Foreword

WORLD-WIDE ONTOLOGY FRAMEWORK

A Universal Ontology of Geographic Space is about a single global ontology of geographic space, about a unified ontology of spatial planning and spatial analysis, thinking and reasoning, about a universal semantic reference system of geographic space, and about a semantic interoperability framework for geospatial information. Let's indicate first the base things, definitions, primary meanings, and key descriptions of kinds and types; namely, what a global ontology is, what a geographical space means, how they are interconnected, or what the geographical space ontology, semantics, and space syntax stand for.

Nowadays, "ontology" is loosely used to mean almost everything: controlled vocabularies, glossaries and data dictionaries, thesauri and taxonomies, schemas and data models, domain models, formal ontologies, rule inference systems, and what not.

Global Ontology, domain ontologies, semantic models, and unified data schemas are all the rage and furor in the information sciences and computing technologies. And many just try to follow the latest fad, without going into its depth and breadth. The volume is unique in that it reminds where the roots and sources of ontologies are coming from, universal, global, foundational ontology, the source of all sorts of domain theories and applied ontologies. In the Reality book (Reality, Universal Ontology and Knowledge Systems, IGI Global, 2008) it's explained that the Global Ontology not just a matter of feasibility or worth, but an ultimate object of quest for fundamental knowledge. We proposed to think of philosophical global ontology as putting the universe in the human heads. Hence the formal global ontology is putting the world in the computing machines, the internet, and the World Wide Web, thus structuring the whole digital world and bridging it with the physical counterpart.

We advanced an integrated/federated modeling schema:

A Federated/Integrated Ontology = A Global/Universal Ontology + Domain Ontologies.

All the world representation is distributed between a central ontology (maintaining a global schema, general semantics, and common interoperability framework) and multiple regional ontologies with own local schemas and specific information sources. One can merge ontologies of different schemes, languages, scope, degree, granularity in several ways, like the different cultures in a society: (a) multiculturalism (multi-ontologies, loose and free as birds, like a bottom-up folksonomy, a people's taxonomy); (b) melting pot (mixing and amalgamating ontologies); (c) monoculturism (absorbing all the numerosity of ontologies into a single whole); (d) core culture (Leitkultur, a top-bottom globally federated ontology).

So, a global/universal ontology is about generic standards, structures, rules, policies, procedures, and processes applied globally and locally. It provides a comprehensive, consistent, converging and merging holistic framework, for specific theories, models, and strategies.

As distinguished convergence trends, take a look at the current effort to unify Science, Arts, and Technology. Look at all sorts of technology convergence, the interlinking of information technologies, computing, media technology and content, and telecommunication networks, which is hardly possible without a common interoperability framework, 'a world-wide ICT ontology.' And the most disruptive converging technology is the Future Internet, a Single Global Network, merging and converging all the world's multimedia, systems, networks, infrastructures, facilities, and communities and emerging as the Internet of Things, Knowledge, and People, the critical contribution to a Smart Sustainable World (a keynote at CIT 2011, *The 11th IEEE International Conference on Computer and Information Technology*).

GEOGRAPHICAL SPACE, GEOGRAPHY, AND GEO-ONTOLOGY

Here is a hierarchy of spaces, ontological space > physical space > geographical space > regional space > urban space > building space. As a complex form of ontological space, geographical space, the Earth surface extent and continuum, defies a clear definition and transparent classification, as much as the natural resources taxonomies of origin, development stage, renewability, availability, or distribution.

Al in all, there are abstract geographical space and concrete geographical space; land space, airspace and water space; territory, region, urban space, and building space; open space and private space; the natural environment and the built environment, and, of course, the digital space, geo cyberspace, or the virtual world.

The cyberspace, with such tools as a geospatial information system, GIS, and the knowledge field as geographic information science, GIS, digitally represents Earth's spatial areas, presenting all types of spatial information, all sorts of geographically referenced data, by converging topography, cartography, geostatistical analysis, spatial analysis and database technologies. It allows a new type of geography, *web geography*, to view the GIS data over the Internet, generating all sorts of web mapping services, web cartography, real-time web maps, and mobile web mapping, with animation, interactivity, usability, and multimedia integration.

The traditional field of study of geographic space is geographics, or *geography*, studying the Earth's surface, its shape, and features, including the human environment and the natural environment. Geography is traditionally parted as *human geography* and *physical geography*. The *physical geography* focuses on the natural landscape or physical spaces, domain areas, or spheres, such as lithosphere, hydrosphere, atmosphere, pedosphere, and biosphere. The *human geography* is about spatial interactions of humans and the physical environment, with the following key aspects, economic, political, social, cultural, and human, and the subfields: economic geography, political geography, social geography, cultural geography, etc.

