Geo-spatial Domain Ontology: The Case of the Socio-Cultural Infrastructures

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ABSTRACT
This paper presents a geo-spatial domain ontology (CriSO) modeling approach, which is based on the RCC-8 model complemented by directional relations encoded by cone-shaped or alternatively, projection-based relations. Ontologies can be defined as a kind of semantic networks for the the real world description, they are essentially graphs between concepts linked by relations such as is_a, has_a, part_whole. But the scope of geographic ontologies applied to sociocultural features requires to describe not only the geographic features, but also their spatial relationships. Usually, only topological relations are defined, but other spatial, geographic relations and cultural knowledge must be considered as well. Thus, CriSO allows to annotate, to organize data, to facilitate information retrieval by introducing a semantic layer in the on-based Knowledge Management Systems and to integrate the local knowledge in the cloud of the Linked Open Data.

General Terms
Ontologies, Semantic Web, Spatial Reasoning

Keywords
Ontology, Geographic Ontology, Sociocultural Infrastructure, Knowledge Management Systems, Linked Open Data

1. INTRODUCTION
To promote the indigenous knowledge, some media have been proposed: a permanent (re)education, the radio broadcasting, Television and of course the Internet, which seems to be the best media. It reduces distances between civilizations instantaneously. Thus, it is an opportunity to disseminate the local knowledge on a large scale. But, this is not sufficient to make the Internet an ultimate solution to the African culture (in particular) vulgarization. It does not create anything itself. It is the African responsibility to build the content of the “empty shell” that is the Internet and make the rational use to enjoy opportunities it offers.

To get there, new computational technologies (semantic technologies) are needed to manage these large repositories of sociocultural data and to discover useful patterns and knowledge from them. Semantic Web vision proposed by Tim Berners-Lee (1994) revolutionized the Web architecture. It switched from the documentary graphs to the published and interconnected databases with capabilities to “understand” their semantics and reasoning on them [1][2]. Technically are introduced into the Web architecture stack the RDF data model and the URI standard for modeling and resources identification on the Web. As result, the “Web is spreading in the World and the World is spreading in the Web” with issues such as the “cultural digital divide”. Indeed, a cultural void in the Web of Data is the lack of this culture at the applicative level (e-tourism, e-infrastructure, etc.) of the Web of Data.

The fundamental components of Semantic Web named ontologies can contribute to reduce that ”divide by content” and consequently increases cultures visibility, accessibility at least regarding the following points: organization, preservation, vulgarization, sharing and knowledge reuse on the Web. Out of ontology types, there are domain ontologies such as geographic ontologies. In the past geographic ontologies organized the geographic objects with conventional relations. However, it can be seen immediately that, such vision is insufficient to describe space [3]. From the different issues relevant to the geographic ontologies, just a few shall be mentioned subsequently, namely the status of space, the spatial relations, the target features and linguistic problems. An additional example can be taken from [4], where a prototypic geographic ontology is described via geometric types of its features. But now, geographic ontologies integrate better (rich) representations of space and spatial relationships.

The objective of this study is to model a fine geographic ontology, a lower-level ontology that brings closer to space domain reality and so enables a detailed description and identification of the relevant concepts and relations. Thus, the modeled vocabulary organizes data, facilitates information retrieval and enables the semantic interoperability by introducing a geo-spatial reasoning in the on-based KMS (Knowledge Management Systems). These KMS will help to preserve the local knowledge by sharing, and enabling the “memory” of places, environments and infrastructures available on the Web.

The rest of the paper is schemed as follows. Section II defines some main concepts, which could facilitate the understanding of the following sections and the scientific contribution. Section III reviews some existing geo-spatial ontologies for the Web. The section ends with a synthesis, which states the strengths and limitations of these vocabularies. Then, the Section IV presents the model named CriSO (Crisp Spatial Ontologies). CriSO presentation consists of modeling approach, concepts, relationships, alignment, rules and performance evaluation. The paper ends with a conclusion and future work in the Section V.

2. CONCEPTUAL FRAMEWORK
In this section are defined some main concepts, which could facilitate the understanding of the following sections and the setting of the contribution of this study.

