Adjustment of ontologies for GeoSpatial SWRL rules

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Abstract

The world is witnessing the change in technology and when such changes occur the components of previous technology need to be adjusted in new environment. The spatial component of conventional database system needs to be adjusted in the new semantic web framework. This paper presents a method of adjusting spatial components in semantic web technology.

Keywords: Spatial data, Knowledge Management, Semantic Web, Inference Rules, Geospatial Analysis

1. Introduction

The emergence of the Internet technology has provided a strong base to share information in actual sense. The technology has matured enough to share all kind of information whether they are strictly based on semantic information or consist of other forms of information as spatial and temporal information. The world has witnessed the monumental growth of this technology in last couple of decades. It in one hand is an enormous source of information but has its own problems. The share volume of information on the Internet has created huge problem in managing them. It seems it is now not possible to manage them through the human intelligence. Hence, the efforts of including machine through machine interpretable technology to assist human to manage the ever increasing volume of information on web are being researched and implemented. The idea was proposed by Tim-Berners Lee in his paper (Berners-Lee, Hendler, & Lassila, 2001) and termed it as next generation web where the information is given with well-defined meaning, better enabling computers and people to work in cooperation. They call the technology as “Semantic Web”. Since then lots of research have been conducted in this area.

Knowledge technologies are closely linked to the Semantic Web technology. As both of them use machine learning capabilities to process the information they both have the common approach. The close association of knowledge inside semantic web technology has been viewed as a possibility of the technology providing a platform toward the developments of knowledge management systems (Stojanovi & Handschuh, 2002). The formalization of the information for machine to understand through various tools and techniques within the technology has provided an opportunity to collaborate with machine to manage this sea of information.

This paper discusses the integration of geospatial data into the semantic web technology. During the years the spatial technology has grown up tremendously. Existing web services allow to the geospatial information shared through web. There is a huge potentiality in managing those spatial information through semantic web technology. However, little has been explored on the direction of usage of different components of the technology to carry out spatial analysis and more emphasis is given to use the technology for interoperability of spatial dataset among various platforms. This paper presents the result of our research work to integrate spatial component in the semantic web technology and use geospatial analyses in the form of inference rules involving spatial functions and operations.

This paper is arranged in the following manner. Section 2 discusses the motivation of our research work keeping in terms with the existing works. Section 3 discusses the technologies whereas chapter 4 discusses the underlying concept and methodology behind the research. Chapter 5 demonstrates results of the research work.

2. Previous Works

This section discusses the previous research works in this area and their limitations which prompted us to carry our research works in this area.

2.1. Previous Works

The semantic web technology is slowly gaining acceptance in the wider community. It is thus paramount to include every type of information within the technology. The core within semantic web technology is the semantics of the resources. These semantics may be the spatial and non-spatial. However, the focus of the technology is mainly on utilizing the non-spatial semantics for managing the information. Thus, the spatial information is widely neglected. Nevertheless, it has been realized inclusion of spatial components within semantic web framework is important and the researches are carried out to create geospatial ontologies at different levels. Those researches mainly focus on semantic interoperability of spatial data for efficient exchange of spatial data over heterogeneous platforms or efficient data integration. In cases like [(Cruz, Sunna, & Chaudhry, 2004); (Cruz, Geospatial Data Integration, 2004)], the ontologies are used to map their concepts to a global concept within a global ontology and thus providing a common platform for data integration. This is a common trend of practice for managing heterogeneous data source through semantic web technology. The same practice is applied for geospatial data sources. In other cases like (Tanasescu, et al., 2006), ontologies are used manage the semantics within different data sources to maintain the semantic interoperability of spatial data within different platforms.

In the realm of geospatial and temporal concepts and relationships, the work has not yet reached a level of either consensus or *actionability* which would allow it to be basis of knowledge interoperability (Lieberman, 2007). Open Geospatial Consortium (OGC) is playing a major role to develop a consensus among different stakeholder on various aspect of geospatial technology. Data interoperability is a major area in which OGC is concerned upon and it has developed different standards for this. Groups like Geospatial Incubator have taken the works of OGC to formulate steps in updating the w3c geo vocabulary and preparing the groundwork to develop comprehensive geospatial ontology. In the process it has reported different spatial ontologies that exist in the web (Lieberman, Singh, & Goad, W3C Geospatial Ontologies - W3C Incubator Report, 2007).

