Journal of Research and Didactics in Geography (J-READING), 2, 5, Dec., 2016, pp. 51-62
DOI: 10.4458/7800-04

J - READING
JOURNAL OF RESEARCH AND DIDACTICS IN
GEOGRAPHY
homepage: www.j-reading.org

Rethinking Geo-Ontologies from a Philosophical Point of View

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Received: October 2015 – Accepted: January 2016

Abstract

This article is intended as a philosophical introduction to geo-ontologies, in response to their increasing diffusion within the contemporary debate, where philosophy plays a fundamental, though still unexplored, role. The first part is concerned with the analysis of geo-ontologies, underlining their general and specific aims, and distinguishing three different disciplinary contexts which make up the geo-informatics domain: informatics, philosophy and geography. Secondly, I analyze the importance of common sense conceptualizations and their ontological structures, the connection between ontology of geography and theory of spatial representation, in terms of geographical entities, borders, theoretical tools (such as mereology, topology and theory of spatial location) and the distinction between classical and non-classical geographies. Finally, the main contemporary geo-ontologies are classified, through the analysis of their main contents and distinctive features, in geomatics/topological/geometrical, physical/natural and human ontologies.

Keywords: Geo-Ontologies, Ontology of Geography, Informatics, Spatial Representations, Common Sense Conceptualizations

1. Introduction

This article is intended as a philosophical introduction to geo-ontologies, in response to their increasing diffusion within the contemporary debate, where philosophy plays a fundamental, though still unexplored, role. The first part is concerned with the analysis of geo-ontologies, underlining their general and specific aims, and distinguishing three different disciplinary contexts which make up the geo-informatics domain: informatics, philosophy and geography (§§ 1-5, 8). Secondly, I analyze the importance of common sense conceptualizations and their ontological structures (§§ 6-7), the connection between ontology of geography and theory of spatial representation, in terms of geographical entities, borders, theoretical tools (such as mereology, topology and theory of spatial location) and the distinction between classical and non-classical geographies (§§ 9-13). Finally, the main contemporary geo-ontologies are classified, through the analysis of their main contents and distinctive features, in geomatics/topological/geometrical, physical/natural and human ontologies (§ 14-18). As to proper content of the paper, I would like to underline my intellectual debt to Tambassi, Magro (2015) for §§ 1, 14-18, Smith, Mark (2001) for §§ 2-3, 5, 7, Geus, Thiering (2014) for § 6, Casati, Smith, Varzi (1998) for §§ 9-10, 12-13, Casati, Varzi (1999) for § 11.

2. Geo-ontologies

Over the last few years, the innovations in on-line cartographic visualization have created a revolution and many new applications have broken down traditional divisions between browsing and searching, thematic layers, web content, spatial processing and geographic datasets. Placed at the intersection between geographic computing and web-based information technology, these rapid developments cannot be precisely labelled by any single body of academic literature. A variety of terms is in use for one or another aspect of this domain: from *web mapping* to *neogeography*, *social cartography*, *geoweb*, *webGIS* or *volunteered geographic information*[1]. In this context, geographical and geospatial ontologies[2] are receiving a considerable attention in information technology area[3], due to four different factors:

- the growing diffusion of Geographic Information Systems (GIS);
- their use in different applications;
- the impulse of Semantic Web[4] in this research area[5];
- the demand systematization, cataloguing and mapping of geographic information.

The most general (and generally shared) aims of these ontologies are essentially three: accessibility (both for the scientific community and for general public), informativeness and completeness. Instead, the most specific goals reflect the point(s) of view of the community sharing the (specific) ontology and the particular aims for which ontologies are created. Geo-ontologies rarely propose conceptualizations aimed at describing the overall geographical domain, but only some specific geographical aspects. Moreover, in the same ontology, there might be elements belonging to different geographical branches, incomplete inventories, vague distinctions and conceptualizations created by non-professional geographers in which common sense plays a central role, making a rigid and unambiguous classification of these ontologies complicated.

But what does ontology mean in this domain? What are its main objectives? What are the philosophical problems arising from geo-ontologies? What are the philosophical tools used for supporting them? How can we classify the contemporary geo-ontologies?