2.1 Spatial Objects
Spatial objects represent the simple objects required for digital spatial processing, which can be used to construct the well-

defined aggregates or user-defined composite objects that represent a more complex realization of the real world. Geometric objects are simple spatial objects. In this category, there are zero, one, two dimensional and three-dimensional definitions, valid in planar and non-planar, Euclidean geometry, as well as simple curved surfaces such as the sphere or ellipsoid. The so-called non-geometric objects are designated by complex space objects. They are composed of the geometric objects. For example a road, a river, a town, a mountain, a building, a tourist site, etc. [5].

2.2 Geographic Information

Space objects are located through geographic information. Geographic information is the representation of an object as a real phenomenon or imaginary, present, past or future, localized in space at a given time and whatever the size and the scale of representation [5]. Geographic information is defined by three data levels as follows [6] :

- *Semantic level: i*nformation relative to the object's nature and aspect. It is constituted by the set of attributes of an object such as the cadastral plot number, name of a road, name of a town, size of a region, etc.;
- *Spatial relations level:* it deals with potential relationships with other objects or phenomena: contiguity of localities, inclusion of an object in another, adjacency between different segment nodes of the cadastral parcels, etc. In this component, there are three types of relationships: topological, projective and distance.
- *Geometric level: T*his is the object's shape and location information on the earth's surface, expressed in a specific coordinate system, for example, the polar or spherical coordinates longitude/latitude geographic type or map coordinates from one map projection like Lambert projection or the World Geodetic System WGS84.

2.3 Geographic Ontologies

The desire of supporting spatial data with information on their existence, their meaning, their content, their organization, their structure, in Geographic Information Systems (geo-database) and Web services led to the introduction of new concepts and new paradigms for expressing the semantics of spatial data [7]. These are referred to ontologies. They allow the better understanding of geographic phenomena. When the geographic scope (spatial) is considered, it's designated as geographic ontologies. There are three types of geographic ontologies that may be described as follows [6][8]:

- *Space ontology*: specifically devoted to the concepts description that characterize space as point, line, polygon, etc. ;
- *Geographical domain ontology*: ontologies which model some domain of knowledge as hydraulics domain, electrical networks, etc.;
- *Spatio-temporal ontology*: ontologies that concepts are localized in space. A temporal component is often needed as complemented information. Indeed, due to the administrative purposes, the existence of a location may be affected by laws or physically by natural disasters, that make a location or object to no longer exist. Thus, a location may disappear.

In this study, the spatial aspect of the spatio-temporal ontologies is only considered.

3. GEO-SPATIAL ONTOLOGIES FOR THE WEB

Over the years, many spatial ontologies have been developed and shared. They provide an excellent basis for extension and reuse in some cases. An ontology that serves as that basis for domain-specific is often referred to as a foundational ontology, or an upper-level ontology. The following is a list of some ontologies or vocabularies that can be used as reference or basis in the spatial domain: GeoRSS, GeoOWL, GeoNames Ontology, Ordnance survey ontology and SWEET ontologies:

