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Administrative Units, an Ontological Perspective

Francisco J. López-Pellicer, Aneta J. Florczyk, Javier Lacasta,
Francisco Javier Zarazaga-Soria, and Pedro R. Muro-Medrano

Department of Computer Science and Systems Engineering,
Centro Politécnico Superior, University of Saragossa,
María de Luna 1, 50018, Saragossa, Spain
{fjlopez,florczyk,jlacasta,javy,prmuro}@unizar.es
http://iaaa.cps.unizar.es/

Abstract. The administrative units have been created with the purpose of covering specific territorial and functional scopes over time. Therefore, there are heterogeneity not only among states but also at any level of subdivision. In the context of Spatial Data Infrastructures, administrative units are part of the core data model and they are often exploited in the development of web services. International, cross-border, even national web services may face different and superposed administrative models. The administrative models are complex and they may not be well understood by users and developers in some scenarios, i.e. a query in boundary areas with different administrative models. This paper proposes an ontology that can describe administrative models and also serve as a knowledge base that may facilitate mappings between different types of administrative units.

Key words: SDI, Ontology, Interoperability, Administrative Model

1 Introduction

Spatial Data Infrastructures (SDI) are a coordinated approach to technology, policies, standards, and human resources necessary for the effective acquisition, management, distribution and utilization of geographic information at different organization levels and involving both public and private institutions. This effort has resulted in the formation of cross-jurisdictional partnerships as is stated in Rajabifard et al. [15]. Cross-jurisdictional partnerships often implies services and data models able to deal with different kinds of administrative. For example, the European Union (EU) directive establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), that promotes the development of SDIs in Europe, includes the administrative units as one of the spatial themes that should be harmonized first.

Modern life requires clearly bounded territorial spaces which act as geographical containers of social processes. Territorial space means here a social constructed place (e.g. Spain) generically dependent on a physical place (e.g. a region on Earth bounded by coordinates). Along with the territorial space, the society construct special social organizations for the governance of portions the

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territorial space over time. These entities are units of administration for local, regional, national or international governance with specific roles separated by crisp administrative boundaries. In this paper we use the term *jurisdictional domain* (JD) to identify them. This term comes from the context of business transactions [9]. A jurisdictional domain is a territorial jurisdiction that is source of legal constraints for rational agents (e.g. an human being, an organization) and other jurisdictional domains, often dependent (e.g. a county). Each jurisdictional domain controls a geographical extent that governs and can create other jurisdictional domains within the extent of its jurisdiction. These new jurisdictional domains are recognized by law as distinct legal and/or regulatory frameworks. For example, in order to ease the territorial management, states often allows administrative divisions (e.g. provinces, territories, cantons, länders, etc.) to create their own administrative subdivisions. Jurisdictional domains can also be combined to form new entities with an associated extent as big as a continent (e.g. EU) or as small as a river island (e.g., Pheasant Island, condominium of Spain and France located in the River Bidasoa).

Jurisdictional domains are not static entities. They are created, destroyed or merged. Their properties may also vary: their associated extension can be modified, and even they can be transformed into another type of entity. In the same way, the original purpose of the entity can evolve along time.

Administrative units are far from being adjusted to a stable and uniform hierarchy of types and instances. The complexity in their diversity and peculiarities mixed with its evolving nature has created the necessity to provide a coherent model that might simplify their use in SDI systems. This paper proposes a representation of administrative units based on a reusable domain ontology, which defines the general structure of the units and their relationships. Additionally the paper provides an example of application ontology describing the administrative units system of Spain.

The paper is organized as follows. Section 2 presents the state-of-art. Section 3 describes the domain ontology and its characteristics. Section 4 presents the application ontology. Section 5 shows the uses of the ontology in an SDI. The paper ends with conclusions and further work.

2 State-of-Art

In the SDI context there are works such as Irie and Sundheim [10], Manov et al. [12] and international standards such as ISO 19109:2005 *Geographic information - Rules for application schema* (ISO 19109) that propose general purpose models able to represent any type of geographical entity. In the narrower scope of the administrative units, there are administrative schemes based on different knowledge organization models such as lists [14, 16], thesauri [6] or ontologies [4] to describe the structure of the different countries. They use the generic definition of feature as "a meaningful object in the selected domain of discourse" (ISO 19109) and support geographic relation types. Others, as the international standard ISO 19112:2003 *Geographic information - Spatial referencing by ge-*

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ographic identifiers, describe the logical model of an authorized dictionary of names (gazetteer) and present the administrative units as a hierarchy.