3. Informatics

In the computer and information science domain, the aim of ontology is to describe the results of eliciting ontologies from information systems, database specifications, and so on, in order to represent the information they receive and make explicit the conceptualizations. So, in information science context, ontology coincides with knowledge-representation and must be distinguished from the philosophical domain, in which the discipline is concerned with what exists, not only in terms of representation.

We engage with the world from day to day in a variety of different ways. Each of these ways of engaging with the world, we shall now say, involves a certain conceptualization. What this means is that it involves a system of concepts and categories which divide up the corresponding universe of discourse into objects, processes and relations in different sorts of ways. These conceptualizations are often tacit, that

[1] Cfr. Afferni and Tambassi, 2016. About this fast-moving field, see Turner, 2006; Goodchild, 2007; Boll, 2008; Hudson-Smith, 2008.
[2] Cfr. Mark, 1993; Frank, 1997; Smith and Mark, 1998; Bittner and Winter, 1999; Rodríguez et al., 1999; Bishr and Kuhn, 2000; Câmara et al., 2000; Frank, 2001; Kuhn, 2001; Rodrìguez and Egenhofer, 2004; Visser, 2004; Kavouras et al., 2005; Janowicz, 2006; Euzenat and Shvaiko, 2007; Buccella, Perez and Cechich, 2008.
[3] Cfr. Abdelmoty, Smart and Jones, 2005; Ressler, Deam and Kolas, 2010; Battle and Kolas, 2012; Perry and Herring, 2012; Kyzirakos, Vlachopoulos, Savva, Manegold and Koubarakis, 2014.
[4] Cfr. Berners-Lee, Hendler and Lassila, 2001.
[5] Cfr. Khun, 2005.

is, they are often invisible components of our cognitive apparatus, which are not specified or thematized in any systematic way. But tools can be developed to render them explicit (to specify and to clarify the concepts involved and to establish their logical structure) (Smith and Mark, 2001, p. 593).

In this way, ontology might be understood as "a neutral and computationally tractable description or theory of a given domain which can be accepted and reused by all information gatherers in that domain" (Smith and Mark, 2001, p. 594). It starts with conceptualizations and goes to a description of corresponding domains of objects (or closed world data models), putting various information together (reuniting different scientific domains), resolving terminological and conceptual incompatibilities, specifying the (most general) concepts used and rules of inference within different domains, and constituting an essential tool in data integration and semantic interoperability between software applications. Furthermore, ontology might also be identified as "a dictionary of terms formulated in a canonical syntax and with commonly accepted definitions designed to yield a lexical or taxonomical framework for knowledge-representation which can be shared by different information systems communities". More formally, an ontology is a theory "within which not only definitions but also a supporting framework of axioms is included (perhaps the axioms themselves provide implicit definitions of the terms involved)" (Smith, 2004, p. 158).

4. Philosophy

From a philosophical point of view, the term "ontology" has a generally shared meaning, at least in the analytic area, denoting a philosophical discipline concerned with the question of *what entities exist*, a task that is often identified with that of drafting a complete and detailed inventory of the universe. In this way, ontology is described as the science of being, that is the discipline that, using logical and empirical methods, focuses on the totality of (kinds of) entities "which make up the world on different levels of focus and granularity, and whose different parts and aspects are studied by the different folk and scientific disciplines" (Smith, 2004, p. 158). In the analytic area, it is also common to think of ontology as a proper part of metaphysics (that part that has to do with what there is), and to consider ontology in some way prior over metaphysics. Ontology aims at establishing *what there is*, whereas metaphysics is the study of *what it is*, seeking to explain the ultimate nature of the items included in the inventory (and their necessary characteristics), and the reasons why there is what there is. More precisely, one must first of all figure out what (kinds of) things exist (or might exist); "then one can attend to the further question of what they are, specify their nature, speculate on those features that make each thing the thing it is" (Varzi, 2006, p. 408)[6].

