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Toward The Foundation Of Building Geographic Ontologies

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ABSTRACT: Building domain ontologies is gradually changing; however building geographic ontologies has not been well explored given the specificity of the spatial characteristic of its concepts and relationships. To this purpose, we propose an approach of building geographic ontologies which defines a process of building founded on two phases: a meta-modeling preceding a modeling phase. The proposed process adds a step of *spatialization* to the steps of building domain ontologies [6]. The new step of spatialization is to provide concepts and relationships of a geographic ontology by spatial characteristics. We apply the defined process on the road domain to finally obtain a road ontology named "OntoRoad".

Keywords : Geographic ontologies; building ontologies; spatialization; meta-modeling; modeling; OntoRoad.

1 Introduction

The diversity of geometric applications has led to a lot of proposals both for the modeling of spatial data and for the building of geographic ontologies integrating traditional alphanumeric data as well as geometric data. In literature by now the general opinion prevails that spacial data types are necessary to model geometry and to enable geometric data to be efficiently represented in ontologies. These data types are commonly denoted as spatial data types, such as, for example, point, line, or polygon. The quality of a geographic ontology depends on the definition of spatial data types and operations expressing the spatial semantics visible at the user level and the mechanisms for providing them to the user; thing that makes building geographic ontologies more complex than that of other domain ontologies. Indeed, geographic ontologies have specific needs that are related to the needs to define spatiality using spatial data types (Line, Point and Polygon) and spatial relationships such as topological relationships. However, although several models have been developed for building domain ontologies, geographic ontologies are to be built; something that has led us to propose an approach of building geographic ontologies. This approach defines a process of building geographic ontologies founded in two phases: a meta-modeling phase preceding a modeling phase. The proposed process adds a step of spatialization to the steps of building domain ontologies. The new step of spatialization is to provide concepts and relationships of a geographic ontology by spatial characteristics. In the second section of this paper, we present the definition of a geographic ontology and the particularity of its concepts and its relationships. In the second section we describe the different phases of the proposed process of building a geographic ontology. In the third section, we apply our work on the road domain to finally get a road ontology named "OntoRoad". We conclude this paper by presenting encountered difficulties and future work we intend to accomplish.

2 Geographic ontologies and spatial relationships

According to Gruber [8], ontology is a “body of formally represented knowledge [that] is based on a conceptualization: the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them”. We define a geographic ontology by: “a specification of a spatial conceptualization of a geographic domain”. A geographic ontology is composed of spatial concepts, conceptual relationships expressing a semantic mean and spatial relationships. A spatial concept is an ontology concept expressing a given semantics of the studied field and having a spatial characteristic that is other than its graphic form in the geographic space. Although “ontologies are also not limited to conservative definitions, that is, definitions in the traditional logic sense that only introduce terminology and do not add any knowledge about the world” [8], eventually in computer science and artificial intelligence community, the so-called relationships only target the logical relationships between the concepts. Indeed, besides the logic sense, the spatial relationships between spatial features are the particular identity of Geographic Information Science. Spatial relationships normally include such relationships of equal, within, contain, touch, disjoin, intersect, union, exclusive, and difference between spatial features. The scientific foundation to determine spatial relationships is computational geometry; that is to say, we cannot use logics to derive and determine the spatial relationships [21]. The problem of identifying spatial relationships between concepts is discussed in several works [5], [20], [10], [17]. If a spatial ontology does not cover spatial relationships but is full of logical relationships, it cannot be called a spatial ontology; instead, it looks like a conceptual and logic model [21]. Although existing semantic technology may be able to handle logic rules, unfortunately, it cannot support reasoning spatial relationships. To develop a spatial ontology, we need new ideas in which the key is to determine and reason the spatial relationship and not just conceptual and logical relationships [21]. For this purpose, we propose an approach of building geographic ontologies which defines a process of building adding a step of spatialization which may provide the ontology concepts by spatial characteristics and express spatial relationships between concepts. Next section presents the proposed process of building geographic ontologies.

