Toward A Foundational Ontology of the Landscape

Gaurav Sinha[1], David Mark[2]

[1]Department of Geography, Ohio University, Athens, OH 45701 USA
Email: sinhag@ohio.edu

[2]NCGIA & Department of Geography, University at Buffalo, NY 14261 USA
Email: dmark@buffalo.edu

1. Why A Foundational Ontology of the Landscape?

Previous research suggests that different languages and cultures recognize different (and incompatible) kinds and characteristics of landforms in the landscape (Mark and Turk 2003; Mark et al. 2007). Landscape concepts and their lexicalization also vary, due to the varied physiographic settings that influenced the evolution of the world's languages and cultures. If it is limited to principles common to all languages and cultures, a foundational ontology of the physical landscape is likely to be quite sparse; however, research is still needed to identify the core context-independent entities and properties. This landscape ontology will clarify, constrain, and align other landscape ontological commitments. Moreover, if this is explicitly aligned with an appropriate domain-independent, upper-ontology, it will greatly facilitate interoperability and integration with the semantic web.

Natural language is an important resource for gaining insight into the stable concepts and categories that people naively acquire. However, common sense categories (e.g., mountain, lake, or valley) and their instances are problematic in a universal ontology since the category definitions are context dependent, where we broadly define context to include *language, culture, individual's mental model, situation, knowledge` system, use case,* and *geographic scale,* or any combination of these. We believe that there are no natural kinds in the inorganic landscape domain, but there are some physical percepts offered by the landscape that all human beings will notice similarly, irrespective of context. We draw our inspiration from several sources, including Gibson's (1979) theory of *environmental affordances*, Horton's (1982) *primary theory*, and Lakoff's (1987) idea of *experiential realism*. Based on the assumption that there is a *commonly experienced* version of the landscape for all people, we propose the following constituents of the foundational landscape ontology:

- one primary physical geographic entity: the earth's surface;
- natural and anthropogenic secondary entities (e.g., trees, roads, and buildings) all of which are considered physically attached to that surface;
- observable and measurable physical characteristics such as location, shape, size, elevation, gradient, depth, color, material, etc;
- a limited number of localized, observable surface features (protuberance, peak, ridgeline, fault, layer, hollow, depression, cliff, incline, slope break, edge, etc.); and
- fundamental spatial and temporal relations between surface features (e.g., proximity, direction, topology, temporal overlap, composition, parthood, etc.).

2. Selection of an Upper-Ontology

We needed to formalize these ideas using an upper ontology so that our landscape ontology can be ontologically consistent and can be integrated with ontologies of other environmental domains. Upper ontologies represent only those top-level entities that can have domain-independent meaning. There are still multiple candidates due to different philosophical traditions and objectives. The Basic Formal Ontology (BFO), with its revisionist commitment, aims to represent the *intrinsic* nature of reality. The Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) is designed instead to capture the universal linguistic and cognitive *descriptions* of reality (Guarino et al. 2003); it stays neutral about existentiality. BFO is committed to actualism and reductionism: it admits only those entities that can have physical existence and allows only one entity to exist at a location in space-time. DOLCE is committed to possibilism and is multiplicative: it allows all possible views of reality, and different entities to co-exist in space-time. Other popular Upper Ontologies include SUMO, OCHRE, and OpenCyc, have their own commitments. Regardless of these differences, all Upper Ontologies serve as starting points for domain ontologies, and serve as a reference for common modeling tasks.

In comparison to the foundational landscape ontology, the various contextual landscape ontologies will be much more interesting, and much more challenging to capture through formalisms. While a foundational landscape ontology should be revisionary in scope, contextual landscape ontologies must be descriptive and multiplicative. We also need a modular approach that will enable easy alignment of contextual ontologies with the referent landscape ontology.

Given these considerations, we find DOLCE's theoretical commitment to capturing the categories and concepts underlying language and cognition, and practical commitment to modular ontology engineering the most appropriate foundational ontology. Its creators have also released a simplified version compatible with the Web Ontology Language (OWL), the preferred computational language for implementing ontologies. The WonderWeb project, from which DOLCE originated, also developed modules for extending DOLCE with concepts for representing socially constructed reality, entities of the information processing domain, and generic spatial and temporal relations. This kind of support for modularly integrating ontologies will prove to be invaluable for landscape ontology modeling.