- *Towntology*: Towntology (2002-2003) is a preconsensual ontology that has been done around the Towntology project, even if it has not been developed within Semantic Web. It mentionned because the finality design (urban) seems to be a part of this work. In fact, modeling spatial aspects necessarily involves a consideration of the urban aspect. However, during the development of this ontology, designers felt need to develop their own language based on XML, and not using the formal ontology languages, making it impossible to be reused. Nevertheless, in our model; will be reused some concepts (classes) of the Towntology project.
- *GeoRSS*: GeoRSS (2003) is a vocabulary of terms that can be used in RDF documents to represent geo-spatial information. The primary purpose of the project is to provide a common vocabulary of geo-spatial terms for using in RSS feeds. The GeoRSS model supports the concepts of points, lines, boxes, and polygons. All of the points are latitude/longitude pairs according to the world Geodetic System from 1984 (WGS84). Conceptually, GeoRSS is a very convenient framework, but it can sometimes be difficult to work with this data in RDF because the values are concatenated as string [9]. In other to use this data, these strings must be parsed and the values extracted. For this reason, many Semantic Web applications use the basic Geo vocabulary.
- *GeoOWL*: GeoOWL (2005) is the OWL-based geographic ontology. The basic Geo Vocabulary is a simple RDF encoding for WGS84 latitude and longitude values. It defines a point class as well as lat, long and alt predicates to describe a point's location in terms of latitude, longitude and altitude [9]. A latitude/longitude system is a convenient way for referencing a point on the surface of a planet, such as Earth or Mars. However, we need a richer representation than simple latitude /longitude pairs. In clear, while this vocabulary is simple to reuse, it just models a geographical component of the geographic information. GeoOWL doesn't consider semantic and topological level.
- *SWEET ontologies*: The ontologies within the Semantic Web for Earth and Environmental Terminology (SWEET) developed in 2004 by NASAs Jet Propulsion lab are oriented to Earth system science. The SWEET ontologies package contains several ontologies such as EarthRealm, Non-LivingSubstances, LivingSubstances, PhysicalProcesses, Units, Time, Space, Numerics,

PhysicalPhenomena, HumanActivities, Data ontologies and those ontologies related using the OWL language [10]. Space ontology is essentially a multidimensional numerical scale with the specific terminology to the spatial domain. In space ontology; spatial extents and relations are special cases of numeric extents and relations, respectively. Spatial extents include: country, Antarctica, equator, inlet, etc. Spatial relations include: aboveOf, NorthOf. Nevertheless, SWEET onologies is an upper-level ontology, not dedicated for handling domain knowledge.

- *Ordnance Survey Ontology*: Ordnance survey ontology (2007) describes the administrative and voting area geography of Great Britain. Ordnance survey ontologies offer a complete set of crisp spatial relationships for traditional GIS. Althought, this vocabulary used crisp relationships, reusable.. But, due to the fact that its modeling is vote-oriented, all concepts are not semantically reusable in the sociocultural context. In addition, infrastructures are not targeted in its modeling aim.
- *GeoNames Ontology*: GeoNames Ontology (2007) describes the GeoNames features properties using the Web Ontology Language, the features classes and codes being described in the SKOS language [9]. GeoNames is a geographical database available and accessible through various Web services, under a Creative Commons attribution License. All features are categorized into one of nine feature classes (Hydrographic, Vegetation, Road, Undersea, Area, Buiding, Administrative, Population, and Hypsoraphic) and further subcategorized into one of 645 feature codes. Beyond names of places in various languages, data stored include latitude, longitude, elevation, population, administrative subdivision and postal codes. All coordinates use the World Geodetic System 1984 (WGS84). This ontology is wide and oriented to the organization of spatial object names. In its inception, most of the sociocultural infrastructures concepts such as GeoNames:AreFeature, GeoNames:AdministrativeFeature and GeoNames:BuildingFeature were modeled, but its last version 3.2 becomes abstract and models solely the different levels of administrative subdivision without taking into account the sociocultural infrastructures location.
- *GeoConcepts*: Geoconcept ontology (2008) enables Geoconcepts framework, which allows storing and retrieval of abstract geo-referenced content in order to overcome the current limitations of Geographic Information Systems (GIS), by taking advantage of social information spaces and geo-tagged resources in the Web as data sources of geo-referenced abstract concepts [11]. Due to the fact that, the Web 2.0 is data source, geoconcept entity is still abstract. Indeed, It can be an event, a person, an activity. It means that there is not prior knowledge about geoconcept. In addition, the geoconcepts spatial relationships are no crisp, but present a degree of uncertainty. In contrary, in this case which aim is avoiding abstract concept and fuzzy reasoning.

