OceanLink: Using Patterns for Discovery in EarthCube

Pascal Hitzler
DaSe Lab for Data Semantics
Wright State University
http://www.pascal-hitzler.de

OceanLink Collaborators

DaSe Lab

Robert Arko, Columbia University
Suzanne Carbotte, Columbia University
Cynthia Chandler, Woods Hole Oceanographic Institution
Michelle Cheatham, Wright State University
Timothy Finin, University of Maryland, Baltimore County
Pascal Hitzler, Wright State University
Krzysztof Janowicz, University of California, Santa Barbara
Adila Krisnadhi, Wright State University
Thomas Narock, Marymount University
Lisa Raymond, Woods Hole Oceanographic Institution
Adam Shepherd, Woods Hole Oceanographic Institution
Peter Wiebe, Woods Hole Oceanographic Institution

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

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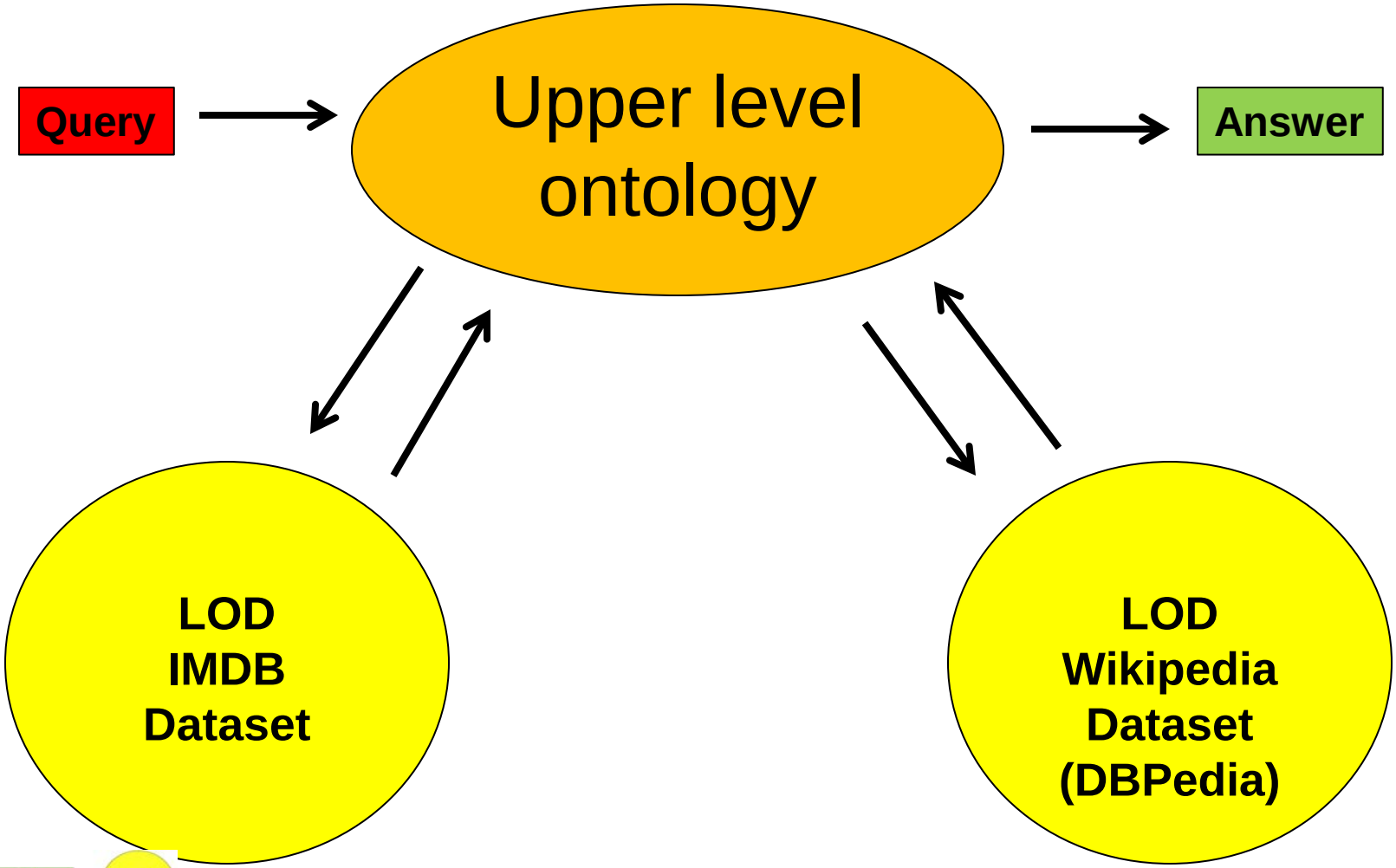
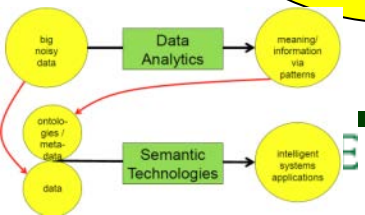
Classical ontology-based integration



[ODBASE 2012, JWS 2007]



Example querying LoD

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"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."

In principle, all the knowledge is there:

- **GovTrack**
- **GeoNames**
- **DBPedia**
- **US Census**

But even with LoD we cannot answer this query.

Example querying LoD

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"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."

Some missing puzzle pieces:

- Where is the data?
  - GovTrack
    GeoNames
    US Census
    requires intimate knowledge of the LoD data sets

Example querying LoD

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"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."

Some missing puzzle pieces:

- Where is the data?
  (smart federation needed)
- Missing background (schema) knowledge.
  (enhancements of the LoD cloud)
- Crucial info still hidden in texts.
  (ontology learning from texts)
- Added reasoning capabilities (e.g., spatial).
  (new ontology language features)

