Towards ontology patterns for ocean science repository integration

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The presented work is part of the NSF OceanLink project:
EarthCube Building Blocks, Leveraging Semantics and Linked Data for Geoscience Data Sharing and Discovery
OceanLink and EarthCube

EarthCube:
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.”
OceanLink

Bottom-up constructed project.

Currently first phase:

- Integrating ocean science repositories BCO-DMO and R2R, as well as datasets from the WHOI Library, AGU abstracts, NSF projects.

- Demonstrable added value (faceted integrated search).

- Key: extensible architecture that has the potential to grow to EarthCube size
Logic

Many axioms / strong theory

Few models
Many inferences

Few axioms / weak theory

Many models
Few inferences
Ontologies

Strong / many ontological commitments

Few models
Many inferences
Not very reusable

Weak / few ontological commitments

Many models
Few inferences
More easily reusable
Ontology Design Patterns

- Strong / many ontological commitments
  - Few models
  - Many inferences
  - Not very reusable

- Weak / few ontological commitments
  - Many models
  - Few inferences
  - More easily reusable
“An ontology design pattern is a reusable successful solution to a recurrent modeling problem.”

So-called content patterns usually encode specific abstract notions, such as process, event, agent, etc.
E.g., “Event”

Event \sqsubseteq \text{occursAtTime} . \text{xsd:dateTime}

Event \sqsubseteq \text{occursAtPlace} . \text{xsd:string}
Better Event (more general)

But what about events taking place in Second Life?
Perhaps even ...

Event

<TemporalThing>

<Place>

<Agent>

occursAtTime

occursAtPlace

hasParticipant
There are several things wrong here!
Shortcuts / views

\[
a:occursAtPlace \circ a:hasName \equiv b:occursAtPlace
\]

Better, but …
Shortcuts / views

\[
\begin{align*}
&\text{Event} \quad \text{xsd:string} \\
\text{a:occursAtPlace} & \land \text{a:hasName} \sqsubseteq \text{b:occursAtPlace} \\
\text{a:occursAtPlace} \land \text{a:hasName} & \sqsubseteq \text{b:occursAtPlace} \\
The \text{latter is not in OWL!}
\end{align*}
\]
The latter is not in OWL!
Similar problem

Splitting a role:

hasParent

hasFather

hasMother

hasFather \sqsubseteq \textit{hasParent}

hasMother \sqsubseteq \textit{hasParent}

\textit{hasParent} \sqsubseteq \textit{hasFather} \sqcup \textit{hasMother}
Cruise

For us: ocean science cruise.

A cruise is a type of event.

But what kind of place does it occur at?
Cruise

A trajectory!
Semantic Trajectories

[Hu, Janowicz, Carral, Scheider, Kuhn, Berg-Cross, Hitzler, Dean, COSIT2013]
Semantic Trajectories
Semantics in OWL

\[ \text{Fix} \sqsubseteq \exists \text{atTime.OWL-Time:Temporal Thing} \cap \exists \text{hasLocation.Position} \]
\[ \cap \exists \text{hasFix SemanticTrajectory} \]

\[ \text{Segment} \sqsubseteq \exists \text{startsFrom.Fix} \cap \exists \text{endsAt.Fix} \]
\[ \top \sqsubseteq 1 \text{startsFrom.} \top \]
\[ \top \sqsubseteq 1 \text{endsAt.} \top \]

\[ \text{Segment} \sqsubseteq \exists \text{hasSegment SemanticTrajectory} \]

\[ \text{startsFrom} \circ \text{endsAt} \sqsubseteq \text{hasNext} \]
\[ \text{hasNext} \sqsubseteq \text{hasSuccessor} \]
\[ \text{hasSuccessor} \circ \text{hasSuccessor} \sqsubseteq \text{hasSuccessor} \]
\[ \text{hasNext} \sqsubseteq \text{hasPrevious} \]
\[ \text{hasSuccessor} \sqsubseteq \text{hasPredecesor} \]
Semantics in OWL

