
442 % If we have the taxonomy's axiomatization, then a24 becomes a
443 % theorem
444 % Ax |= "th_nonSortalsAreEndurantsThatAreNotSortals_a24";
445 % conjecture commented for convenience
446
447 % fof(th_nonSortalsAreEndurantsThatAreNotSortals_a24, conjecture, (
448 %   ![NS]: ((nonSortal(NS)) <=> (endurantType(NS) & ~sortal(NS)))
449 % )).
450
451 % Ax |= "th_kindsAreRigid_t9"; conjecture commented for convenience
452
453 % fof(th_kindsAreRigid_t9, conjecture, (
454 %   ![U]: ((kind(U)) => (rigid(U)))
455 % )).
456
457 % Ax |= "th_kindsHaveDisjointExtensions_t10"; conjecture commented

```

```

450         for convenience
451 % fof(th_kindsHaveDisjointExtensions_t10, conjecture, (
452 %   ![K1,K2]: ((kind(K1) & kind(K2) & ~(K1=K2)) => (
453 %     ~?[X,W1,W2]: (world(W1) & world(W2) & iof(X,K1,W1) & iof(X,K2
454 %   )
455 %   )).
456
457 % Ax |= "th_kindsHaveDisjointTaxonomies_t11"; conjecture commented
458 %   for convenience
459 % fof(th_kindsHaveDisjointTaxonomies_t11, conjecture, (
460 %   ![K1,K2]: ((kind(K1) & kind(K2) & ~(K1=K2)) => (
461 %     ~?[T]: (specializes(T,K1) & specializes(T,K2)))
462 %   )
463 %   )).
464
465 % Ax |= "th_kindsAreSortal_t12"; conjecture commented for
466 %   convenience
467 % fof(th_kindsAreSortal_t12, conjecture, (
468 %   ![K]: ((kind(K)) => (sortal(K)))
469 %   )).
470
471 % Ax |= "th_sortalSpecializeKinds_t13"; conjecture commented for
472 %   convenience
473 % fof(th_sortalSpecializeKinds_t13, conjecture, (
474 %   ![S]: ((sortal(S)) => (?[K]: (kind(K) & specializes(S,K))))
475 %   )).
476
477 % Ax |= "th_sortalsSpecializeAUniqueKind_t14"; conjecture commented
478 %   for convenience
479 % fof(th_sortalsSpecializeAUniqueKind_t14, conjecture, (
480 %   ![S]: ((sortal(S)) => (~?[U,U2]: (kind(U) & kind(U2) &
481 %     specializes(S,U) & specializes(S,U2) & ~(U=U2))))
482 %   )).
483 % Sortality properties
484 % (tested to rule out trivial models)
485
486 % fof(ax_sortalityInUse, axiom, (
487 %   endurant(e5_1) & endurant(e5_2) & world(w5) & kind(k5_1) & kind
488 %   (k5_2) & iof(e5_1,k5_1,w5) & iof(e5_1,k5_1,w5) & ~(k5_1=k5_2)
489 %   )).
490 % Sortality + Rigidity
491
492 fof(ax_rigidSortalsAreRigidAndSortal_xx, axiom, (
493   ![T]: ((rigidSortal(T)) <=> (rigid(T) & sortal(T)))
494   )).
495
496 fof(ax_antiRigidSortalsAreAntiRigidAndSortal_xx, axiom, (
497   ![T]: ((antiRigidSortal(T)) <=> (antiRigid(T) & sortal(T)))
498   )).

```