3 Process of building geographic ontologies

In this section, we propose a process of building geographic ontologies composed of two phases: a meta-modeling phase preceding a modeling phase. Each phase of the process is therefore carried out in four steps. The meta-modeling phase defines, for each step of the process a meta-model that will serve as a reference later, during the modeling phase. The proposed process is based on the conventional steps of the process of building domain ontologies [6]. However, we feel

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the need of an intermediate step of definition and explanation of spatial relationships in the context of geographic ontologies. To this end, we define a process based on the following four steps: Conceptualization, Spatialization, Ontologization [9] and Operationalization. The spatialization step is meant to provide concepts and relationships of a geographic ontology with a spatial characteristic. For example, the concept "Road" belonging to the road domain which is characterized by a name, a length, a flow direction, a width ... These characteristics express the semantics of the concept "Road" but no spatial information (like the graphic form) is up explored here. For this reason, the spatialization step is supposed to add the spatial characteristics to a concept. Figure 1 presents the process of building geographic ontologies.

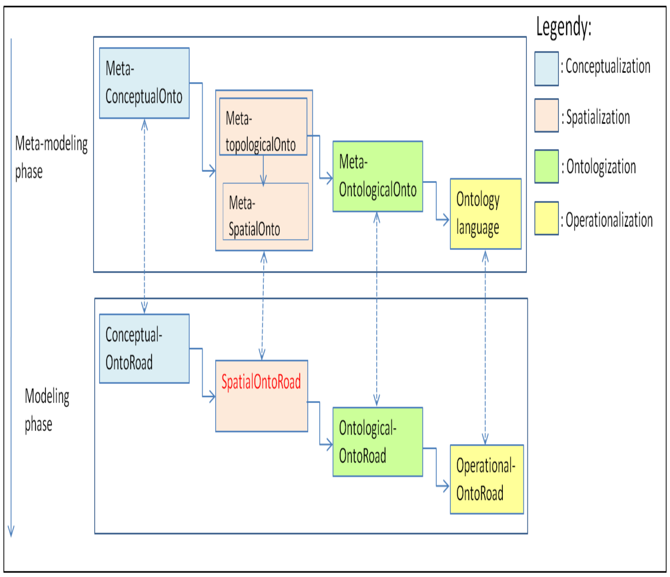

Fig. 1. *The Geographic ontologies building Process.*

We detail in what follows, for each phase of the process of building, the specificity of its steps and we present the different models and meta-models.

3.1 Meta-modeling of the process of building geographic ontologies

The meta-modeling phase studies in a high level of abstraction the nature of concepts and relationships that can exist in a geographic ontology. More details will be presented in the next section.The meta-modeling phase defines for each step of the process a meta-model. We get to the end four meta-models.

The Conceptualization step. The conceptualization step is to identify the domain knowledge and to clarify the conceptual nature (concepts, relationships, properties of relationships and concepts, rules, constraints, etc.) extracted from the corpus of knowledge. In fact we chose the object-oriented paradigm for conceptualizing spatial domain, thing that has been widely discussed in the literature [18], [4]. All proposed models and meta-models are modeled with class diagrams of UML [15]. We then proceeded to investigate the nature of knowledge that may exist in a geographic ontology. We felt, then, it was important that the geographic ontology concepts should have conceptual characteristics such as the length of a street or the surface of a forest. Also, the ontology relationships will exceed the inheritance relationship (subsumption) and recognize the association relationship of UML which is characterized by a semantic relationship [19], [12], [1], [3]. “Association” relationship represents a structural relationship that connects two classes, it is characterized by a “name” describing the meaning of a link between the involved classes. We propose then, a conceptual meta-model "Meta-conceptualOnto" representing the various conceptual components of a geographic ontology.

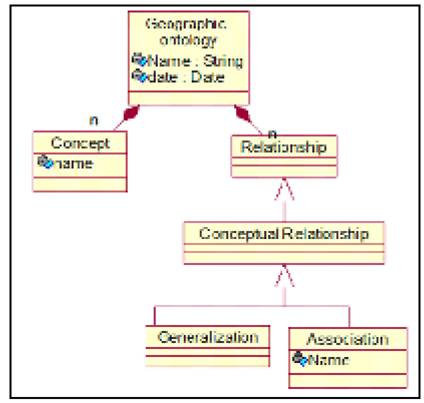

Fig. 2. *The conceptual meta-model of a geographic ontology: "Meta-ConceptualOnto".*

