(Towards) Ontology Virtualization for Smart Environments

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Big Data As The New Natural Resource

http://www.ibmbigdatahub.com/infographic/big-data-new-natural-resource

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A suitable analogy?

- **Natural**, i.e., not man-made
- **Exhaustible**, finite quantity
- **Renewable**, replenishable
- **Consumed**, altered
- **Building block**

If we don't even **understand** what data are, how should we make **sense** out of them?

The Internet of Things

The Internet of Things is more than just millions of connected devices. It is about the **interaction** of **cyber-systems** with the **physical environment**, **individuals**, and **society**. At its core it is about the communication of **humans with their devices**, even though this may involve long chains of inter-device communication (e.g., in a smart city context).

Consequently,

- **Low-level sensor observations** have to be lifted to **human-scale events**
- Multiple perspectives, themes, cultural and individual differences, media formats, and so forth have to be **integrated**
- Different spatial, temporal, and thematic **resolutions** have to be supported
- Public, private, anonymized, misleading, and contradictory **data** have to be handled

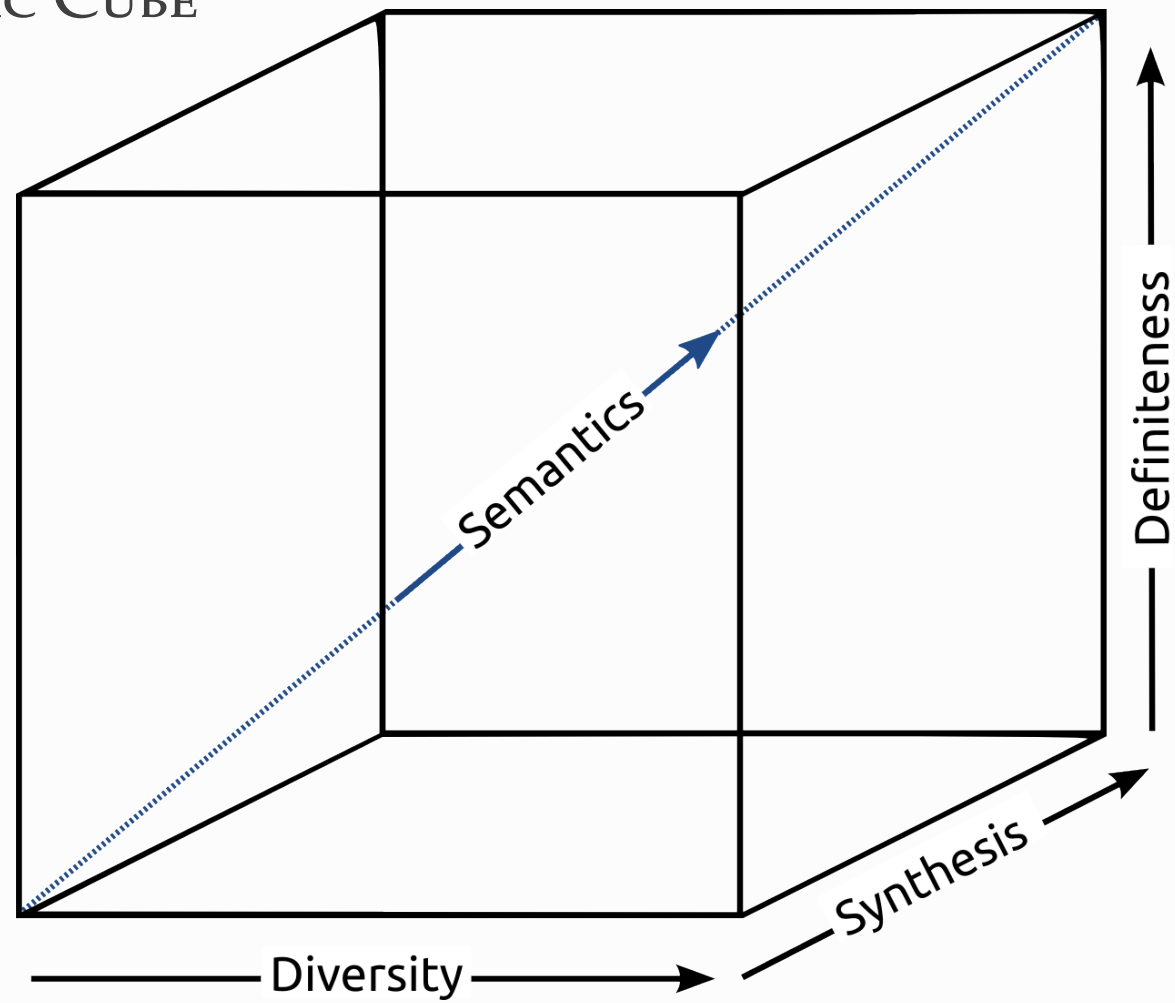
Goal: Forster interoperability without restricting heterogeneity.

