Geo-Processes and Properties Observed by Sensors: Can We Relate Them?

Anusuriya Devaraju[1] and Tomi Kauppinen[2]

[1,2] Institute for Geoinformatics (ifgi), University of Muenster, Germany
{anusuriya.devaraju, tomi.kauppinen}@uni-muenster.de

Abstract. This paper introduces an ontology-based approach to relate properties observed by sensors to geographical processes and events. We use the basic categories in DOLCE to classify them. We illustrate our approach with examples from the surface hydrology domain.

1 INTRODUCTION

Geographic phenomena such as floods, droughts, epidemics and wildfires are complex as they occur continuously over space and time and involve interactions between several geographic features. Environmental sensors provide a key element for understanding processes associated with geographic phenomena. For example, a flood event is predicted via stream gauges at flood-prone areas. In this case, observed properties such as a stream depth and a stream flow result from a runoff process, which is facilitated by other processes such as a sustained rainfall or a rapid snow melt. Interactions between environmental processes and sensor data are difficult to capture due to two main factors. Firstly, effort is required to interpret and integrate sensor data based on heterogeneous schemas; the heterogeneities related to sensors observations may exist at syntactic, structural and semantic levels (Bishr 1998). Secondly, high-level domain conceptualization of environmental processes is required to express geographical processes not only in terms of their properties but also in terms of their relations with other processes. These two factors open a new challenge–the need for an approach that supports an explicit representation of geo-phenomena dynamics and presents a unified view over heterogeneous sensor data.

In this paper we introduce an *ontology-based approach* that relates geographical processes to physical properties observed by sensors. There are a number of top-level ontologies formalizing the notions such as quality, continuant and occurrence; providing categorical distinctions, and some of them becoming accepted standards (Natalya 2004). In our approach, we use a top-level ontology, namely the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) (Masolo et al. 2003) to identify foundational categories needed to classify geographical processes and related entities. The relations between the categories in our ontology are used to handle differences in the interpretation of the vocabularies used to encode observed properties and geographical processes. Our research is based on a view that neither material bodies (i.e., physical object, amount of matter) nor occurrences (i.e., process, event) are ontological prior to the other (Galton et al. 2009). In this paper, we argue that understanding, modelling and fully using a sensor observation is only possible if we first understand and model an occurrence in which a material body with observable properties participates.

In the next sections, the concepts describing processes and properties are discussed. We illustrate our ontological approach by using some examples from the surface hydrology domain. Finally, we describe the future work.

2 An Ontological Representation: From Processes To Properties

In this section, we discuss the relevance of basic categories in DOLCE to form relations between hydro-processes and observed properties. The top categories of DOLCE are *endurant, perdurant, quality* and *abstract*. Endurants exist in full at an instant of time; they may change their properties over some period of time. *Physical object*, *amount of matter* and *feature* are examples of physical endurants. See (Devaraju et al. 2010) for definitions of these categories with examples from the surface hydrology domain.

2.1 Event and Process

Perdurants[1], are only partially present at any time, at which they exist. For example, a process or an event is a perdurant. Perdurant types in DOLCE are classified based on 'aspectual' view as proposed in linguistics (Vendler 1967). The following criteria are considered: (a) a perdurant type is *cumulative (CM)* if it holds of the mereological sum of two of its instances; (b) a perdurant is *homeomeric (HOM)* if all its temporal parts can be described in the same way used for the whole occurrence; (c) a perdurant is *atomic (AT)* if it does not have temporal sub-parts. Table 1 describes the conditions on perdurant types specified in DOLCE.

Table 1: Perdurant types in DOLCE (Masolo et al. 2003)

Perdurant	Condition	Examples
State	CM $\wedge$ HOM	The *freezing of raindrops* while they are falling through a below-freezing layer of air near the earth's surface is categorized as *state* as (a) two freezing

[1]The term 'perdurant' is a synonym for 'occurrence'

		occurrences of raindrops are perdurants of the same kind, and (b) each such a freezing occurrence goes on over each subinterval of its interval.
Process	CM ∧ ¬HOM	*Raining* is a process by which water particles in a liquid form fall from the atmosphere and reach the ground. Here, we are referring to the *process* of 'deposition of liquid water droplets'. Some temporal parts of a raining process are instances of the same most specific perdurant, and some are not (e.g., when raindrops evaporate before they reach the ground)
Accomplish-ment	¬CM ∧ ¬AT	A particular *rainshower* can be conceptualized as an *accomplishment* if we refer to what has brought such an event to occur. For example, a rainshower event composed of sub-events like a creation of saturated conditions in the atmosphere, a condensation of water vapor into liquid water and a growth of small droplets by collisions and coalescences until they become large enough to precipitate.
Achieve-ment	¬CM ∧ AT	An *achievement* is an instantaneous event. Consider the 'moment' in which some raindrops hit the ground. Note that the whole event consisting of a perceptible water generation and a deposition is not regarded as an achievement event.

