Spatial Concepts and OWL issues in a Topographic Ontology Framework

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1. Introduction

The aim of the GeoSemantics programme at Ordnance Survey is to develop the methods and tools needed to create a topographic ontology and support interoperability between Ordnance Survey's data, their topographic ontology, customers' ontologies and data. This paper focuses on how to consistently represent and model spatial entities and non-spatial concepts that are related to spatial entities in an ontology. This is a fundamental piece of research, as this spatial entities ontology module will be reused within the topographic ontology that is being built by Ordnance Survey (Dolbear at al., 2006a).

2. Background

Ordnance Survey, the national mapping agency for Great Britain, supplies complex data products that represent a topographic interpretation of the landscape and its significant structures and features. Our customers currently face significant costs in integrating these data with their own data and business processes and consequently these costs are a major barrier to the adoption and efficient exploitation of complex data sets, for example Ordnance Survey's MasterMap®. The Ordnance Survey topographic ontology will encode knowledge about topographic objects surveyed by Ordnance Survey, describe these objects and their relationships, and link this encoded information to a GI data base. One of the important steps in this process is developing a conceptual framework for how the spatial aspects of physical and non-physical topographic objects will be encoded. For more information on the technical aspects of our work, please consult Dolbear et al. (2006b).

An important point to note is that location is only one aspect in the description of a real world object (such as a building). Other important aspects include *what* the object is and *how* it relates both semantically and spatially to other objects. For this reason we regard a real world object not only as a geometric entity (such as a polygon) with attribution assigned to it but also a semantic object that has uses and functions that has spatial information assigned to it.

3. Analysis and Discussion

There are two main categories of topographic objects – those that are physical and those that are non physical. These will now be introduced.

3.1 Physical topographic objects and Space

Physical topographic objects such as a building, a mountain or a lake, have several qualities that are spatially relevant but not all these qualities are relevant for any given domain. A building has a volume of space it occupies in three dimensions, an area of its outside surfaces, a height and a depth, if it has under ground levels. A building also has a footprint on a two dimensional surface (such as an earth surface), as well as a roof footprint area which may be different from its ground level footprint.

Other physical objects such as a river or a mountain have a different set of spatially relevant qualities. A river has a volume of space it occupies in three dimensions, a surface area and a footprint in two dimensional space. Its channel has a cross sectional area, a width, and a depth. The river may have a depth that is different from the depth of its channel. A mountain also has a volume that the materials making up the mountain (soil, rocks, etc.) occupy in three dimensional space. It has a footprint projected downward on a two dimensional surface, its sides have an area and its peak has a height. Again, in a given domain ontology, not all of these different spatial qualities are relevant. On the ontological treatment and delimitation of landforms, the work of Mark and Sinha (2006) suggests that "landforms may form continua and the land form classes may be based on perceptual factors."

Which ones of these spatial qualities are relevant for which object depends on the domain ontology. An architecture or mining ontology would look at space in a very different way from how a topographic ontology needs to consider space. As the aim of this work is to create a topographic ontology, we have to identify a set of spatial qualities relevant for topographic objects.

All physical topographic objects have a footprint – a projection onto a two-dimensional space that is relatable to one or more polygons in a GI data set. We express this in two ways, using Rabbit (a kind of controlled English developed and used by the Ordnance Survey) and OWL, the Web Ontology Language (McGuinness, and van Harmelen, 2004):

Rabbit: A physical topographic object has a footprint
OWL: All PhysicalTopographicObject HasFootprint Some Footprint

Since we are interested in space from a topographic point of view this two dimensional space is the Earth's surface – or rather a model of the Earth's surface given as a map projection. All physical topographic objects also have a height relative to their surroundings although, in case of a plain and a river, this height may be zero. All physical topographic objects also have a height above sea level. Some physical topographic objects such as rivers or buildings may have a depth (a negative height) relative to the height of the surrounding land. In fact, a building with levels both above and below ground and an embanked river or canal will have both height and depth. Some physical topographic objects, such as buildings also have other spatial qualities that are relevant to them, such as the length of their frontage, or the area of their roof. These other spatial qualities may or may not be relevant in topography.

Physical Topographic Objects could be divided up into three main categories: Water bodies (lakes, rivers, etc.), Land objects (for lack of a better term, such as mountains, plains, etc.) and Structures (buildings, bridges, etc.). The footprints of water bodies, land objects and structures may overlap and may include pieces of water area, land area or both (tidal areas). In natural language we would say: a lake is on a mountain. The mountain is an object and has a footprint. A lake is an object and has a footprint. The two footprints overlap because the material the mountain is made of is still present under the lake and because the mountain is a topographic unit. This way, "the lake is located on a mountain" relationship could be represented with the RCC8:Non Tangential Proper Part (Randell et al., 1992) relationship.