Linked Data: Variety

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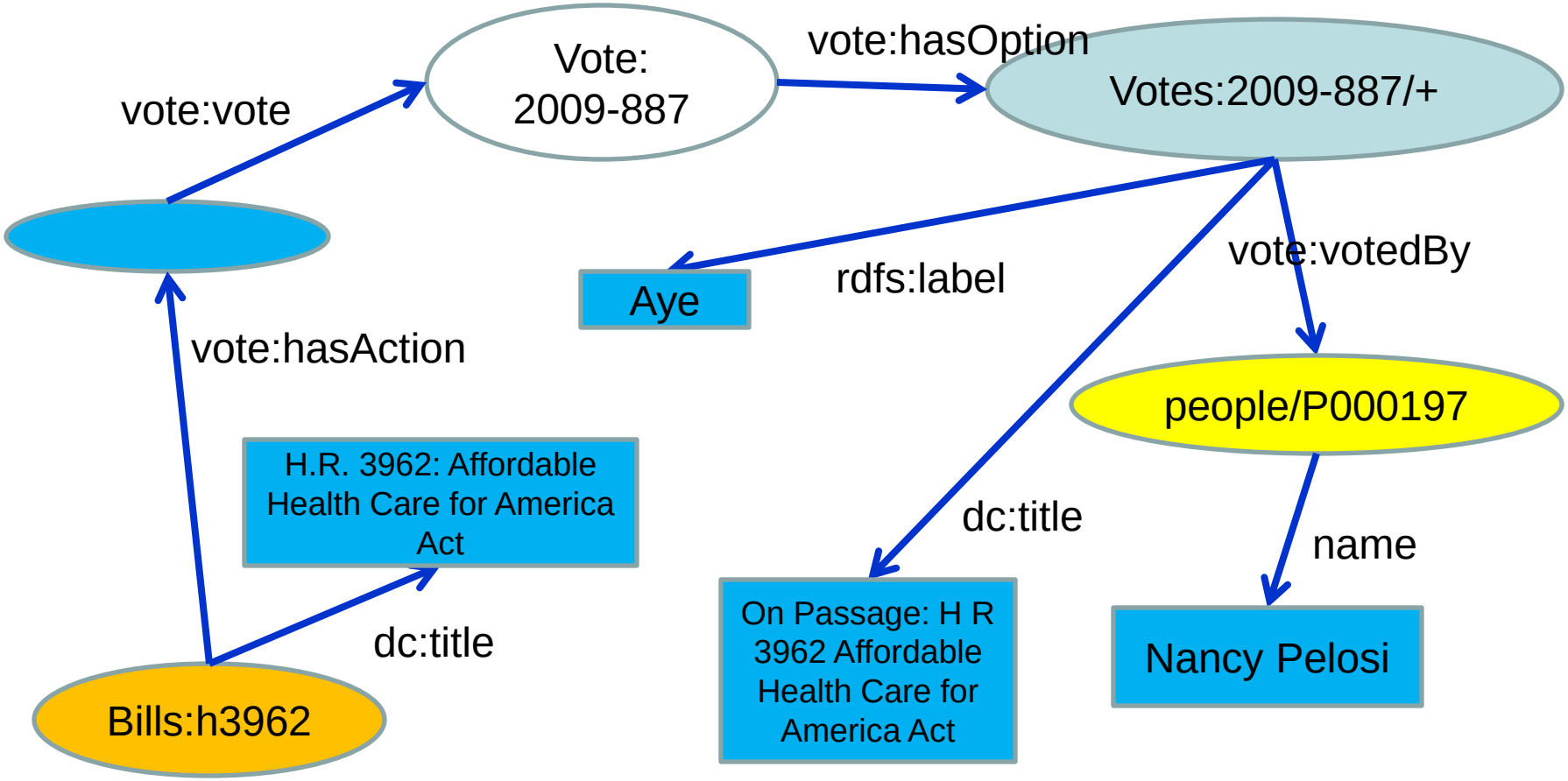
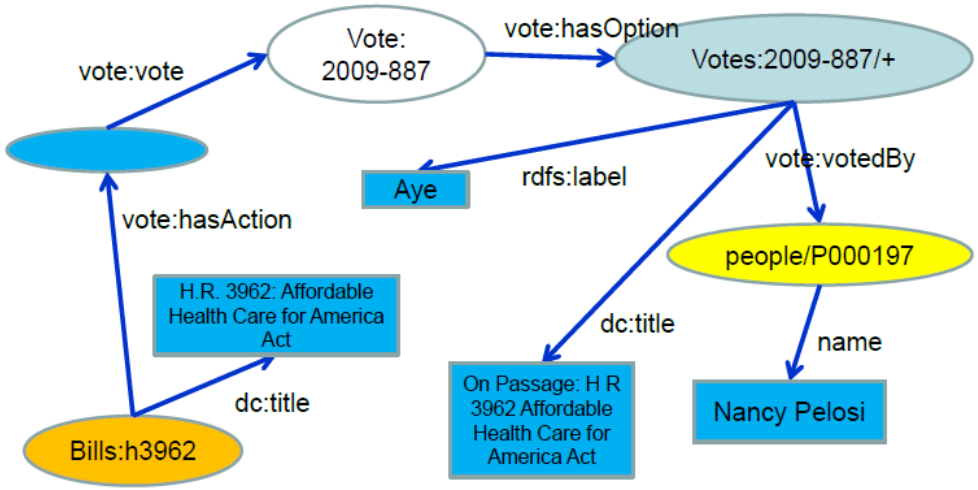
“Nancy Pelosi voted in favor of the Health Care Bill.”