\[
\begin{align*}
Fix \sqcap \neg \exists \text{endsAt.Sequential} & \sqsubseteq \text{StartingFix} \\
Fix \sqcap \neg \exists \text{startsFrom.Sequential} & \sqsubseteq \text{EndingFix} \\
\text{Segment} \sqcap \exists \text{startsFrom.Sequential.}\text{StartingFix} & \sqsubseteq \text{StartingSegment} \\
\text{Segment} \sqcap \exists \text{endsAt.Sequential.}\text{EndingFix} & \sqsubseteq \text{EndingSegment} \\
\text{SemanticTrajectory} & \sqsubseteq \exists \text{hasSegment.Sequential.} \\
\text{hasSegment} \circ \text{startsFrom.Sequential} & \sqsubseteq \text{hasFix} \\
\text{hasSegment} \circ \text{endsAt.Sequential} & \sqsubseteq \text{hasFix} \\
\exists \text{hasSegment.Sequential} & \sqsubseteq \text{SemanticTrajectory} \\
\exists \text{hasSegment}^\neg \text{.SemanticTrajectory} & \sqsubseteq \text{Segment} \\
\exists \text{hasFix.Sequential} & \sqsubseteq \text{SemanticTrajectory} \\
\exists \text{hasFix}^\neg \text{.SemanticTrajectory} & \sqsubseteq \text{Fix}
\end{align*}
\]
Ocean Science Cruise (draft)
Cruise trajectory (draft)
\[
\text{Cruise}(x) \land \text{hasTrajectory}(x, y) \\
\land \text{hasSegment}(y, z) \land \text{isTraversedBy}(z, v) \\
\rightarrow \text{participatesIn}(v, z)
\]
Cruise trajectory

\[ \text{Cruise}(x) \land \text{hasTrajectory}(x, y) \]
\[ \land \text{hasSegment}(y, z) \land \text{isTraversedBy}(z, v) \]
\[ \rightarrow \text{participatesIn}(v, z) \]

\[ \text{Cruise} \equiv \exists \text{cruise.Self} \]
\[ \text{cruise} \circ \text{hasTrajectory} \circ \text{hasSegment} \circ \text{isTraversedBy} \]
\[ \sqsubseteq \text{hasParticipant} \]
\[ \text{hasParticipant} \equiv \text{participatesIn}^\text{−} \]
\[
\text{Fix}(x) \land \text{hasAttribute}(x, \#\text{portStopArrival}) \\
\land \text{atPort}(x, y) \land \text{hasSpatialFootprint}(y, z) \\
\land \text{hasLocation}(x, w) \rightarrow \text{locatedIn}(w, z)
\]
Cruise trajectory

\[ \text{Fix}(x) \land \text{hasAttribute}(x, \#\text{portStopArrival}) \]
\[ \land \text{atPort}(x, y) \land \text{hasSpatialFootprint}(y, z) \]
\[ \land \text{hasLocation}(x, w) \rightarrow \text{locatedIn}(w, z) \]

\[ \text{Fix} \land \exists \text{hasTrajectory}.\{\#\text{portStopArrival}\} \equiv \exists \text{fixps}.\text{Self} \]
\[ \text{hasLocation}^\rightarrow \circ \text{fixps} \circ \text{atPort} \circ \text{hasSpatialFootprint} \subseteq \text{locatedIn} \]
Traditionally, ODPs are thought of as building blocks for ontology modeling.

This idea is certainly valid in the context of special purpose ontology-based systems.

However, it can be argued that ODPs can be much more than mere building blocks.
Horizontal alignment via patterns
OceanLink setup

User Interface

UI Views

OceanLink Patterns

- R2R
- BCO-DMO
- WHOI Library
- AGU
- NSF

mappings
Other added values of patterns

- Pattern-driven GUIs
- Pattern-driven mapping tools
- Pattern-driven query rewriting
- Pattern-driven reasoning modularization
- …
OceanLink setup

User Interface

UI Views

EarthCube Patterns

repository
repository
repository
repository
repository
mappings
Thanks!
References

• R2R: Rolling Deck to Repository, http://www.rvdata.us
• OceanLink website and publications are forthcoming
• http://ontologydesignpatterns.org
General References

General References

General References