The examples in Table 1 show that there are different views referred to a perdurant. There can be indecision on where to align a perdurant-oriented category and such a classification is mainly based on the modeler's choices. Our work focuses on the notions of *process* and *accomplishment*. In the following, we will use the term *event* to denote an *accomplishment event*. In addition to the definitions of *process* and *accomplishment event* introduced in DOLCE, we regard an *event* as an occurrence which has a definite beginning and a definite end, and that takes place over an interval. A single event is temporally non-dissective, therefore the time of the event is the whole interval, not any proper subinterval of it (Galton 2007). We consider a *process* as non-atomic since we cannot collapse the time interval of a process into a time point.

3 PHYSICAL AND TEMPORAL PROPERTIES

Qualities[2] are temporal or physical properties we perceive or measure. The separation of physical and temporal properties based on enduring and perduring entities allows one to identify the spatial location of different participants in a perdurant (Probst 2006).

[2] In DOLCE terminology, the notion 'quality' is used instead of the notion 'property'

In DOLCE, a physical endurant can have only physical qualities. However, in the context of geographic information (GI), a perdurant is often expressed as the bearer of a physical property. For example, a traffic flow process in a road network has properties such as a speed, a density, and a rate of flow or an increase or a decrease of the flow of water in a river (Galton 2007). We consider the above examples as properties that 'emerge' from the mutual dependency between perdurants and their participants. For instance, a discharge or a streamflow is a quality inherent in a cross section of a river. The cross section is a *feature* type and its *host* is a water body (a *physical object*). When a particular cross section and its host (e.g., a river) and amount of water participate in a water flow occurrence, a complex quality like discharge emerges. Therefore, our approach is in agreement with the 'physical endurant-physical quality' relation in DOLCE, but would include occurrence as well as its participants to describe a dynamic property. In Table 2 we describe selected ontological relations of DOLCE between domain categories with examples from the surface hydrology domain.

Table 2: Basic relations in DOLCE (Masolo et al. 2003)

Relation	Description	Example from Hydrology
Inherent-in, Has-quality	A physical quality is inherent in a physical endurant. A temporal quality is inherent in a perdurant.	*Amount of air* has a quality like an *air temperature*. A *precipitation duration* is a temporal quality of a *precipitation process*.
Part-of, Temporary-part-of	A parthood relation applies to a pair of endurants or a pair of perdurants. A temporary parthood is a relation between two endurants where one is a part of the other at a particular time. A-temporal parthood is a time independent relation between two perdurants or two abstract entities.	An instance of *organic matter* is part-of an instance of *soil* and this relation holds over a period of time. An instance of *melting* (i.e., a process of transformation of snowflakes into raindrops) is a part of an instance of perdurant *raining*.
Generic-constituent	Constitution depends on some layering of the world described by the ontology. A constituent is an entity belonging to a lower layer.	A *water body* is conceptualized at a different layer from the *water molecules* that constitute it.
Has-participant, Participant-in	This relation holds between the endurants and the perdurants.	Portions of *Amount of water* and *porous soil* are the participants of a *percolation* process.

4 EXAMPLE: BLIZZARD EVENT

The Figure 1 depicts the categories describing blizzard phenomena. A simple event is ‘made of’ one or more processes. A complex event comprises multiple events and each sub-event is ‘made of’ several processes. We use the *constitution* relation to relate perduring entities at different level of granularities. There is discontinuity between the constituted and the constituent entity (Masolo et al. 2003). For example, a *blizzard* is an event made of several processes such as a *wind* (i.e., the motion of air) and a heavy *snowfall* (i.e., the process of snowflakes falling from the atmosphere to the ground). An occurrence involves one or more material things or portions of matter. For instance, a *snowfall* process has participants like a *terrain* (i.e., an area of land) and portions of *snowflakes*.

