Modular Ontology Design and Use Case: The GeoLink Example

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This Tutorial (all parts)

- **Pascal Hitzler (60 mins):**
  Introduction and first examples
- **Monika Solanki (30 mins):**
  Example "modeling vaccine traceability"

coffee

- **Pascal Hitzler (60 mins):**
  Example "GeoLink Modular Ontology"
- **Agnieszka Lawrynowicz (30 mins):**
  Example "Reporting Event ODP"

lunch

- **Karl Hammar with all others (3h):**
  Hands-on, the WebProtege XDP plug-in

EarthCube GeoLink Scenario

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The NSF EarthCube Program:

Developing a Community-Driven Data and Knowledge Environment for the Geosciences

“concepts and approaches to create integrated data management infrastructures across the Geosciences.”

“EarthCube aims to create a well-connected and facile environment to share data and knowledge in an open, transparent, and inclusive manner, thus accelerating our ability to understand and predict the Earth system.”

EarthCube GeoLink Scenario

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GeoLink: An EarthCube "Building Block" project (2014-2017)

How to realize data search across many large-scale geoscience data repositories, such that

- **The approach is extendable to new repositories.**
- **The scope can extend across all of the Geosciences.**
- **The search capabilities can be made more fine-grained in the future if desired.**

Central idea: Use a modular, extendable ontology for the integration of metadata.

GeoLink

An interactive demonstration of the integrated GeoLink data is available at

http://demo.geolink.org

At http://www.geolink.org/ there are links to the complete schema, a SPARQL Endpoint, publications, etc.

The GeoLink Framework

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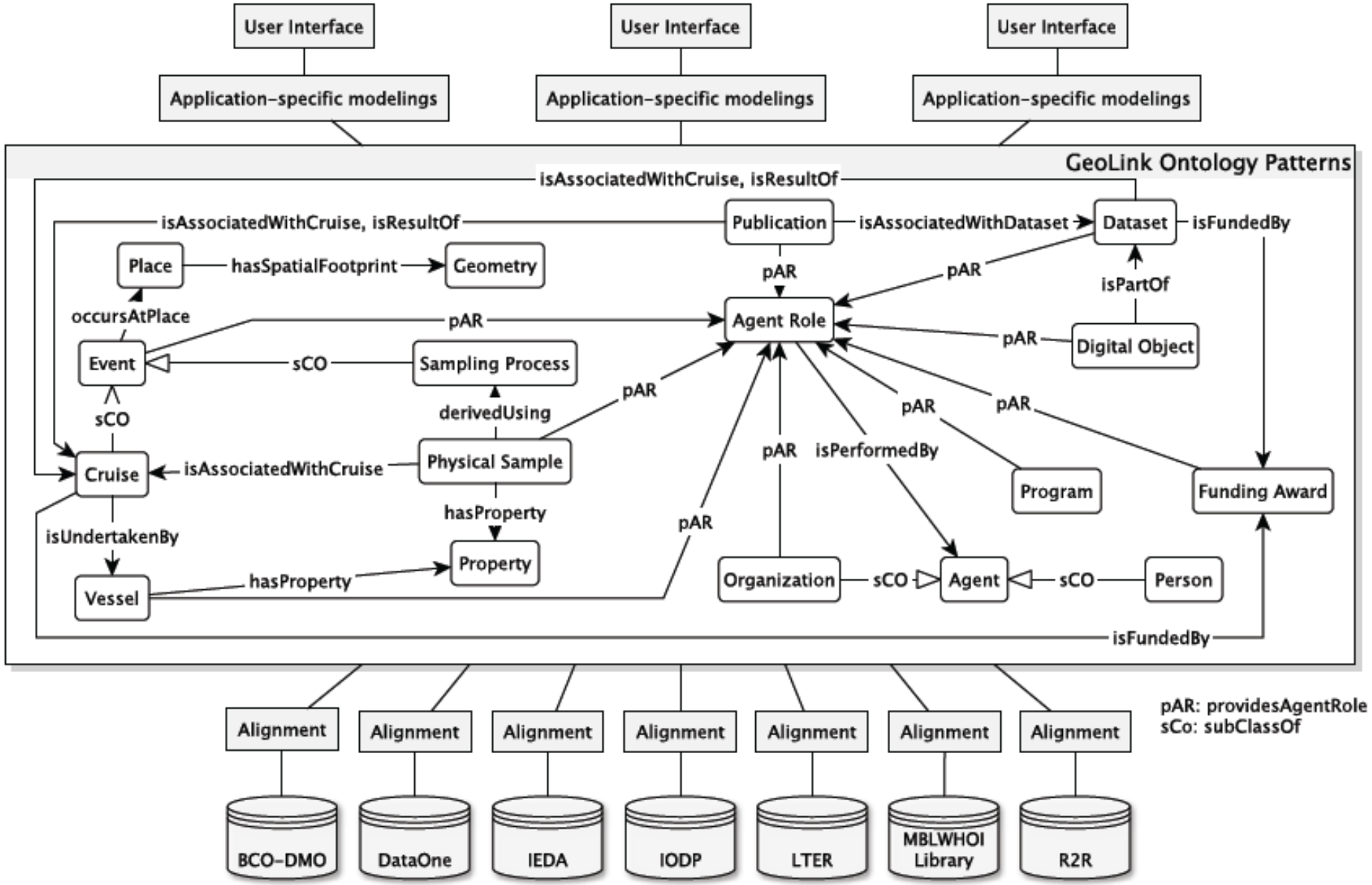

The GeoLink Modular Ontology

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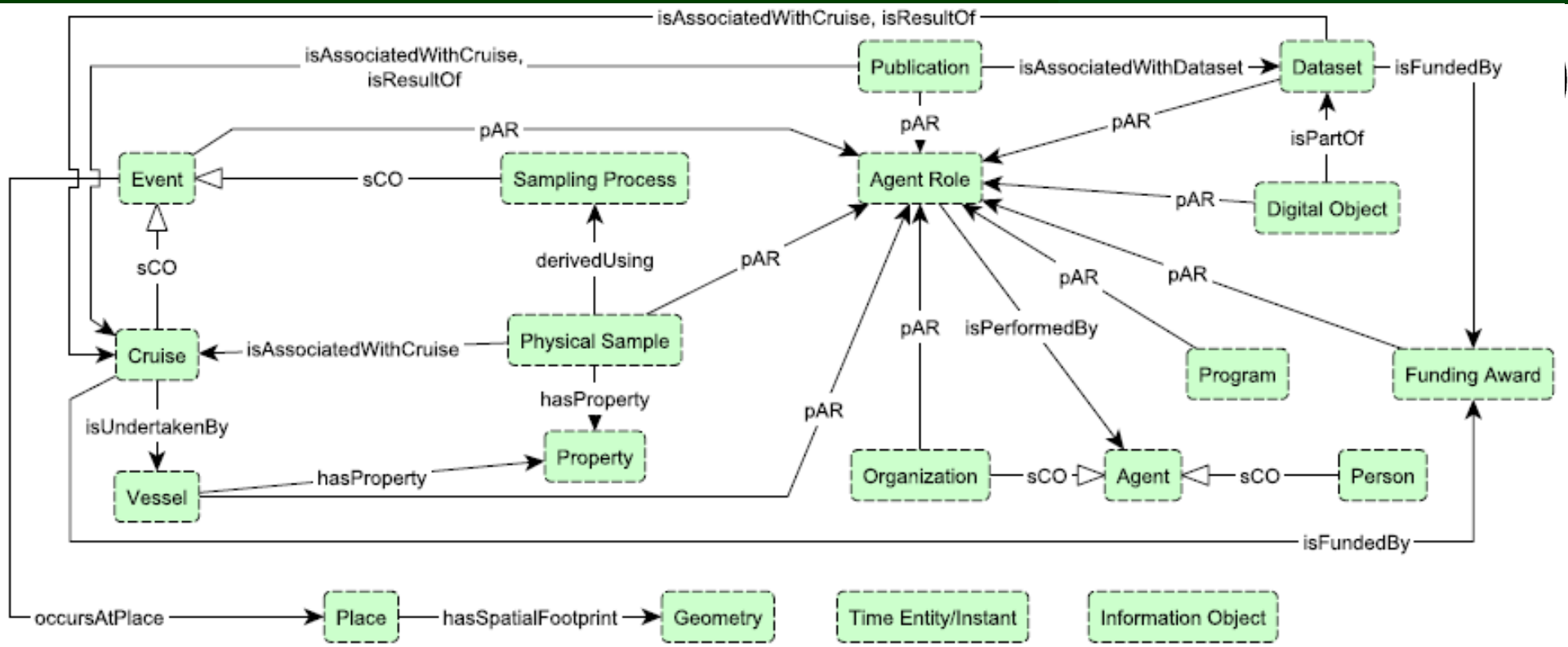
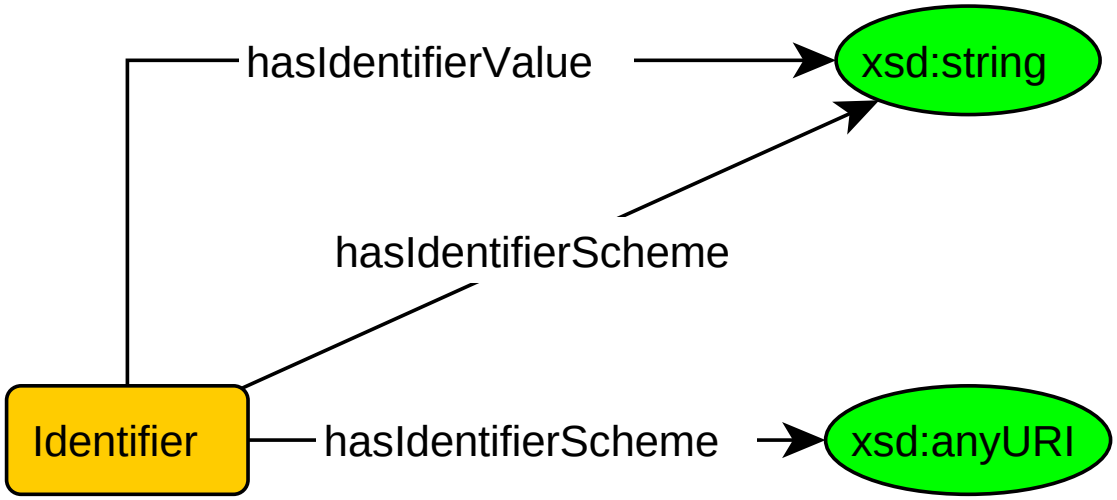


High-level overview of the GeoLink Modular Ontology (GMO).

