Temporally qualified continuants for BFO 2 OWL

A bottom-up view

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Relations between continuants

- Binary relations between occurrents non-ambiguous:

  partOf^2 (Battle_of_Stalingrad, Second_World_War)

- Binary relations between continuants ambiguous:

  partOf^2 (Montreal, Canada)

- Ternary relations between continuants non-ambiguous:

  partOf^3 (Montreal, British Empire, 1860)

  partOf^3 (Montreal, Canada, 2013)

Problem: restriction to binary relations in OWL

- Instantiation ambiguous:
  - Montreal rdf:type *City*
  - Canada rdf:type *Country*
- Relations ambiguous:
  - Montreal partOf BritishEmpire
  - Montreal partOf Canada
- Conflicts with the axiom
  (partOf value BritishEmpire) and
  (partOf value Canada) subClassOf Nothing

Class level axioms

- How to interpret standard OWL axioms like:

  City subClassOf partOf some *Country* ?

  – **Temporary relatedness**: every city is part of some country at least at some time

  $$\forall a \forall t_1 \exists t_2: inst^3(a, A, t_1) \wedge inst^3(a, A, t_2) \rightarrow$$
  $$\exists b: (inst^3(b, B, t_2) \wedge rel^3(a, b, t_1))$$

  – **Permanent generic relatedness**: at all times, every city is part of some country

  $$\forall a \forall t: inst^3(a, A, t) \rightarrow \exists b: inst^3(b, B, t) \wedge rel^3(a, b, t)$$

  – **Permanent specific relatedness**: at all times, every city is part of the same country

  $$\forall a \forall t_1: [inst^3(a, A, t) \rightarrow \exists b: (inst^3(b, B, t) \wedge rel^3(a, b, t)$$
  $$\forall t: (inst^3(a, A, t) \rightarrow (rel^3(a, b, t) \wedge inst^3(b, B, t))))]$$

Importance of expressing permanent generic relatedness

- Every mammal has some portion of blood as part at all times (but not always the same portion)

- Every material entity is always located at some place (but not always the same place)

- Every pdf file generically depends on some hardware but not always on the same hardware

- Every cell nucleus is part of some cell but not always the same cell

- Every animal cell has some ribosome as part but not always the same

Possible solutions

1. **Use binary relations and interpret them as permanent generically related** (as most of DL community has done for decades): may be acceptable as long no non-rigid classes and no instances are used (?)

2. **Reify ternary relations**: (n-ary relations ODP) Complicated, user-unfriendly and difficult to get transitivity into it

3. **Use temporalized relations** (as in BFO 2 OWL Graz version): works only for temporary relatedness and permanent specific relatedness, but not for permanent generic relatedness.

4. **Use temporally qualified continuants**. See following slides

ContinuantTQ

- Continuants in OWL ontology can be referred to in the context of a time frame:
  Continuant TQ = continuant, temporally qualified
- "*façon de parler*" – way of speaking
- Examples:
  - London during the First World War
  - Mr. X's heart transplant, occupying an operation room at May 20th, 2013, 1pm
  - my left thumb now
  - my heart, since my birth
  - the HD of my laptop during the whole day of July 6th, 2013

ContinuantTQ

- ContinuantTQs are specific DL constructs
- ContinuantTQs in DL axioms translate into a sequence of FOL statements with ternary relations
- ContinuantTQs are ontological neutral: $c@t1 = c$ at time $t1$ is not a different individual than $c@t2$. It is only referred to at a different time
- In OWL, a ContinuantTQ class can be instantiated by any kind of (contiguous) temporal references at any time