5. Ontology and scientific disciplines

Thus, ontology presents itself as an investigation of the ontological commitments or presuppositions embodied in different scientific theories and common-sense domain, and as an analysis of the categorial and hierarchical structure of reality. The latter aspect specifically regards the basic constituents of reality (entities such as objects, properties, relations, events, processes, etc.), and the structural relationships among them. Consequently, the connection between ontology and (the results of different) scientific and social disciplines has been increased towards two directions. On the one side, this improvement has allowed to make explicit the assumptions and the ontological commitments of these non-philosophical disciplines. On the other side, it has lead to a proliferation of regional ontologies[7], aimed at providing an inventory of what there is within the domain of each specific discipline. The non-reductionist hypothesis embraced by these ontologies is that the (fundamental) entities

[6] Obviously, the close interdependence between these two disciplines makes a partition of the respective goals very difficult: it is not clear how to establish what there is without say what it is (cfr. Ferraris, 2008, pp. 16-7; Bianchi and Bottani, 2003). Nowadays, there is much debate on the disciplinary distinction between ontology and metaphysics, however there is no high agreement about how to draw such a distinction (cfr. Berto, 2010).

[7] Cfr. Ferraris, 2008.

postulated by different disciplines are irreducible to the entities postulated by other disciplines, providing a specific (or sectorial) inventory of what exists, deserving a specific and separate study, and increasing our explanatory resources[8].

6. Geography

Among regional ontologies, the ontology of geography owes its development primarily (but not exclusively) to the pioneeristic works of Roberto Casati, David Mark, Barry Smith and Achille Varzi. According to Smith and Mark, the aim of this ontology is to analyze the mesoscopic world of geographical partitions in order to:

- establish whether and what kinds of geographical entities exist;
- determinate how they can be defined and classified in an ontological system which gather them together;
- argue whether and how the geographic descriptions of reality emerging from common sense can be combined with descriptions derived from different scientific disciplines.

> Mesoscopic geography deals mostly with qualitative phenomena, with phenomena which can be expressed in the qualitative terms of natural language; the corresponding scientific disciplines, in contrast, deal with the same domain but consider features which are quantitative and measurable. GIS thus requires methods that will allow the transformation of quantitative geospatial data into the sorts of qualitative representations of geospatial phenomena that are tractable to non-expert users—and for this [...] we need a sound theory of the ontology of geospatial common sense. […] One of the most important characteristics of the geographical domain is the way in which geographical objects are not merely located in space, but are typically parts of the Earth's surface, and inherit mereological properties from that surface (Smith and Mark, 2001, p. 596).

[8] For an analysis of the proliferation of ontological researches in analytic area, see Martin and Heil, 1999. For a classification of the contemporary (philosophical) ontologies, see D'Agostini, 2002; Runggaldier and Kanzian, 1998; Varzi, 2005.

7. Common sense geography

In this sense, the study of the ways non-experts have conceptualized given domains of reality might help to maximize the usability of corresponding information systems, rendering the results of work in geospatial ontology compatible with the results of ontological investigations of neighboring domains (hanging them together) and yielding robust and tractable standardizations of geographical terms and concepts (Smith and Mark, 2001, p. 595). As a result, common sense geography (CSG) became a topic of discussion in the final decades of the last century when software developers tried to design virtual spaces which were designed according to objective parameters which differ from human sensation and experience. But, what do we intend when we speak of CSG? In *Common Sense Geography and Mental Modelling: Setting the Stage* Klaus Geus and Martin Thiering sketch some of its features, which might be resumed as follow. CSG:

- denotes the ways non-experts conceptualize geography in terms of beliefs, theories and knowledge;
- concerns the belief about general regularities in the mesoscopic domain and the consensus of an epistemic collective or community (so, it is to be understood as "shared" knowledge and beliefs);
- refers to a "naïve" perception and description of space and the use of "intuitive" arguments in geographical contexts;
- is transparent to reality and accessible also for non-expert users;
- consists of naïve physics, folk psychology and it is strictly related to (physical-geographic) mesoscopic phenomena that is quite independent from our knowledge and culture, and immediately accessible to human beings in everyday perception and actions;
- has been and for the most part still is dismissed at best as a sort of pre- or sub-scientific "knowledge";
- denotes a "lower" geography, to be distinguished from "professional" or "higher" geography, that is, the phenomenon of the spread and application of geographical

knowledge outside of expert circles and disciplinary contexts.