Table 1. Foundational Geo-spatial Ontologies Synthesis

Ontologies	**Year**	**Target level representation**
Towntology	2003	Semantic
GeoRSS	2003	Geometric
SWEET Ontologies	2004	Geometric
GeoOWL	2005	Geometric
Ordonance Survey	2007	Topological
GeoNames	2007	Semantic, Geometric
GeoConcepts	2008	Semantic, Geometric

4. SYNTHESIS

According to the geo-spatial domain, a review of the existing ontologies for the Web has been made. One clear objective of any semantic project is the use of existing standards and models that fit its needs. Many studies have been carried out related to spatial representations, especially, topological relations [11][3] but with very few real applications, almost nothing on metric, projective relationships and uncertainty. In addition, according to W3C Geo-spatial, while the rigor of the OGC and ISO/TC 211 General Feature Model is essential for clarity of spatial representations, the breadth and depth of geographic information handling developed by those organizations are considered to be beyond the needs of most Web use cases [12]. The same notice is done in this case. In fact, according to the objective of this paper, which is to have a RDFS/OWL sociocultural feature ontology which must be lower-level, taking into consideration for each feature, semantic, spatial and semantic relations and geometric level in their geographical representation (Table I). Modeling a new ontology is required.

5. CRISP SPATIAL ONTOLOGY

This section presents the ontology, this is from modeling approach to performance evaluation.

5.1 Modeling Approach

Practically, ontological engineering does not propose a standardized methodology for designing ontologies [13]. Regarding the main objective, which is to handle semantic, spatial and projective relations used commonly to locate spatial objects and how annotate them, the most widespread formalism for representing spatial relations is the Region Connection Calculus (RCC) formalism introduced in 1992 by [14]. With mapping techniques, the model helps to model relations between regions of a country, and between features and localities. Projective relations are defined based on cone-shaped areas. Eight directional relations can be identified namely by NorthOf, NorthEastOf, EastOf, SouthEastOf, SouthOf, SouthWestOf, WestOf and NorthWestOf following the cone-shaped regions approach. These projective relations complement the knowledge acquisition related to localities relations among them.

Due to the fact that the concern is the domain ontology modeling, upper-level concepts ontosoc:infrastructure and ontosoc:locality are deduced from the upper-level sociocultural ontology modeled in our previous work [15]. Thereafter, to better define hierarchy, we intended to "think up" before making specifications. This is the top-down development process that begins with definition of the most general concepts in the domain and continues with sub-concepts specialization.

CriSO (Crisp Spatial Ontology) is a RDFS/OWL formalized ontology edited by Protégé, the widespread ontologies editor. It allows the spatial annotations of sociocultural infrastructures in RDFS/OWL format based-on not-fuzzy spatial expressions. Therefore, it captures the non-linear natural semantics associated to the annotated resources. It enables semantic queries against the Knowledge Base and new statements deducting thereof using SPARQL queries. The following Fig.1 overviews some CriSO concepts. The key idea of RDFs abstract model is to break information into small pieces, and each small piece has clearly defined semantics so that machine can "understand" it and do useful things with it. The implementation of the above key idea is expressed by classes and relationships between them. When classes structure spatial knowledge, relationships connect semantically these classes. As shown in Fig.1, there are two upper-level concepts (Locality, Infrastructure) with different granularity connected by some RCC-8 on-based relationships.

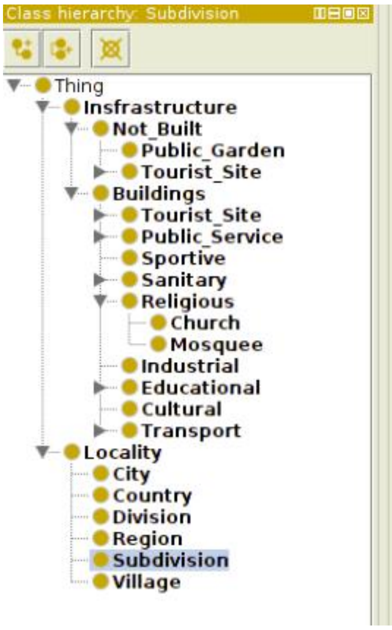

Fig.1 CriSO Concepts

5.2 Concepts

5.2.1 Infrastructure

ontosoc: Infrastructure concept models the so-called socio-cultural infrastructure. It is the abstract concept from where are directly linked BuiltArea, and notBuiltArea. Respectively, BuiltArea, organizes the human-made infrastructures through socio-cultural activities. Thus, are proposed Sportive, Educational, Sanitary, Religious, Cultural, Industrial, Transport, Public Service, and Tourist Site sub-concepts. From notBuiltArea abstract concept, are deduced two lowers concepts, Tourist-Site and Public-Garden as depicted by Fig.2.