Each box stands for a module, which has been modeled in its own right.

Identifier pattern



$$Identifier \sqsubseteq (\leqslant 1\ hasIdentifierScheme.(xsd:anyURI \sqcup xsd:string))$$

$$Identifier \sqsubseteq (=1\ hasIdentifierValue.xsd:string)$$

$$\exists hasIdentifierScheme.(xsd:anyURI \sqcup xsd:string) \sqsubseteq Identifier$$

$$\exists hasIdentifierValue.xsd:string \sqsubseteq Identifier$$

$$Identifier \sqsubseteq \forall hasIdentifierScheme.(xsd:anyURI \sqcup xsd:string)$$

$$Identifier \sqsubseteq \forall hasIdentifierValue.xsd:string$$

OWLAx

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Ontology Axiomatization Support (OWLAx)

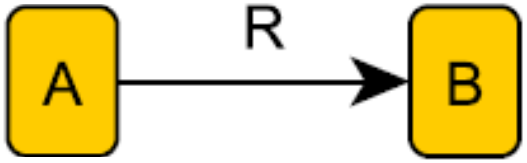
- **Protégé Plug-In**
- **Md. Kamruzzaman Sarker, Adila A. Krisnadhi, Pascal Hitzler, OWLAx: A Protege Plugin to Support Ontology Axiomatization through Diagramming. Proceedings Posters and Demos Track at ISWC 2016.**

- **Insert class diagram using graphical UI**
- **System asks you whether to include corresponding axioms (taken from a pool of most common axioms for the diagram)**
- **You can of course also manually add further axioms.**

http://dase.cs.wright.edu/content/ontology-axiomatization-support

Axioms – Systematically

1. $A \sqcap B \sqsubseteq \bot$
2. $\exists R.\top \sqsubseteq A$
3. $\exists R.B \sqsubseteq A$
4. $\top \sqsubseteq \forall R.B$
5. $A \sqsubseteq \forall R.B$
6. $A \sqsubseteq R.B$
7. $B \sqsubseteq R^{-}.A$
8. $\top \sqsubseteq \leq 1 R.\top$
9. $\top \sqsubseteq \leq 1 R.B$
10. $A \sqsubseteq \leq 1 R.\top$
11. $A \sqsubseteq \leq 1 R.B$
12. $\top \sqsubseteq \leq 1 R^{-}.\top$
13. $\top \sqsubseteq \leq 1 R^{-}.A$
14. $B \sqsubseteq \leq 1 R^{-}.\top$
15. $B \sqsubseteq \leq 1 R^{-}.A$



1. A DisjointWith B (disjointness)
2. R some `owl:Thing` SubClassOf A (domain)
3. R some B SubClassOf A (scoped domain)
4. `owl:Thing` SubClassOf R only B (range)
5. A SubClassOf R only B (scoped range)
6. A SubClassOf R some B (existential)
7. B SubClassOf inverse R some A (inverse existential)
8. `owl:Thing` SubClassOf R max 1 `owl:Thing` (functionality)
9. `owl:Thing` SubClassOf R max 1 B (qualified functionality)
10. A SubClassOf R max 1 `owl:Thing` (scoped functionality)
11. A SubClassOf R max 1 B (qualified scoped functionality)
12. `owl:Thing` SubClassOf inverse R max 1 `owl:Thing` (inverse functionality)
13. `owl:Thing` SubClassOf inverse R max 1 A (inverse qualified functionality)
14. B SubClassOf inverse R max 1 `owl:Thing` (inverse scoped functionality)
15. B SubClassOf inverse R max 1 A (inverse qualified scoped functionality)

OWLAx Protégé plug-in

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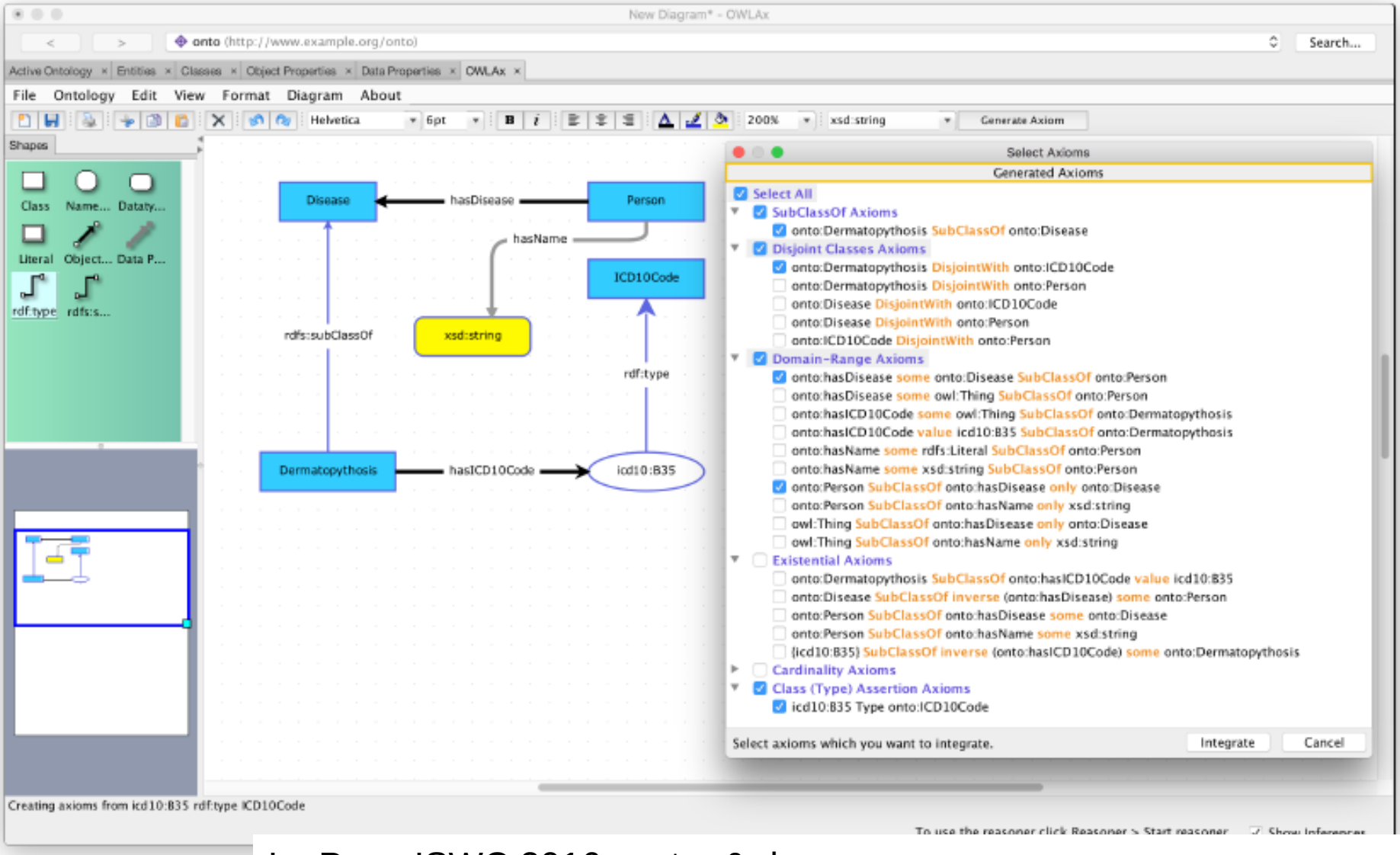

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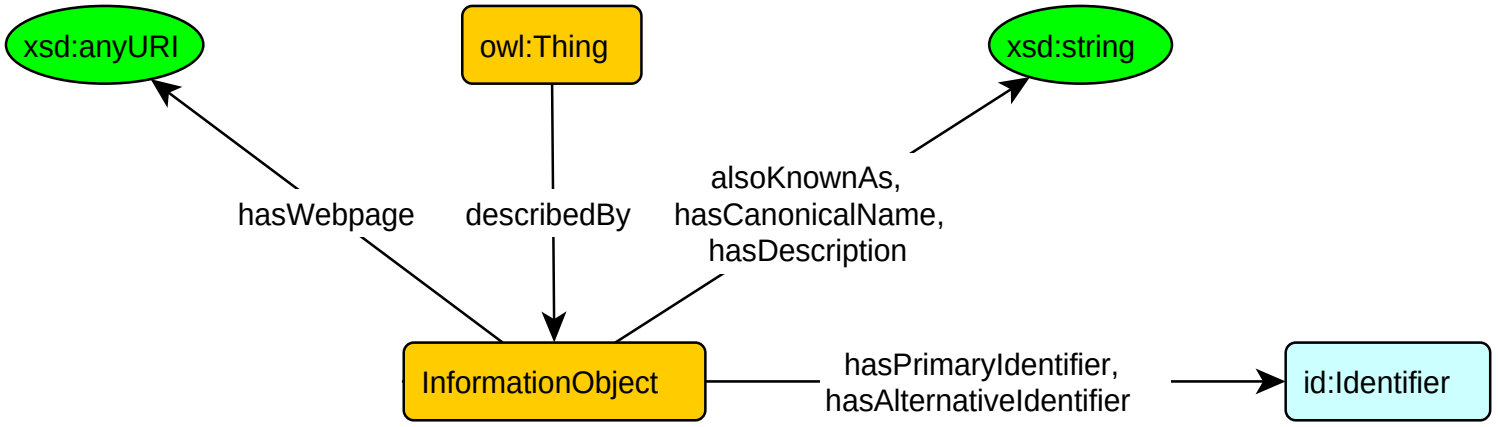
In: Proc. ISWC 2016 poster & demos
http://dase.cs.wright.edu/content/ontology-axiomatization-support