3.2 Non-physical topographic objects and Space

Not all topographic objects are physical. Some are non-physical topographic objects which are also called FIAT objects (Smith and Varzi, 2000) such as administrative units (districts, counties, parishes, etc.), settlements (cities, towns, villages, etc.) and informal named extents (e.g., 'The Cotswolds', local neighbourhood names, etc.). All these have a physical spatial region associated with them. This physical spatial region has a footprint. It has been suggested that it would be much easier to say that a county has a footprint and use spatial operators on that footprint, as we did with the physical topographic objects. However, a county is an administrative unit, which is an abstract concept, not a physical concept. It is not a two or three dimensional object and hence cannot occupy space on a two-dimensional surface. It would be ontologically wrong to say that an abstract concept spatially contains or spatially overlaps with another abstract concept. Instead, the concept of a spatial region is used to allow the abstract concept to have a footprint (spatial extent). A spatial region would then be defined as a physical piece of space with definable boundaries and with no height.

We admit that this is computationally intensive (and probably inefficient) when we have to operate on thousands of instances, therefore we accept an alternative solution: using a different relationship to relate Non-physical topographic objects to their footprint. We see this later solution as a creative compromise (or syntactic sugar (Marsolo et al., 2003)) that allows us to retain the conceptual subtlety of the domain while also keeping in mind the computational limitations encountered while working with large data sets.

So instead of saying:
Rabbit: A non-physical topographic object has a spatial region that has a footprint.
OWL: All NonPhysicalTopographicObject HasSpatialRegion Some SpatialRegion.
All SpatialRegion HasFootprint Some Footprint

We would say:
Rabbit: A non-physical topographic object has a related footprint.
OWL: All NonPhysicalTopographicObject HasRelatedFootprint Some Footprint

3.3 Land Cover, Land Use and Space

Land cover types, such as forest, field, meadow, and sand, are (more or less specific) groupings of vegetation and/or materials that are associated with a piece of land. Land use types (pasture land, industrial areas, etc.) are abstract concepts that reflect how a piece of land is used, and are similar to land cover type in that we consider them as qualities that Physical topographic objects (land objects) have. We do not consider that land cover and land use types are Physical topographic objects directly. Rather, we consider them as qualities (Marsolo et al., 2003) that Physical topographic objects (land objects) or Spatial Regions have. This is useful because while land use may change rapidly (go from pasture to residential in less than a year) land objects (mountains, cliffs) are much more stable in time (barring land slides and earth quakes). Also, the nature of a mountain does not change whether it is covered with a forest or a meadow. It is only the cover associated with it that is changing.

Hence, we could say that:
Rabbit: A Land object has a land cover type.
OWL: All LandObject hasLandCoverType Some LandCoverType.

One might also consider that is also possible for a land cover object to have its own independent existence. For example a forest (for example, the Ampfield Forest) as a topographic unit may be considered a land cover object that would have its own footprint. In this case, land cover may be represented as both a quality and an object. There is no conflict the two; they are merely different representational forms. Since Land Objects, Spatial Regions and Land Cover Objects have footprints, their qualities also become associated with their footprint, and hence it will be possible to express RCC spatial relationships with other objects that also have a footprint.

We are aware that first, the edges of land cover types or other land objects often do not have clear boundaries and addressing fuzzy boundaries will be necessary. Researchers have argued that modern approaches to geographic information have not been admitting this lack of definition and hence have been suffering from its shortcomings (Fisher and Wood, 1998).We also think that this may not need to be done at an ontological level alone: it might be best addressed in the data. The degree of fuzziness that needs to be modelled is domain dependent, therefore if addressing fuzziness in an ontology is necessary at all, it might be best be done in a separate ontology module. It is clear that the relationships between land objects (mountain) and land cover types (forest) are not one-to-one. This issue will be best addressed by incorporating it into a spatial relations ontology module, which we are in the process of building.

4. Conclusions

We have highlighted the need to consider topographic objects not only from a spatial but also from a semantic aspect. The ways in which non-physical topographic objects, land use and land cover may be modelled in a topographic ontology were explored. The findings of this paper will be implemented in a spatial entities ontology and used within the topographic ontology that is being built by Ordnance Survey

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