The Smart Data Argument

One of the key arguments underlying the Semantic Web and Linked Data paradigms is to ***make data smart****, not applications. Instead of developing increasingly complex software, the so-called business logic should be moved to the (meta)data. The rationale is that smart data will make all future applications more usable, flexible, and robust, while* ***smarter applications fail to improve data*** *along the same dimensions.*

(**http://goo.gl/fBHie6**)

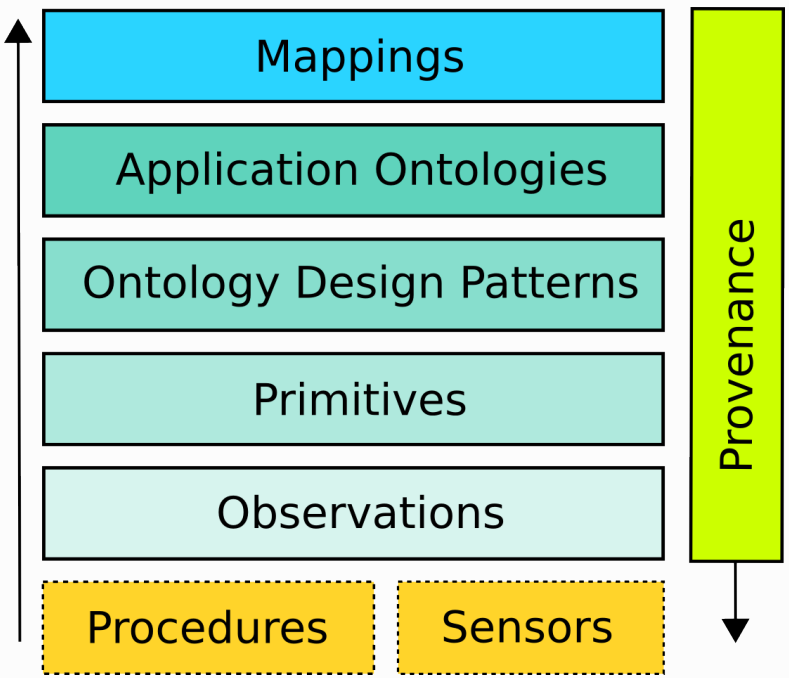
The Semantic Cube



René Descartes (1637): '*[As] for logic, its syllogisms and the majority of its other precepts are of avail rather in the communication of what we already know,[...] than in the investigation of the unknown.*'

http://goo.gl/fBHie6

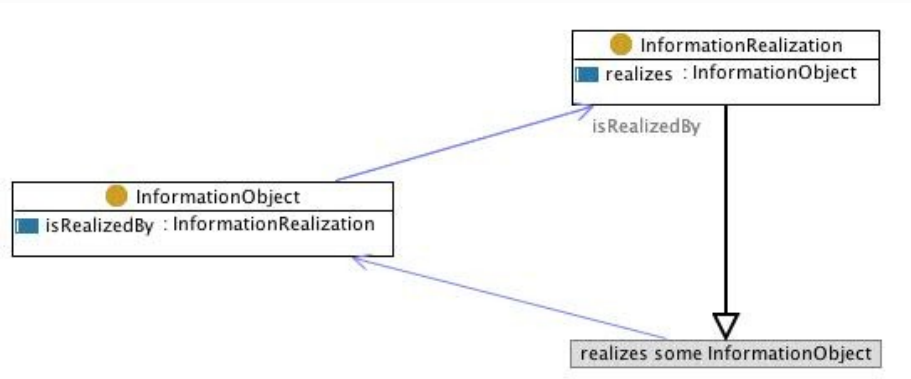
Heterogeneity-Preserving Ontology Engineering