It is evident that the geospatial ontologies are developed to solve individual spatial problem and are not being used to be effective for knowledge formulation within the semantic web framework. The ontologies that exist or in the process of creation are mostly targeting the usage of vocabularies for the proper data management and not the knowledge management. One implication of such approach is that there is no possibility geospatial reasoning to enhance the knowledge base. It is widely noticed there is the lack of a known, robust geospatial reasoners. Furthermore, it has been argued that while geospatial reasoning is an ever-evolving field of research, spatial data constructs are not yet accommodated within most current Semantic Web languages as OWL (Reitsma & Hiramatsu, 2006).

There is a clear limitation on approaches of existing research works. They focus heavily on spatial interoperability through semantic web technologies. They do not consider the spatial analyses through knowledge modelling. We consider the process of geospatial analysis is the set of spatial rules that are carried out to achieve certain goal. The knowledge technology within semantic web provides the potentialities to execute rules through its inference engines.

This research work benefits from the existing inference technology to deliver the inference rules and combines spatial components along them through spatial functions and operations as spatial rules to enrich the knowledge base.

2.2. ArchaeoKM – A Case Study in Industrial Archaeology

The research work takes the case of Industrial Archaeology to provide its argument. It should be noted that we take the example of archaeology just to provide an example and the concept could be taken in any other discipline.Industrial Archaeology is probably the most suitable area to work on as there exist huge collection of objects during excavation process which needs to be categorized. However due to the lack of time or unidentifiable conditions of these objects, most of them could not be classified on the site. The archaeologists need to be involved to identify the object and classify them later. They do this either through their prior knowledge or through rules defined based on the properties of the excavated objects. The properties could be semantic and spatial so the rules need to encompass both semantic and spatial components. A tool to demonstrate the ideas was developed and is called *ArchaeoKM*.

ArchaeoKM is a web based tool to support the archaeologists to manage their information during their excavations. As already been mentioned it is based on Semantic Web technology and knowledge management. It provides supports archaeologists to manage their data and document collected during excavation through simple but efficient mechanism of annotations. The data and documents are stored in their proprietary format and they are annotated to the relevant objects through semantic annotations. It provides a base for data integration. The objects are identified and tagged within the orthophoto. Those identified objects get populated into the domain ontology which is basically a graphical representation of the excavation site.

ArchaeoKM is a rule based system. It uses the advancement in rule engines through rule languages to manage the knowledge. Once the objects are identified and tagged within the domain ontology, a knowledge base is created which reflects the knowledge of the archaeologist who has tagged the objects. Now this knowledge base could be used to manage the knowledge. ArchaeoKM uses rule languages of rule engines (primarily SWRL and Jena Rule) to manage them. This paper highlights the process of inclusion of spatial rules within ArchaeoKM through built-ins of SWRL.

3. Technology

This section discusses the technologies behind the research work. Basically, the research work is divided into two broader categories of approaches: GIScience and Semantic Web. Hence, the technologies are discussed in the relevant approaches.

3.1. GIScience

The technology in GIScience has matured in the last decades. The shift in technology from file based system to database system has been readily embraced by the technology. Today every GIS system has strong database system to support the storage, management and retrieval of spatial data. Additionally, every existing database systems provide the spatial capabilities through their spatial extensions. This research work utilizes the spatial extension PostGIS 1.5 of PostgreSQL 8.3 for spatial functions and operations. In every GIS, data are represented in two ways Vector and Raster. The existing database systems provide the spatial functions for storing and retrieving vector data.

We begin with how PostgreSQL stores spatial data. A strong tendency has been seen in the last few years that big GIS vendors like GRASS and ESRI have shifted their support towards PostGIS. It supports the storage of point, line, polygon, multipoint, multiline, multipolygon, and geometrycollections. It follows the specification provided by OGC for the simple features to store these objects. Those are specified in the Open GIS Well Know Text (WKT) or

Well Known Binary (WKB) Formats[1]. From as early version as PostGIS 0.9, it supports all the objects and functions specified by OGC "*Simple Features for SQL*" specification. However PostGIS extends by supporting 3D and 4D objects. PostGIS has given those extensions names as EWKB or EWKT (Extended Well Known Binary and Extended Well Known Text). In contrast to the Simple Feature Specification by OGC, those extensions support the embedded SRID information. Hence it can be seen easily that PostGIS supports 2D features by following the Simple Feature Specifications of OGC and storing them in WKB or WKT and 3D features through EWKB or EWKT.