Examples for continuantTQs

1980   1994   1998   2013

John

John@[1980;1994]
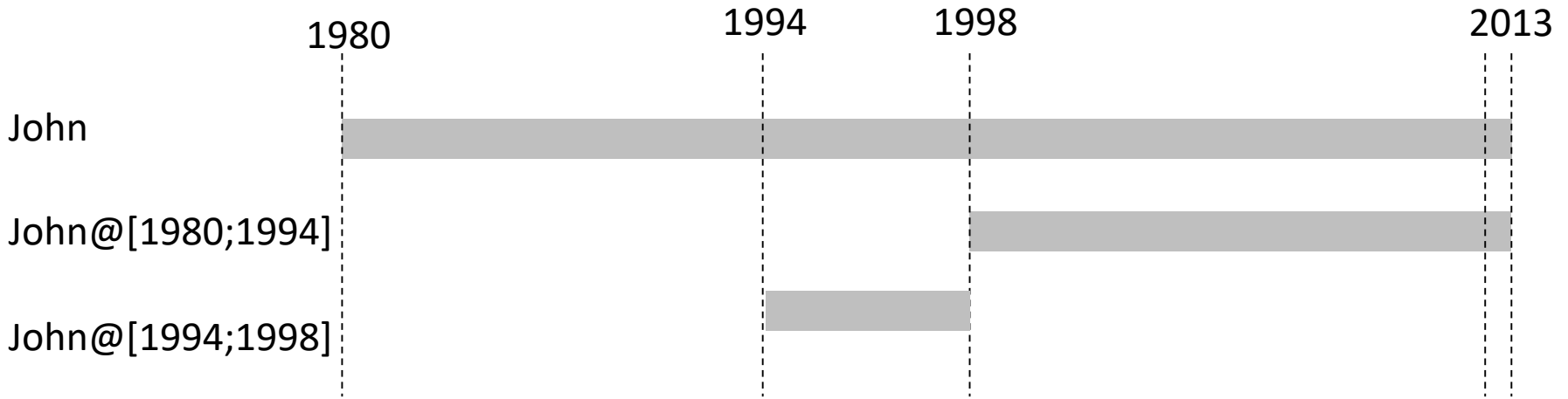
John@[1994;1998]

John rfd:type *Human*
John@[1980;1994] rfd:type *Child*
John@[1994;1998] rfd:type *Teenager*
John@[1998;2013] rfd:type *Adult*
John@[201305201000; 201305201100] rdf:type patientOf some
    (*Appendectomy* and
        hasAgent value
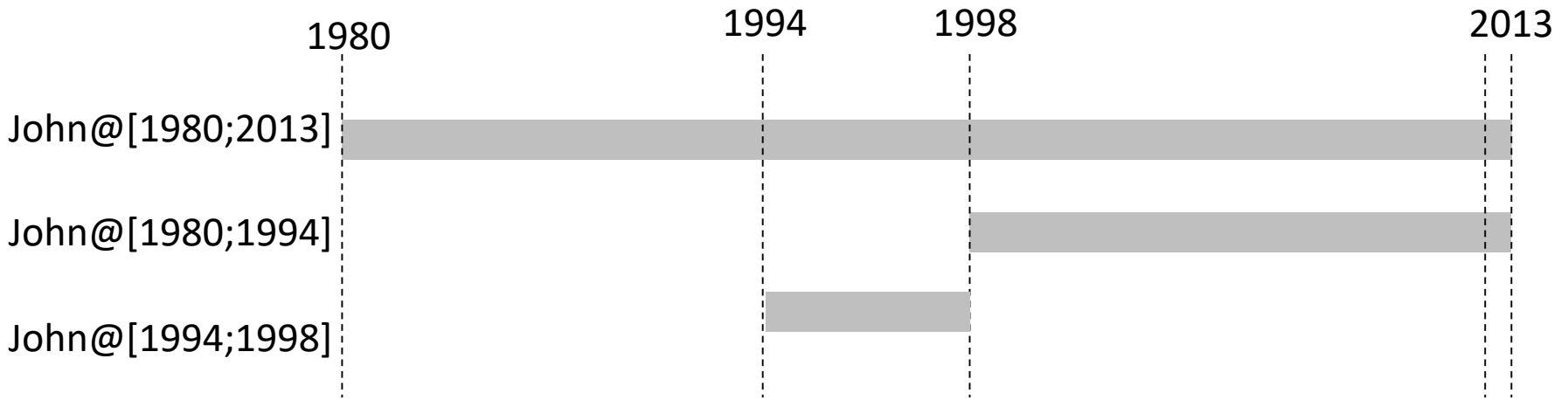   DrSmith@[201305201000; 201305201100]