8. Ontological structure

CSG is generally organized in terms of categorical systems of objects falling under categories, typically determined by prototypical instances. Usually, these systems are organized hierarchically in the form of a tree (they have only one all-embracing category), "with more general categories at the top and successively more specific categories appearing as we move down each of the various branches" (Smith and Mark, 2001, p. 601). Deviations from the tree structure are occasionally proposed, for example systems which do not have one all-embracing category but a collection of trees (a forest).

> The primary axis of a folk ontology is its system of objects. This holds, too, in the realm of geospatial folk categories. The attributes (properties, aspects, features) and relations within the relevant domain form a secondary axis of the ontology, as also do events, processes, actions, states, forces and the like. The system of objects remains primary, however, because attributes are always attributes of objects, relations always relations between objects, events always events involving objects, and so forth, in ways which imply a dependence of entities in these latter categories upon their hosts or bearers in the primary category of objects (Smith and Mark, 2001, p. 601).

Finally, the basic categories are identified on empirical and cognitive grounds, play a special role in common-sense reasoning, and represent a theoretical compromise between two different aims: cognitive economy and informativeness – regarding the latter point, the notions of explanation and causality play a fundamental role.

9. Ontology of geography

Schematically, ontology of geography might be defined as that part of the philosophical ontology which studies, in particular:

- geographic entities (entities such as mountains, oceans, countries, etc.);
- their borders (natural and/or artificial, regardless of the fact that these boundaries might be part of the entities they define);
- their spatial representation (in maps, software, etc.);
- their mereological and topological relations;
- their location.

10. Geographic entities

Therefore, the starting point is to define what geographical entities are, exhibiting their conditions of existence, individuation and persistence, and their criterions of (synchronic and diachronic) identity. Then, it is essential to determine what (geographic) entities have to be included as fundamental, and establish whether we should include only geographical-physical entities (mountains, rivers, deserts, etc.) in our ontology or whether we should also add artifacts produced by human geography (entities like socioeconomic units, nations, cities and so on). In this regard, Casati, Smith and Varzi distinguish three main different positions on the existence of geographic objects:

- *strong methodological individualism* – there are "only people and the tables and chairs they interact with on the mesoscopic level, and no units on the geographic scale at all";
- *geographic realism* – "geographic entities exist over and above the individuals that they appear to be related to and have the same ontological standing as these";
- *weak methodological individualism* – if geographic units exist, "then they depend upon or are supervenient upon individuals. One form of this position would accept both individuals and the behavioural settings in which individuals act. Larger-scale socio-economic units would then be accounted for in terms of various kinds of connections between behavioural settings" (Casati, Smith and Varzi, 1998, p. 79).

11. Borders

A criterion for the individuation of an (autonomous) geographical entity is the possession of boundaries, which "give rise to a number of ontological conundrums and may themselves be difficult to individuate" (Casati, Smith and Varzi, 1998, p. 78). It is possible to distinguish two main different types of borders or boundaries:

- *bona fide boundaries*, sometimes fuzzy or indeterminate and corresponding to qualitative physical differentiations or spatial discontinuities in the underlying territory (coastlines, rivers);
- *fiat boundaries*, corresponding to human-demarcation-induced borders.

Correspondingly, we distinguish between fiat and bona fide objects depending on whether their boundaries are of the fiat or bona fide sort. [...] Most examples of fiat objects in the geographic world are correlated with two-dimensional regions on the surface of the globe. Examples of three-dimensional fiat objects are provided by the subterranean volumes of land to which mineral rights have been assigned, and also by the sectors and corridors in space established for the purposes of air traffic control. These may be quite complicated three-dimensional worms; they may intersect each other and they may have holes. On the other hand, insofar as an object whose boundary is not entirely of the bona fide variety counts as a fiat object, many ordinary geographic entities, such as mountains, will also qualify as three-dimensional fiat objects. This is because the line which separates mountain and valley is a fiat line only (in fact a collection of fiat lines). (Casati, Smith and Varzi, 1998, p. 79)

12. Spatial representation

Geographical ontology also includes the examination of the theoretical tools that are required for the purpose of developing a formal theory of spatial representation (comprehending the modality through which a cognitive system represents the spatial world and its structure), with special reference to spatial phenomena on the geographic scale (in which ontological and empirical considerations are strictly connected).