```

499 fof(ax_rigidNonSortalsAreRigidAndNonSortal_xx, axiom, (
500   ![T]: ((rigidNonSortal(T)) <=> (rigid(T) & nonSortal(T)))
501 ))).
502
503 fof(ax_antiRigidNonSortalsAreAntiRigidAndNonSortal_xx, axiom, (
504   ![T]: ((antiRigidNonSortal(T)) <=> (antiRigid(T) & nonSortal(T)))
505 ))).
506
507 fof(ax_semiRigidNonSortalsAreSemiRigidAndNonSortal_xx, axiom, (
508   ![T]: ((semiRigidNonSortal(T)) <=> (semiRigid(T) & nonSortal(T)))
509 ))).
510
511 % If we have the taxonomy's axiomatization, then a25 becomes a
512 % theorem
513 % Ax |= "th_kindAndSubkindAreDisjoint_a25"; conjecture commented
514 % for convenience
515
516 % fof(th_kindAndSubkindAreDisjoint_a25, conjecture, (
517 %   ~?[T]: (kind(T) & subkind(T))
518 % )).
519
520 % If we have the taxonomy's axiomatization, then a26 becomes a
521 % theorem
522 % Ax |= "th_kindAndSubkindAreRigidSortals_a26"; conjecture
523 % commented for convenience
524
525 % fof(th_kindAndSubkindAreRigidSortals_a26, conjecture, (
526 %   ![T]: ((kind(T) | subkind(T)) <=> (rigid(T) & sortal(T)))
527 % )).
528
529 % If we have the taxonomy's axiomatization, then a27 becomes a
530 % theorem
531 % Ax |= "th_phaseAndRoleAreDisjoint_a27"; conjecture commented for
532 % convenience
533
534 % fof(th_phaseAndRoleAreDisjoint_a27, conjecture, (
535 %   ~?[T]: (phase(T) & role(T))
536 % )).
537
538 % If we have the taxonomy's axiomatization, then a28 becomes a
539 % theorem
540 % Ax |= "th_phaseAndRoleAreAntiRigidSortals_a28"; conjecture
541 % commented for convenience
542
543 % fof(th_phaseAndRoleAreAntiRigidSortals_a28, conjecture, (
544 %   ![T]: ((phase(T) | role(T)) <=> (antiRigid(T) & sortal(T)))
545 % )).
546
547 % Skipping (a29) because we leave the concept of semi-rigid sortals
548 % out of this ontology.
549
550 % If we have the taxonomy's axiomatization, then a30 becomes a
551 % theorem
552 % Ax |= "th_categoriesAreRigidNonSortals_a30"; conjecture commented
553 % for convenience
554

```

```

545 % fof(th_categoriesAreRigidNonSortals_a30, conjecture, (
546 %   ![T]: ((category(T)) <=> (rigid(T) & nonSortal(T)))
547 % )).
548
549 % If we have the taxonomy's axiomatization, then a31 becomes a
    theorem
550 % Ax |= "th_mixinsAreSemiRigidNonSortals_a31"; conjecture commented
    for convenience
551
552 % fof(th_mixinsAreSemiRigidNonSortals_a31, conjecture, (
553 %   ![T]: ((mixin(T)) <=> (semiRigid(T) & nonSortal(T)))
554 % )).
555
556 % If we have the taxonomy's axiomatization, then a32 becomes a
    theorem
557 % Ax |= "th_phaseMixinAndRoleMixinAreDisjoint_a32"; conjecture
    commented for convenience
558
559 % fof(th_phaseMixinAndRoleMixinAreDisjoint_a32, conjecture, (
560 %   ~?[T]: (phaseMixin(T) & roleMixin(T))
561 % )).
562
563 % If we have the taxonomy's axiomatization, then a33 becomes a
    theorem
564 % Ax |= "ax_phaseMixinAndRoleMixinAreAntiRigidSortals_a33";
    conjecture commented for convenience
565
566 % fof(th_phaseMixinAndRoleMixinAreAntiRigidSortals_a33, conjecture,
    (
567 %   ![T]: ((phaseMixin(T) | roleMixin(T)) <=> (antiRigid(T) &
    nonSortal(T)))
568 % )).
569
570 % Ax |= "th_leafCategoriesArePairwiseDisjoint_t18"; conjecture
    commented for convenience
571
572 % fof(th_leafCategoriesArePairwiseDisjoint_t18, conjecture, (
573 %   ~?[T]: (endurantType(T) & (
574 %     (
575 %       (kind(T) & subkind(T))
576 %       | (kind(T) & phase(T))
577 %       | (kind(T) & role(T))
578 %       | (kind(T) & category(T))
579 %       | (kind(T) & mixin(T))
580 %       | (kind(T) & phaseMixin(T))
581 %       | (kind(T) & roleMixin(T))
582 %     ) | (
583 %       (subkind(T) & phase(T))
584 %       | (subkind(T) & role(T))
585 %       | (subkind(T) & category(T))
586 %       | (subkind(T) & mixin(T))
587 %       | (subkind(T) & phaseMixin(T))
588 %       | (subkind(T) & roleMixin(T))
589 %     ) | (
590 %       (phase(T) & role(T))
591 %       | (phase(T) & category(T))
592 %       | (phase(T) & mixin(T))

```