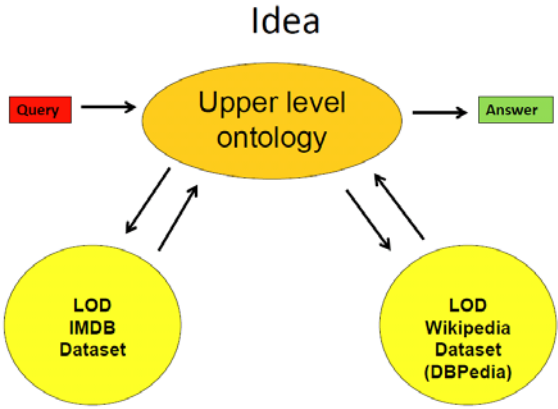


Querying approach

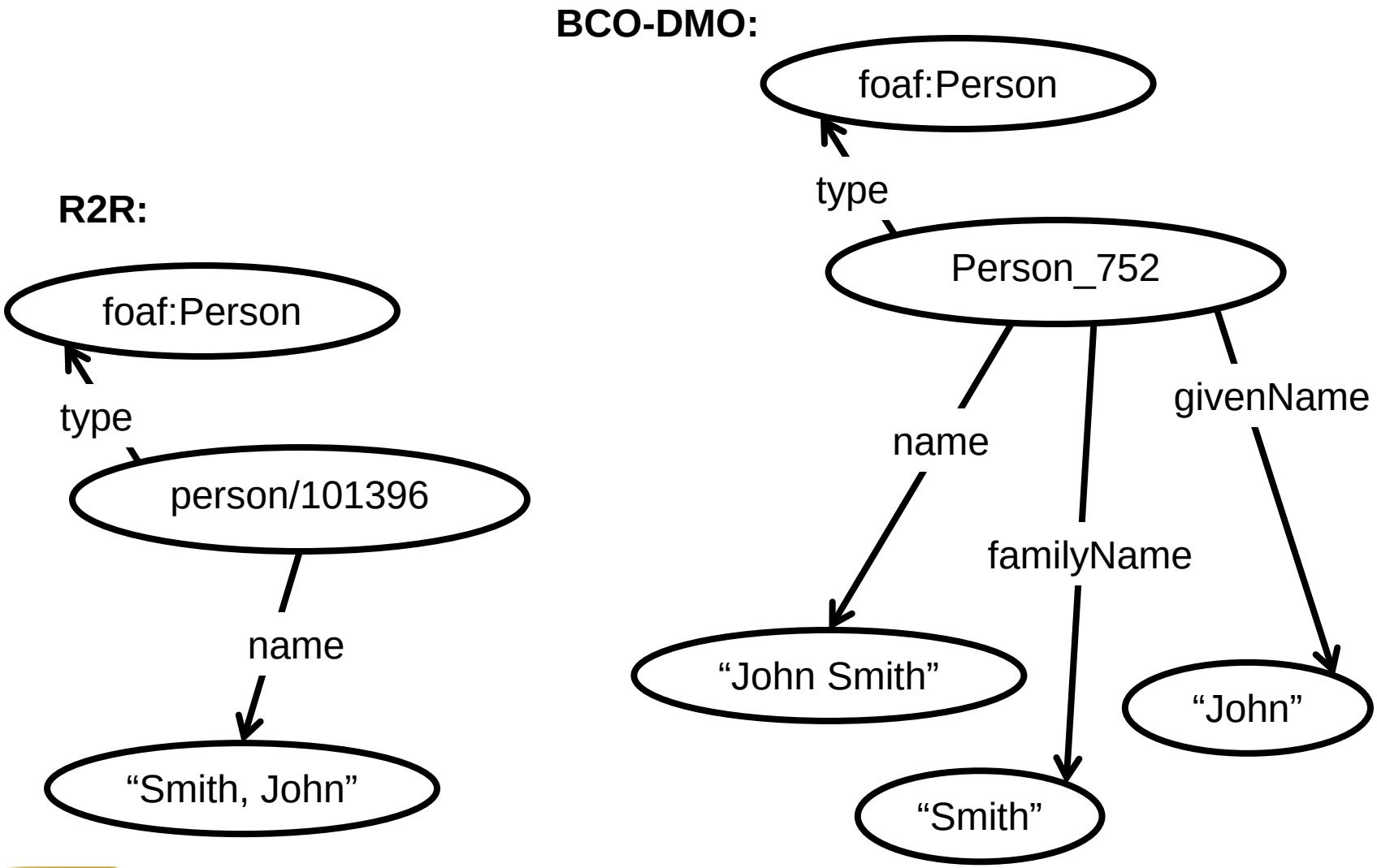


Works very well, but only in some very limited cases.

Cannot deal with graph representations of even very minimal complexity.



Automated federation?



Automated federation?

$$a{:}hasWife \sqsubseteq a{:}hasSpouse$$
$$symmetric(a{:}hasSpouse)$$
$$\exists a{:}hasSpouse.a{:}Female \sqsubseteq a{:}Male$$
$$\exists a{:}hasSpouse.a{:}Male \sqsubseteq a{:}Female$$
$$a{:}hasWife(a{:}john, a{:}mary)$$
$$b{:}Male(a{:}john)$$
$$b{:}Female(a{:}mary)$$
$$a{:}Male \sqcap a{:}Female \sqsubseteq \bot$$

$$symmetric(b{:}hasSpouse)$$
$$b{:}hasSpouse(b{:}mike, b{:}david)$$
$$b{:}Male(b{:}david)$$
$$b{:}Male(b{:}mike)$$
$$b{:}Female(b{:}anna)$$

Ways forward?

How to establish a flexible conceptual architecture using data and ontological modeling?

Ontology Design Patterns

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“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.

Patterns provide modular, reusable, replaceable, pieces.

By agreeing on reuse of generic patterns (but leaving the relationships between the patterns to a specific assembly for a special purpose), we can have reuse while preserving heterogeneity.

Ontology Design Patterns

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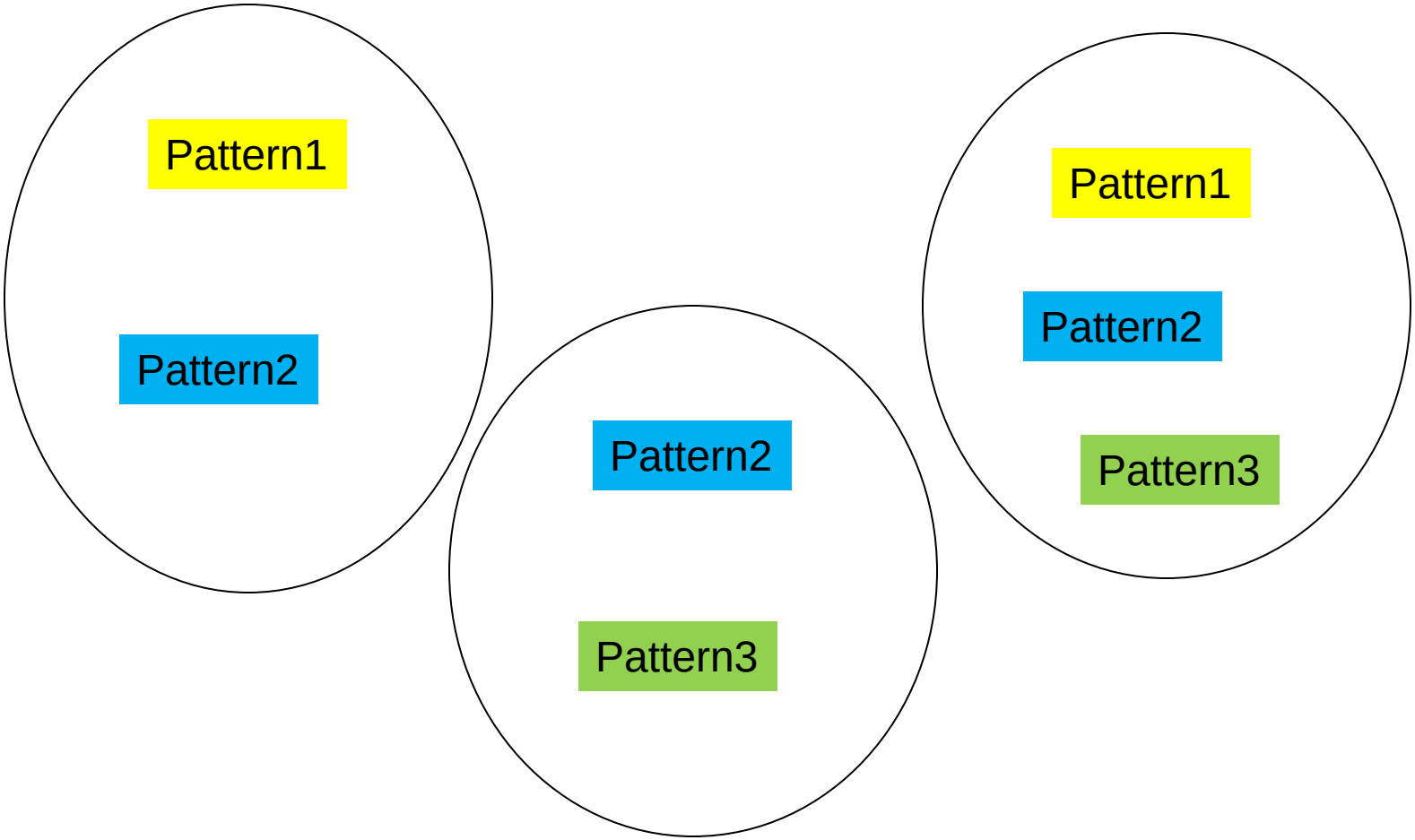
- **Bottom-up homogenization of data representation.**
- **Avoidance of strong ontological commitments.**
- **Avoidance of standardization of specific modeling details.**
- **Well thought-out patterns can be very strong and versatile, thus serve many needs.**