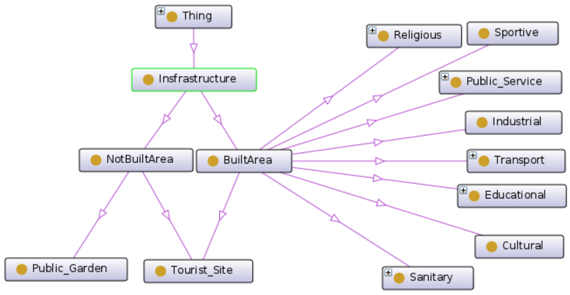

Fig.2 Infrastructure Concept Hierarchy

5.2.2 Locality

ontosoc: Locality class models the administrative spaces such as country, region, division, subdivisions municipalities, city, village, and streets). Fig.4 shows its hierarchy.

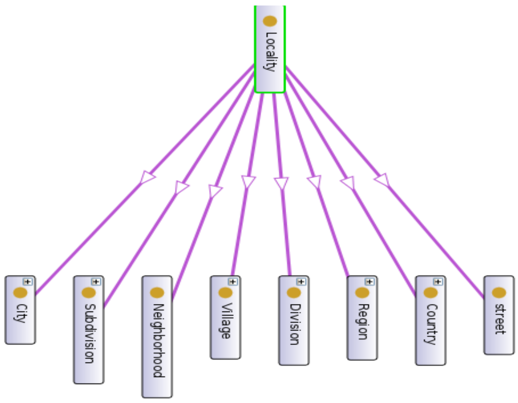

Fig.4 Locality Concept Hierarchy

The following snippet describes Garoua omnisport staduim located in Garoua locality.

[x :Infrastructure
:hasName [x :Name ;
:Name "Stade omnisport de Garoua"] ;
:hasDateConstruction [x :Date ;
:Date "1978 7 5"] ;
:hasLatitude [x :geo:Latitude ;
:geo:Latitude "14.142565"];
:hasLongitude [x :geo:Longitude ;
:geo:Longitude "-10.142565"];
:hasHeigh [x :Heigh ;
:Heigh "20"] ;
:hasSize [x :Size ;
:Size "35 "] ;
:hasType [x :Type ;
:Type [x :Tname;
:TName "sportFeature"] ;
:capacity [x:capacity ;
:capacity "10 000"];
:field [x :field;
:field "Football"]] ;
:islocatedIn [x:locality
:hasName[x :Lname ;
:Lname "Garoua"]]].

Snippet. 1 Maroua Locality Annotation

5.3 Relationships

Based on RCC-8 and projective models the following relations are retained to enable human reasoning:

- isLocatedIn(Infrastructure, Locality): this relation connects every infrastructure individual to its location;
- Overlaps(Infrastructure, Locality): it models the case of an infrastructure such as tourist site, which is not entirely covered by a locality;
- isPartOf (locality, locality): isPartOf models th administrative subdivision level in the context of a country. it is transitive and reflexive and has the following functional sub-relations: isNhPartOf (Street, Neihgborhood); isViPartOf (Neighborhood, Village); isSDpartOf (Village, Subdivision); isDiPartOf (Subdivision, Division); isRgPartOf (Division, Region); isCoPartOf (Region, Country);
- isBorderedBy(Locality, Locality): isBorderedBy models the directional relationships between regions. It is reflexive and has the following transitive sub-properties: NorthBy(Locality, Locality); EastBy(Locality, Locality); WestBy(Locality, Locality); SouthBy(Locality, Locality); North-EastBy(Locality, Locality); NorthWestBy(Locality, Locality); SouthWestBy(Locality, Locality); SouthEastBy(Locality, Locality);
- Contains(Locality, Infrastructure): models the belogging of an infrastructure to a locality. It is inverse relation of isLocatedIn.