Now the spatial interrelationships between the human world and the natural world are covered by the new inter-science, Environmental Geography, developing a dynamic holistic conceptualization of the total environment, with such progressive research areas as sustainability, environmental management, political ecology, or emergency management.

Mapping of geo-spaces is performed by *topography* and *cartography*; the regulation and management of space use, by *spatial planning*, whereas *geostatistics* is dealing with spatiotemporal datasets and spatial networks analysis, *architecture and design*, how beautifully and efficiently organize space, *geomatics* as geographical informatics. How to develop the land space, meeting all specific codes, standards, policies, and principles, is done by *applied geography*, which is mostly concerned with the spatial planning of regions, cities, towns, and rural areas, such as regional planning, urban planning, land use planning, transport planning, community planning, economic planning, and environmental planning. Now it is to emerge an integrated framework of *global geo-ontology*, the fundamental base of *environmental geography* and all its parts and applications, *studying the geographic reality (whole) of the Earth and human world, with the constituent parts of geographical entities and spatial interrelationships.*

GLOBAL GEO-ONTOLOGY AND ONTOLOGICAL GEO-SPACE: AN N-DIMENSIONAL GEO-SPACE

A comprehensive, strategic spatial planning, integrating global spatial planning systems, land use planning, urban planning, regional planning, natural resources planning, social planning, economic planning, and environmental planning, implies a multidimensional mixed geographical space, real and virtual, or ontological geo space.

To effectively represent the geo entities in the world/geographical space the developers need a unifying ontological theory capable to secure the unification of 3D (where) and 4D (where-when) approaches; to afford the adequacy of geo world representation and reasoning; and to allow for the integrity of web data semantics. Such a global theory of things and resources, physical and digital, implies an abstract state space approach, where the geographical space-time continuum is a key part of the whole entity framework.

As far as everything has properties [substantial, qualitative, quantitative, dynamic, or relational], there is the *Ontological State Space (OSS)* marked by a number of fundamental dimensions (N) such as space (3D), time (1D), specific physical quantities, and qualities, each of which is endowed with a certain metrical (topological) structure.

This implies that any geographical entity (sea, land, city, Earth) has its history (biography, trajectory) within the N = (4D + n) state space dimensions, each distinguished by its specific beginnings, stages, endings, or boundaries.

Having constructed the OSS affords us not only the most efficient mapping of the world's content, dynamics and relationships, but also the general reasoning mechanisms (or real logic rules) over its representations, changes, processes and geo relations.

Basing on the ontological space state construct, one can model the knowledge representation and reasoning as a cognitive space, encompassing all sorts of quality spaces, logical spaces, or attribute spaces.

Again, one can now construct the whole Web as an abstract information/knowledge space of interrelated resources, marked by the URI identifications, representation of resources states, and interactions of resources and semantic agents in the Web space—the major design constituents of the web's architecture. At last, one can infuse real substance into current SW languages, just formal and logical inconsistent schemas, employing some healthy ideas from the set theory, formal logic, or natural language, like the RDF triple overriding the grammatical subject-verb-object sentence structure, or OWL modeling or meta-modeling, trying to describe the web content with the empty constructs of classes, properties, values. Since, in its substance, the Web concerns with the comprehensive dynamic modeling of reality (all that exists and changes). One needs to revamp the formal SW schemas and languages with a real world-centric ontology, concordant with all manner of conceptual models, theories, and schemas, in order to uniformly represent the geographical information about the world, its data meaning.

INTEROPERABILITY

Interoperability is a critical idea needing depth and breadth and common foundation framework. Its extent or scope is as wide as railways, public safety, government, telecommunications, medical industry, business, and software. Its depth as different as physical interoperability, business process interoperability, computing interoperability, information interoperability, syntactic interoperability, semantic interoperability, or conceptual interoperability; or industrial, national, international, or global interoperability.

In general, Interoperability implies common standard, formats, categorizations and integration, unifying models and schemas, like as the software interoperability—the same data formats, the same communication protocols, and the same binary codes.

The General Interoperability Framework, GIF, looks closely connected with a world/domain reference model as common foundation ontology. What ideally makes an all-purpose world model/schema providing the foundation basis for specialized domains as well as supporting various forms and levels of interoperability, technical, semantic, or ontological.