We are currently establishing many geo-patterns in a series of hands-on workshops, the GeoVoCamps, see http://vocamp.org/

Ontology Design Patterns



“Horizontal” alignment via patterns

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

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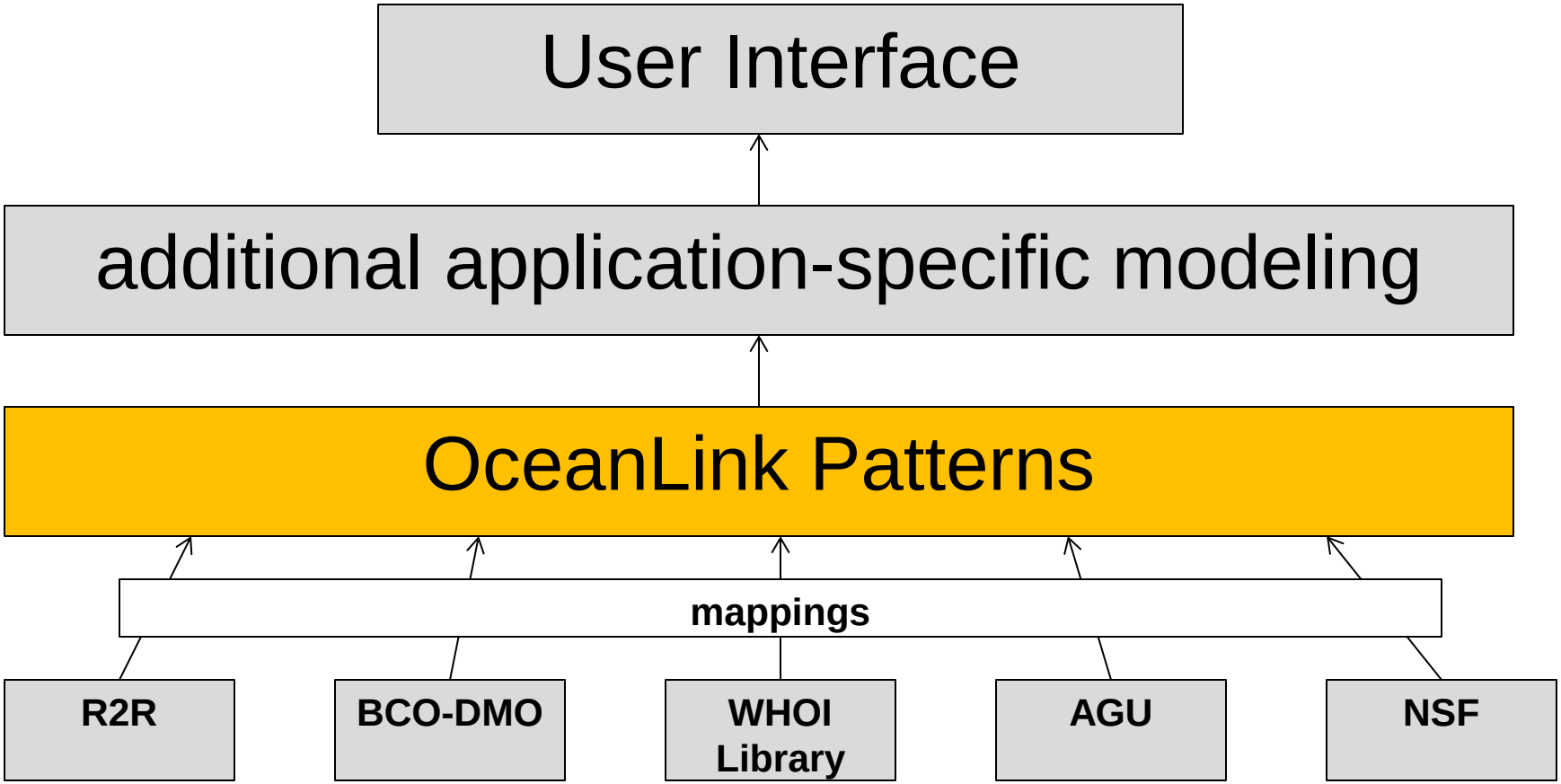
NSF EarthCube project “OceanLink”:

- **Integration of existing ocean science data repositories.**
- **For faceted browsing and semantic search.**
- **To be done in a flexible, extendable, modular way.**
- **With minimal effort for additional data providers to integrate their content.**

National Science Foundation award 1354778 "EAGER: Collaborative Research: EarthCube Building Blocks, Leveraging Semantics and Linked Data for Geoscience Data Sharing and Discovery."

OceanLink setup



OceanLink patterns

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Some central patterns:

- **Cruise**
- **Trajectory**
- **Person**
- **Organization**
- **Roles of Agents**
- **Repository Object**
- **Data Set**
- **Document**

We’re not starting from zero of course.