The Spatialization step. Spatialization is the second step of the process of building a geographic ontology. This step is to give spatial characteristics to the ontology concepts and relationships. We consider that the spatial characteristic of one concept is reflected in its graphic form, which is a Point, a Line or a Polygon. So, we classify the geographic ontology concepts according to their graphic form. This classification is useful then to allow expressing spatial relationships between ontology concepts.Therefore we define: a “Point” is a graphic form of one ontology concept. It is characterized by an abscissa and an ordinate of integer types. A “Line” is a graphic form of one ontology concept. It is characterized by a length of integer, a direction that takes a value from the DIRECTION set: {North, South, East, West, North_East, North_West, South_East, South_West}, and an initial-section (IS) and an End-section (ES) which are concepts of Point graphic form. A “Polygon” is characterized by at least three Points representing its extremities. Recall that the spatialization step is to provide concepts and relationships of a geographic ontology by spatial characteristics. Indeed, we consider in our work different types of relationships especially: metric or distance relationships, directional relationships and topological relationships. Distance relationships express a distance with a value and a unit of measure. Directional relationships model the nine cardinal positions of a spatial concept and express its position relative to another. Directional relationships are defined throughout the set DIRECTION already presented above. Finally, a topological relationship between two spatial concepts is characterized by the graphic form of the concept forming the intersection of these two concepts. To represent topological relationships, we use the formalism of connection, interior and border to express that two spatial concepts share the same geographical area. Table 1 presents the existence of topological relationships between graphic forms of spatial concepts. For example, the “connection” topological relationship may exist between two concepts of respective graphic forms Point and Polygon; also it may exist between two concepts of re-

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spective graphic forms Line and Polygon.

TABLE 1. *EXISTENCE OF TOPOLOGICAL RELATIONSHIPS BETWEEN GRAPHIC FORMS OF SPATIAL CONCEPTS.*

Graphic Form Topological relationship	Point / Point	Point /Line	Point / Poly gon	Line/ Line	Line/ Poly gon	Poly gon/ Poly gon
Equality	x			x		x
Extremity		x				
Inclusion		x	x	x	x	x
Connection			x		x	x
Junction				x		
Joint				x		
Meet				x	x	
Adjacency				x	x	
Superposition				x		
Partial-Recovery						x

We modelled a topological meta-model "Meta-topologicalOnto" [16] where the classes represent different graphical forms of concepts with their spatial characteristics and the relationships represent the topological relationships supported by our approach. After considering the different spatial relationships of our ontology, we proceed to define a spatial meta-model "meta-SpatialOnto" which extends “meta-conceptualOnto” by graphical forms of concepts and spatial relationships. Reading this meta-model is as follow: A spatial concept is characterized by a name and it can be a Point, a Line, or a Polygon. A geographic ontology relationship is of two types: a conceptual relationship or a spatial relationship. A spatial relationship can be a metric relationship, a directional relationship or a topological relationship. A metric relationship is of two types: a distance relationship or an approximate relationship. Figure 2 presents the spatial meta-model of a geographic ontology named "meta-SpatialOnto".

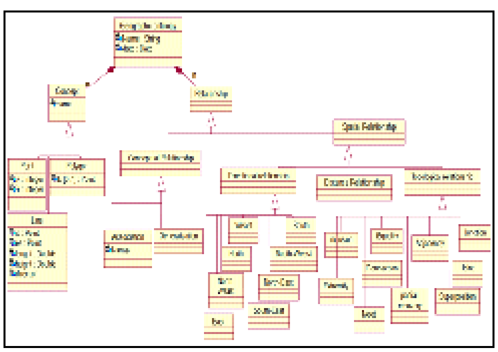

Fig. 3. *The spatial meta-model of a geographic ontology: "meta-SpatialOnto".*

The ontologization step. This step consists to model, in a formalizing language, the domain properties. The objective is to obtain a model in which almost all of the ambiguities inherent in natural language to be lifted. The meta-ontological modeling of our geographic ontology is to formally write the spatial characteristic of the ontology concepts and relationships. First recall that a geographic ontology is composed of spatial concepts and conceptual and spatial relationships. The formalization of conceptual relationships of our ontology refers to formal definitions [5] of UML relationships. The formalization of the spatial aspect of concepts and spatial relationships is to define usage rules using descriptive logic. The set of these rules is called a formal meta-model of a geographic ontology named "meta-OntologicalOnto" [16]. A formal writing has been given to all the components of the ontology.