- Local and crisp **microtheories** instead of global ontologies
- Mine ontological primitives out of real **observation data**
- Assist domain experts in becoming knowledge engineers by developing reusable **patterns**
- **Defer** the introduction of classes that are heavy on ontological **commitments** (e.g., 'vulnerability')
- Be driven by publishing, **discovery**, **reuse**, and integration needs.

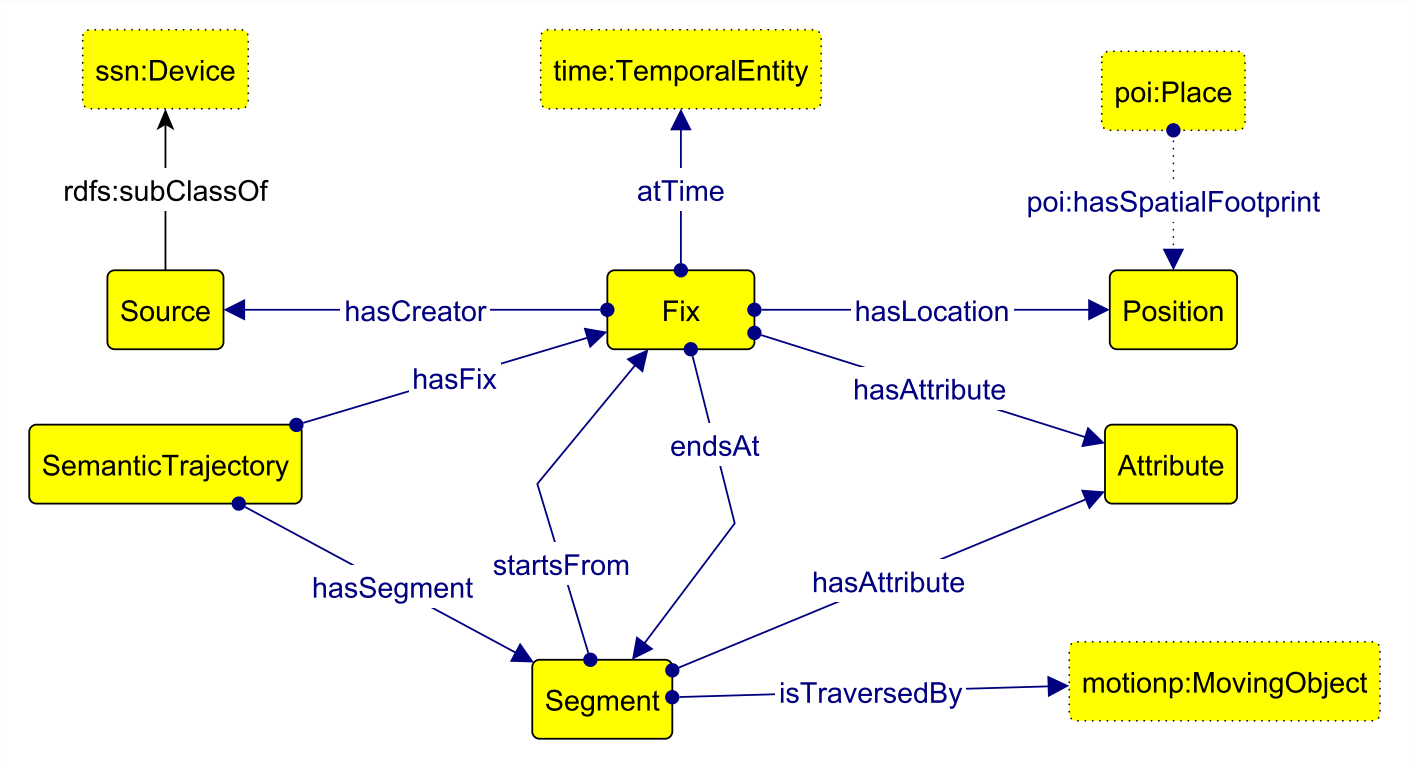
- **Monolithic** (upper-level) ontologies do not perform well in highly heterogeneous settings.