```

593 %      | (phase(T) & phaseMixin(T))
594 %      | (phase(T) & roleMixin(T))
595 %      ) | (
596 %      (role(T) & category(T))
597 %      | (role(T) & mixin(T))
598 %      | (role(T) & phaseMixin(T))
599 %      | (role(T) & roleMixin(T))
600 %      ) | (
601 %      (category(T) & mixin(T))
602 %      | (category(T) & phaseMixin(T))
603 %      | (category(T) & roleMixin(T))
604 %      ) | (
605 %      (mixin(T) & phaseMixin(T))
606 %      | (mixin(T) & roleMixin(T))
607 %      ) | (
608 %      (phaseMixin(T) & roleMixin(T))
609 %      )
610 %    ))
611 % )).
612
613 % Ax |= "th_leafCategoriesCompletelyCategorizeAllEndurantTypes_t19
        "; conjecture commented for convenience
614
615 % fof(th_leafCategoriesCompletelyCategorizeAllEndurantTypes_t19,
        conjecture, (
616 %   ![T]: (endurantType(T) => (
617 %     kind(T) | subkind(T) | phase(T) | role(T) | category(T) |
        mixin(T) | phaseMixin(T) | roleMixin(T)
618 %   ))
619 % )).
620
621 % Sortality and rigidity properties combined
622 % (tested to rule out trivial models)
623
624 % fof(ax_sortalityAndRigidityInUse, axiom, (
625 %   endurant(e6_1) & endurant(e6_2) & world(w6) & kind(k6_1) & kind
        (k6_2) & iof(e6_1,k6_1,w6) & iof(e6_1,k6_1,w6) & ~(k6_1=k6_2)
626 % )).

```

2.1.8 Defining Endurant Types

```

630 % Defining the taxonomy of types of ontological natures through the
        categorization of the taxonomy of concrete individuals
631
632 fof(ax_perdurantTypeDefinition_a44, axiom, (
633 %   ![T]: (perdurantType(T) <=> (
634 %     type_(T) & (![P,W]: ((world(W) & iof(P,T,W)) => (perdurant(P)))
        )
635 %   ))
636 % )).
637
638 fof(ax_endurantTypeDefinition_a44, axiom, (
639 %   ![T]: (endurantType(T) <=> (
640 %     type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (endurant(E))))
        )
641 %   ))
642 % )).
643
644 fof(ax_substantialTypeDefinition_a44, axiom, (

```



```

645     ![T]: (substantialType(T) <=> (
646         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (substantial(E)
647         )))
648     )).
649
650 fof(ax_momentTypeDefinition_a44, axiom, (
651     ![T]: (momentType(T) <=> (
652         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (moment(E))))
653     ))
654 )).
655
656 fof(ax_objectTypeDefinition_a44, axiom, (
657     ![T]: (objectType(T) <=> (
658         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (object(E))))
659     ))
660 )).
661
662 fof(ax_collectiveTypeDefinition_a44, axiom, (
663     ![T]: (collectiveType(T) <=> (
664         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (collective(E))))
665     ))
666 )).
667
668 fof(ax_quantityTypeDefinition_a44, axiom, (
669     ![T]: (quantityType(T) <=> (
670         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (quantity(E))))
671     ))
672 )).
673
674 fof(ax_intrinsicMomentTypeDefinition_a44, axiom, (
675     ![T]: (intrinsicMomentType(T) <=> (
676         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (
677             intrinsicMoment(E))))
678     ))
679 )).
680
681 fof(ax_relatorTypeDefinition_a44, axiom, (
682     ![T]: (relatorType(T) <=> (
683         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (relator(E))))
684     ))
685 )).
686
687 fof(ax_qualityTypeDefinition_a44, axiom, (
688     ![T]: (qualityType(T) <=> (
689         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (quality(E))))
690     ))
691 )).
692
693 fof(ax_modeTypeDefinition_a44, axiom, (
694     ![T]: (modeType(T) <=> (
695         type_(T) & (![E,W]: ((world(W) & iof(E,T,W)) => (mode(E))))
696     ))
697 )).
698 % Types Definition

```