However, as some experts suggest in Bleakly [1], they do not consider important issues such as the unique identification of items (unique name ID), multilingualism, duration (time frame for names), reliability of data (source reliability, data accuracy), spatial characteristics (elevation, map and image files, and both, point and bounding box for coordinates) and tabular data (population data); moreover, the most common characteristic of the above models and schemes is the lack of an appropriate semantic representation of the types of administrative units and their spatial and temporal relations.

3 Ontology of Administrative Units

3.1 Framework

Our proposal is the result of the analysis of three existing standard models: the Nomenclature of Territorial Units for Statistics (NUTS) developed by the EU; the FIPS 10-4 standard for countries, dependencies, areas of special sovereignty and their principal administrative divisions developed by the United States Federal Government; and the ISO 3166 Codes for the representation of names of countries and their subdivisions.

It has been possible to identify the common elements used for referencing real or instrumental countries, dependent areas, and subdivisions with a political, statistical, environmental or commercial purpose. This analysis has detected among others problems that the provided set of units might not be exhaustive (lack of some subdivisions of the administrative units), there is no guarantee that the name used to identify the unit is administratively recognized and there is no consistency in the representation of the spatial properties.

Furthermore, the most difficult problem detected is that these models follow the vernacular hierarchical view based on the perception of the administrative unit as a geographic container. To deal with this issue we propose an approach based on the development of dual geographic and administrative hierarchies.

We follow the scheme proposed by Guarino [8] for building domain and application ontologies. This scheme has three layers:

- (1) A high-level ontology that defines data types and general relations which are independent of context.
- (2) A domain ontology which defines concepts and relations that can be reused in the context of the administrative models of different countries.
- (3) And an application ontology per country, which represents the specific types of administrative units of each country, along with specific instances of existing units.

As high-level ontology, DOLCE [5] has been selected because it contains all the basic concepts and relationships needed to build the domain ontology. DOLCE is $\mathcal{SHION}(\mathcal{D})$ in description logic. OWL-DL closely correspond to it with some

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limitations on datatypes. The use of this high-level ontology in other environments simplifies the combination of our domain ontology with existing ones. The predicates previously presented in DOLCE literature [2, 3, 11, 13] we will refer to are:

- $\texttt{ORG}(\texttt{x})$ standing for "x is an organization", a socially-constructed person with a complex articulation of tasks, roles and figures that has sovereignty over a definite territory.
- $\texttt{PGO}(\texttt{x})$ standing for "x is a political geographic object", i.e. a geographical place, conventionally accepted by a community.
- $\texttt{COL}(\texttt{x})$ standing for "x is a collection", i.e. a federation is collection of states.
- $\texttt{INST}(\texttt{x},\texttt{y})$ standing for "x institutionalizes y" when such a concept "x" is used by a description that is valid for "y", i.e. public administration can be applied as a province description.
- $\texttt{PRE}(\texttt{x},\texttt{t})$ standing for "x is present at time t", i.e. France is present now.
- $\texttt{MEM}(\texttt{x},\texttt{c},\texttt{t})$ standing for "x is member of c at time t", that implies "c" is a collection by definition, i.e. Spain is member of the EU.
- $\texttt{PC}(\texttt{x},\texttt{y},\texttt{t})$ standing for "x is part of y at time t"
- $\texttt{GP}(\texttt{x},\texttt{y},\texttt{t})$ standing for "x is geographic part of y at time t", that implies "x" and "y" are political geographic objects by definition.