To more capture the human reasoning about the location of the spatial objects. In addition, to infrastructure and locality concepts, five main relations connect them. For locating any infrastructure in the space, isLocaltedin and Overlaps have been used. Then the rest, which are isPartOf and its sub-relations, isBorderedBy and its sub-relations and contains circumscribe and customize sociocultural infrastructures in the context of the administrative organization in the country context.

5.4 Semantic Interoperability

In order to enable semantic interoperability from one ontological representation to another, mappings between the two ontologies are required. Determining these mappings is called aligning the ontologies. OWL supports many constructs that make it easy to express relationships among concepts. Relationships between concepts in different ontologies can be used to infer the desired results. Some of the most useful features include owl:equivalentClass, owl:equivalentProperty, owl:sameAs and owl:inverseOf. In addition, the rdfs:subClassOf and rdfs:subPropertyOf predicates provide very useful semantics. Aligning domain ontologies is more interesting, but with many requirements. Interesting, because, thanks to the fine granularity of concepts and rich semantics captured by these ontologies, the richer Web of Data could be built. Ontologies designed according to perspectives and heterogeneous semantic formalization principles pushes increasingly the improvement of data integration that is beginning to bring solution to the multiplicity of the used languages [16]. Thus, to enable semantic transparency between other spatial vocabularies, a two-ways alignment are used: bottom-up and bottom alignment. The bottom-up alignment is enabled by OntoSOC [15], the upper-level ontology through ontosoc:Infrastructure and ontosoc:locality concept. To improve semantic interoperability and integration between spatial ontologies some concepts of GeoOWL (geo:lat, geo:long), Dbpedia (dbpedia:locality, dbpedia:infrastructure, dbpedia:country), FOAF (foaf:person) are reused.

5.5 Rules and Reasoning

RDFS/OWL format allows applications to parse ontology and create a list of axioms based on the ontology and all the facts are expressed as RDF statements. In CriSO, some semantics have been expressed through rdfs:subClassOf, rdf:type, owl:Class, rdfs:range, rdfs:domain, owl:ObjectProperty and owl:DataProperty constructs. Otherwise, OWL provides a number of property classes that provide additional semantics to property descriptions. Some of them were used to add semantics and enable reasoning in our ontology: isPartOf property is transitive. This enables semantic propagation: if isPartOf(A, B)and isPartOf(B, C) the application could implicitly add isPartOf(A, C) axiom. The same semantic propagation is enabled by all sub-properties of isBorderedBy. For example, if NorthBy(A, B) and NorthBy(B, C) then NorthBy(A, C) statement will implicitly be asserted for every individual. But, transitivity and PartOf are partial, i.e. acceptable on small territories and not acceptable in vast territories: Semantic propagation of transitivity and isPartOf are not always true for the globe area. In the case of transitivity, if EastOf(Belluno, Beijing) and EastOf(Beijing, Washington) then EastOf(Washington, Belluno). It's also true that, if a locality A is north bordered by a locality B, it implicitly means that, locality B is south bordered by locality A. To enable it, we defined the inverse of characteristic as follows: NorthBy is inverse of SouthBy, WestBy is inverse of EastBy, NorthWestBy is inverse of SouthEastBy, NorthEastBy is inverse of SouthWestBy.

Rule is a mean of representing knowledge that often goes beyond OWL or easier to understand than what can be expressed using OWL. In Semantic Web, rule is typically a conditional statement. New knowledge is added only if a particular statements is true. The newly added statements are not mentioned anywhere or not explicitly expressed. To go further with semantic reasoning, thanks to rules, inferences are means that applications can add new RDF statements into the existing collection of statements. Thus, based on the composition tables of RCC-8 and cone-shaped directional relations, the following prototypes rules are proposed :

- isPartOf(A, B) and hasType(B, country) then isCoPartOf(A, B) and hasType(A, Region);
- isLocatedIn(A, B) and isLocatedIn(C, D) and NorthBy(B, D), the following statement will be added NorthBy(A, C);
- WestBy(A, B) and NorthBy(A, B), the following statements are true NorthWestBy(A, B), WestBy(A, B), NorthBy(A, B).