Information Object pattern



$$\top \sqsubseteq (\leqslant 1\ describedBy.InformationObject)$$

$$InformationObject \sqsubseteq (=1\ describedBy^{-}.\top)$$

$$InformationObject \sqsubseteq \neg\exists describedBy.InformationObject$$

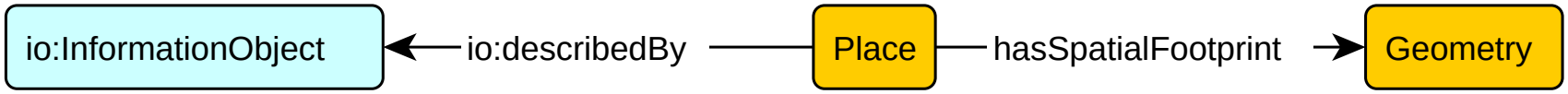
$$\exists hasWebpage.xsd:anyURI \sqsubseteq InformationObject$$

$$\exists alsoKnownAs.xsd:string \sqsubseteq InformationObject$$

$$\exists hasCanonicalName.xsd:string \sqsubseteq InformationObject$$

$$\exists hasDescription.xsd:string \sqsubseteq InformationObject$$

Place



Alignment to external ontologies or vocabularies,
rather than direct reuse:

GeoSPARQL, `http://www.opengis.net/ont/geosparql`

```
PREFIX geo:  <http://www.opengis.net/ont/geosparql#>
```

Good axioms

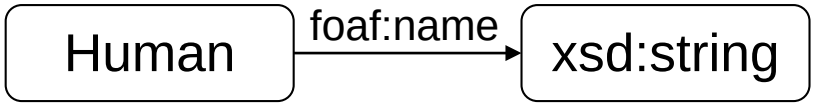
Specificity matters: Problems with domain/range.

Recommendations often heard (but are problematic):

- **Indicate domain and range for your properties.**
- **Reuse as many existing vocabularies as you can.**

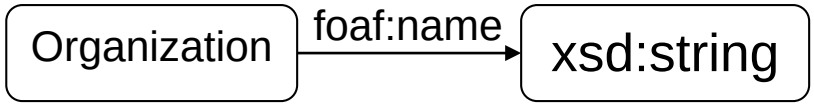
But there are problems with this:

Ontology 1:



domain(foaf:name) = Human

Ontology 2:



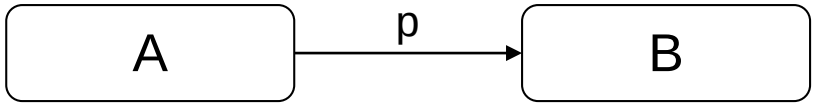
domain(foaf:name) = Organization

Logical consequence after merge: Human ≡ Organization

Recommendations

- **Make rich axiomatizations**
- **Avoid re-use of external vocabularies (rather provide an additional file with mappings for those who want to use it)**
- **Avoid naïve domain and range axioms.**

Alternative to naïve domain/range: scoped domain and range.

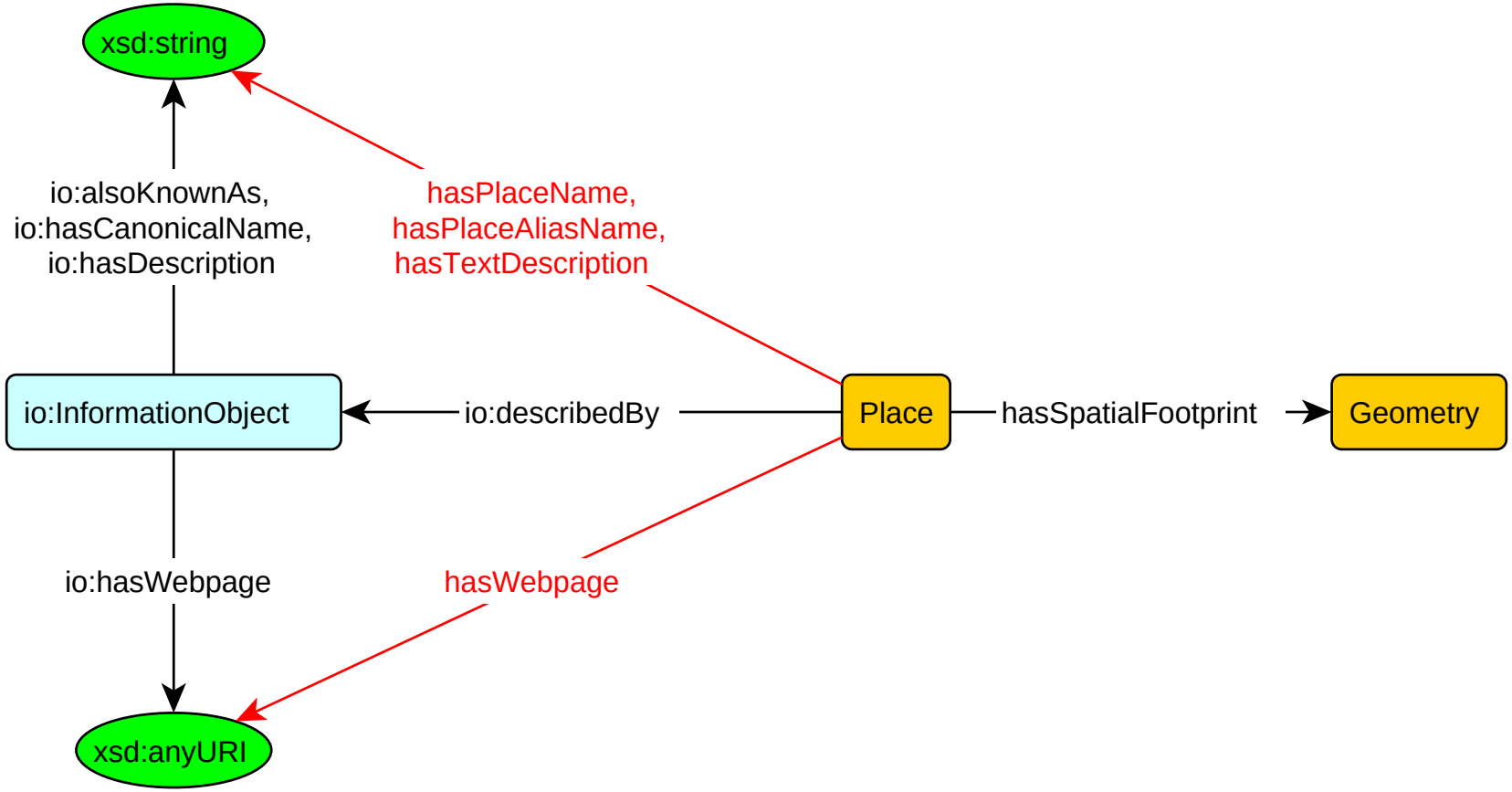


$$A(x) \wedge p(x,y) \rightarrow B(y)$$ **scoped range**

$$B(y) \wedge p(y,x) \rightarrow A(x)$$ **scoped domain**

both rules can be expressed in OWL.

Place shortcuts



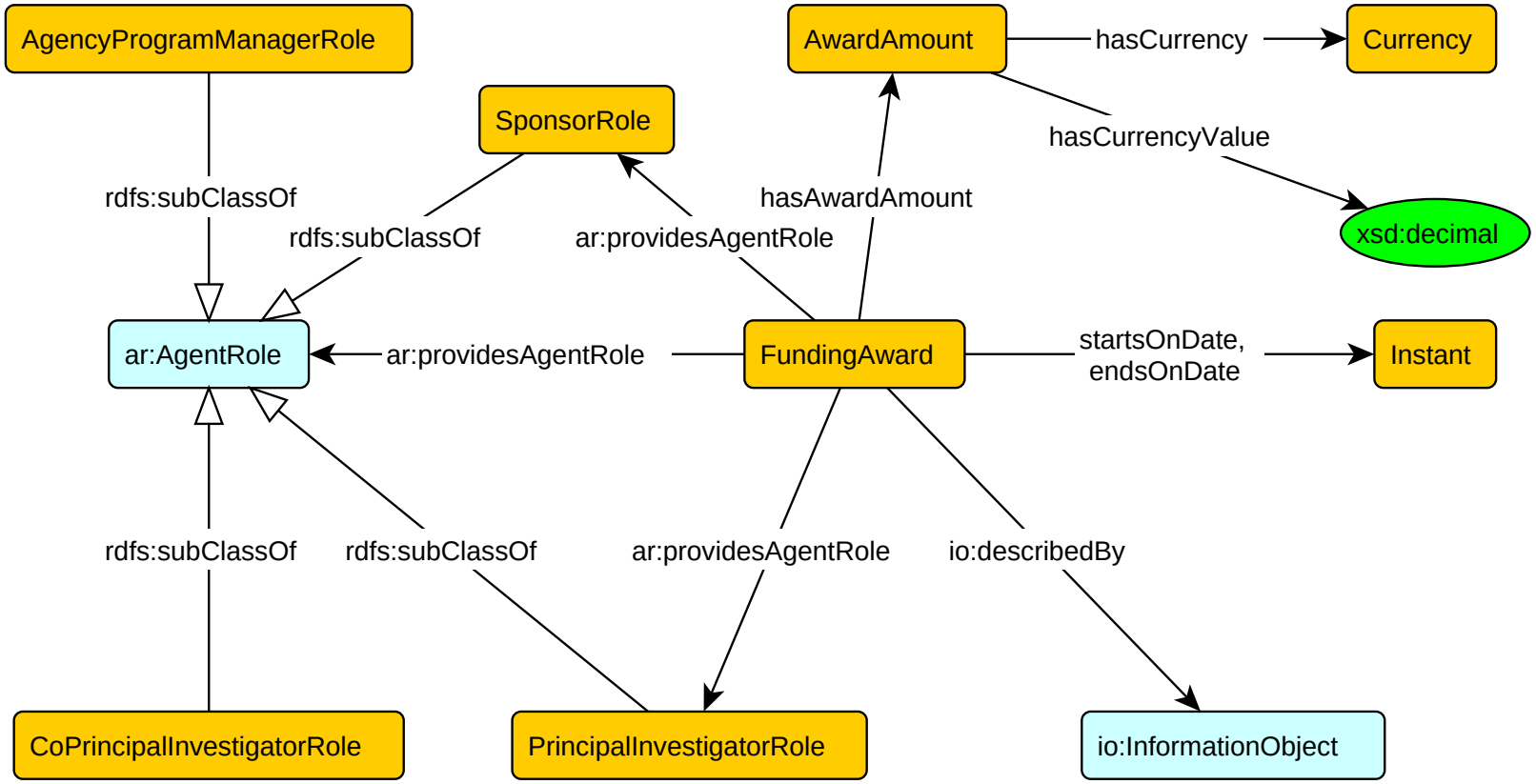
$$Place(x) \wedge io{:}describedBy(x, y) \wedge io{:}hasCanonicalName(y, z) \rightarrow hasPlaceName(x, z)$$

$$Place(x) \wedge io{:}describedBy(x, y) \wedge io{:}alsoKnownAs(y, z) \rightarrow hasPlaceAliasName(x, z)$$