3. Landscape Ontology Modeling with DOLCE

DOLCE is an ontology of *particulars*, which are entities that cannot be instantiated (as opposed to *universals* or kinds). It identifies four top level particulars: endurant, perdurant, quality, and abstract. Of these, endurant and quality are of special relevance to us. Endurants are further specialized into physical, non-physical, and arbitrary sum; physical endurants, in turn, can be arbitrary amounts of matter, physical objects, or features that depend 'parasitically' on physical objects for their 'existence'. Qualities can be abstract, physical, or temporal. Every quality must inhere in some entity, while every entity must possess some quality.

Interpreting the foundational landscape ontology in DOLCE parlance, both planet earth and its physical surface (part) are *non-agentive physical objects*. All physical characteristics would be mapped to *physical quality*; location of qualities or features can be classified as *spatial location* (a direct subclass of physical quality). Surface features would be *features* (either of type *relevant part* or *dependent place*), that are 'hosted' by the physical surface. The spatial and temporal relations between surface features would be treated as *universals* in DOLCE; particulars can only participate in (instances of) these relations. The DOLCE provides modules for optional import of spatial and temporal relations; until a more comprehensive foundational ontology of the geographic domain becomes available, landscape relations should be derived from the DOLCE foundational ontologies.

Since DOLCE is both descriptive and multiplicative, it allows modeling the same geographic entities, and classes of entities, in more than one way. Convex landforms provide an example. In the foundational landscape ontology, they are dependent, relevant parts (features) of the earth surface. However, in other contexts, such as a language or belief system, a convex landform, such as a hill, could be considered to be any of DOLCE's three main kinds of physical endurants: a *physical object*, a *feature*, or an *amount of matter*. Choosing one of these in a domain ontology for landscape will limit operations and relations. For example, a butte as a *physical object* or as a *feature* could not be used as material for the construction of a highway, whereas a butte considered as an *amount of matter* can be quarried and used in road construction. Such ontological mismatch may contribute to environmental conflict. An example might be the conflict regarding Woodruff Butte in Arizona, considered to be a sacred site (*physical object*, perhaps even *agentive physical object*), by some American Indian tribes, but considered to be just an *amount of matter* to the land owner.

4. Conclusion

Natural language terms and common-sense landscape categories are too 'rich' to find an exact counterpart (synonym/synset) in every other language or culture. For ontology alignment, we need simple or atomic concepts that richer concepts can be expressed in terms of. We have conceived the foundational landscape ontology from that minimalist perspective. It includes only those landscape characteristics that are guaranteed (by definition) to have the same intended interpretation in all contexts. For example, the idea of a part of the landscape, its concave shape, or the material water collected in that concavity is communicable to anybody. What about the ontological status of these universally recognizable landscape structures? We think they are 'brute facts' of reality, existing independently of our cognition. This realist stance cannot be expressed fully within DOLCE, but, it still seems to be the best framework for achieving our real goal: a flexible, foundational framework for clarifying and harmonizing mismatches in people's landscape conceptualizations.

References

Gibson JJ, 1979, *The Ecological Approach to Visual Perception*, Houghton Mifflin, Boston, MA, USA.

Horton R, 1982, Tradition and Modernity Revisited. In: *Rationality and Relativism* Hollis M and Lukes S (eds.), Basil Blackwell, Oxford, UK, 201-260.

Lakoff G, 1987, *Women, Fire, and Dangerous Things: What Categories Reveal about the Mind*, University of Chicago Press, Chicago USA.

Mark DM and Turk AG, 2003, Landscape Categories in Yindjibarndi: Ontology, Environment, and Language. In: Kuhn W, Worboys M and Timpf S (eds), *Spatial Information Theory: Foundations of Geographic Information Science, Lecture Notes in Computer Science No. 2825*, Springer-Verlag, Berlin, 31-49.

Mark DM, Turk AG and Stea D, 2007, Progress on Yindjibarndi Ethnophysiography. In: Winter S, Duckham M, Kulik L and Kuipers A, (eds.) *Spatial Information Theory, Lecture Notes in Computer Science No. 4736*, Melbourne, Australia, 1-19.

Masolo C, Borgo S, Gangemi A, Guarino N and Oltramari A, 2003. *WonderWeb Deliverable D18 Ontology Library (final)*, http://wonderweb.semanticweb.org/deliverables/documents/D18.pdf.