The operationalization step. The operationalization step is to make operational or functional ontology. First, must select the ontology language and the tool of building the ontology. We choose the Web Ontology Language (OWL) to build the meta-model of operational geographic ontology because it is the most widely used language in the domain of ontologies in particular geographic ontologies [2] [13]. Mainly, we consider that the syntax and rules of writing of OWL are the operational meta-model of the ontology to build. Before this translation, we must choose the transformation rules of a class diagram [7]. In fact, we choose the generic classes are abstract classes and become attributes in special classes. Precisely, we note that the "spatial meta-model" contains a generic class: *Concept* characterized by a *name* and three specialized classes: *Point*, *Line* and *Polygon*. Each ontology concept is therefore modeled as specialization of one of these three classes. Thus, each class will be transformed into an attribute called "graphic-form" in the specialized class whose value will be the name of its generic class. Translation between conceptualization and operationalization languages is as follows [11] [19]: taxonomy of UML classes is transformed into OWL taxonomy: UML classes are translated to OWL classes, the attributes of UML classes are translated into OWL properties, generalization relationships of UML are translated into OWL subclasses, UML associations are translated into (ObjectProperty) and attributes are translated into (DataType Properties). In conclusion, we have detailed the steps of the meta-modeling phase of the process of building a geographic ontology which adds to the steps of building domain ontologies a new step of spatialization. This step may provide the ontology concepts and relationships by spatial characteristics. The proposed process of building a geographic ontology defines, for each step of the process of building a geographic ontology, a meta-model that will be used later as a reference during the modeling phase. We detail, in the following the modeling phase steps.

3.2 Modeling of the process of building geographic ontologies

The modeling phase depends on the ontology domain and consists to define, for each step of the process of building a geographic ontology, a model containing the domain concepts and relationships. The result of this phase is a geographic ontology model instantiable depending on the user data. In our work, we choose the road domain as an application domain. The result ontology is called “*OntoRoad”*. We present in what follows the different steps of the modeling phase of the road domain.

The conceptualization step. This step consists first to identify the conceptual vocabulary of the considered domain. Indeed, we have identified the road domain vocabulary by referring to the domain experts, the GDT[1] (le Grand Dictionnaire Terminologique) and to the Web. To each term of the domain are assigned its characteristics. Then a detailed study of the extracted vocabulary is performed to deduct conceptual relationships that can exist between concepts always referring to their

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formal definitions (Figure 1). This step result is a conceptual model named "Conceptual-OntoRoad" containing 74 concepts and 64 conceptual relationships. The "Conceptual-OntoRoad" is read as follows: There is a generalization relationship between the concepts “Voie_routière” and “Voie_urbaine” . There is an association relationship named “*aboutit_à”* between the concepts “Route” and “*Bretelle”*. Figure 4 shows an extract of the “conceptual-OntoRoad”.

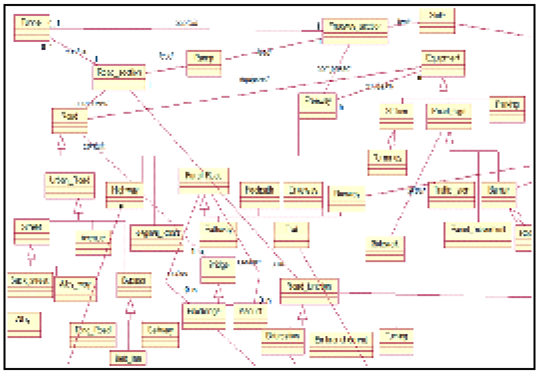

Fig. 4. *Extract of the “Conceptual-OntoRoad”.*

The Spatialization step. This step models the spatial characteristic of the road concepts of “OntoRoad” ontology and models spatial relationships that may exist between these concepts referring to "meta-spatialOnto" and "meta-OntologicalOnto". We obtain as a result of this step, a spatial model named "Spacial-OntoRoad" containing 180 spatial relationships and where all concepts are characterized by their graphic forms. The "Spacial-OntoRoad" model is read as follows: the “*Voie_routière*” concept is a *Line* and admits a Joint topological relationship with itself. The “*Autoroute”* concept is a *Line* and admits an *Inclusion* topological relationship with “*Tronçon_d'autoroute”* concept. The “*Nœud_routier”* concept is a *Point*. Figure 4 shows an extract of the "Spacial-OntoRoad" model.