3.2 Domain Ontology

The next step is of defining what a jurisdictional domain is and its basic taxonomy (see Fig. 1). To deal with the hierarchical view based on the perception of the administrative unit as a geographic container we need to define a concept that only holds spatial information. We introduce the concept of *jurisdictional geographic object* (JGO). It is the spatial area on which a *jurisdictional domain* rules and depends on. Here it is sufficient to point that jurisdictional geographic objects are political geographic objects whose spatial properties may vary over time.

$$\texttt{JGO}(\texttt{x}) \rightarrow \texttt{PGO}(\texttt{x}) \tag{1}$$

A *jursidictional domain* (JD) is defined as any social entity recognized by the law as a distinct legal and/or regulatory framework with the role of public administration. Jurisdictional domains are organizations which are described by the role *public administration* and are grounded by dependant jurisdictional geographic objects during the whole period in which the jurisdictional domain is present:

$$\begin{aligned}\texttt{JD}(\texttt{x}) \rightarrow\ & \texttt{ORG}(\texttt{x}) \wedge \texttt{INST}(\mathit{PublicAdministration},\texttt{x}) \\ & \wedge\exists\texttt{t}\,(\texttt{PRE}(\texttt{x},\texttt{t})) \wedge \forall\texttt{t}\,(\texttt{PRE}(\texttt{x},\texttt{t}) \rightarrow \exists\texttt{y}\,(\texttt{JGO}(\texttt{y}) \wedge \texttt{PC}(\texttt{y},\texttt{x},\texttt{t})))\end{aligned} \tag{2}$$

The jurisdictional domain may be described playing other roles which are defined upon the functions that the administrative unit may have. For example, "local power" is the role of municipality (the closest to citizens). The jurisdictional domain concept may be specialized in states, administrative divisions and

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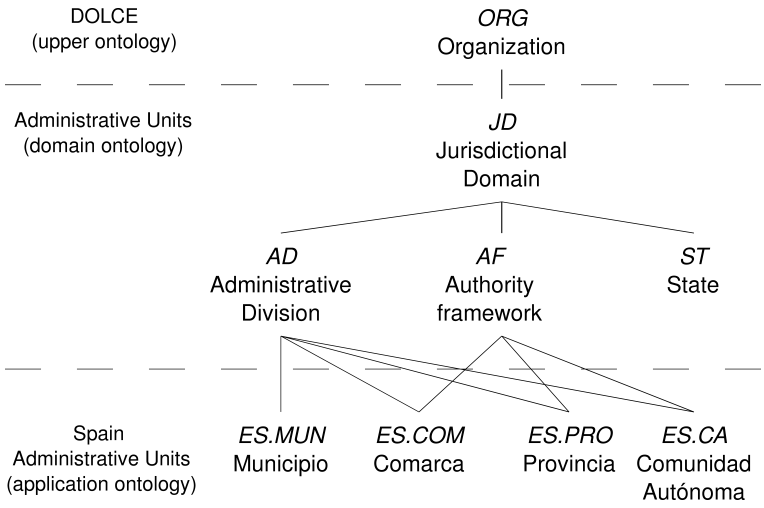

Fig. 1. The jurisdictional domain taxonomy: main concepts and a subset of concepts drawn from an application ontology.

authority frameworks. An *administrative division* (AD) represents any division in a jurisdictional domain. This concept is characterized by the temporal part-hood relation which relates with their parent jurisdiction. Examples of instances are Saragossa, Huesca and Teruel which are Municipalities of Spain.

$$\mathtt{AD}(\mathtt{x}) \rightarrow \mathtt{JD}(\mathtt{x}) \wedge \forall \mathtt{t}\,(\mathtt{PRE}\,(\mathtt{x},\mathtt{t}) \rightarrow \exists \mathtt{y}\,(\mathtt{JD}(\mathtt{y}) \wedge \mathtt{PC}\,(\mathtt{x},\mathtt{y},\mathtt{t}))) \tag{3}$$

An *authority framework* (AF) represents any jurisdictional domain constructed as aggregation of other jurisdictional domains. Jurisdictional Domains have no restriction in the number of memberships. Examples of instances are the EU (an aggregation made of States) and the Warsaw voivodeship in Poland (an aggregation made of counties), which is also an administrative division.

$$\mathtt{AF}(\mathtt{x}) \rightarrow \mathtt{JD}(\mathtt{x}) \wedge \forall \mathtt{t}\,(\mathtt{PRE}\,(\mathtt{x},\mathtt{t}) \rightarrow \exists \mathtt{y}\,(\mathtt{JD}(\mathtt{y}) \wedge \mathtt{MEM}\,(\mathtt{y},\mathtt{x},\mathtt{t}))) \tag{4}$$