Thus anything: product, system, agent, service, network, or technology, to be interoperable must be compatible with the same standard, ideally, with a standard ontology reference framework. For example, for the information exchange interoperability, there are nation-level programs as EU Interoperability Framework, USA NIEM, or UK e-GIF.

Take the US National Information Exchange Model: "It is designed to develop, disseminate and support enterprise-wide information exchange standards and processes that can enable jurisdictions to effectively share critical information in emergency situations, as well as support the day-to-day operations of agencies throughout the nation."

Its syntactic operability is to be achieved by using the XML Schema data model, constructs, and methods, seemingly, thus supporting existing "legacy systems", across all levels of the Government, federal, state, and local.

However, the issue of issues is how to achieve computable Semantic Interoperability, among any and all communicating entities, legacy ones or not. Seemingly, it's only by developing the GIF implying a standard system of entities and relationships, providing the semantic basis (meaning exchange/interpretation standards and processes) for more specialized domains and fields and applications. Given that, to obtain the General Semantic Interoperability standard, costing hundreds billions per year, means to develop a single world reference model, of which the global geo ontology is the foundational part.

PLANETARY GEO-SPACE APPLICATIONS: ENVIRONMENT INFRASTRUCTURE

The Earth/Environment Monitoring and Measuring Networks Infrastructure is under active development, including seismic monitoring, tidal monitoring, meteorological monitoring, and fluviometric monitoring networks, as well as GNSS, EOS, Geodetic benchmarks, and Geospatial Data Infrastructure. But it needs a dynamic integration of data, processes and functions, leveraging the WWW as a global data space with its new applications as social networking sites oriented data space communities and enclaves.

As such, it the global geo ontology could be a roadmap strategy for the most innovative solutions to emerging global problems. Take our current unsustainable world plagued with all sorts of threats, risks and crises; namely, a critical sample of the global schema, the Global Risk Model: Since 2004, the World Economic Forum has been producing Global Risk Network Reports and Risk Interconnection Maps, seeking to systematize global threats (now numbered as 37 risks) under several broad categories, Economics, Geopolitics, Environment, Society and Technology, but without any big success to predict them.

One of the principal reasons why the big threats, as financial (the current deep economic recession), technological (the Japan ongoing nuclear crisis), environmental (the catastrophic oil gush in the Gulf of Mexico), geopolitical (the Arab revolutions) could not be predicted is the lack of the Global Risk Management Ontology, describing and monitoring global challenges by systematically organizing all possible planetary risks, with their location, scale, causes, impacts, effects, costs, and preventive measures, political, economic, social, or technological.

ENVIRONMENTAL LESSONS

If it was a must at least a 3D Facility Information Model, acting on a generic GEO ontology, and successfully applied in the AEC industry, then the authorities and general public could know how to prevent and whom really to blame for the catastrophic oil gush in the Gulf of Mexico: The rig owner (Transocean, its safety systems and devices); the blowout preventer faulty design (Cameron Int); the cement contractor (Halliburton). As a result of lacking the FIM, now the public should observe their rows in the federal court, where BP is suing Transoceanic for $ 40b in damages, while the latter one goes against BP, HB, and many other companies and suppliers, with no visible end and use for the public. But the saddest result, it is all the suffering of simple people and bad disturbing of the ocean food chain. And it all comes by defaulting the ontology-driven Facility Information Modeling Systems.

Here is another technogenic disaster, the Japan's ongoing nuclear crisis, which could be prevented by following a simple mechanical geo-ontological ruling: "Japan is located in the earthquake zone. Nuclear power stations are banned in the earthquake zones. Japan is prohibited to have nuclear power stations."

Having developed the Global Geo-Ontology Reasoning System, the globe has never had the Fukushima nuclear accidents. And let's remember, the world has about 440 reactors, and most of them are risky, following different nuclear energy policies and safety standards. The price of the question (build or not to build a GLOBAL GEO-ONTOLOGY with its global applications) is too high, it's our future, the future of our children, the future of our world.

THE CONTENT

"Universal Geospatial Ontology for the Semantic Interoperability of Data: What are the Risks and How to Approach Them?" This chapter is both interesting and most fitting to the subject, studying a universal ontology-based semantic interoperability of heterogeneous geospatial data. The authors argue that universal ontology-based interoperability remains vulnerable to the semantic risks (misinterpretation) of geospatial data, discussing these risks and proposing a systematic approach. It is shown how the general framework can help make the appropriate decisions about the suspension or the continuation of interoperability process. The suggested framework contributes to the realization of efficient interoperability between information systems relying on universal geospatial ontology.