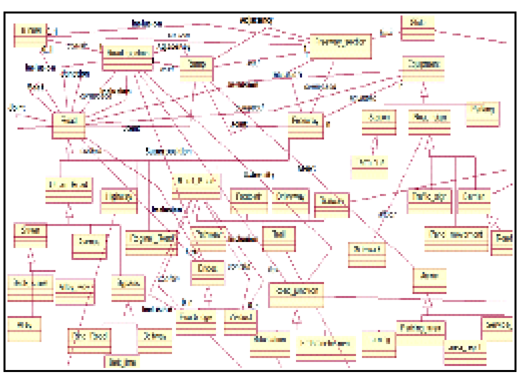

Fig. 5. *Extract of “Spatial-OntoRoad”.*

Operational Modeling. We used the Protege_4.2_beta tool [14] to construct "OntoRoad" Ontology. Protege is a free editor for building domain ontology. First, we proceeded to create concepts, then to assign properties, finally to define the relationships. Figure 5 shows an extract of the ontology concepts, relationships as well as properties and relationships of "voie_routière" concept.

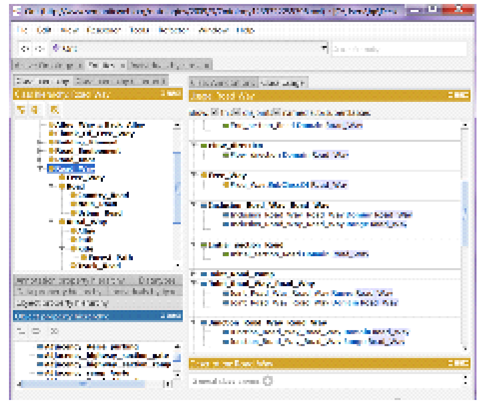

Fig. 6. *Extract of OntoRoad ontology using Protege.*

After defining the elements (concepts, properties and relationships) of the “OntoRoad” ontology, we generate the ontology OWL file. This functionality is integrated in *Protege*. We named the resulting file: “Operational-OntoRoad”. Figure 6 shows an extract of “operational-OntoRoad” and figure 7 shows an extract of “OntoRoad” graph using OWLViz plugin.

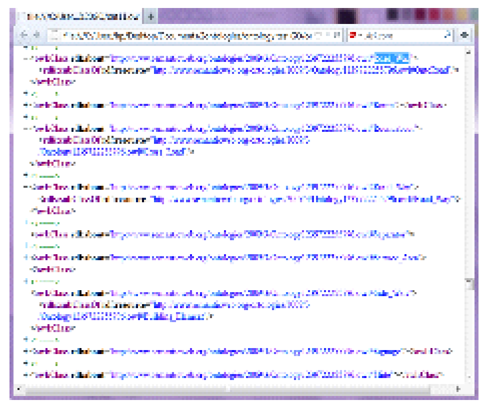

Fig. 7. *Extract of “operational-OntoRoad”.*

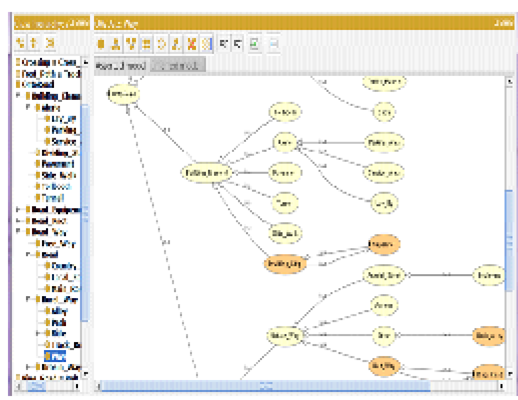

Fig. 8. *Graph of OntoRoad ontology using OWLViz plugin.*

4 Conclusion

In this paper we presented an approach of building geographic ontologies, which defines a process of building based on four steps: conceptualization, spatialization, formalization and operationalization. The proposed process is realised in two phas-

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es: the meta-modeling phase preceding the modeling phase. Our approach has been applied to the road domain to give as a result a road ontology named “OntoRoad”. This ontology has been instantiated with data from several geographic areas of Sfax city in Tunisia in purposes of geo-localization.

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