Modular Ontology Architecture for Data Integration in the GeoLink Project

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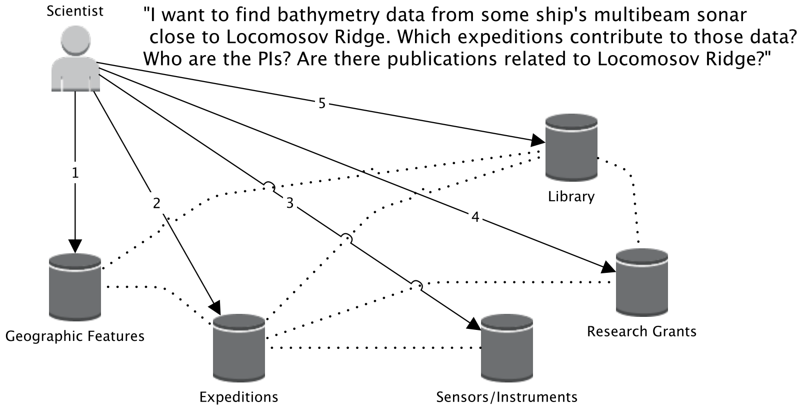
Motivation



Needed!

Data integration: providing unified view over data at different sources.

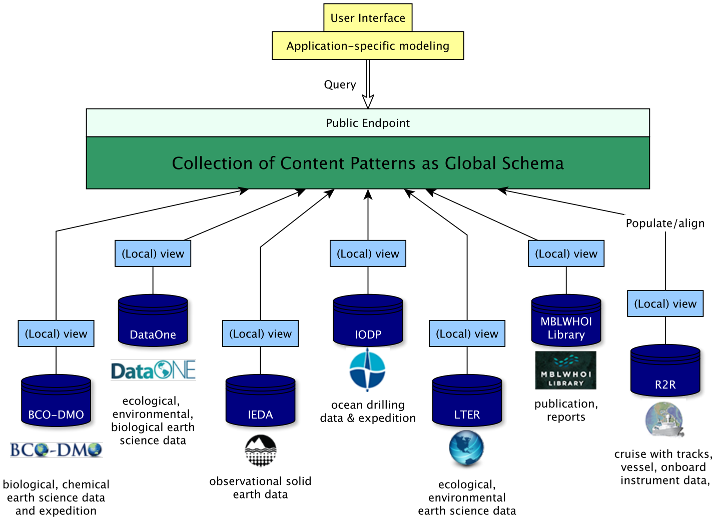
DI Challenges and GeoLink Project

- Challenges (regardless of architecture):
  - Syntactic heterogeneity: different data formats, serializations.
  - Semantic heterogeneity: different vocabulary, different level of granularity in data, different conceptualization.
  - Social/non-technical: inability/unwillingness to participate, fear of unanticipated cost, worry with major changes in their local system, skeptic with scalability
- GeoLink Project (`www.geolink.org`)
  - Part of NSF's EarthCube Program – one among dozens of building block projects.
  - Linked Data + Ontology design pattern-based integration.

Why Ontology Patterns?

- Upper-level and many domain ontologies are:
  - Hard to understand — too many terms, too abstract, too complicated axioms, too far from real data
  - Impose ontological commitments that may not be acceptable by all parties.
  - Brittle — costly/hard to extend, carelessly extending may cause the whole thing breaks.
- Ontology design pattern (ODP): a ("reusable") solution of a frequently occurring modeling problem in the domain and can act as a building block of a more complex ontology.
- Content pattern (CP): an ODP that models a particular generic notion in a particular domain.
- Community engagement via collaborative modeling