Spatial functions and operations are the queries performed on the spatial data set to generate the results which can be visually interpreted. It is a process that leads to the spatial analysis. The spatial operations take different spatial properties of an object like the topological, geometric or geographic properties for carrying out the spatial analysis. All major database systems support these functions and operations. They are basically coupled with SQL SELECT statement.

The general syntax of usage of these operations within SQL SELECT statement is similar no matter the type of spatial operations. The syntax

```
SELECT column_name(s), spatial_function(geometry column)
FROM   table_having_geometry_column
WHERE filter(s)
```

is just an extension of SELECT statement syntax to adjust the spatial operations. There exist huge collection of spatial operations and functions in PostGIS libraries which can be used on spatial object. This paper lists out these functions and operations in terms of their nature. In general they can classify in four categories as listed below in table 1 but we will be discussing the last two categories as they comprise maximum number of spatial operations and functions.

Category	Spatial Function/Operation	SQL Statement
GeoQueries	Area/Length	SELECT column_name FROM table WHERE ST_Area/ST_Length(geom) > value;
GeoMeasurement	Area/Length/Distance	SELECT ST_Area/ST_Length(geom);
		SELECT ST_Distance ((_fromgeom), (_togeom));
GeoProcessing	Buffer/Union/Intersection/ Difference	SELECT ST_Buffer(geom);
		SELECT ST_Union/ST_Intersection/ST_Difference(geom1), (geom2));
GeoRelationship	Disjoints/Equals/Touches/Within /Overlaps	SELECT ST_Disjoints/ST_Equals/ST_Touches/ST_Within/ST _Overlaps((geom1),(geom2));

Table 1: Spatial functions and operations in DBMS

The**GeoRelationship functions** are generally binary functions. These functions return a Boolean value. However, when they are used with a proper SQL statement, these functions can be used to identify the objects with which they are related to. The functions are used as SQL statement. The examples of spatial functions under this category are *touch, disjoint, overlap,within* and are used through *st_touch, st_disjoint, st_overlap, st_*within respectively in PostGIS.

The **GeoProcessing functions** provided in this section allow the processing of the object geometries. The results themselves are sets of geometries. Spatial functions like *buffer, intersection,Difference* and *Union* come under this category. Those functions are executed through*st_buffer, st_intersection, st_difference*and*st_union* respectively in PostGIS.

3.2. Semantic Web

The World Wide Web (WWW or the web) is the single largest repository of information. The information are conventionally are presented through web browsers with very less or no involvement of the users accessing these information. Those systems are presentation based and do not consider contents behind them. However, content based systems emerged but they lack the proper definition of semantics within the contents. A need of intelligent systems which could exploit the wide range of information those are available within WWW is widely felt. Semantic web is envisaged to address the need. The term *Semantic Web* is coined by Tim Berners-Lee in his work (Berners-Lee, Hendler, & Lassila, 2001) to purpose the inclusion of semantic for better enabling machine-people cooperation for handling the huge information that exists in the net.

3.2.1. OWL

OWL is a knowledge representation language and a standard (W3C recommendation) for expressing ontologies in the Semantic Web. The OWL language facilitates greater machine understandability of Web resources by providing additional constructors for building class, property descriptions and new axioms, along with a formal semantics. Concepts are sets of classes of individual objects. Classes provide an abstraction mechanism for grouping resources with similar characteristics (Bechhofer, et al., 2004). In any graphical representation of knowledge classes are represented through the nodes. Descriptions on OWL classes are discussed in details in (Bechhofer, et al., 2004). A property restriction is an unnamed class containing all individuals that satisfy the restriction. Properties are binary relationships between two objects. In general they are the relationships between two classes which apply to the individuals of those classes. They are known as roles in description logic and are represented through links in the graphical representation. OWL provides two main categories of properties: Object properties – relationships between concepts and consequently instances of the concepts and Data properties – relation of an instance to the data value.