"Geographic Space Ontology, Locus-Object, and Spatial Data Representation Semantic Theory." Locus, object, and localization are viewed as the key ontological elements constituting geographic space. The links and relations between locus and object are mathematically formalized by geospatiology, the study of the logical role of space in the study of entities on the surface of the Earth. These three ontological components of the geographic space, the locus-object-localization, permits to product a conceptualized and formalized description of the Earth surface and can be integrated in GIS or represented in cartography or image processing mapping.

"Toward an Architecture for Enhancing Semantic Interoperability Based on Enrichment of Geospatial Data Semantics." In this chapter, the authors propose a conceptual architecture that focuses on enrichment of geospatial data semantics to support geospatial data semantic interoperability. The proposed conceptual architecture includes different modules, which implement different types of semantic enrichment methods that support various semantic interoperability tasks. Within the different enrichment methods, they argue for the role of global ontologies, and that global ontologies play a key role to improve semantic interoperability, illustrating with an application example.

"Geographical Process Representation: Issues and Challenges." This chapter discusses the issues and challenges arising while building a general spatio-temporal ontology for representing and reasoning about geographical processes, as part of a universal semantic reference system of geographic space. It also examines the foundations and formalisms upon which the development of such an ontological model of geographical processes can be based. The authors present a set of key desiderata for space, time, object, state, event, and process to develop a comprehensive spatio-temporal ontology of the geographic domain.

"Human Cognition: People in the World and World in their Minds." This chapter focuses on a universal ontology of geographic space in the context of the human cognition of spatial information and spatial representations from different cultural and temporal backgrounds. It outlines possible difficulties of designing a universal ontology describing geographic space on an interregional and global scale. Geographic space is simplified as a system of entities and actions while ontology is merely defined as the study of general classifications of things in the world, and of relationships between them.

"Representing Geospatial Concepts: Activities or Entities?" The author compares two diverging approaches, taxonomy-based and mereology-based ontologies, based on cases drawn from physical geography, transportation and hydrology. The differences in core concepts and tools are discussed in relation to universal ontologies of geographic space. It is argued that function representation in geospatial ontologies, in combination with structure-based concepts of geospatial entities, is both necessary and challenging. As a basis of study, a geographical space is taken as a system of entities and a system of actions, which perspective integration is planned in further research.

"Ontology Engineering Method for Integrating Building Models: The Case of IFC and CityGML." An intermediate unified building model is proposed that facilitates the mutual transfer of spatial information between the Industry Foundation Classes (IFC) and City Geography Markup Language (CityGML), as two heterogeneous semantic models for the representation of Building Information Models (BIM) and geospatial objects. A unified model is defined as a superset model that is extended to contain all the features and objects from both IFC and CityGML building models. The study is limited by a 3D city model, defined as a digital representation of the Earth's surface and the built city environment, while the AEC industry starts practicing a unified 5D city reference model.

"Semantically Enriched POI as Ontological Foundation for Web-Based and Mobile Spatial Applications." This chapter attempts at bridging the gap between universality and domain-specificity, presenting ideas on the development of an ontology for POI (Points-of-Interest) as part of a concrete spatial application running as web- and mobile system to support travel planning. This conceptual approach raised several questions concerning the domain dependence of the POI ontology on the one side, and universal aspects of the ontology on the other.

"Ontologies for the Design of Ecosystems." This chapter presents guidelines and experiences about the modeling and implementation of utility ontologies for the design of ecosystems, together with a case study. Utility ontologies are knowledge representations that include general concepts that most services need to use to represent spatial and temporal data. As examples of the formalization, three utility ontologies for the general concepts of address, calendar, and landscape have been presented, which are needed during the process of modeling ecosystems.

"Unified Rule Approach and the Semantic Enrichment of Economic Movement Data." This chapter suggests a methodology for semantic enrichment of spatial data resulting from economic behavior. The proposed methodology has a universal scope and could be applied to any behavior involving the movement of an entity for economic reasons. The proposed methodology has its foundations in an evolutionary approach and subscribes to the axioms of evolutionary ontology, with a focus on human activities in geographic space in terms of a unified rule system (knowledge) approach. The ontological, analytical, and theoretical propositions are applied to a data set of historical ship movements.

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