Ocean Science Cruise (draft)

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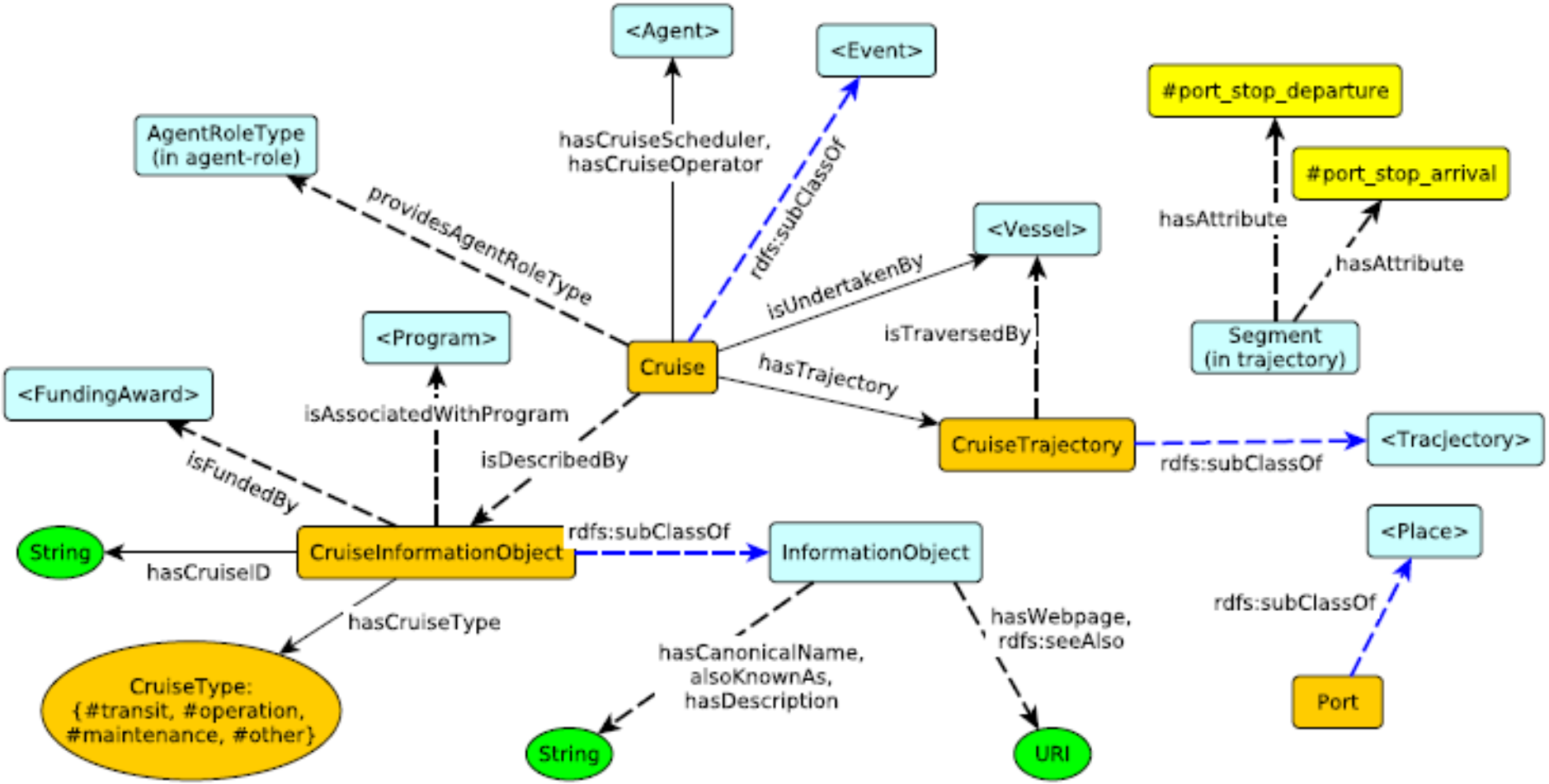

Cruise trajectory (draft)

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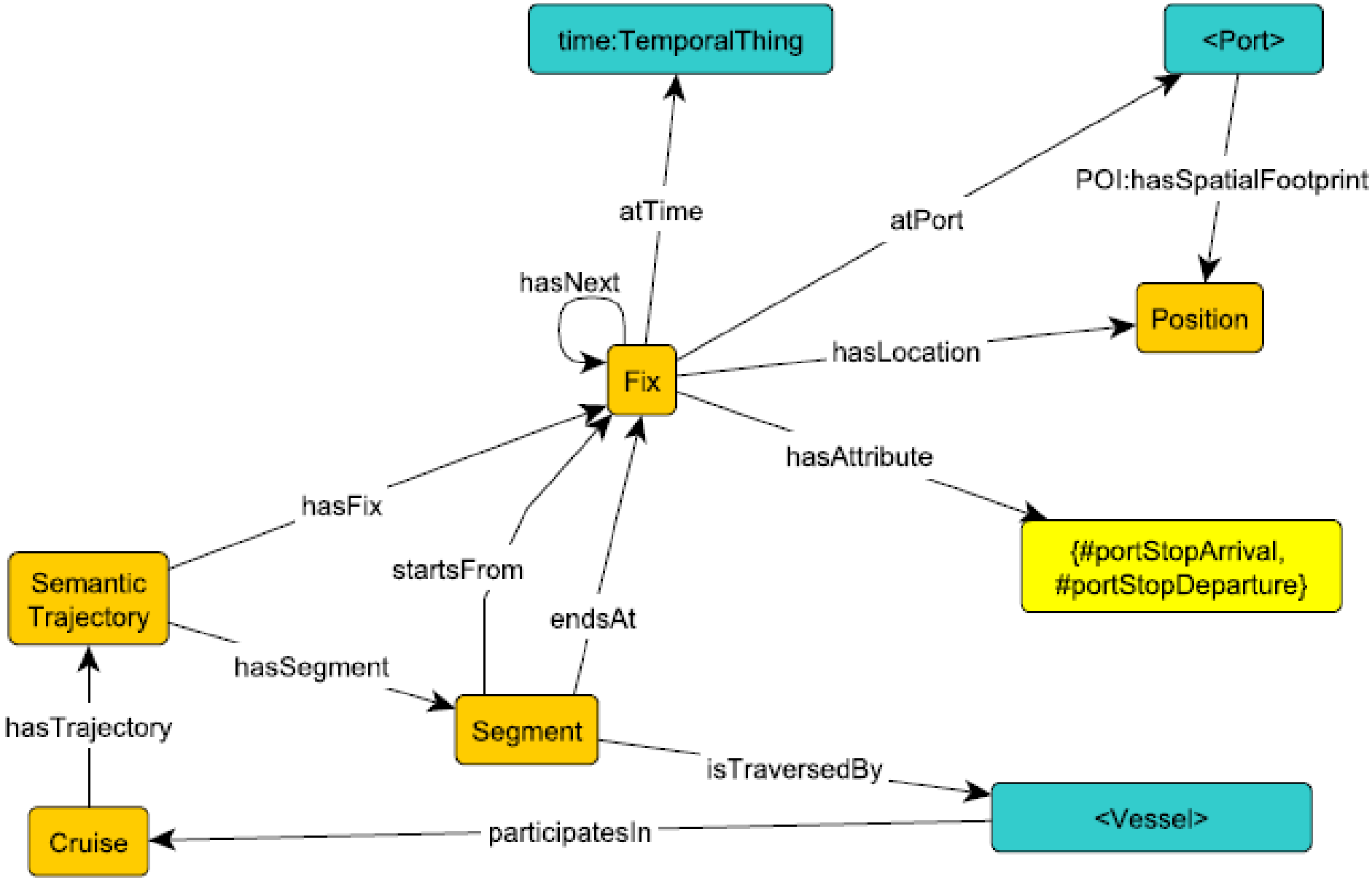