3.2.2. SWRL

Semantic Web Rule Language (SWRL) (Horrocks, Schneider, Boley, Tabelt, Grosof, & Dean, 2004) is a rule language based on the combination of the OWL-DL (SHOIN(D)) with Unary/Binary DatalogRuleML which is a sublanguage of the Rule Markup Language. One restriction on SWRL called DL-safe rules were designed in order to keep the decidability of deduction algorithms. This restriction is not about the components of the language but on its interaction. SWRL includes a high-level abstract syntax for Horn-like rules.

The SWRL as the form, *antecedent*→*consequent*, where both antecedent and consequent are conjunctions of atoms written $a_1 \wedge \ldots \wedge a_n$. Atoms in rules can be of the form *C*(x), *P*(x,y), *Q*(x,z), *sameAs*(x,y), *differentFrom*(x,y), or *builtIn*(*pred*, z1, …, zn), where *C* is an OWL description, *P* is an OWL individual-valued property, *Q* is an OWL data-valued property, *pred* is a datatype predicate URIref, x and y are either individual-valued variables or OWL individuals, and z, $z_1, \ldots z_n$ are either data-valued variables or OWL data literals. An OWL data literal is either a typed literal or a plain literal [2]. Variables are indicated by using the standard convention of prefixing them with a question mark (e.g., ?x). URI references (URIrefs) are used to identify ontology elements such as classes, individual-valued properties and data-valued properties. For instance, the following rule asserts that one's parents' brothers are one's uncles where parent, brother and uncle are all individual-valued properties. This could be executed with the SWRL presented in rule (Pan & Horrock, 2005).

parent(?x, ?p) ^ brother(?p, ?u) → uncle(?x, ?u)

3.2.3. SWRL Built-ins

The set of built-ins for SWRL is motivated by a modular approach that will allow further extensions in future releases within a (hierarchical) taxonomy. SWRL's built-ins approach is also based on the reuse of existing built-ins in XQuery and XPath, which are themselves based on XML Schema by using the datatypes. This system of built-ins should also help in the interoperation of SWRL with other Web formalisms by providing an extensible, modular built-ins infrastructure for Semantic Web Languages, Web Services, and Web applications. Many built-ins are defined and a non-exhaustive list can be found below.

- *Comparisons*
- *Math Built-Ins*
- *Built-Ins for Boolean Values*
- *Built-Ins for Strings, etc.*

The next SWRL rule is an example using the Math built-in “swrlb:greaterThan”. If the result of the built-in is true for a Person ?p then this Person ?p is a member of the of the concept Adult.

Person(?p) ^ hasAge(?p, ?age) ^ swrlb:greaterThan(?age, 18) → Adult(?p)

4. Background Concept and Methodology

Spatial components are integrated as built-ins within the semantic web tools. Ontology represented through OWL is an integral part of semantic web which represents real world abstraction in class-properties approach. The ontology needs to be adjusted to include the spatial components within. Two groups of spatial operations have been discussed in previous sections. These two groups of operations are included in ontology in distinct approaches.

4.1. Ontological Adjustment

The ontology representing the real world abstraction and base of any knowledge technology should accommodate spatial components inside to provide spatial prospects to the knowledge base. This is done by relating the classes representing real world to those accommodated spatial components through certain strictly defined relationships.This paper uses the domain ontology described in ArchaeoKM [(Karmacharya A. , Cruz, Boochs, & Marzani, ArchaeoKM: Toward a Better Archaeological Spatial Data Dets Management, 2009); (Karmacharya A. , Cruz, Boochs, & Marzani, Support of Spatial Analysis through a Knowledgebase - A new concept to exploit information shown for Industrial Archaeology, 2009); (Karmacharya A. , Cruz, Boochs, & Marzani, ArchaeKM: Managing Archaeological data through Archaeological Knowledge, 2010)] and consists in adding new axioms (classes, relationships, attributes, etc.) for our purpose. However, it should be noted that the concept could be applied to any domain ontologies having tangible spatial objects.