A good theory of spatial representation must be combined with (if not grounded on) an account of the sorts of entity that may enter into the scope of the theory, an account of the sorts of entity that can be located or take place in space—in short, an account of what may be collected under the rubric of *spatial entities* (as opposed to purely *spatial items*—as we shall say—such as points, lines, or regions). What is their distinguishing character? What special features make them spatial entities? How are they related to one another, and exactly what is their relation to space? On the methodological side, the issue is the definition of the basic conceptual *tools* required by a theory of spatial representation, understood as a theory of the representation of these entities. There may be some ambiguity here, due to a certain ambiguity of the term 'representation'. We may think of (1) a theory of the way a cognitive system represents its spatial environment (this representation serving the twofold purpose of organizing perceptual inputs and synthesizing behavioral outputs), or (2) a theory of the spatial structure of the environment [...]. The two notions are clearly distinct. Presumably, one can go a long way in the development of a cognitive theory of type 1 without developing a formal theory of type 2, and vice versa. However, both notions share a common concern; both types of theory require an account of the geometric representation of our spatial competence before we can even start looking at the mechanisms underlying our actual performances (Casati and Varzi, 1999, pp. 1-2).

13. Mereology, topology, spatial location

In order to enhance such theory, geo-ontological analysis has developed three main theoretical tools strictly interconnected and mutually interactive: mereology, topology and theory of spatial location. Mereology[9], in general, might be understood as a theory constructed around the relation of "is a part of". It also includes some temporal parameters, in order to specify the criteria of identity for the geographical entities and their constitutive parts. Topology[10] (and its own different branches) provides a systematic description of the basic spatial relations among different geographical entities (for example, connection, overlapping, containment, distance, separation, discontinuity and so on). Accordingly, it examines notions like boundary and border, their spatial and temporal relations, and their relationships with

[9] See also Simons, 1987; Smith and Mark, 1998; Casati and Varzi, 1999; Mark, Smith and Tversky, 1999.

[10] See also Smith, 1994, 1995, 1996.

the entities they connect and circumscribe (in this sense, topology is also strictly related to geometry and morphology)[11]. Finally, theory of spatial location investigates the relation between geographical entities (i.e. objects, events, relations, and so on) and the regions of space they occupy or in which they are located. This relation is not one of identity – a geographical entity is not identical with the spatial region it occupies, besides two or more different geographical entities can share the same location at the same time – and does not imply that any single geographical entity is located somewhere, or that any spatial region is a region at which something is located. Moreover, this also means choosing between absolutist and relational theories of space. The former maintains that the space exists as an independently subsistent individual (a sort of container) over and above its inhabitants (objects, events and spatial relations between objects and events, or without all these entities[12]). On the contrary, the latter considers that spatial entities are cognitively and metaphysically prior to space: "there is no way to identify a region of space except by reference to what is or could be located or take place at that region" (Casati and Varzi, 1999, p. 1).

14. Classical and non-classical geographies

Another key point for a complete theory of spatial representation is to specify the difference between classical and non-classical geography. According to Casati, Smith and Varzi, this distinction presents some specific difficulties stemming from the fact that there is no single universally recognized formulation that precisely indicates what classical geography is. To obviate such difficulties, the three authors characterize a geography on a region *R* as a way of assigning (via the location relation) geographic objects of given types to parts or sub-regions of *R*. Then, they propose to put forward "some principles for a minimal characterization of geographic representation, and which are such that the violation of one or other of them produces intuitively incomplete representations" (Casati, Smith and Varzi, 1998, p. 84). In other words, it means to define a list of axioms in order to characterize classical geography and, therefore, to outline non-classical geographies excluding one or more of those axioms and/or adding others.