Cruise trajectory

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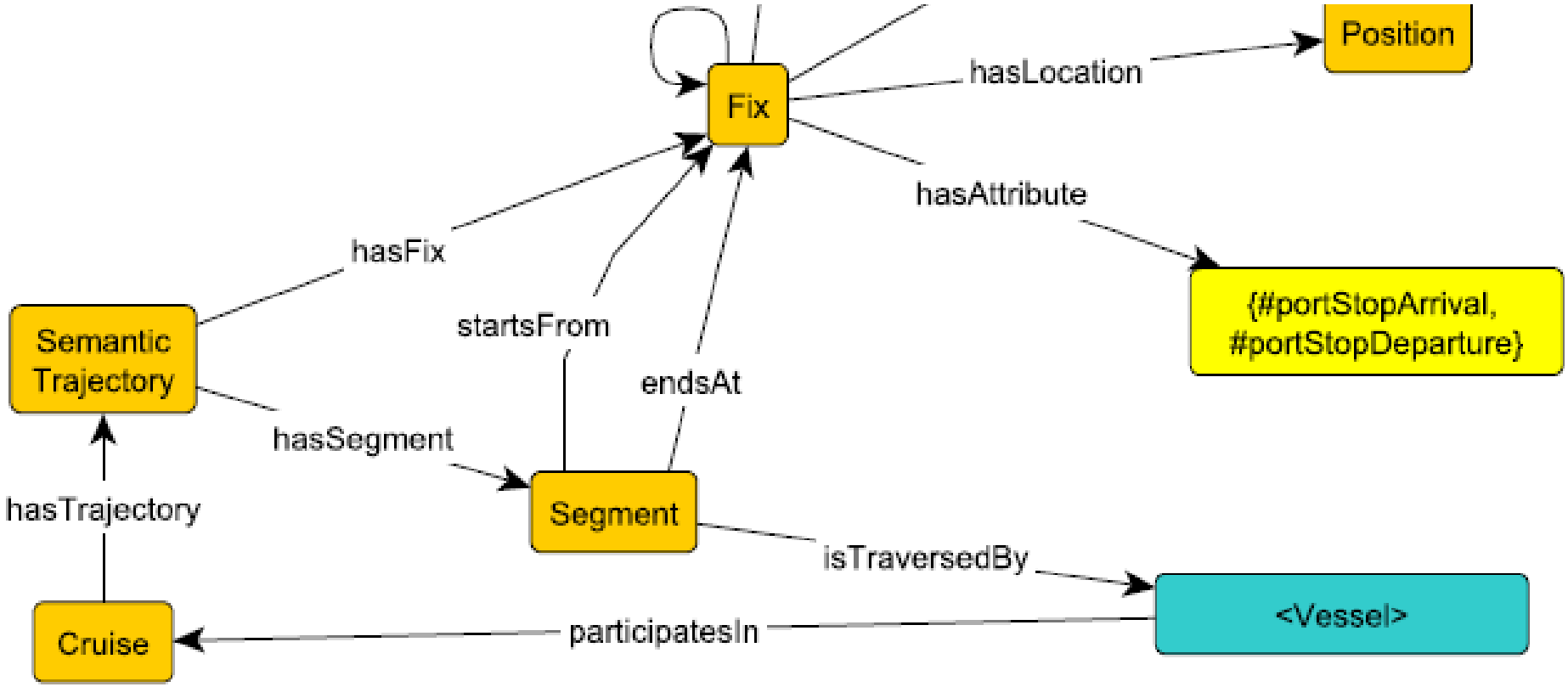
$$\text{Cruise}(x) \wedge \text{hasTrajectory}(x, y)$$
$$\wedge\, \text{hasSegment}(y, z) \wedge \text{isTraversedBy}(z, v)$$
$$\rightarrow \text{participatesIn}(v, z)$$



Cruise trajectory

DaSe Lab

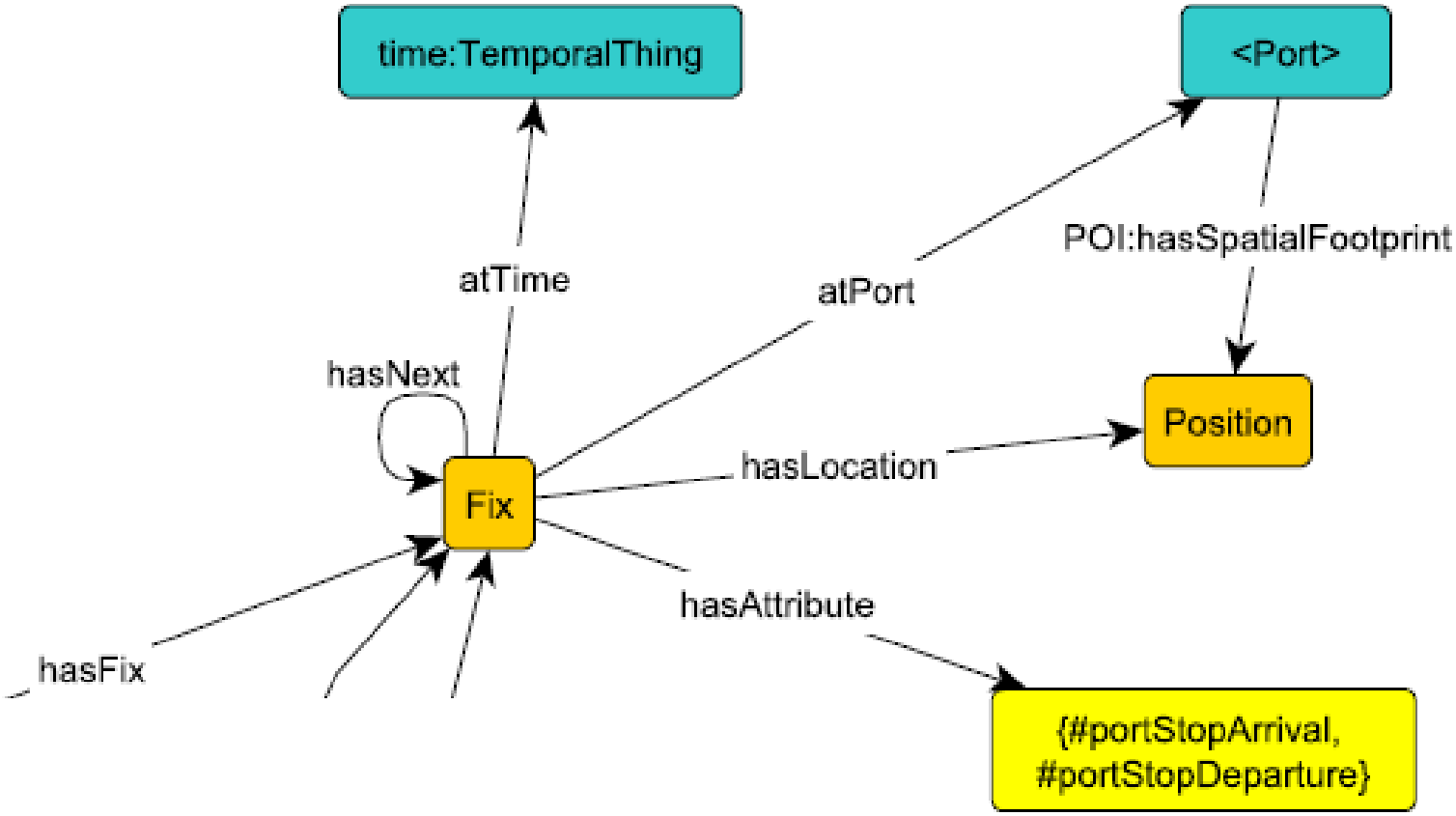
$$\text{Cruise}(x) \wedge \text{hasTrajectory}(x, y) \wedge \text{hasSegment}(y, z) \wedge \text{isTraversedBy}(z, v) \rightarrow \text{participatesIn}(v, z)$$