```

699 % (tested to rule out trivial models)
700 % TODO: investigate why we cannot list four different enduring
      types (it may have something to do with "intrinsicMoment" and "
      intrinsicMomentType")
701
702 % fof(ax_typesDefinitionsInstances, axiom, (
703 %   objectType(ot7) & collectiveType(ct7) & modeType(mt7)
704 % )).
705
706 % Ax |= "th_leafCategoriesArePairwiseDisjoint_t21"; conjecture
      commented for convenience
707 % Having the previously defined taxonomy, this should be quite
      trivial
708
709 % fof(th_leafCategoriesArePairwiseDisjoint_t21, conjecture, (
710 %   ~?[T]: (type_(T) & (
711 %     (
712 %       (objectType(T) & collectiveType(T)) | (objectType(T) &
713 %         quantityType(T)) | (objectType(T) & modeType(T)) | (objectType(
714 %           T) & qualityType(T)) | (objectType(T) & relatorType(T)) | (
715 %             objectType(T) & perdurantType(T))
716 %     ) | (
717 %       (collectiveType(T) & quantityType(T)) | (collectiveType(T)
718 %         & modeType(T)) | (collectiveType(T) & qualityType(T)) | (
719 %           collectiveType(T) & relatorType(T)) | (collectiveType(T) &
720 %             perdurantType(T))
721 %     ) | (
722 %       (quantityType(T) & modeType(T)) | (quantityType(T) &
723 %         qualityType(T)) | (quantityType(T) & relatorType(T)) | (
724 %           quantityType(T) & perdurantType(T))
725 %     ) | (
726 %       (modeType(T) & qualityType(T)) | (modeType(T) & relatorType
727 %         (T)) | (modeType(T) & perdurantType(T))
728 %     ) | (
729 %       (qualityType(T) & relatorType(T)) | (qualityType(T) &
730 %         perdurantType(T))
731 %     ) | (
732 %       relatorType(T) & perdurantType(T)
733 %     )
734 %   ))
735 % )).
736
737 % Ultimate Sortals Definitions (by ontological nature)
738
739 fof(ax_objectKindDefinition_a45, axiom, (
740   ![T]: (objectKind(T) <=> (objectType(T) & kind(T)))
741 )).
742
743 fof(ax_collectiveKindDefinition_a45, axiom, (
744   ![T]: (collectiveKind(T) <=> (collectiveType(T) & kind(T)))
745 )).
746
747 fof(ax_quantityKindDefinition_a45, axiom, (
748   ![T]: (quantityKind(T) <=> (quantityType(T) & kind(T)))
749 )).
750
751 fof(ax_modeKindDefinition_a45, axiom, (

```

```

742 ![T]: (modeKind(T) <=> (modeType(T) & kind(T)))
743 )).
744
745 fof(ax_qualityKindDefinition_a45, axiom, (
746   ![T]: (qualityKind(T) <=> (qualityType(T) & kind(T)))
747 )).
748
749 fof(ax_relatorKindDefinition_a45, axiom, (
750   ![T]: (relatorKind(T) <=> (relatorType(T) & kind(T)))
751 )).
752
753 % Ultimate sortals (by ontological nature) instances
754 % (tested to rule out trivial models)
755 % TODO: investigate why we cannot list all different types of
       ultimate sortals at once
756
757 % fof(ax_typesDefinitionsInstances, axiom, (
758 %   objectKind(ok9) & collectiveKind(ck9) & quantityKind(quank9) &
       relatorKind(rk9) & modeKind(mk9) & qualityKind(qualk9)
759 % )).
760
761 % Skipping (t22) because (a21) makes it trivial
762
763 fof(ax_typesDefinitionsInstances_a46, axiom, (
764   ![E]: (endurant(E) => (
765     ?[K]: ((objectKind(K) | collectiveKind(K) | quantityKind(K) |
       modeKind(K) | qualityKind(K) | relatorKind(K))
766     & (![W]: (iof(E,K,W))))
767   ))
768 )).
769
770 % Ax |= "th_endurantSortalsCompleteness_t23"; conjecture commented
       for convenience
771 % Thanks to the taxonomy, we already have "sortal(T) =>
       endurantType(T)", but I leave it like this to be consistent
       with the paper
772
773 % fof(th_endurantSortalsCompleteness_t23, conjecture, (
774 %   ![T]: ((endurantType(T) & sortal(T)) => (objectKind(T) |
       collectiveKind(T) | quantityKind(T) | qualityKind(T) | modeKind
       (T) | relatorKind(T) | phase(T) | role(T)))
775 % )).
776
777 % Ax |= "th_objectTypesSpecializeAKindOfSameNature_t24"; conjecture
       commented for convenience
778
779 % fof(th_objectTypesSpecializeAKindOfSameNature_t24, conjecture, (
780 %   ![T]: ((objectType(T) & sortal(T)) <=> (?[K]: (objectKind(K) &
       specializes(T,K))))
781 % )).
782
783 % Ax |= "th_collectiveTypesSpecializeAKindOfSameNature_t24";
       conjecture commented for convenience
784
785 % fof(th_collectiveTypesSpecializeAKindOfSameNature_t24, conjecture
       , (
786 %   ![T]: ((collectiveType(T) & sortal(T)) <=> (?[K]: (

```