On these presuppositions, the three authors uphold that "the term 'classical geography' does not carry any normative claim. It simply describes a rather robust way of *tiling* regions in the presence of certain general constraints" (Casati, Smith and Varzi, 1998, p. 84). These constraints specify that every single geographic entity (nations, lakes, rivers, islands, etc. but also mereological combinations of these entities) is located at some unique spatial region and every spatial region has a unique geographic entity located at it. Consequently, a geography can be considered as "non-classical" if it excludes one or more of the previous axioms or adds axioms to those of classical geography. For example, to deny that every geographical entity is located at some unique region allows to include also non-spatial geographical entities, entities with multiple location or duplicates of the same geographical entity. Again, to discard that every spatial region has a unique geographic entity located at it allows to consider maps with regions that are assigned no entity, or two or more competing units. Finally, we can also obtain a non-classical geography, adding other axioms. For example,

> an axiom to the effect that all geographic units are connected. We might finally consider how the properties of geographic boundaries relate to the axioms of classical geography. We shall say that a boundary is geometrically two-sided if it divides two adjacent units. In a classical geography, the geometric two-sidedness of any boundary is secured by the completeness of the tiling. This is no longer the case if non-classical geographies are considered. For instance, in a gappy geography the boundaries of objects at the edges of non-assigned zones will be one-sided only. And so, in a glutty geography, will be the boundaries of objects at the edges of zones assigned to more than one object (Casati, Smith and Varzi, 1998, p. 85).

[11] For an analysis of the connection between mereology and topology, see Smith, 1995. For an analysis of the relation between the notions of topology and border, see Smith and Varzi, 1997; Casati, Smith and Varzi, 1998.

[12] Moreover, we can also conceive objects and events in terms of predicates assigned to corresponding spatial regions.

15. A possible classification

In order to provide a classification of contemporary geo-ontologies, we might distinguish between three different kinds of ontologies, depending on their main contents:

- geomatics/topological/geometrical ontologies (GTGO);
- physical/natural ontologies (PNO);
- human (HO) ontologies.

The aim of this classification is to guide the reader through the main geo-ontologies of the contemporary debate, analyzing their fundamental, common and distinctive features, and showing the overlaps between different geographical domains. Obviously, the list is not complete and includes the most discussed, reused[13] and quoted geo-ontologies, together with some non strictly geographical ontologies in which some geographical aspects are described.

[13] "Paraphrasing the general understanding of reuse in adjacent engineering disciplines ontology reuse can be defined as the process in which existing ontological knowledge is used as input to generate new ontologies. The ability of efficiently and effectively performing reuse is commonly acknowledged to play a crucial role in the large scale dissemination of ontologies and ontology-driven technologies, being thus a pre-requisite for the ongoing realization of the Semantic Web. Firstly, being reusable is an intrinsic property of ontologies, originally defined as means for 'knowledge sharing and reuse'. Sharing and reusing existing ontologies increase the quality of the applications using them, as these applications become interoperable and are provided with a deeper, machine-processable and commonly agreed understanding of the underlying domain of interest. Secondly, analogously to other engineering disciplines, reusing existing ontologies, if performed in an efficient way, reduces the costs related to ontology development, because it avoids the re-implementation of ontological components, which are already available on the Web and can be directly – or after 41 some additional customization – integrated into a target ontology. Furthermore, it contributes to an enhancement of the quality of the ontological content, which is by reuse continuously revised by various parties", and to an mutual understanding between different communities, and integration and aggregation of data and information (Pâslaru-Bontaş, 2007, pp. 41-42).