Ontology Design Pattern in a Nutshell



- **Modular** but **self-contained** building blocks
- Some patterns are **strategies**
- **Reusable** and **extendible**
- Even huge ontologies can be modularized using ODP (for example **DOLCE**)
- **No need** to import **full** ontology and **all** *ontological* ***commitments***
- Different **types** of patterns, e.g. **content** vs. logical
- How **many patterns** are there?

A (More Complex) Semantic Trajectory Pattern



A pattern for **discrete** trajectories of people, wildlife, vessels, and so forth.

Ontology Design Patterns Can Be Specialized

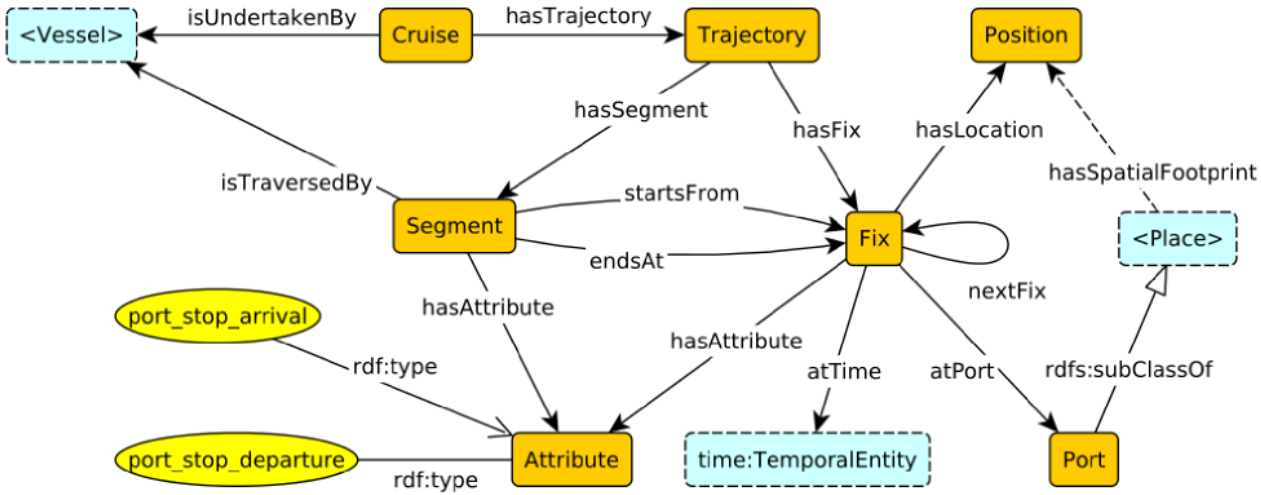


Figure 13.2: ⟨Trajectory⟩ pattern specialised for cruises

$$\mathsf{Fix} \sqsubseteq \exists \mathsf{hasLocation}.\mathsf{Position} \sqcap \exists \mathsf{atTime}.\mathsf{time{:}TemporalEntity} \sqcap (=1\ \mathsf{hasFix}^{-}.\mathsf{Trajectory}) \sqcap (\leqslant 1\ \mathsf{nextFix}.\mathsf{Fix}) \sqcap \neg \exists \mathsf{nextFix}.\mathsf{Self}$$

$$\mathsf{Segment} \sqsubseteq (=1\ \mathsf{startsFrom}.\mathsf{Fix}) \sqcap (=1\ \mathsf{endsAt}.\mathsf{Fix}) \sqcap (=1\ \mathsf{hasSegment}^{-}.\mathsf{Trajectory})$$

$$\exists \mathsf{nextFix}.\mathsf{Fix} \sqsubseteq (=1\ \mathsf{startsFrom}^{-}.\mathsf{Segment})$$