$$\text{Cruise} \equiv \exists \text{cruise}.\text{Self}$$

$$\text{cruise} \circ \text{hasTrajectory} \circ \text{hasSegment} \circ \text{isTraversedBy} \sqsubseteq \text{hasParticipant}$$

$$\text{hasParticipant} \equiv \text{participatesIn}^{-}$$

Cruise trajectory



$$\mathrm{Fix}(x) \wedge \mathrm{hasAttribute}(x, \#\mathrm{portStopArrival})$$
$$\wedge\, \mathrm{atPort}(x, y) \wedge \mathrm{hasSpatialFootprint}(y, z)$$
$$\wedge\, \mathrm{hasLocation}(x, w) \rightarrow \mathrm{locatedIn}(w, z)$$

Cruise trajectory

$$\mathrm{Fix}(x) \wedge \mathrm{hasAttribute}(x, \#\mathrm{portStopArrival}) \wedge \mathrm{atPort}(x, y) \wedge \mathrm{hasSpatialFootprint}(y, z) \wedge \mathrm{hasLocation}(x, w) \rightarrow \mathrm{locatedIn}(w, z)$$

$$\mathrm{Fix} \wedge \exists \mathrm{hasTrajectory}.\{\#\mathrm{portStopArrival}\} \equiv \exists \mathrm{fixps}.\mathrm{Self}$$

$$\mathrm{hasLocation}^{-} \circ \mathrm{fixps} \circ \mathrm{atPort} \circ \mathrm{hasSpatialFootprint} \sqsubseteq \mathrm{locatedIn}$$

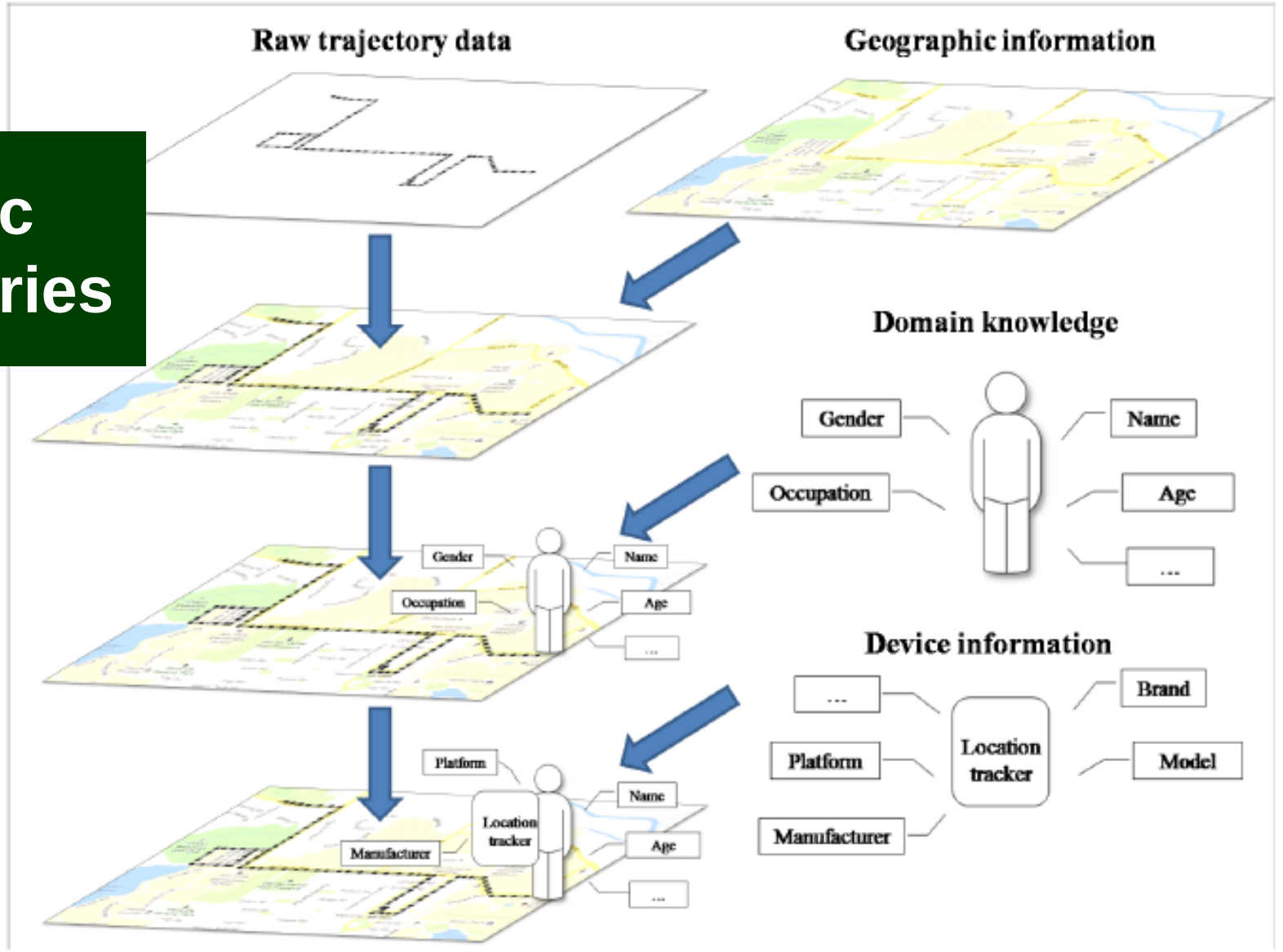
Ways forward

- **Establish a flexible conceptual architecture using data and ontological modeling.**
- **A principled use of patterns, including**
  - **the development of a theory of patterns and**
  - **the provision of a critical amount of central patterns**

  may provide a primary path forward.