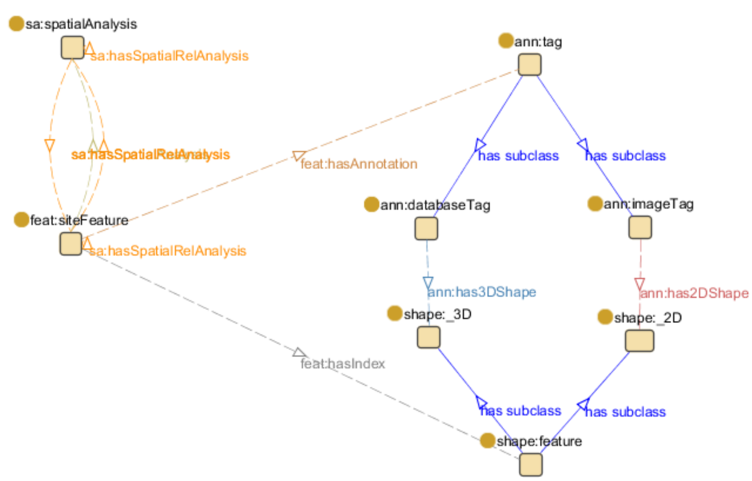

Figure 1: Classes and Relationships for the ontology adjustment process

This ontological settlement is taken advantage by semantic web technologies to perform their task. It needs to be underlined that the semantic web technologies like reasoning engines and SPARQL benefit from this adjustment to reason the knowledge base spatially or to query the knowledge base but we focus on Inference rule language like

SWRL to put forward our view. The spatial functions are included as spatial components within SWRL and when these rules are executed, the results of these rules will generate information that have to be stored in the enriched part of the ontology. The main process of enriching the ontology schema consists in adding the concept *feat:siteFeature* (e.g. Figure. 1).

All the objects, that define a domain concept and have a geometrical definition in the spatial database, requires to be instances of the concept *feat:siteFeature*. This concept is important as it allows the definition of links between the adjusted domain ontology and the spatial functions. These spatial analysis properies are specializations the relationship *sa:hasSpatialRelAnalysis*. The concept *sa:spatialAnalysis* refers to the spatial functions as its specialized concepts and are defined through its inheritance. In addition, the links between the ontology and the database are defined using the link *feat:hasAnnotation*. The *shape:feature* relates to the geometrical definition of excavated objects and the *an:tag*refers to the same geometrical definition but stored into the database. Details on how *an:tag* or *feat:Annotation* functions can be read in [(Karmacharya A. , Cruz, Boochs, & Marzani, Support of Spatial Analysis through a Knowledgebase - A new concept to exploit information shown for Industrial Archaeology, 2009); (Karmacharya A. , Cruz, Boochs, & Marzani, ArchaeoKM: Toward a better archaeological dataset management, 2009)].

4.1.1. GeoRelationship functions

GeoRelationship functions demonstrate the spatial relation of objects. These types of functions are represented through object properties with an OWL file. A relation *sa:hasSpatialAnalysis*is introduced in the ontology and the functions under this category are represented as its specialized properties. The following four sub-relation of the relationship *sa:hasSpatialRelAnalysis* define spatial relationships between two objects. The result of a spatial function process between two objects of the kind of the concept *feat:siteFeature* can be a new link between them. This new link is of kind of *sa:hasDisjoint*, *sa:hasTouch*, *sa:hasWithin* or *sa:hasOverlaps* (e.g. Table 1).

Spatial Relationship Functions	ObjectProperties
Disjoint	sa:hasDisjoint(x,y)
Touches	sa:hasTouch(x,y)
Within	sa:hasWithin(x,y)
Overlaps	sa:hasOverlaps(x,y)

Table 2: Ontology adjustment concerning the Spatial Relation Functions

The variables x and y are of the type of the concept *feat:siteFeature*. It means that it could be an object or the result of a spatial processing function.

4.1.2. GeoProcessing functions

These functions need to store the spatial data through their executions and hence represented as classes within the OWL files. They are related to the real world object through the object properties representing them. For example if there is a class *Buffer* then there should also be a property *hasBuffer* which relates the *Buffer* class to the classes representing real world.