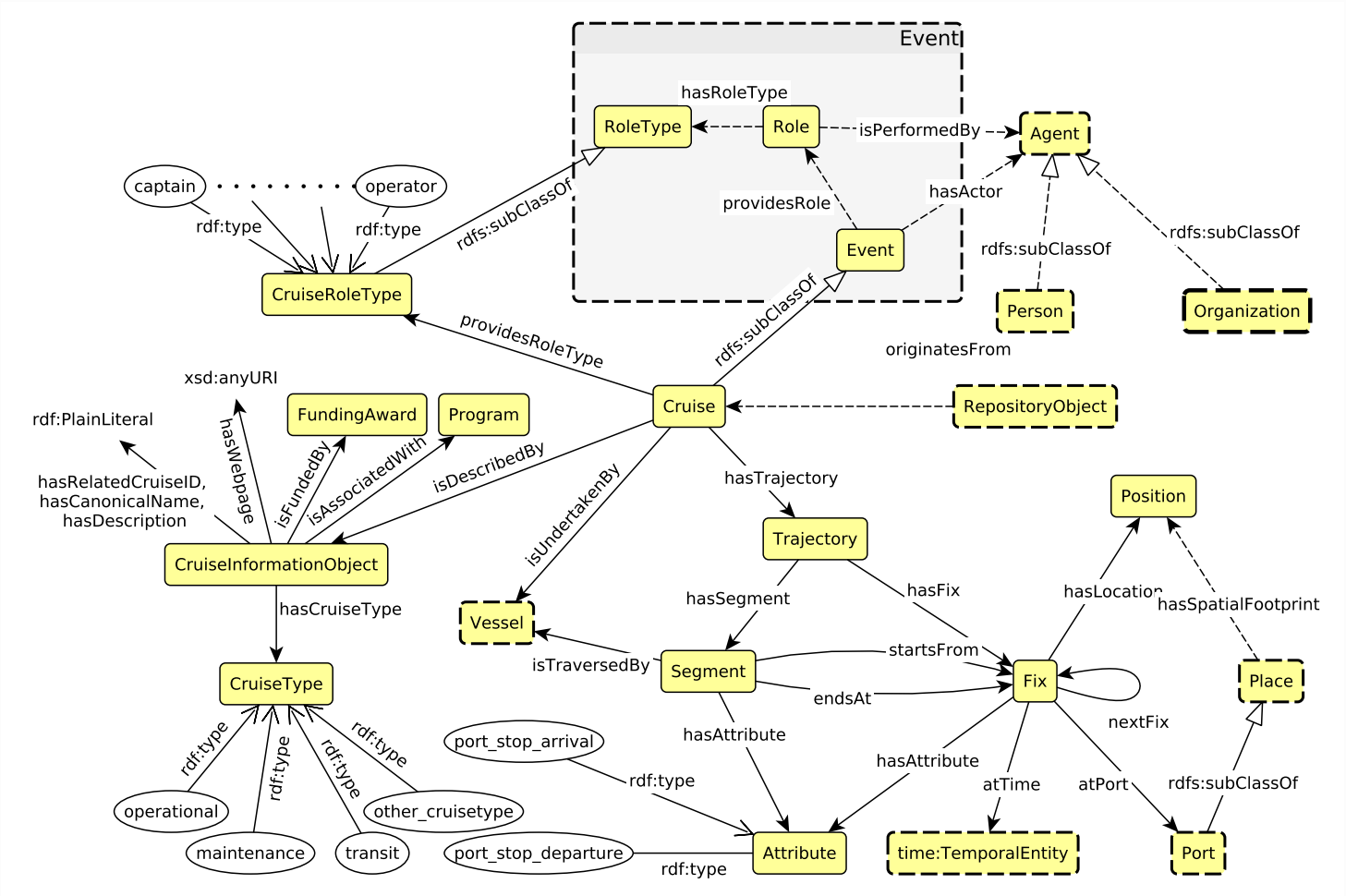
$$\exists \mathsf{nextFix}^{-}.\mathsf{Fix} \sqsubseteq (=1\ \mathsf{endsAt}^{-}.\mathsf{Segment})$$