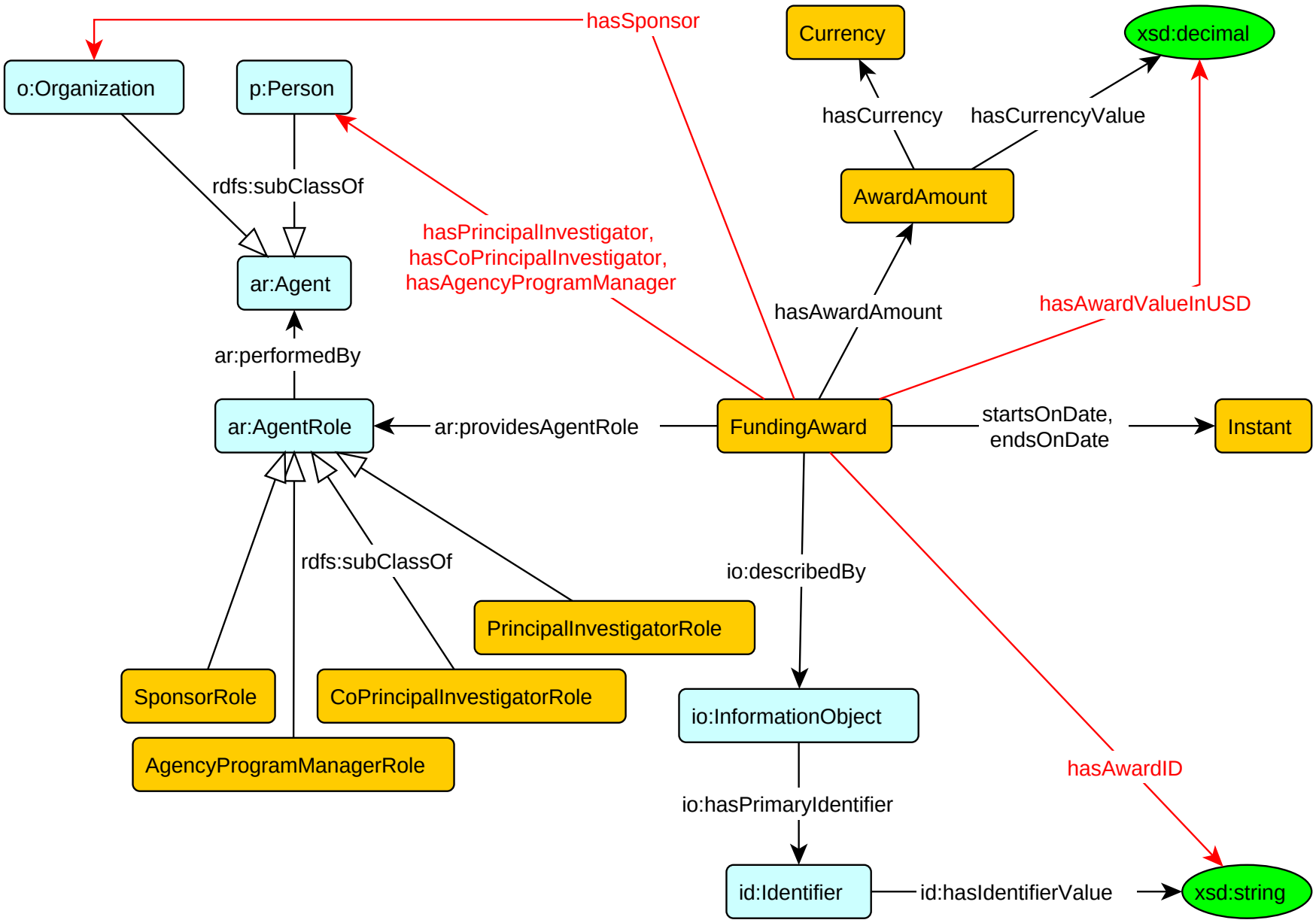
$$Place(x) \wedge io{:}describedBy(x, y) \wedge io{:}hasDescription(y, z) \rightarrow hasTextDescription(x, z)$$

$$Place(x) \wedge io{:}describedBy(x, y) \wedge io{:}hasWebpage(y, z) \rightarrow hasWebpage(x, z)$$