A *state* (ST) consist of a bordered territory under effective and civil government. In Weber [17] words, have the "monopoly on the legitimate use of physical force within a given territory". This concept disjoint administrative division. State instances are often the root element in many administrative code lists (e.g., FIPS 10-4, ISO 3166, NUTS). Examples of instances are the French Republic, United Kingdom and Spain.

$$\mathtt{ST}(\mathtt{x}) \rightarrow \mathtt{JD}(\mathtt{x}) \wedge \neg \mathtt{AD}\,(\mathtt{x}) \tag{5}$$

3.3 Application Ontology

The administrative unit model of Spain is quite complex. Table 1 shows the most important types. Territorial areas separated from the mainland have their own

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special administrative units (Isla, Ciudad Autónoma). Some autonomous communities have their own administrative subdivisions (Aragon, Basque Country, Castile and Leon, Catalonia, Galicia and Navarre). Fig. 2 shows only a subset of

Name	Description	Units	ADL Feature Type
Comunidad Autónoma	autononomous community	17	countries,
Ciudad Autónoma	autonomous city	2	1st order division
Provincia	province	50	countries,
Isla	island	11	2nd order division
Veguería	group of district (Catalonia)	6	
Comarca	district (Aragon, Basque Country, Castile and Leon, Catalonia)	81	countries, 3rd order division
Mancomunidad	municipality association	1.019	
Área metropolitana	metropolitan area	4	
Facería	common land (Navarre)	64	
Municipio	municipality	8.111	
E.Á.T.I.M.	minor civil unit	1.019	countries,
Parroquia	parish (Galicia)	3.781	4th order division

Table 1. Spain administrative units[14].

the application ontology in the scope of the autonomous community of Catalonia. The following conventions are assumed: concepts are represented in capital letters, individuals are represented in small letters, relations between individuals are represented by dashed labeled arrows and the relation between an individual and the concept is labeled by *i-of*. The jurisdictional domains shown here are state (ST), autonomous community (ES.CA), province (ES.PRO), district (ES.COM) and municipality (ES.MUN). Each jurisdictional domain is related with their jurisdictional geographic object which represents the physical area where the unit governs. Fig. 3 shows the geographic containment among the jurisdictional geographic objects. This is the typical geographic containment hierarchy that can be found in models such as Geonames [7]. Our application ontology can model the more complex relations among jurisdictional objects as figure 4shows. This figure shows that Catalonia, Barcelona and Cubelles are part of Spain. Garraf is also part of Catalonia because is a subdivision of Catalonia and because the part relation is transitive is also part of Spain. Cubelles is also part of Catalonia as constituent. Barcelona (province) and Garraf (district) are defined by law as an aggregation of municipalities. Why Garraf is not part of Barcelona? Why Barcelona is not part of Catalonia? Because they belong to different but spatially superposed administrative hierarchies.

4 Applications of the Administrative Unit Ontology

The administrative relations added by the ontology improve the conceptual search. The addition of spatial restrictions allows the construction of more pow-

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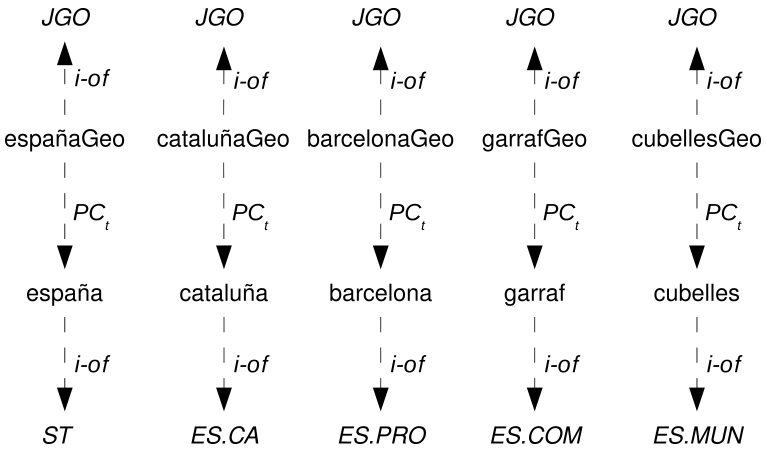

Fig. 2. Elements of the application ontology

Fig. 3. The geographic containment hierarchy.

