Abstracting *Transport* to an Ontology Design Pattern for the Geosciences

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Abstract. A core concept in geoscience/physical science research is the concept of transport. We present an ontology design pattern for the notion of *transport* in the geosciences using natural language coupled with a concept map. The top level concepts of the Transport Pattern are *transport entity*, *transport mechanism*, and *transport event*. These concepts are described in detail, and a brief example is provided to illustrate the usefulness of the pattern.

1 Introduction & Related Work

The term *transport* is used to describe a variety of phenomena from different contexts, and occurring across varying spatial scales. In the field of transportation, transport primarily refers to the movement of people or goods within an infrastructure such as a road or airline network. In physical and chemical systems, transport refers to the movement of molecules or other physical matter, energy, or momentum, from one system to another. In computer networking, packets of digital information are transported. We also talk about humans transporting thoughts, ideas, and opinions through communication. In all these cases, there is movement of some entity via a transport mechanism from one place to another.

The *Semantic Transport* Ontology Design Pattern (ODP) is designed as a basic, extensible foundation for modelling transport concepts and relations in an ontology [4, 7]. In the geosciences, transport is a prevalent concept. Within the popular Semantic Web for Earth and Environmental Terminology (SWEET) ontology[7] [8], for example, there are at least 22 different concepts that reference "transport" in some form. By using it as a template for describing the relations between the mechanisms and entities involved in transport events, the *Semantic Transport* ODP can enrich descriptions of scientific data sets to aid in their interoperability, and re-use; as well as for data mining.

[7] http://sweet.jpl.nasa.gov/ontology/

The *Semantic Transport* ODP is designed to be compatible with other ODPs generated during the GeoVoCamp[8] series of workshops. Previous workshops focused on a range of geo-spatial topics from cartographic map scaling [2] to semantic trajectories [5]. Of particular note, the *Semantic Transport* ODP can operate in tandem with the the *Semantic Trajectory* pattern [5] as the former describes the entity and energy of transport, and the latter describes the path along which the transport occurred.

The *Semantic Transport* pattern is also conceptually related to the proposed *Move* ontology design pattern[9] that is derived from the CIDOC model [3]. The *Semantic Transport* pattern, however, decouples the source energy from the entity being displaced while capturing their interdependence.

2 Transport Pattern

In this section we present the core elements of the *Semantic Transport* pattern, and describe how it can be extended to cover two different types of transport: active and passive. We focus on applying the *Semantic Transport* ODP in the context of physical systems, though it may also be useful for other domains, e.g. describing cultural transmission.

2.1 Core elements

The *Semantic Transport* pattern consists of three core concepts: Event, Entity, and Mechanism (see Manchester OWL syntax following this paragraph). The *TransportEvent* acts as the top level concept for the pattern. A *TransportEvent* describes a specific *transport* phenomenon, as movement of some mass or energy (measurable entity) from one location to another, based on a common and persistent frame of reference. Induction of the mass or energy movement can arise from the transported entity itself, or from external sources. The *TransportEvent* thus has two main parts, *TransportEntity* and *TransportMechanism*. The *TransportEntity* concept represents the identity of the circumscribed portion of energy or mass that is moved. The *TransportMechanism* concept captures the nature of the source that acts upon the *TransportEntity*, and thus induces a *TransportEvent*.

```
Class: TransportEvent
TransportEvent SubClassOf owl:Thing
TransportEntity SubClassOf partOf some TransportEvent
TransportMechanim SubClassOf partOf some TransportEvent

Class: TransportMechanim
TransportMechanim SubClassOf owl:Thing
TransportMechanim SubClassOf partOf some TransportEvent
```

[8] http://vocamp.org/wiki/GeoVoCampSB2013
[9] http://ontologydesignpatterns.org/wiki/Submissions:Move

```
Class: TransportEntity
TransportEntity SubClassOf owl:Thing
TransportEntity SubClassOf partOf some TransportEvent
```

The *TransportEvent* has one top level property, the *referenceFrame* (see Manchester OWL syntax following this paragraph). The *referenceFrame* provides context to the pattern by specifying spatial and temporal qualities of any associated observations via the specification of time and location information associated with the *TransportEvent*. As time and location can be fixed or relative, abstracting the property types serves to facilitate semantic interoperability between disparate data entities.

```
ObjectProperty: referenceFrame
referenceFrame Domain TransportEvent
referenceFrame Range TransportEvent
```

It is worth noting that even if the transported entities were to return somehow to their exact place of departure, they still participated in a *TransportEvent*, even if their initial and final locations result in no net change in location.