$$\mathsf{startsFrom} \circ \mathsf{nextFix} \sqsubseteq \mathsf{endsAt}$$

$$\mathsf{hasFix} \circ \mathsf{startsFrom}^{-} \sqsubseteq \mathsf{hasSegment}$$

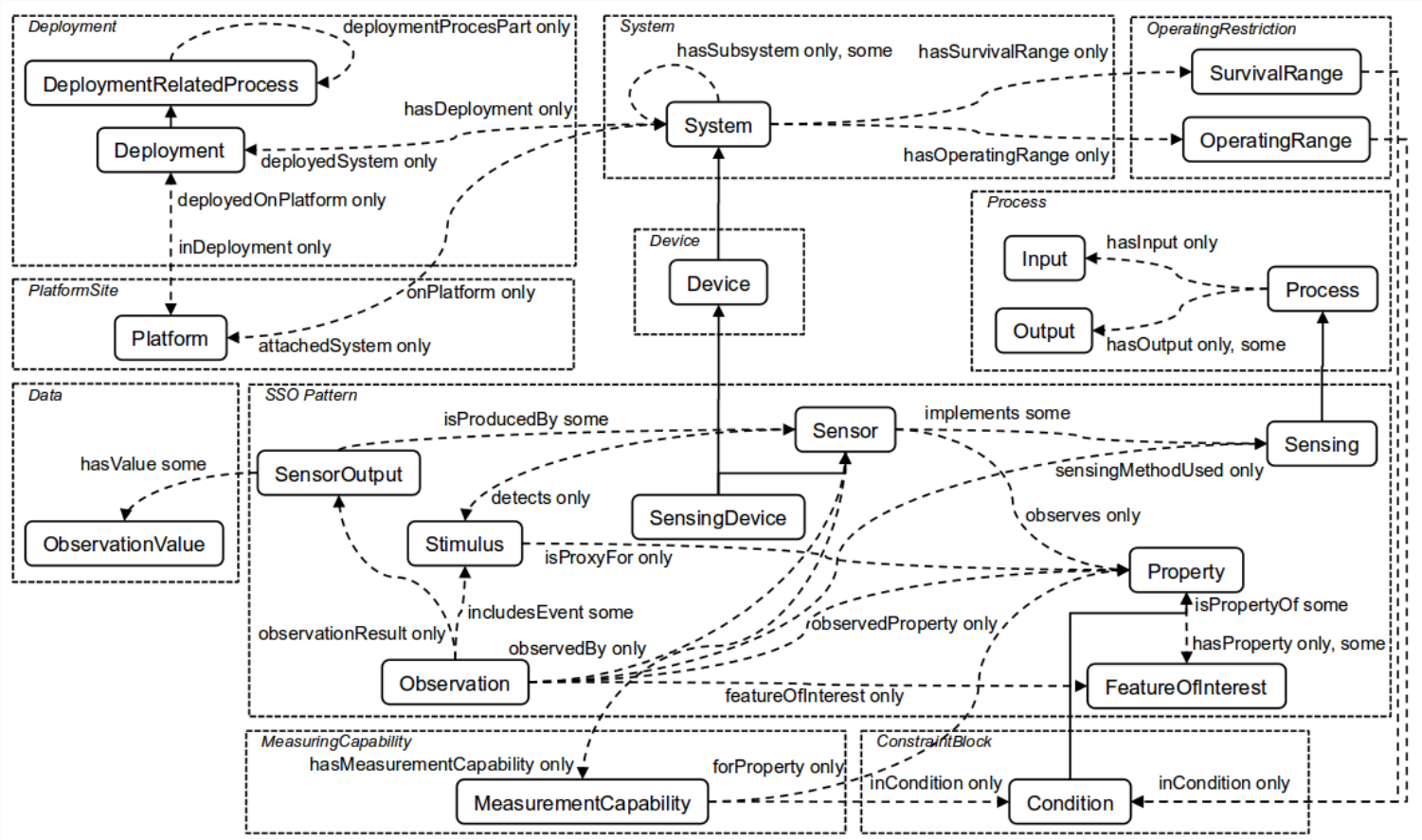
Trajectories that model the research **cruises** of scientific vessels