```

      collectiveKind(K) & specializes(T,K)))
787 %)).
788
789 % Ax |= "th_quantityTypesSpecializeAKindOfSameNature_t24";
      conjecture commented for convenience
790
791 % fof(th_quantityTypesSpecializeAKindOfSameNature_t24, conjecture,
      (
792 %   ![T]: ((quantityType(T) & sortal(T)) <=> (?[K]: (quantityKind(K)
      ) & specializes(T,K))))
793 %)).
794
795 % Ax |= "th_modeTypesSpecializeAKindOfSameNature_t24"; conjecture
      commented for convenience
796
797 % fof(th_modeTypesSpecializeAKindOfSameNature_t24, conjecture, (
798 %   ![T]: ((modeType(T) & sortal(T)) <=> (?[K]: (modeKind(K) &
      specializes(T,K))))
799 %)).
800
801 % Ax |= "th_qualityTypesSpecializeAKindOfSameNature_t24";
      conjecture commented for convenience
802
803 % fof(th_qualityTypesSpecializeAKindOfSameNature_t24, conjecture, (
804 %   ![T]: ((qualityType(T) & sortal(T)) <=> (?[K]: (qualityKind(K)
      & specializes(T,K))))
805 %)).
806
807 % Ax |= "th_relatorTypesSpecializeAKindOfSameNature_t24";
      conjecture commented for convenience
808
809 % fof(th_relatorTypesSpecializeAKindOfSameNature_t24, conjecture, (
810 %   ![T]: ((relatorType(T) & sortal(T)) <=> (?[K]: (relatorKind(K)
      ) & specializes(T,K))))
811 %)).
812
813 % Ax |= "th_sortalLeafCategoriesAreDisjoint_t25"; conjecture
      commented for convenience
814
815 % fof(th_sortalLeafCategoriesAreDisjoint_t25, conjecture, (
816 %   ![T]: (objectKind(T) => (~ (collectiveKind(T) | quantityKind(T)
      | modeKind(T) | qualityKind(T) | relatorKind(T) | category(T) |
      mixin(T) | phaseMixin(T) | roleMixin(T))))
817 %   & ![T]: (collectiveKind(T) => (~ (objectKind(T) | quantityKind(T)
      | modeKind(T) | qualityKind(T) | relatorKind(T) | category(T) |
      mixin(T) | phaseMixin(T) | roleMixin(T))))
818 %   & ![T]: (quantityKind(T) => (~ (objectKind(T) | collectiveKind(T)
      | modeKind(T) | qualityKind(T) | relatorKind(T) | category(T) |
      mixin(T) | phaseMixin(T) | roleMixin(T))))
819 %   & ![T]: (modeKind(T) => (~ (objectKind(T) | quantityKind(T) |
      collectiveKind(T) | qualityKind(T) | relatorKind(T) | category(
      T) | mixin(T) | phaseMixin(T) | roleMixin(T))))
820 %   & ![T]: (qualityKind(T) => (~ (objectKind(T) | quantityKind(T) |
      modeKind(T) | collectiveKind(T) | relatorKind(T) | category(T) |
      mixin(T) | phaseMixin(T) | roleMixin(T))))
821 %   & ![T]: (relatorKind(T) => (~ (objectKind(T) | quantityKind(T) |
      modeKind(T) | qualityKind(T) | collectiveKind(T) | category(T)

```

```

      | mixin(T) | phaseMixin(T) | roleMixin(T)))
822 % & ![T]: (category(T) => (~(objectKind(T) | quantityKind(T) |
      modeKind(T) | qualityKind(T) | relatorKind(T) | collectiveKind(
      T) | mixin(T) | phaseMixin(T) | roleMixin(T))))
823 % & ![T]: (mixin(T) => (~(objectKind(T) | quantityKind(T) |
      modeKind(T) | qualityKind(T) | relatorKind(T) | category(T) |
      collectiveKind(T) | phaseMixin(T) | roleMixin(T))))
824 % & ![T]: (phaseMixin(T) => (~(objectKind(T) | quantityKind(T) |
      modeKind(T) | qualityKind(T) | relatorKind(T) | category(T) |
      mixin(T) | collectiveKind(T) | roleMixin(T))))
825 % & ![T]: (roleMixin(T) => (~(objectKind(T) | quantityKind(T) |
      modeKind(T) | qualityKind(T) | relatorKind(T) | category(T) |
      mixin(T) | phaseMixin(T) | collectiveKind(T))))
826 % )).
827
828 % Ax |= "th_sortalLeafCategoriesAreComplete_t26"; conjecture
      commented for convenience
829
830 % fof(th_sortalLeafCategoriesAreComplete_t26, conjecture, (
831 %   ![T]: ((endurantType(T)) => (objectKind(T) | collectiveKind(T)
      | quantityKind(T) | qualityKind(T) | modeKind(T) | relatorKind(
      T) | phase(T) | role(T) | category(T) | mixin(T) | phaseMixin(T)
      ) | roleMixin(T)))
832 % )).

```