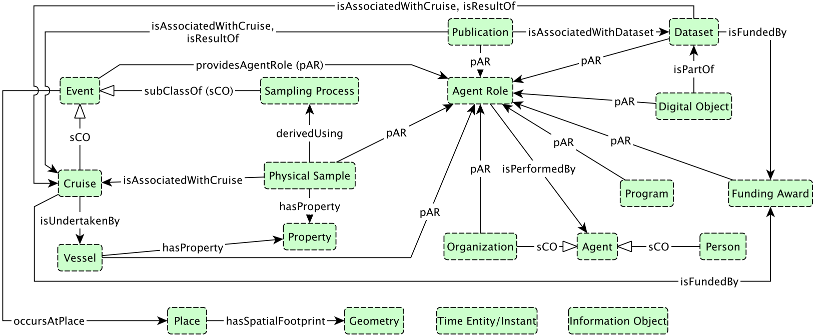
GeoLink Integration Architecture



Modeled Notions

- Content patterns corresponding to concrete domain notions:
  - Cruise, Vessel, Person, Organization, Funding Award, Program, Physical Sample, Dataset, Digital Object, Publication, Platform, Place, Time.
- Content patterns from abstraction in modeling:
  - Agent, Agent Role, Event, Information Object, Identifier, Personal Info Item, Person Name, Property Value.

Ontology Overview



Each node represents a content pattern.

CP Example: Cruise

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- Generate competency questions
  - "Find all cruises passing through Gulf of Maine in August 2013."
  - "Show the tracks of cruises in operation in September 2013."
  - "List all cruise vessels that departed from Woods Hole in 2012."
  - "Find the chief scientists of any cruise that collected samples of carbon-isotope data in Lake Superior."
  - "What datasets were produced by the cruise AE0901?"
  - "Which cruises are funded by the NSF award DBI-0424599?"
- Understand the nature of things we model.
  - Cruise .... is an Event
  - Track .... maybe complex, reuse Trajectory pattern?[1]
  - Vessel .... maybe complex
  - Chief scientist ..... a role of an agent
  - Dataset .... maybe complex
  - Funding award .... maybe complex

[1] Hu, et al. "A geo-ontology design pattern for semantic trajectories", COSIT 2013

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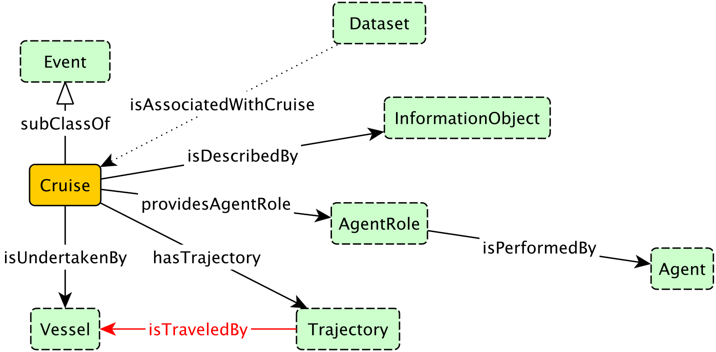
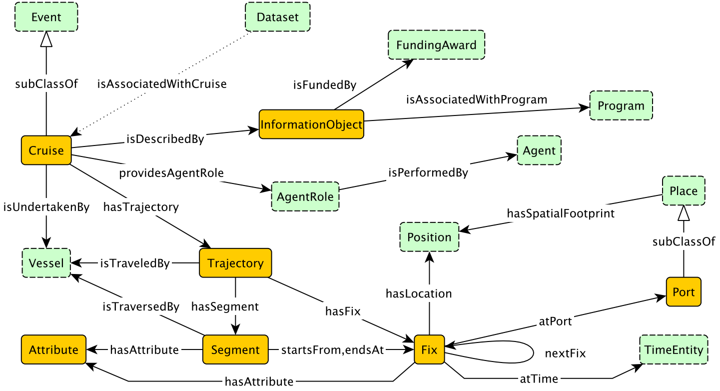

Dataset
Event
isAssociatedWithCruise
InformationObject
subClassOf
isDescribedBy
Cruise
providesAgentRole
AgentRole
isPerformedBy
Agent
isUndertakenBy
hasTrajectory
Vessel
isTraveledBy
Trajectory

Use informal natural language to model axioms together with domain experts/data providers.