5.6 Performance Evaluation

CriSO populating was done with data related to some localities and infrastructures in the Cameroonian context. Protégé offers a number of reasoning engines and SPARQL endpoint in its standard distribution. A reasoner checks for consistency of description of class, subsumption between classes, taxonomy of class names (classification) and finds classes that match known instances. The performance of the proposed ontology has been evaluated at the following levels: classification, consistency checking using a reasoner, and competence question checking by SPARQL queries. According to the classification checking, we tried to identify by classifying functions; if instances are automatically classified in a defined class. The same evaluation has been done for all classes. For consistency checking, it was verified, if there is any class which could never have an instance due to its definition. The competence question checking allowed by SPARQL endpoint enables us to verify, if CriSO can answer a competency question that guided its design. Thus, we focused on various infrastructures located in a locality to evaluate consistency of the Knowledge Base, and check for infinite the query (eventually). The following extract function aims to retrieve some infrastructures by locality

```
/**
* Displays infrastructures of a locality
* Displays infrastructures to 5 levels localities
* If you want more level you'll need to repeat the UNION but respecting ontology hierarchy
**/
function displayInfras($locality){

        include_once('config.php');
        $store = ARC2::getStore($config);

        $q = "PREFIX  relationship: <http://localhost/wiki/index.php/Special:URIResolver/Property-3A
                PREFIX  class: <http://localhost/wiki/index.php/Special:URIResolver/Category
                SELECT  DISTINCT ?nom ?s
                WHERE {
                                ?s relationship:Se_trouve ?o.
                                ?s rdf:type ?n.
                                ?s rdfs:label ?nom.
                                OPTIONAL{?n rdfs:subClassOf ?q.
                                        OPTIONAL{?q rdfs:subClassOf ?e.
                                                OPTIONAL{?e rdfs:subClassOf class:In
                                                }
                                        }
                                {
                                                {?o rdfs:label ?p.
                                                FILTER(?p=\"${locality}\")}
                                UNION
```

Fig.5 An extract of the Infrastructure retrieval function

6. CONCLUSION

This paper proposes a spatial domain ontology for sociocultural features named CriSO. The modeling approach is based on RCC-8 model complemented by directional relations encoded by cone-shaped or alternatively, projection-based relations. This ontology shows how annotate and capture the human reasoning related to sociocultural infrastructures. In addition, compared to others (table 1), CriSO models the three aspects of geographic information, which are semantic, geographic and spatial relations.

Usually, two categories of features and relations can be distinguished, crisp and fuzzy. This study focused on the crisp objects and relations. Crisp objects must have well-defined boundaries such as administrative objects (countries, regions, provinces, natural parks, parcels, etc.) and anthropic objects such as streets, buildings. Crisp relations are those relations without uncertainty. The crisp spatial relations in the ontology is based-on RCC-8 relations (NTPP(x,y), PO(x,y), NTPPi(x,y), and EC(x,y)) and directive relations. To point out their social meanings, these relations have been mapped : NTPP(x,y),PO(x,y), EC(x,y), and NTPPi(x,y) are respectively equal (semantically) to isLocaltedIn(x,y) and isPartOf(x,y), overlaps(x,y), isBorderedBy(x,y), hasPartOf(x,y). Due to the fact that some spatial facts cannot be explicitly expressed by RDFS/OWL, some rules have been defined, which could allow KMS to infer and add some statements to the RDF graph. For interoperability issues, the bottom-up alignment was done through OntoSOC the upper-level sociocultural ontology and with the existing spatial domain ontology such are GeoNames, GeoOWL aforementionned for the bottom case. To evaluate the performance, CriSO has been populated with data taken from Cameroonian context. Reasoner included in Protégé and some SPARQL queries have been run (Fig. 6).

To complement the spatial human reasoning, we plan as perspective of this study to formalize the fuzzy aspect of the spatial human reasoning devoted to sociocultural features.

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