16. Geomatics, topological and geometrical ontologies

GTGO are related to the computational processing of geographical data in GIS, GPS and maps, and are generally aimed at analyzing (spatially) Earth's surface, locating (coordinates) and representing different geographic entities on maps, specifying the topological relations between these entities (disjunction, intersection, overlapping, inclusion, etc.) and the geometric aspects of geographical investigation (elements like points, areas, solids, taxonomies, concepts, implicit and explicit geometries and so on). A common feature of these ontologies is the high frequency of their (total or partial) reuse in other ontologies. This usage is not surprising: the possibility of locating points, lines and surfaces on a map is, in general, a recurring feature of geo-informatics ontologies and a widespread need in many of their applications. Some examples of GTGO are: OGC GeoSPARQL, Spatial Schema – ISO 19107, Spatial referencing by coordinates – ISO 19111, Schema for coverage geometry and functions – ISO 19123, Geography Markup Language (GML) – ISO 19136, WGS84 Geo positioning, Geometry (Ordnance Survey), Spatial Relations (Ordnance Survey), NeoGeo Geometry Ontology, NeoGeo Spatial Ontology and Geometria (Spanish GeoData).

17. Physical and natural ontologies

PNO are focused on those Earth aspects that are related to physical and natural phenomena (i.e. lithosphere, hydrosphere, atmosphere, pedosphere, biosphere, geomorphology, climatology and so forth), are numerically inferior to the GTGO and strictly connected with the HO. Specifically, among PNO, GEOSP – Geospecies represents the partitions of Earth's surface in different ecozones in order to describe geographical distribution of living species, define their habitats and gather information about them. NDH Ontology (USGS) and Hydro Ontology (Spanish GeoData) are aimed at mapping the hydrological systems, respectively, of United States and Spain, connecting them with some morphological elements. Sweet (Semantic Web for Earth and Environmental Terminology) Ontologies describe some aspects of Earth's geospheres, cryosphere, heliosphere, atmosphere, hydrosphere, land surface, ecological and physical phenomena, as well as their representations and transformations over time.

18. Human ontologies

HO deal with dynamics (for example, historical and temporal modifications) and artifacts produced by political, administrative, social, urban, economical, population, cultural (heritage), archaeological, historical, tourism, transportation geography, and so forth. The ontologies related to human geography constitute a numerically significant subgroup of the overall analyzed ontologies. This prominence is probably due to two different factors: the heterogeneity of the areas of research involved and the fact that, being closely related to human activity, they are mainly influenced by its organizing action. Their specificity, however, does not coincide with their reuse, that is generally lower than other ontologies. Some examples of HO are: FAO Geopolitical Ontology, INSEE, Landinndelingen i Norge, The administrative geography and civil voting area ontology (Ordnance Survey), Geopolitica (Spanish Geodata), Vocabulario de Localizaciones, Postcode (Ordnance Survey), ISA Programme Location Core Vocabulary, Transportes (Spanish GeoData) and NUTS (Nomenclature of territorial units for statistics).

19. Other ontologies

Erlangen CRM/OWL, Proton, LinkedGeoData, The Place Ontology, US Topographic and GeoNames need a separate discussion. Some of them are parts of larger projects, where geography is only one of the different aspects analyzed. Almost all of these ontologies range transversely across the three geographical domains just identified (GTGO, PNO and HO), and propose geographical conceptualizations attempting to bring these domains together (without claiming to be complete). Regarding the geographic domain, they endorse physical, natural and human features, to the detriment of geometric and spatial aspects. In this sense, the multiplicity of geographical domains which have been analyzed and their own different aims make the inclusion of these ontologies in the suggested classification difficult.

20. Conclusion

The purpose of these pages was to sketch a philosophical introduction to geo-ontologies, circumscribing their domain, outlining the main ontological issues and tools, and suggesting a classification of the contemporary geo-ontologies focused on the geographical contents involved. Obviously, it is possible to propose other classifications, for example by highlighting the different ontological structures and systematizations of the entities involved, or by specifying the geography (classical or non-classical) or the conceptualizations (common sense or non-common sense) which lie behind these ontologies. Hopefully, the progressive synergy between geography and information technology will provide the guidelines for a more precise classification, in which the development of geo-ontologies will follow different sub-disciplines within the same geography.

Acknowledgements

This paper was supported by a fellowship at the Research Institute of the University of Bucharest (ICUB). Thanks are due to Raffaella Afferni, Maurizio Lana, Giulia Lasagni, Diego Magro, Cristina Meini and Cristina Travanini for providing comments and feedback, and for their invaluable support.

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