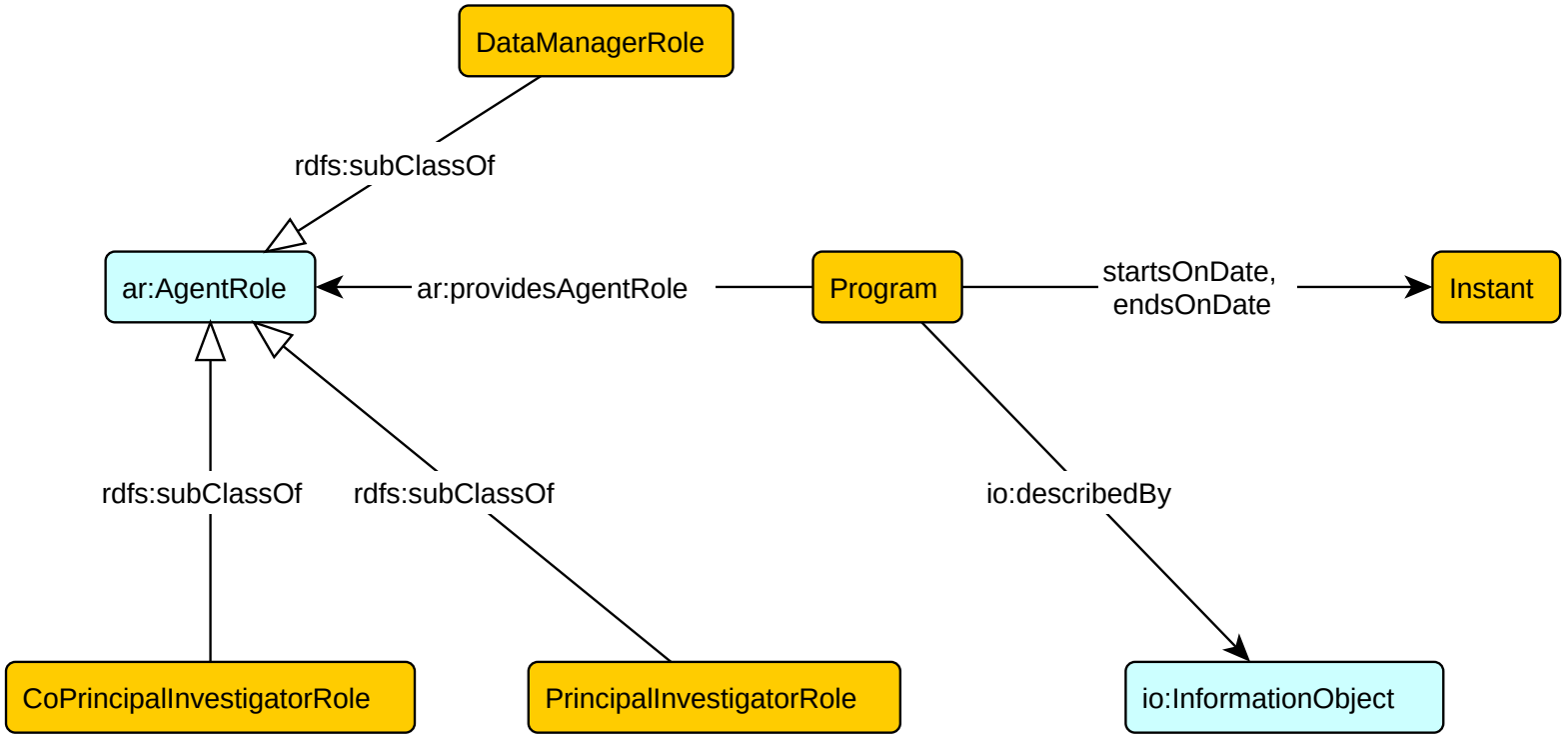
Funding Award pattern



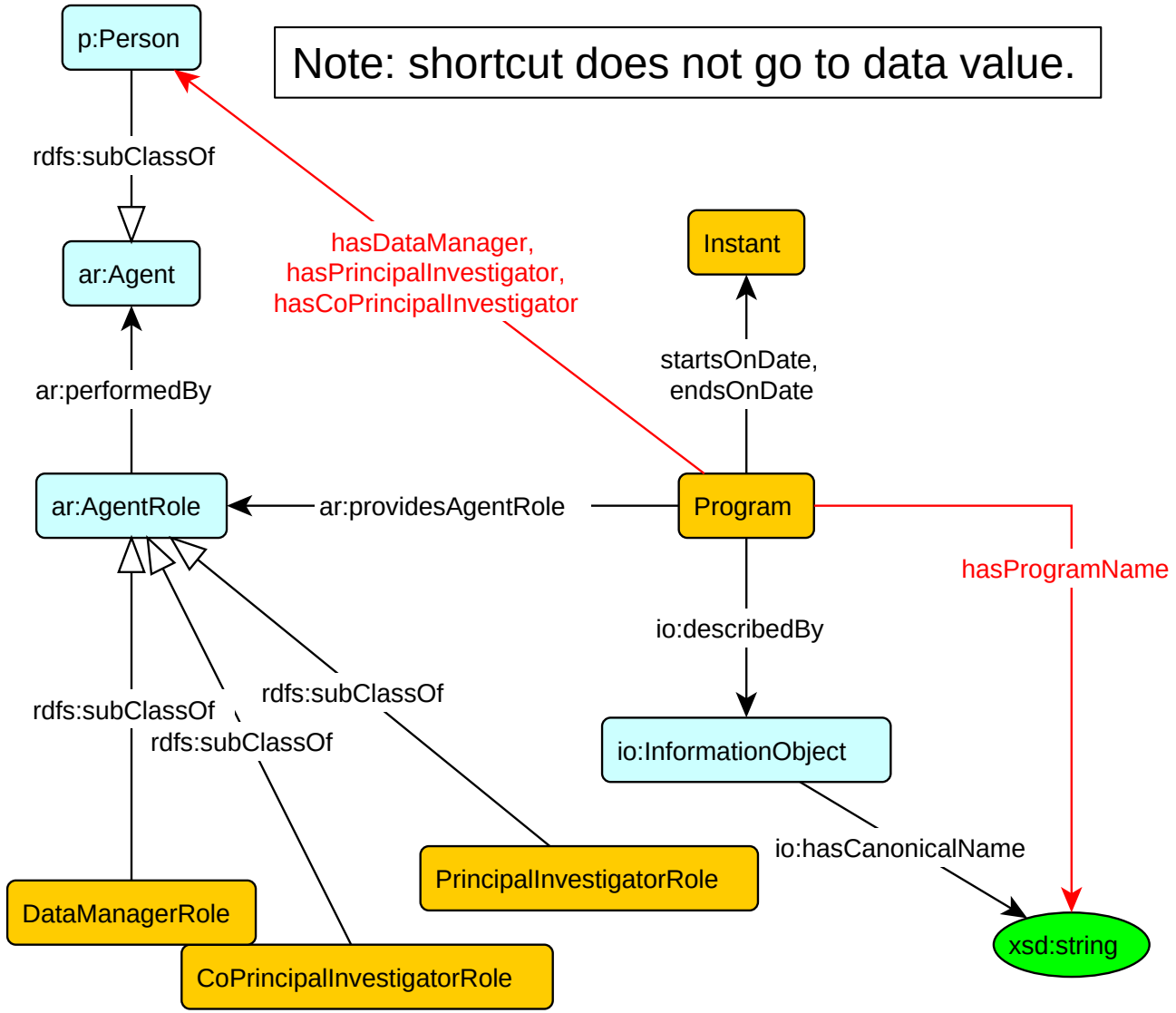
Funding Award shortcuts



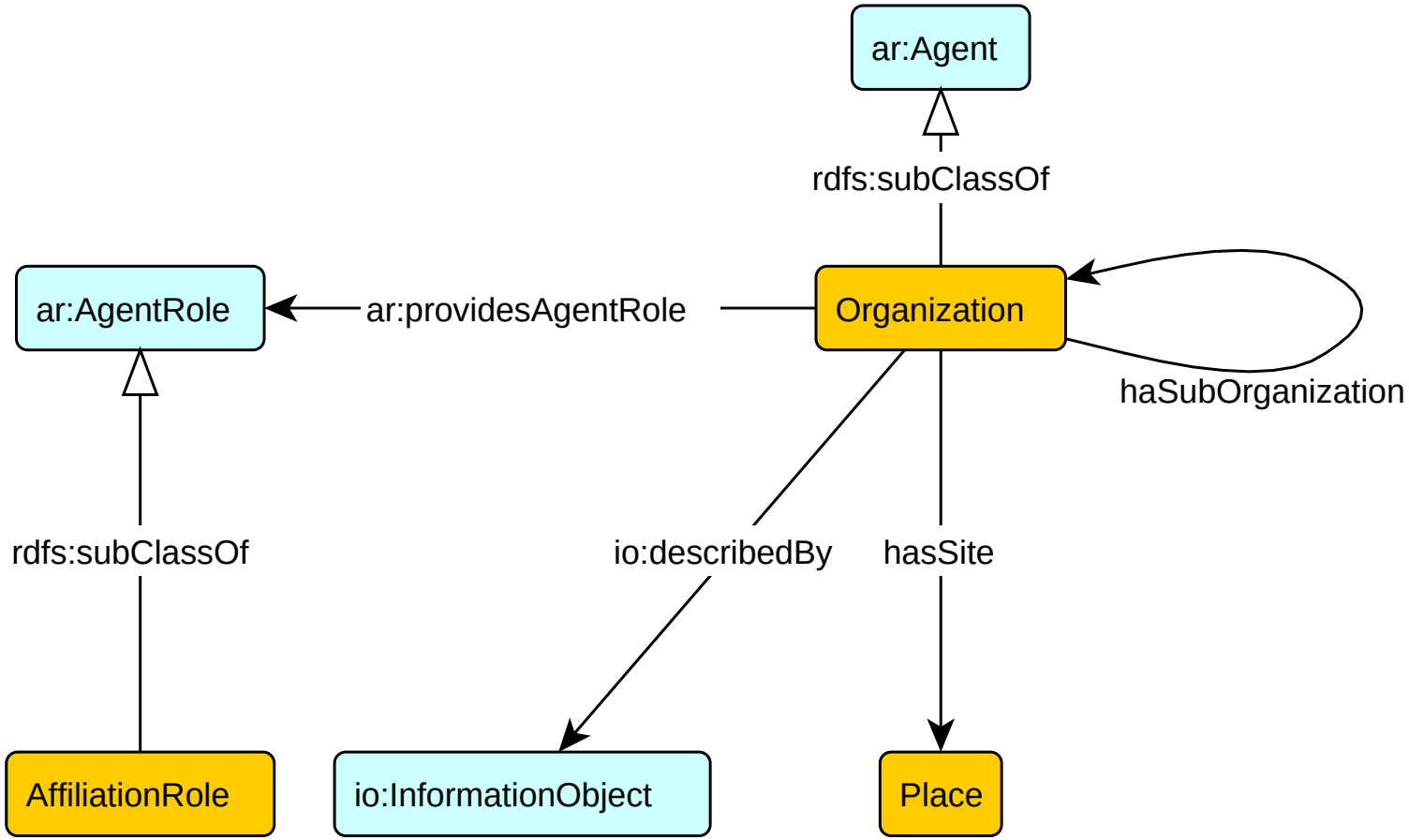
Program


DataManagerRole
rdfs:subClassOf
ar:AgentRole
ar:providesAgentRole
Program
startsOnDate,
endsOnDate
Instant
rdfs:subClassOf
rdfs:subClassOf
io:describedBy
CoPrincipalInvestigatorRole
PrincipalInvestigatorRole
io:InformationObject