A Micro-Ontology for Cruises



Combining the InformationObject, Event, Vessel, and Trajectory patterns

W3C Semantic Sensor Network XG Ontology



The Ontology Standartization Argument

*Given the early success of **data format standardization**, we assume that **standardizing meaning** (via ontologies) is less difficult and more persistent than aligning and translating local (micro-) ontologies. What if standardization is the more difficult task?*

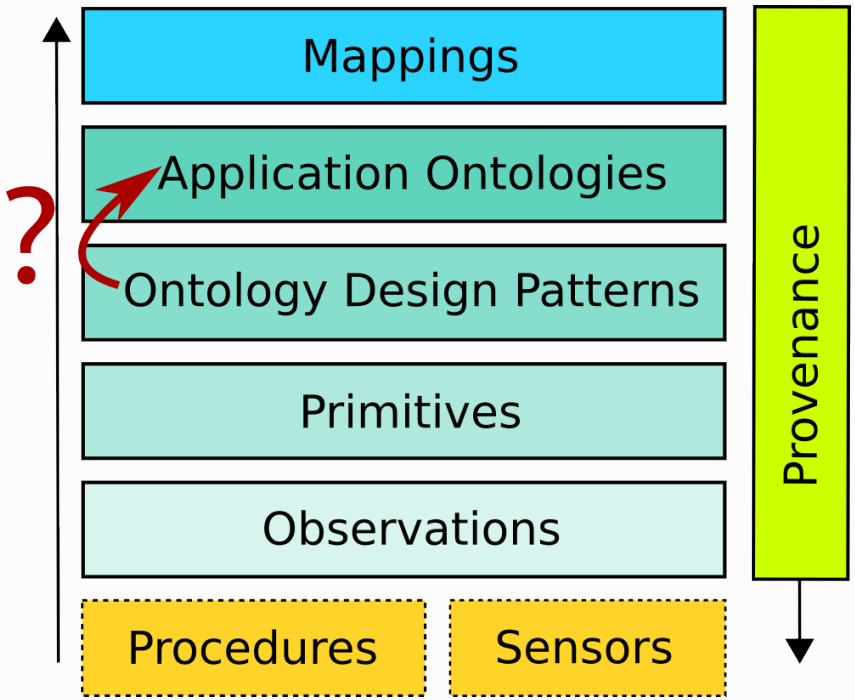
(**http://goo.gl/2e751**)

Towards Ontology Virtualization

In analogy to hardware virtualization: given a set of ontology design patterns and their combination into micro-ontologies, we can abstract from the underlying axiomatization by:

- Dynamically reconfiguring patterns in a **plug&play** style
- **Bridging** between different patterns an micro-theories
- Providing ontological **views** and **semantic shortcuts** that suit particular provider, user, and use case needs by highlighting or hiding certain aspects of the underlying ontological model
- Map between major **modeling styles**,e.g., the use of instances versus classes

The Missing Pieces: Views



- A **view** is simply a DL axiom or rule whose sole purpose is to ease the user task of expressing certain important queries. Although it is expressed as axioms, It does not constraint the meaning of a pattern, i.e., it makes **no ontological commitment**. In a sense, a view is simply a shortcut for queries analogous to the notion of view in relational databases.

(http://goo.gl/S8Ws0M)