"Phased Sortals"

Relations
hasMax, *maxOf*, *atSomeTime, spans*

- *hasMax* (inverse *maxOf*) relates a ContinuantTQ instance to its related instance with the maximal temporal extension

- *atSomeTime* relates a ContinuantTQ with each other a ContinuantTQ related to the same continuant

- $atSomeTime \equiv hasMax \bullet maxOf$

- *maxOf* subPropertyOf *atSomeTime* (not necessary if *hasMax* is reflexive)

- *spans* relates a continuantTQ with its defining time interval

Relations:
hasMax, maxOf, atSomeTime, spans

John@[1980;2013] maxOf John@[1994;1998]

John@[1998;2013] atSomeTime John@[201305201000; 201305201100]

John@[1998;2013] spans [1998; 2013]

Translations FOL, ternary → DL, binary

partOf³ (Montreal, BritishEmpire, 1860) →

partOf (Montreal@1860, BritishEmpire@1860)
spans (Montreal@1860, 1860)
hasMax (Montreal@1860, Montreal@max)
spans (BritishEmpire@1860, 1860)
hasMax (BritishEmpire@1860, BritishEmpire@max)

partOf³ (Montreal, Canada,1925) →

partOf (Montreal@1925, Canada@1925)
spans (Montreal@1925, 1925)
hasMax (Montreal@1925, Montreal@max)
spans (Canada@1925, 1925)
hasMax (Canada@1925, Canada@max)

instanceOf³ (Montreal, *Settlement*, 1700) →

Montreal@1700 rdf:Type *Settlement*
spans (Montreal@1700, 1700)
hasMax (Montreal@1700, Montreal@max)

instanceOf³ (Montreal, *City*, 1925) →

Montreal@1925 rdf:Type *City*
spans (Montreal@1925, 1925)
hasMax (Montreal@1925, Montreal@max)

Examples, Class level

Permanent generic parthood

"Each city is always part of some country"

$\forall a, t:$ inst³ $(x, City, t) \rightarrow$
  $\exists b:$ inst³ $(b, Country, t) \wedge$
    part of³ (x, y, t)

$\Longrightarrow$

City subClassOf partOf some *Country*

partOf eq inverse(hasPart)

partOf Domain *ContinuantQC or Occurrent*

partOf Range *ContinuantQC or Occurrent*

Temporary parthood

"Each medieval city has had a gate at some time"

$\forall x, t_1:$ inst³ $(x, MCity, t_1) \rightarrow$
    $\exists t_2, \exists y:$ inst³ $(x, MCity, t_2) \wedge$
        inst³ $(y, Gate, t_2) \wedge$
        hasPart³ (x, y, t_2)

$\Longrightarrow$

MCity subClassOf
    atSomeTime some
        (hasPart some *Gate*)

Examples

City subClassOf partOf some *Country*
Country subClassOf partOf some *Continent*

City subClassOf partOf some *Continent*
Not necessarily always the same country

CityGate subClassOf atSomeTime some (partOf some *City*)
CityGateDoor subClassOf partOf some *CityGate*

Does not entail that *CityGateDoor* is part of a city at
some time (door built in after destruction of city)

CellNucleolus subClassOf partOf some *CellNucleus*
CellNucleus subClassOf partOf some *Cell*