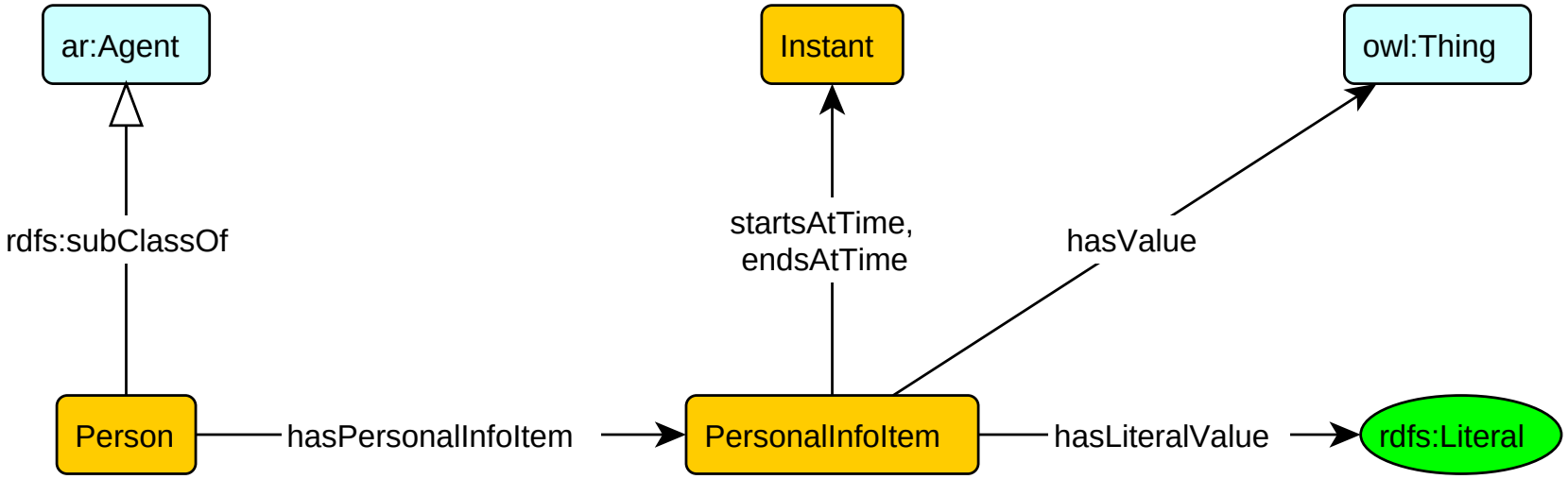
Program shortcuts



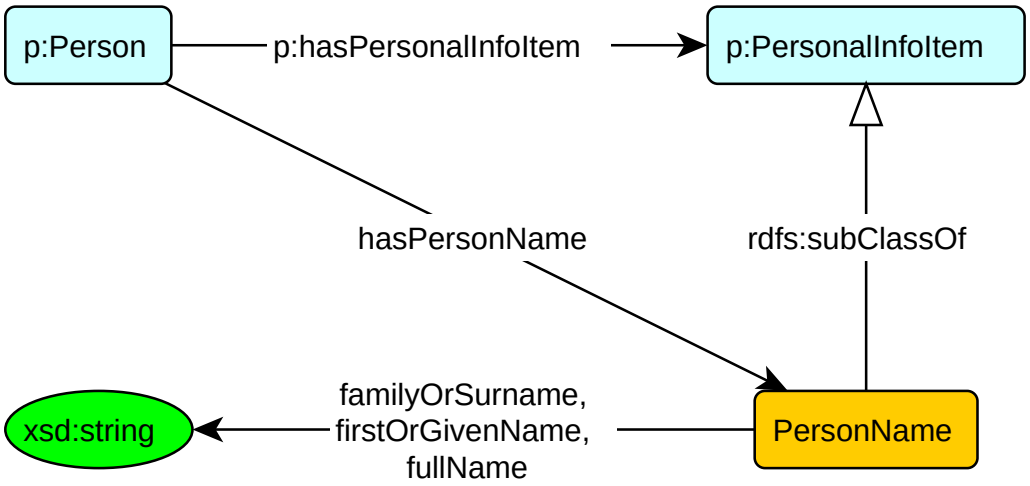
Organization pattern

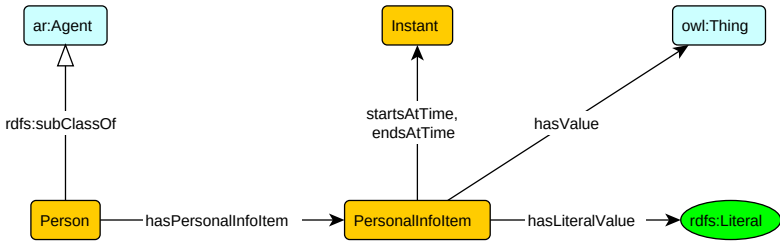


Person


ar:Agent
Instant
owl:Thing
rdfs:subClassOf
startsAtTime,
endsAtTime
hasValue
Person
hasPersonalInfoItem
PersonalInfoItem
hasLiteralValue
rdfs:Literal

Person Name





$$Person \sqsubseteq ar{:}Agent$$

$$PersonalInfoItem \sqsubseteq (=1\ hasPersonalInfoItem^{-}.Person)$$

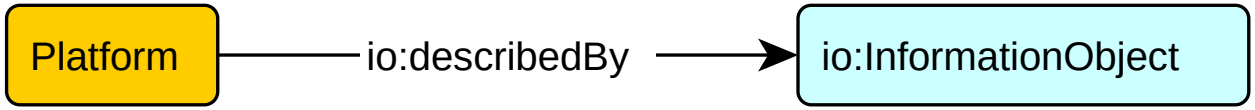
$$PersonalInfoItem \sqsubseteq (=1\ startsAtTime.Instant)$$

$$PersonalInfoItem \sqsubseteq (\leqslant 1\ endsAtTime.Instant)$$

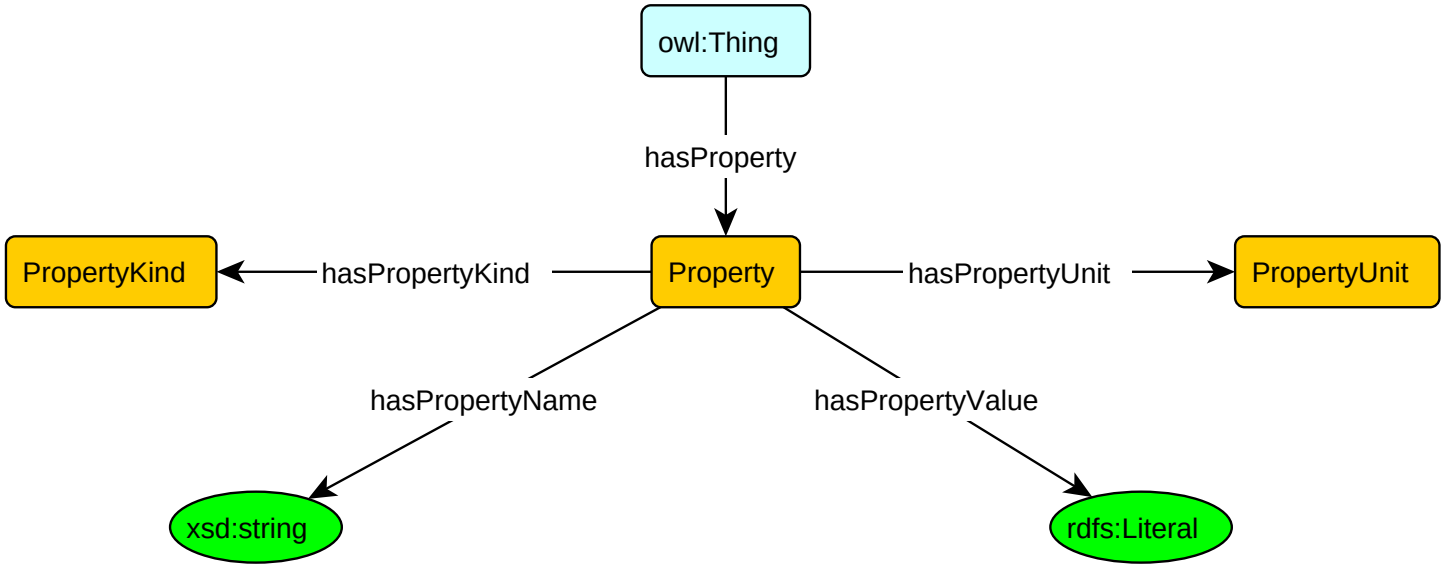
$$\exists hasPersonalInfoItem.PersonalInfoItem \sqsubseteq Person$$

$$\exists startsAtTime.Instant \sqsubseteq PersonalInfoItem$$

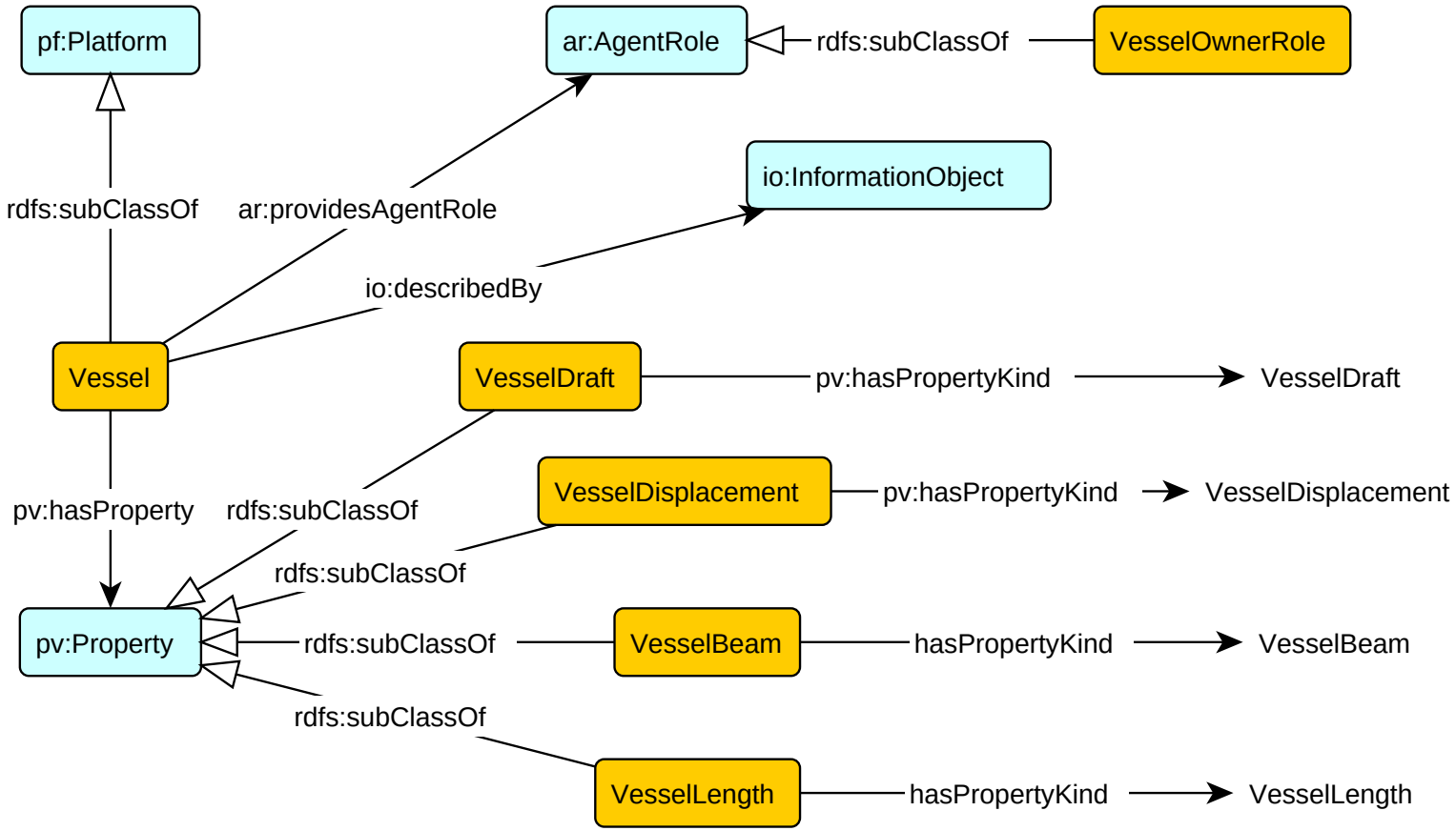
Platform pattern (stub)