There are varying definitions for blizzard which are described in terms of different properties such as a wind speed, a wind chill, a snow depth and an air temperature.[3] In order to relate physical properties to an occurrence, it is necessary to express the properties thresholds in the form of rules (Sheth et al. 2008) according to the definitions from different countries. For example, according to Environment Canada[4], particular conditions (*wind speed* ≥ 50km/h, *visibility* ≤ 1km, and *wind chill* ≤ −25°C) should occur and last for four or more hours before a storm can be properly called a blizzard; whereas, the National Weather Service of US defines blizzard as ‘sustained 56 km/h winds which lead to blowing snow and cause visibilities of 0.4km or less, lasting for at least 3 hours’.[5]

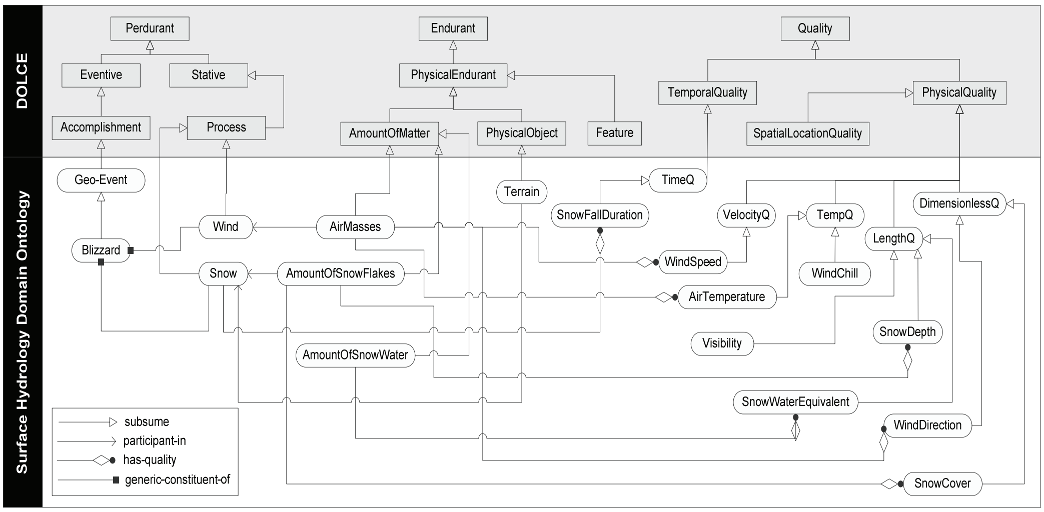

Figure 1: A partial conceptual illustration of a blizzard event.

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3 http://en.wikipedia.org/wiki/Blizzard
4 http://www.on.ec.gc.ca/severe-weather/winterwx_factsheet_e.html
5 http://www.wrh.noaa.gov/fgz/science/blizzard.php?wfo=fgz

5 CONCLUSIONS

In this paper we argued that ontology-based modeling of processes of an observable phenomenon enables to understand data coming from heterogenous environmental sensors observing that phenomenon. The key challenge that we identified is the lack of semantic interoperability due to the heterogeneity of data produced by sensors. Ontologies are commonly used to provide solutions for improving semantic interoperability. In this spirit, we made use of the foundational ontology DOLCE for classifying geographical processes and related entities. Finally, we evaluated our approach by giving examples from the surface hydrology domain. As a part of the future work we plan to examine what kind of reasoning mechanisms can be built by using the models we presented. It would also be interesting to apply these reasoning mechanisms for classifying real data coming from heterogenous environmental sensors.

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6 REFERENCES

Bishr Y (1998). "Overcoming the semantic and other barriers to GIS interoperability." International Journal of Geographical Information Science 12(4): 299–314.

Devaraju A and Kuhn W. (2010). A Process-Centric Ontological Approach for Integrating Geo-Sensor Data, In: Galton A and Mizoguchi R (eds.), Formal Ontology in Information Systems Proceedings of the Sixth International Conference (FOIS 2010), IOS Press, 199–212.

Galton A (2007). "Experience and History: Processes and their Relation to Events." Journal of Logic and Computation 18(3): 323–340.

Galton A and Mizoguchi R (2009). "The water falls but the waterfall does not fall: New perspectives on objects, processes and events." Journal of Applied Ontology 4(2): 71–107.

Masolo C, Borgo S, Gangemi A, Guarino N, Oltramari A and Schneider L (2003). WonderWeb EU Project Deliverable D18: The WonderWeb Library of Foundational Ontologies, 349.

Natalya F N (2004). "Semantic integration: a survey of ontology-based approaches." SIGMOD Rec. 33(4): 65–70.

Probst F (2006). Ontological Analysis of Observations and Measurements, In: Raubal M, Miller H J, Frank A U and Goodchild M F (eds.), Proceedings of the 4th International Conference of Geographic Information Science, Germany, 304–320.

Sheth A, Henson C and Sahoo S S (2008). "Semantic Sensor Web." IEEE Internet Computing 12(1): 78–83.

Vendler Z (1967). Linguistics in Philosophy, Cornell University Press, Ithaca.