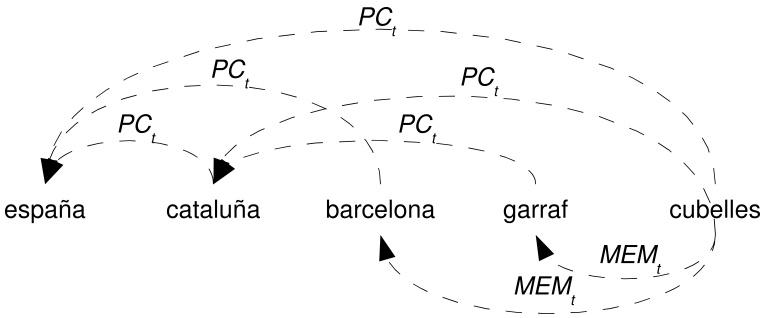

Fig. 4. The multipath administrative hierarchy.

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erful queries. Furthermore, the ontology can facilitate the identification of equivalent units from different administrative structures thanks to the alignment of roles, their spatial characteristics and their position in the hierarchy. The proper management of different administrative organization models is crucial for the behaviour of SDI services and service chaining functionality. Assuming that two administrative units are equivalent when they play equivalent roles, one can create a complete map of roles shared among units of different administrative unit models. This approach could facilitate the management of resources in border areas. For example, let us think about the search for local ski facilities in municipalities of the Pyrenees. Spanish users may ask for "Municipios" and queries are made about "Muncipios" and "Communes" because we may have inferred that they play a similar role (Fig. 4) as they have a similar position in their respective hierarchies and are responsible of ski facilities.

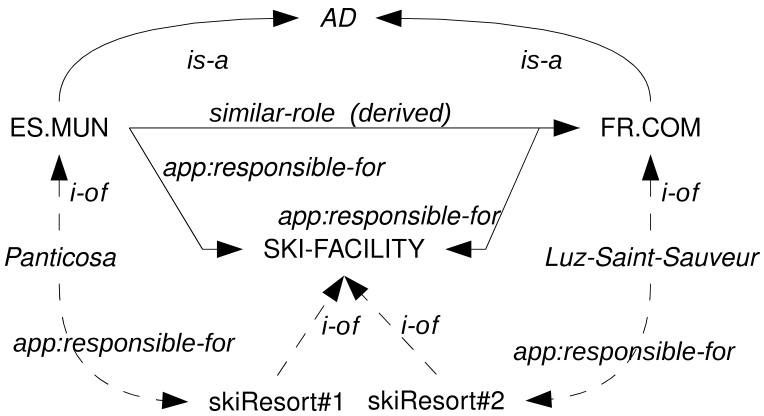

Fig. 5. Municipalities and ski resorts.

5 Conclusions and Future Work

This paper has presented an administrative unit ontology to model the administrative structure of a country and it has described possible advantages derived from the use of such ontology.

The following steps of this work will be the development of a semiautomatic process to generate the administrative instances for the cases of France, United Kingdom, Portugal and Spain. This task can be more complex than expected because of the complexity and diversity in the administrative structure of each country, and the difficulty of obtaining official data. For example, in Spain, the Ministry for Public Administration has a registry of local administrative units, but each autonomous community may have its own registry for their specific

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administrative subdivisions. Therefore, a whole model always needs to merge data form quite different sources.

It is important to stress that the high frequency of changes in the administrative organization (shape, structure, name or administrative capabilities) makes necessary to establish specialised policies and techniques for updating all the elements of the infrastructure that uses this model. Also the quality of the data sources is an issue that should be considered. If the official name, code or coordinates of a unit are not accurate, associated services in the SDI that use this information will obtain poor results.

With the resulting administrative knowledge base, the efforts will focus on providing mechanisms for service chaining and semantic annotation for SDI based on the knowledge base.

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