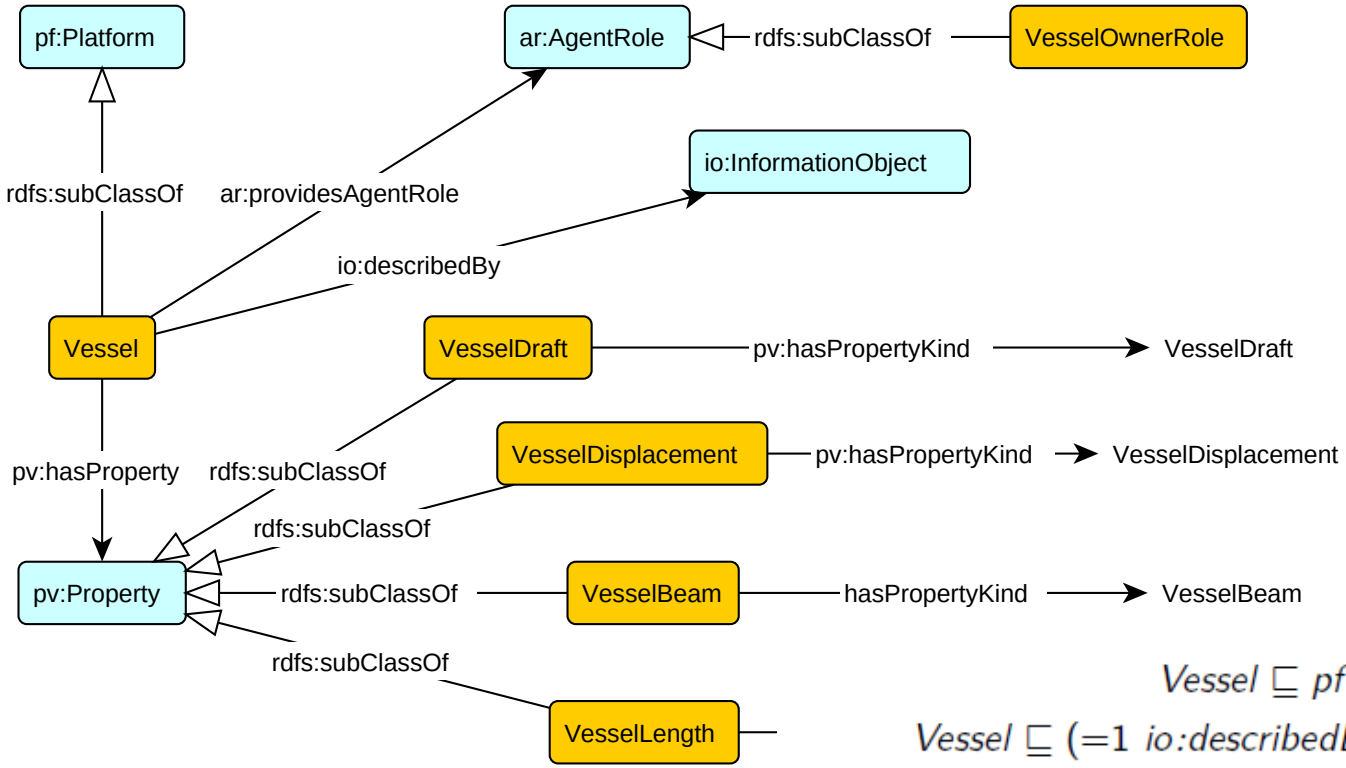
Property Value pattern



Vessel module



Vessel module



$$Vessel \sqsubseteq pf:Platform$$

$$Vessel \sqsubseteq (=1\ io:describedBy.io:InformationObject)$$

$$Vessel \sqsubseteq \exists ar:providesAgentRole.VesselOwnerRole$$

$$Vessel \sqsubseteq \exists pv:hasProperty.VesselBeam$$

$$Vessel \sqsubseteq \exists pv:hasProperty.VesselDisplacement$$

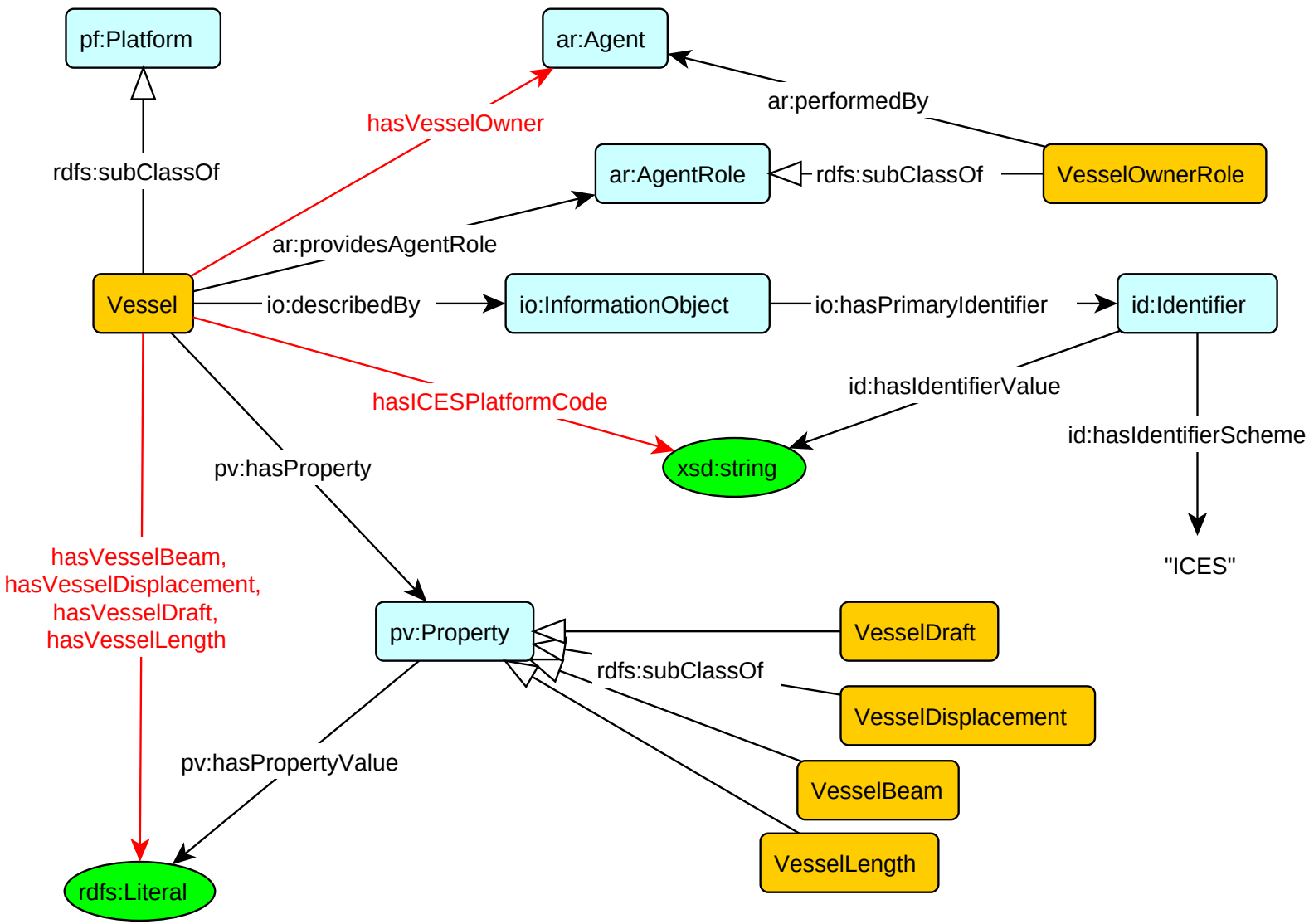
$$Vessel \sqsubseteq \exists pv:hasProperty.VesselDraft$$

$$Vessel \sqsubseteq \exists pv:hasProperty.VesselLength$$

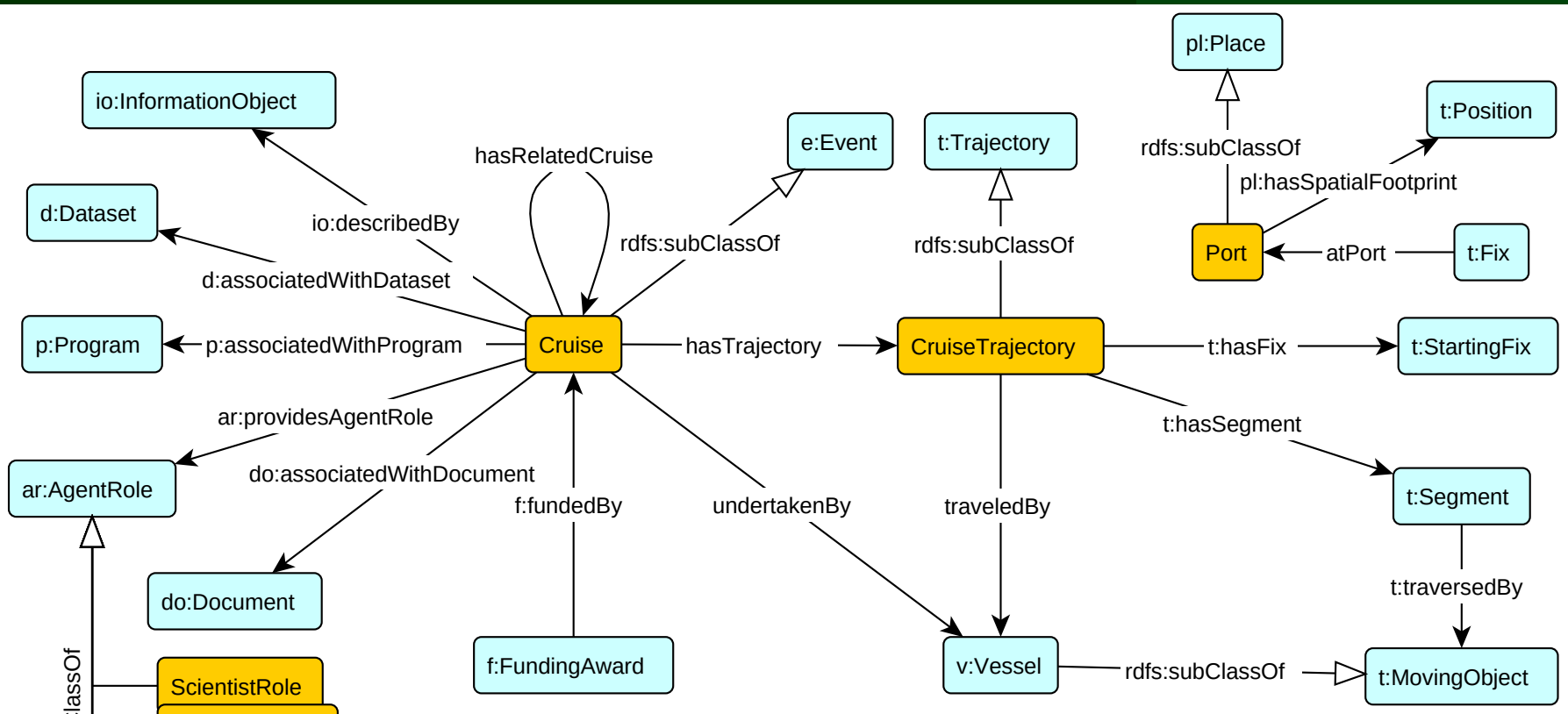
$$VesselBeam \sqsubseteq \exists pv:hasPropertyKind.\{VesselBeam\}$$

$$VesselDisplacement \sqsubseteq \exists pv:hasPropertyKind.\{VesselDisplacement\}$$