CellNucleolus subClassOf partOf some *Cell*
(not necessary that the cell is always the same, e.g.
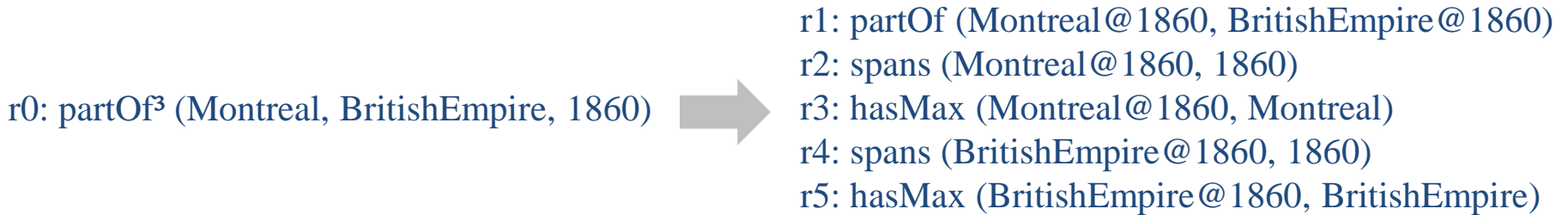after division)

Apple subClassOf atSomeTime some (partOf some *AppleTree*)
AppleSeed subClassOf atSomeTime some (partOf some *Apple*)
Does not entail that part Apple seeds are parts of apple trees

Consistency of A-boxes

r0: partOf³ (Montreal, BritishEmpire, 1860)

r1: partOf (Montreal@1860, BritishEmpire@1860)
r2: spans (Montreal@1860, 1860)
r3: hasMax (Montreal@1860, Montreal)
r4: spans (BritishEmpire@1860, 1860)
r5: hasMax (BritishEmpire@1860, BritishEmpire)

One ternary relation rel (a, b, t) is translated into a set of five binary relations.

r1: rel (a@t, b@t)
r2: spans (a@t, t)
r3: hasMax (a@t, a@max)
r4: spans (b@t , t)
r5: hasMax (b@t, b@max)

OWL Rule for consistency checking:

TemporallyQualifiedContinuant(?x), TemporallyQualifiedContinuant(?y),
spans (?x,?t1), spans(?y,?t2), topObjectProperty(?x,?y) - > equal(?t1,?t2)

Participation of TQCs in Processes

- Temporal extension of *C@max* included in temporal extensions of Process *P* →all TQCs of *C* participate in *P*:
  C subclassOf **participatesIn** some *P*
  Example: *Organism* subClassOf **participatesIn** some *Life*

- Temporal extension of *C@max* larger → some TQCs participate
  C subclassOf **atSomeTime** some (**participatesIn** some *P*)
  Example: *Human* subClassOf **participatesIn** some *BirthProcess*

- Process P has at all time some participant of type C: all temporal parts of a process have some TQC of type C as participant
  temporalPartOf some *P* subClassOf **hasParticipant** some *C*
  Example: *Breathing* subClassOf **hasParticipant** some *PortionOfAir*

- Process P has at some time a participant of type C:
  P subClassOf **hasParticipant** some *C*

- Example: *Fecundation* subClassOf **hasParticipant** some *Spermatozoon*

Adaptation of BFO2Graz

- removal of TRs
- "rel at some time" -> "rel"
- checking of axioms that use rel
- restitution of transitivity if necessary
- Special cases:
  - has continuant part at all times that part exists
  - part of continuant at all times that whole exists
- Attached axioms need to be analyzed one by one

Found 15 uses of 'obo:has continuant part at all times that part exists'

▼──● 'obo:continuant fiat boundary'
      ● 'obo:continuant fiat boundary' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** 'obo:continuant fiat boundary'