Thanks!

Semantic Trajectories



[Hu, Janowicz, Carral, Scheider, Kuhn, Berg-Cross, Hitzler, Dean, COSIT2013]

Semantic Trajectories

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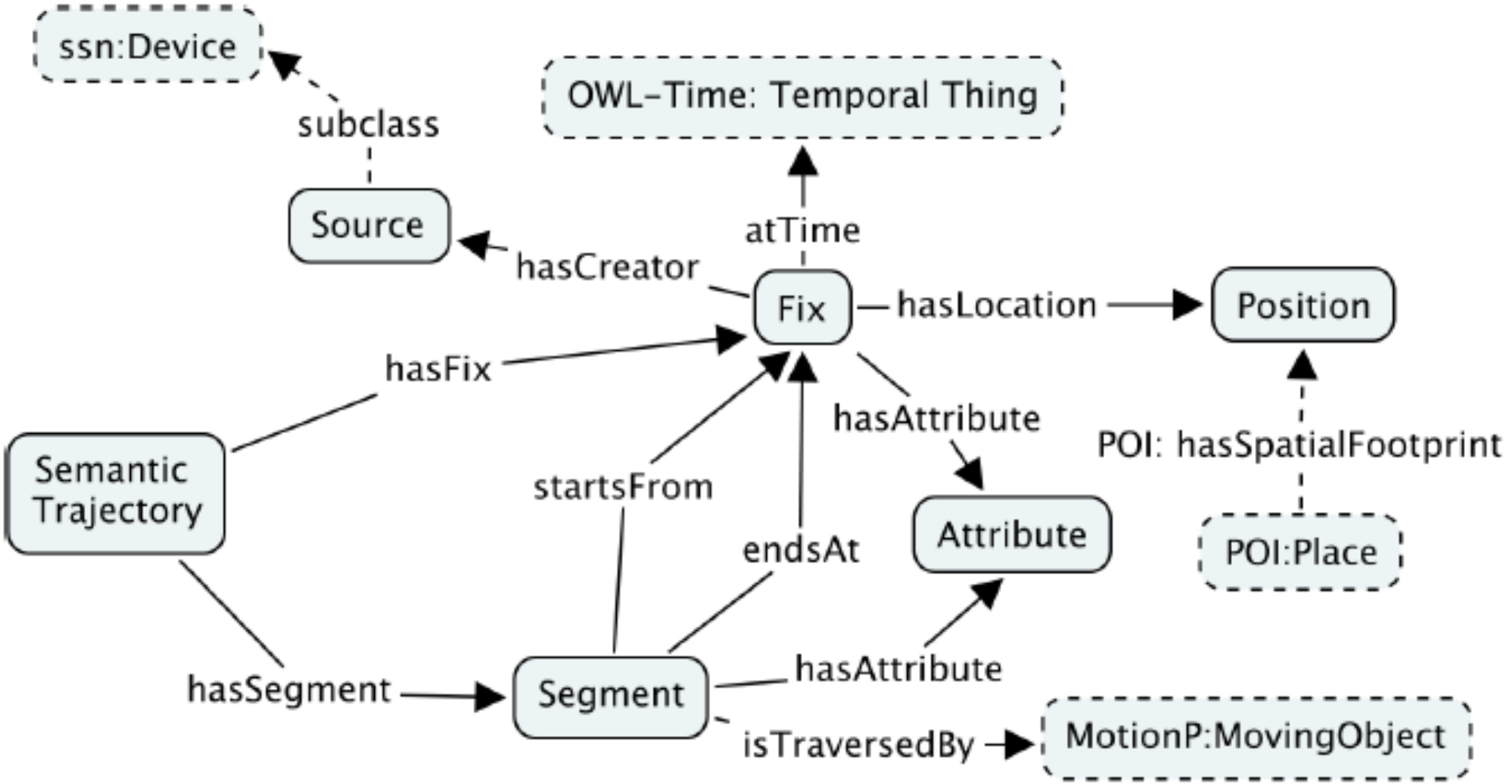

Semantics in OWL

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$$Fix \sqsubseteq \exists atTime.OWL\text{-}Time{:}Temporal\ \ Thing \sqcap \exists hasLocation.Position \sqcap \exists hasFix^{-}.SemanticTrajectory \quad (1)$$

$$Segment \sqsubseteq \exists startsFrom.Fix \sqcap \exists endsAt.Fix \quad (2)$$

$$\top \sqsubseteq \leq 1 startsFrom.\top \quad (3)$$

$$\top \sqsubseteq \leq 1 endsAt.\top \quad (4)$$

$$Segment \sqsubseteq \exists hasSegment^{-}.SemanticTrajectory \quad (5)$$

$$startsFrom^{-} \circ endsAt \sqsubseteq hasNext \quad (6)$$

$$hasNext \sqsubseteq hasSuccessor \quad (7)$$

$$hasSuccessor \circ hasSuccessor \sqsubseteq hasSuccessor \quad (8)$$

$$hasNext^{-} \sqsubseteq hasPrevious \quad (9)$$

$$hasSuccessor^{-} \sqsubseteq hasPredecesor \quad (10)$$

Semantics in OWL

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$$Fix \sqcap \neg \exists endsAt.Segment \sqsubseteq StartingFix \quad (11)$$

$$Fix \sqcap \neg \exists startsFrom.Segment \sqsubseteq EndingFix \quad (12)$$

$$Segment \sqcap \exists startsFrom.StartingFix \sqsubseteq StartingSegment \quad (13)$$

$$Segment \sqcap \exists endsAt.EndingFix \sqsubseteq EndingSegment \quad (14)$$

$$SemanticTrajectory \sqsubseteq \exists hasSegment.Segment \quad (15)$$

$$hasSegment \circ startsFrom \sqsubseteq hasFix \quad (16)$$

$$hasSegment \circ endsAt \sqsubseteq hasFix \quad (17)$$

$$\exists hasSegment.Segment \sqsubseteq SemanticTrajectory \quad (18)$$

$$\exists hasSegment^{-}.SemanticTrajectory \sqsubseteq Segment \quad (19)$$

$$\exists hasFix.Segment \sqsubseteq SemanticTrajectory \quad (20)$$

$$\exists hasFix^{-}.SemanticTrajectory \sqsubseteq Fix \quad (21)$$

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