The four spatial processing functions which are discussed in this paper are Buffer, Union, Intersection and Difference. Contrary to the spatial relationship functions, they compute new spatial geometries. These new geometries are also stored in the spatial database in order to be computed by future spatial functions. As a solution, we definition four new classes called *feat:sp_buffer, feat:sp_union, feat:sp_Intersection*and*feat:sp_difference* which are of kind of *feat:siteFeature*. By inheritance, these four concepts have a spatial definition in the spatial database which are defined with the help of the relationship *feat:hasAnnotation* like any other finding objects. There is also four *sa:hasSpatialRelAnalysis* defined corresponding to each spatial processing function (*sa:hasBuffer,* *sa:hasUnion, sa:hasIntersection, sa:hasDifference*). They are used to keep a link between the first spatial geometry of the spatial function and the results of this spatial function (*feat:sp_buffer, feat:sp_union, feat:sp_Intersection or feat:sp_difference*) (e.g. Table 3).

Spatial Processing Functions	Concept	Object Property
Buffer	feat:sp_Buffer	sa:hasBuffer(x,y)
Union	feat:sp_Union	sa:hasUnion(x,y)
Intersection	feat:sp_Intersection	sa:hasIntersection(x,y)
Difference	feat:sp_Difference	sa:hasDifference(x,y)

Table 3: Ontology adjustment concerning the Spatial Processing Functions

The variables x and y are of the type of the concept "*feat:siteFeature*". It means that it could be an object or the result of a spatial processing function.

4.2. Definition of the Spatial SWRL Built-ins

At this point, the ontology adjustment is defined. From this adjustment, the Spatial SWRL Built-ins can be defined for each spatial function. Before the definition of these Built-ins, it is necessary first to explain how work the engine that translates Spatial SWRL rules into standard SWRL rules. To prove this we present a simple example to determine the location of possible flooding zone when the river bank burst with excessive water during rainy season. This is a very common exercise for a flood management system in hydrology.

River(?x) ^ LandParcel(?y) ^ hasElevation(?y, ?Elv) ^ swrlb:lessThan(?Elv, 25) ^
spatialswrlb:Buffer(?x, 50, ?z) ^ spatialswrlb:Intersection(?z, ?y, ?res)
→FloodingLandParcel(?res).

It is a simple example setting the rule as land parcel having elevation below 25 units and within 50 units of a river is a flooding land parcel. It should be understood that this example is provided just as a proof of the concept hence details on other hydrological factors are ignored on purpose. The example uses five axioms. The axioms*River* and*LandParcel*are concepts which instances possess spatial characteristics which are stored as spatial data type within the database. The axiom *FloodingParcel* is also a concept which groups the resultant instances from the execution of the rule.It means that resulted land parcels *?res* can be flooded if all the axioms of the antecedent are true. This rule is computed for every rivers and land parcels that are present in the ontology. The axiom *spatialswrlb:Buffer* is to compute a buffer for the river *?x*with buffer distance of 50, and the axiom *spatialswrlb:Intersection* is used to compute the intersection of the second feature *?y* with the result of the buffer operation. The land parcels with elevation is determined through axiom *hasElevation(?y, ?Elv)*and the parcels below 25 meters is selected through axiom *swrlb:lessThan(?Elv, 25).*

The role of the translation engine consists in

- *interpreting the Spatial SWRL rules*
- *computing the spatial functions within spatial database*
- *updating the ontology and the spatial database with the results of the spatial functions*
- *translating the spatial SWRL rules into standard SWRL rules*
- *running the rules with the help of a standard rule engine as Racer, Jess or Pellet*

The two next sections explain how the spatial built-ins are translated into SWRL rules. The computing of the spatial functions is out of the scope of this paper. However, it uses SQL statements.

4.2.1. Spatial Relationship Built-ins

Concerning these built-ins, the translation engine computes the spatial function in the database within all the instances of the built-in parameters. For instance, the built-in*spatialswrlb:Disjoint(?x, ?y)* is interpreted by the translation engine and compute all the instances of the kind of the variables ?x and ?y. If the result is true for any couple of instances, then a new relationship *sa:hasDisjoint* is created in the ontology between the couple of instances. After what, the axiom *spatialswrlb:Disjoint(?x, ?y)* is replace in the rule by the axiom *sa:hasDisjoint(?x, ?y)* (e.g. table 4). Consequent, the rule is now a standard rule.