- Cruise $\sqsubseteq$ Event
- Cruise has exactly 1 trajectory and is undertaken by exactly 1 vessel.
  $\text{Cruise} \sqsubseteq (=1\ \text{hasTrajectory.Trajectory}) \sqcap (=1\ \text{isUndertakenBy.Vessel})$
- Cruise is described by exactly 1 information object.
  $\text{Cruise} \sqsubseteq (=1\ \text{isDescribedBy.InformationObject})$
- Trajectory of a cruise must be traveled by the vessel by which the cruise is undertaken.
  $\text{hasTrajectory}^{-} \circ \text{isUndertakenBy} \sqsubseteq \text{isTraveledBy}$

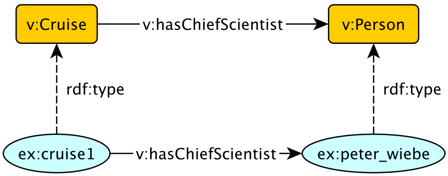
Cruise Trajectory



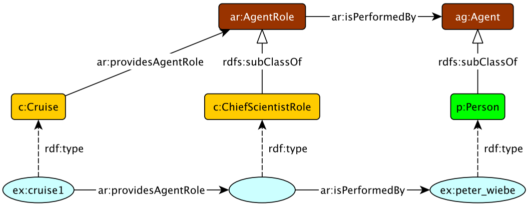
- Since patterns represent key notions as understood by domain experts and data providers, intuitively an appropriate mapping/alignment exists between "local" vocabulary and the patterns.
- A (local) pattern view between a data source and the patterns makes such a mapping explicit.
  - View is a very minimalistic schema (class names, property names, simple domain and range axioms)
  - Separating "core conceptualization" and "nomenclature" issues: vocabulary terms in a local view may be repository-specific and need not be the same as the patterns.
  - Mapping can be expressed in rules that help populating the patterns.
  - Data providers can populate the global schema (pattern collection) by simply populating a local view.
  - Existing controlled vocabulary can also be accommodated as a pattern view.

Pattern View Example

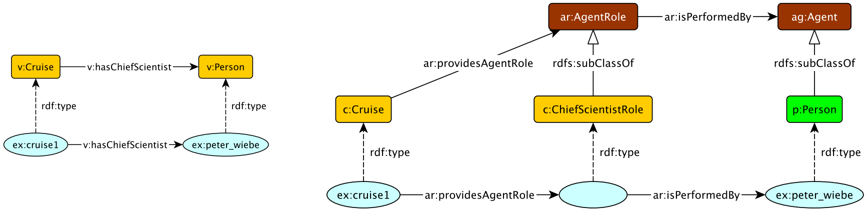
Producer populates view:



to populate Cruise, Agent Role, and Person patterns:



Mapping Rule



$$
\begin{aligned}
&\text{v:Cruise}(X) \wedge \text{v:hasChiefScientist}(X, Y) \wedge \text{v:Person}(Y) \\
&\quad \longrightarrow \exists Z.\big(\text{c:Cruise}(X) \wedge \text{ar:providesAgentRole}(X, Z) \\
&\qquad \wedge \text{c:ChiefScientistRole}(Z) \\
&\qquad \wedge \text{ar:isPerformedBy}(Z, Y) \wedge \text{p:Person}(Y)\big)
\end{aligned}
$$

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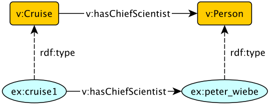

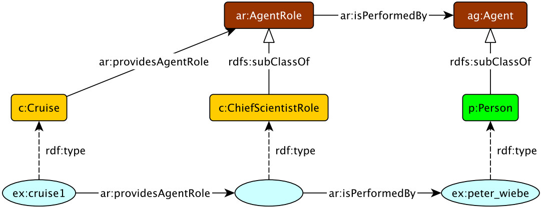


```
CONSTRUCT {
  ?X a c:Cruise ;
     ar:providesAgentRole [ a c:ChiefScientistRole ;
                            ar:isPerformedBy ?Y ] .
  ?Y a p:Person .
}
WHERE {
  ?X a v:Cruise ; v:hasChiefScientist ?Y .
  ?Y a v:Person .
}
```

Conclusion and Outlook

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- The GeoLink modular oceanography ontology = collection of content patterns in oceanography.
- Collaborative modeling approach.
- Two-layered ontology architecture with patterns and local views helps semantic interoperability across different data sources, while allowing data providers to retain their own local vocabulary and schema.
- See also: `http://www.geolink.org`, `http:/schema.geolink.org`

Questions?

Acknowledgement:

- NSF for GeoLink funding