▼──■ 'obo:has continuant part at all times that part exists'
      ■ **Transitive:** 'obo:has continuant part at all times that part exists'
      ■ 'obo:has continuant part at all times that part exists' **SubPropertyOf** 'obo:has continuant part'
      ■ 'obo:has continuant part at all times that part exists' **Range** obo:continuant
      ■ 'obo:has continuant part at all times that part exists' **Domain** obo:continuant
      ■ **ObjectProperty:** 'obo:has continuant part at all times that part exists'

▼──● 'obo:immaterial entity'
      ● 'obo:immaterial entity' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** (**not** ('obo:material entity'))
      ● 'obo:immaterial entity' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** 'obo:immaterial entity'

▼──● 'obo:material entity'
      ● 'obo:material entity' **SubClassOf** 'obo:has continuant part at all times that part exists' **only**
        ('obo:material entity' **or** 'obo:immaterial entity')

▼──● 'obo:one-dimensional continuant fiat boundary'
      ● 'obo:one-dimensional continuant fiat boundary' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** (**not** ('obo:two-dimensional continuant fiat boundary'))

▼──● 'obo:one-dimensional spatial region'
      ● 'obo:one-dimensional spatial region' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** (**not** ('obo:two-dimensional spatial region' **or** 'obo:three-dimensional spatial region'))

▼──● 'obo:spatial region'
      ● 'obo:spatial region' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** 'obo:spatial region'

▼──● 'obo:two-dimensional spatial region'
      ● 'obo:two-dimensional spatial region' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** (**not** ('obo:three-dimensional spatial region'))

▼──● 'obo:zero-dimensional continuant fiat boundary'
      ● 'obo:zero-dimensional continuant fiat boundary' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** (**not** ('obo:one-dimensional continuant fiat boundary' **or** 'obo:two-dimensional continuant fiat boundary'))

▼──● 'obo:zero-dimensional spatial region'
      ● 'obo:zero-dimensional spatial region' **SubClassOf** 'obo:has continuant part at all times that part exists' **only** (**not** ('obo:two-dimensional spatial region' **or** 'obo:one-dimensional spatial region' **or** 'obo:three-dimensional spatial region'))

Found 15 uses of 'obo:part of continuant at all times that whole exists'

▼──● 'obo:continuant fiat boundary'
         └──● 'obo:continuant fiat boundary' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** ('obo:spatial region'))

▼──● obo:disposition
         └──● obo:disposition **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** (obo:role))

▼──● 'obo:generically dependent continuant'
         └──● 'obo:generically dependent continuant' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** ('obo:independent continuant' **or** 'obo:specifically dependent continuant'))

▼──● 'obo:independent continuant'
         └──● 'obo:independent continuant' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** ('obo:specifically dependent continuant' **or** 'obo:generically dependent continuant'))

▼──● 'obo:material entity'
         └──● 'obo:material entity' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** 'obo:material entity'

▼──■ 'obo:part of continuant at all times that whole exists'
         ├──■ 'obo:part of continuant at all times that whole exists' **SubPropertyOf** 'obo:part of continuant'
         ├──■ 'obo:part of continuant at all times that whole exists' **Range** obo:continuant
         ├──■ **ObjectProperty:** 'obo:part of continuant at all times that whole exists'
         ├──■ **Transitive:** 'obo:part of continuant at all times that whole exists'
         └──■ 'obo:part of continuant at all times that whole exists' **Domain** obo:continuant

▼──● obo:quality
         └──● obo:quality **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** ('obo:realizable entity'))

▼──● 'obo:realizable entity'
         └──● 'obo:realizable entity' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** (obo:quality))

▼──● obo:role
         └──● obo:role **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** (obo:disposition))

▼──● 'obo:spatial region'
         └──● 'obo:spatial region' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** 'obo:spatial region'

▼──● 'obo:specifically dependent continuant'
         └──● 'obo:specifically dependent continuant' **SubClassOf** 'obo:part of continuant at all times that whole exists' **only** (**not** ('obo:independent continuant' **or** 'obo:generically dependent continuant'))