Vessel shortcuts



Cruise module



$$Cruise \sqsubseteq e{:}Event$$

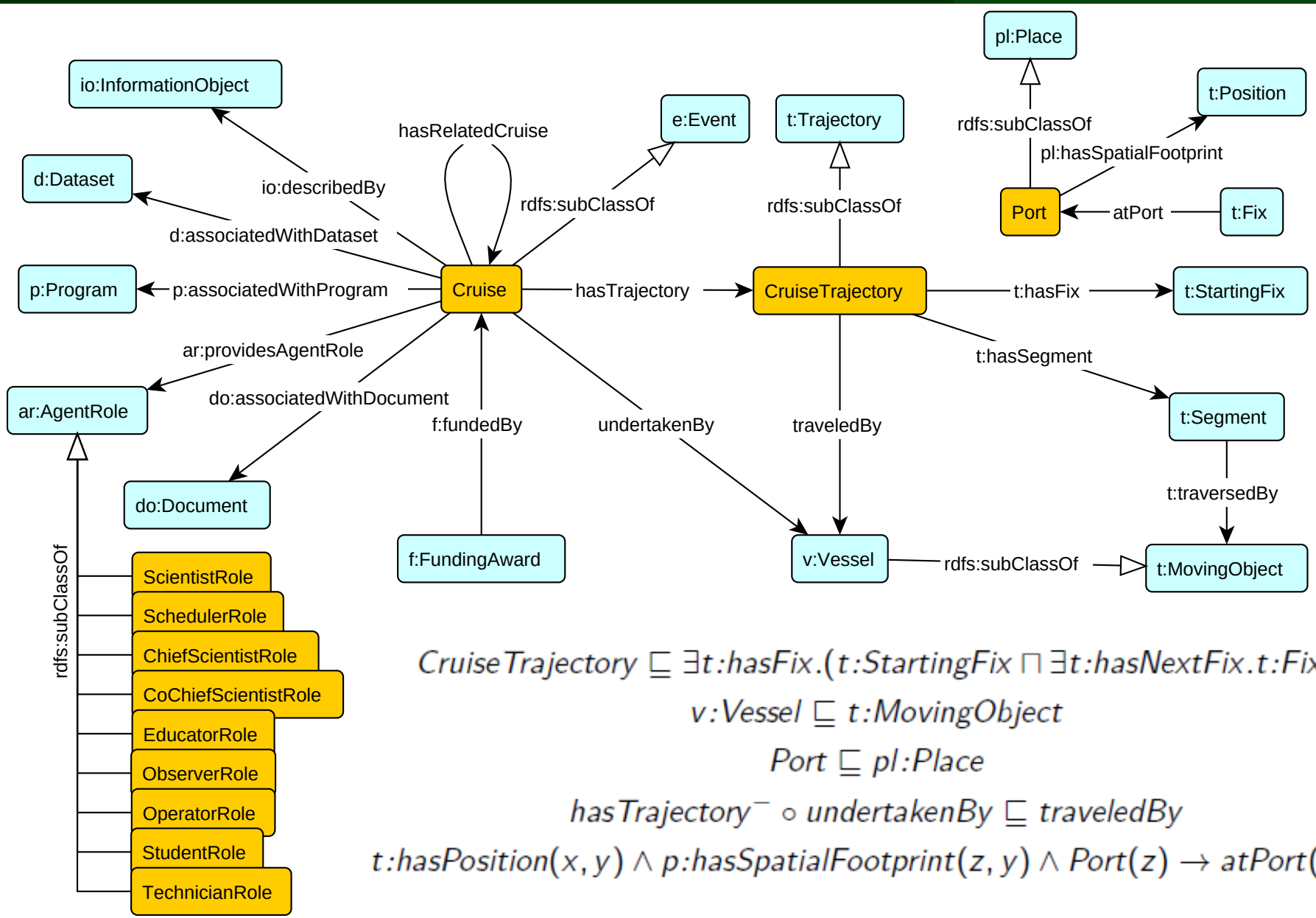
$$Cruise \sqsubseteq (=1\ hasTrajectory.CruiseTrajectory)$$

$$Cruise \sqsubseteq (=1\ undertakenBy.v{:}Vessel)$$

$$Cruise \sqsubseteq (=1\ io{:}describedBy.io{:}InformationObject)$$

$$CruiseTrajectory \sqsubseteq t{:}Trajectory$$

Cruise module



$$CruiseTrajectory \sqsubseteq \exists t{:}hasFix.(t{:}StartingFix \sqcap \exists t{:}hasNextFix.t{:}Fix)$$

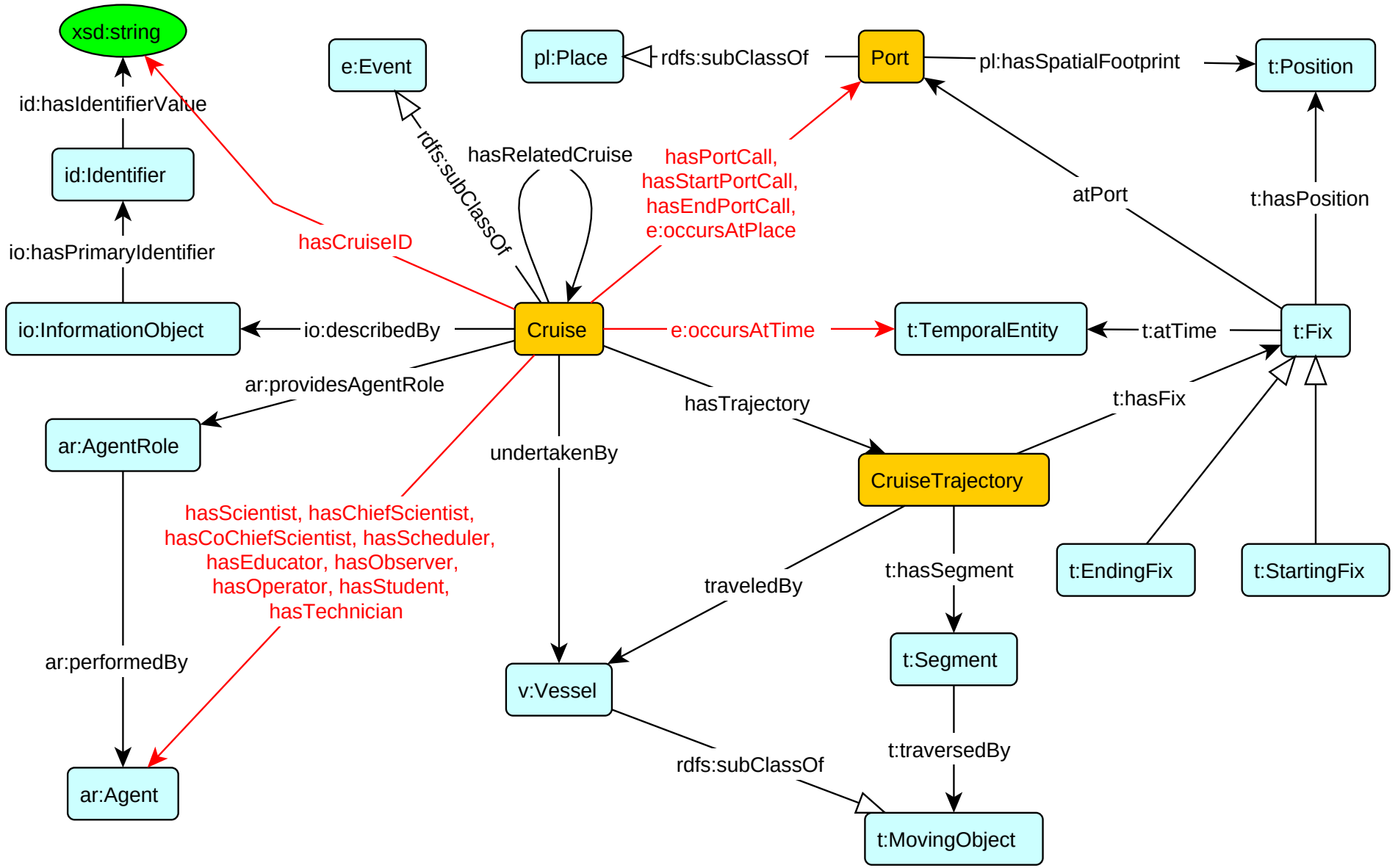
$$v{:}Vessel \sqsubseteq t{:}MovingObject$$

$$Port \sqsubseteq pl{:}Place$$

$$hasTrajectory^{-} \circ undertakenBy \sqsubseteq traveledBy$$

$$t{:}hasPosition(x,y) \wedge p{:}hasSpatialFootprint(z,y) \wedge Port(z) \rightarrow atPort(x,z)$$

Cruise shortcuts



What we need

- A critical amount of simple, general-purpose patterns
  - Well-documented
  - Not too generic, not too specialized
  - Interrelated (e.g., different versions with different granularity of the same notion)
- Languages for describing patterns.
- Languages for describing modular ontologies based on patterns.
- Tools for working directly with patterns in ontology engineering (see afternoon session – Karl Hammar's work)

Thanks!

References

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