2.2 Extending the Transport Pattern

Figure 1 illustrates the *Semantic Transport* pattern along with a few logical extensions to illustrate how the pattern might be used. The pattern constructs are depicted in figure 1 using black text in translucent shapes. Further, all classes in the figure are represented using an oval, and each square box delineates a property. In most cases there will be interest in a more specific description of the event. These additional aspects are accommodated by extending the pattern through subclassing of the existing *TransportMechanism* and *TransportEntity* concepts, while adding properties to the *referenceFrame* (Figure 1). These additional pragmatic components are included in figure 1. Class symbols with red text are examples of the nomenclature that may be used as a *TransportMechanism*. Sub-properties with blue text illustrate examples of modules that may be described as part of the constructs comprising the *referenceFrame*.

The *TransportMechanism* can be usefully subclassed into specialised topics, such as in the case of involving disjoint classes such as *PassiveTransport* and *ActiveTransport*. Classic examples of *PassiveTransport* include, e.g. diffusion or osmosis, while *ActiveTransport* would include, e.g. ATP pumps or air travel [1].

The *referenceFrame* is a non-trivial property. Geoscience phenomena often exhibit unique statistical signatures as mechanical, chemical, and biological processes work in tandem, or asynchronously, through time as they tend toward equilibrium [6]. This property is significant in that it serves to preserve the spatiotemporal information necessary to maintain a consistent granularity of context throughout the pattern.

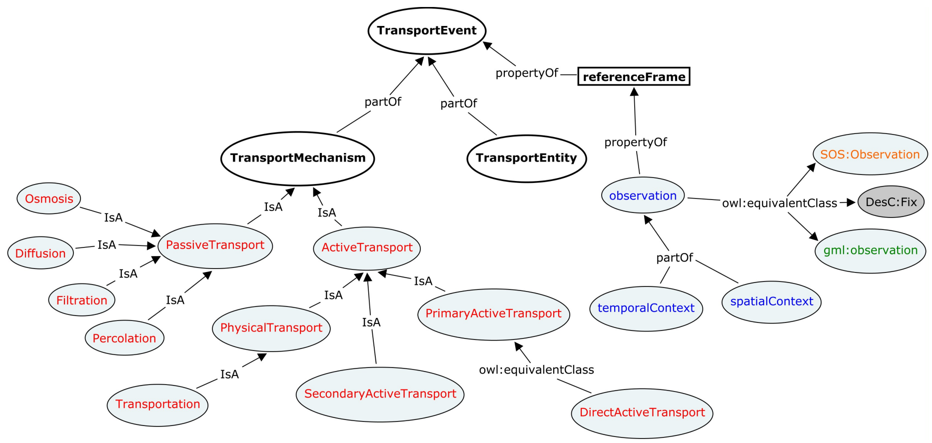

Fig. 1. Transport Pattern extended. Each class in the figure is represented by an oval, and each square box delineates a property. The *Semantic Transport* pattern constructs are depicted using black text in translucent shapes. Classes using red text are logical subclasses, while sub-properties are styled using blue text. Three equivalent class relations are represented on the right of the figure, each one illustrating how the *referenceFrame* can connect to other established schemas.

Further, an *observation* (as it relates to the *referenceFrame* in figure 1) is considered semantically equivalent to other well established geoscience explications, namely the observation entities associated with the Sensor Observation Service[10] (SOS) and the Geography Markup Language[11] (GML), as well as the concept of a "fix" in the *Semantic Trajectory* pattern [5].

Of course, further subclassing will likely be necessary for this pattern to connect, and be useful, to much of the disparate data available to geoscientists. The current framework is complete and extendable. By creating logical semantic equivalences to constructs already used throughout the domain, the *Semantic Transport* pattern can be a powerful module when mining and filtering large data stores.

3 Summary and Future Work

In this paper we presented an ontology design pattern to describe transport phenomena. The core *Semantic Transport* ODP is deliberately simplified to essential elements, to be applicable to a wide range of use cases in the physical sciences. We described how the Transport pattern can be extended for Active and Passive transport and illustrate briefly how it might be used to interoperate over large disparate geoscience data.

[10] http://www.opengeospatial.org/standards/sos
[11] http://www.opengeospatial.org/standards/gml

Next steps will involve how the ODP can be filled out to describe data for a variety of use cases, as well as application and usability testing. An important future extension to the pattern for application to the physical sciences will include explicating the relationship between concepts such as *system* and *energy input* (in terms of entropy of the system).

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