Spatial Relationship Functions	Spatial SWRL rules (Built-ins)	SWRL rules
Disjoint	spatialswrlb:Disjoint(?x, ?y)	sa:hasDisjoint(?x, ?y)
Touches	spatialswrlb:Touches(?x, ?y)	sa:hasTouch(?x, ?y)
Within	spatialswrlb:Within(?x, ?y)	sa:hasWithin(?x, ?y)
Overlaps	spatialswrlb:Overlaps(?x, ?y)	sa:hasOverlaps(?x, ?y)

Table 4: Translations of Spatial Relationship Functionsinto a SWRL rule

4.2.2. Spatial Processing Built-ins

Concerning these built-ins, the translation is a bit more complex. Actually, the translation engine has to interpret the spatial built-ins and to compute the new geometry for each built-in. The resulting geometries are stored in the spatial database and a new individual of the kind of the *feat:sp_Buffer*, for example, is created in order to keep a link with the database. In addition, a link of the kind of the relationship *sa:hasBuffer*, for example, is created in order to keep a relationship between the first individual parameter of the built-in and the new individual *feat:sp_Buffer*. Once the ontology is updated, the axiom *spatialswrlb:Buffer(?x, ?value, ?res)*, for instance, is replace by the following two axioms *sa:hasBuffer(?x, ?res) ^ feat:sp_Buffer(?res, bufDistance(?value))*. The parameter *?res* is to refer the resultant instances of *feat:sp_Buffer*, for instance. Similarly *bufDistance(?value)* defines the buffering distance. It is a data property but is important factor defining a buffer zone. The table 4 shows the complete translations.

Spatial processing Functions	Spatial SWRL rules (Built-ins)	SWRL rules
Buffer	spatialswrlb:Buffer(?x, ?value, ?res)	sa:hasBuffer(?x, ?res) ^ feat:sp_Buffer(?res) ^ bufDistance(?res, ?value) ≡ sa:hasBuffer(?x, ?res) ^ feat:sp_Buffer(?res, bufDistance(?value))
Union	spatialswrlb:Union(?res, ?x, ?y)	sa:hasUnion(?x, ?res) ^ sa:hasUnion(?y, ?res) ^ feat:sp_Union(?res)
Intersection	spatialswrlb:Intersection(?res, ?x, ?y)	sa:hasIntersection(?x, ?res) ^sa:hasIntersection(?y, ?res) ^feat:sp_Intersection(?res)
Difference	spatialswrlb:Difference(?res, ?x, ?y)	sa:hasDifference(?x, ?res) ^ sa:hasDifference(?y, ?res) ^feat:sp_Difference(?res)

Table 5: Translations of Spatial ProcessingFunctionsinto a SWRL rule

Continuing with example, step wise translations are carried out as standard SWRL rules by the translation engine. Meanwhile, the translation engine has computed the necessary geometries and has updated the domain ontology with individuals and relationships allowing the run of the translated rule by a reasoning engine. Thus, a spatial reasoning is possible on the domain ontology. The rule in the example is broken down by the translation engine into

River(?x) ^ LandParcel(?y) ^ hasElevation(?y, ?Elv) ^swrlb:lessThan(?Elv, 25) ^
sa:hasBuffer(?x, ?z) ^ feat: sp_Buffer(?z) ^ sa:bufDistance(?z, 50) ^ feat:Intersection(?res) ^
sa:hasIntersection(?res, ?y) ^ sa:hasIntersection(?res, ?z) →FloodingLandParcel(?res)

And consequently,

River(?x) ^ LandParcel(?y) ^ hasElevation(?y, ?Elv) ^swrlb:lessThan(?Elv, 25) ^

sa:hasBuffer(?x, ?z) ^ feat: sp_Buffer(?z,sa:bufDistance(50)) ^ feat:Intersection(?res) ^ sa:hasIntersection(?res, ?y) ^ sa:hasIntersection(?res, ?z) →FloodingLandParcel(?res)

before finally executing.

5. Realization

This section discusses the realization tool to demonstrate the concept. This tool independent to *ArchaeoKM* as the development work was done parallel to completion of *ArchaeoKM* prototype and was planned to integrate after its completion. Hence, the classes used within the tool are distinct from the classes present in domain ontology of *ArchaeoKM*. This allows us to demonstrate the example discussed in previous section.

The figure 2 shows the execution of the rule through this independent tool.

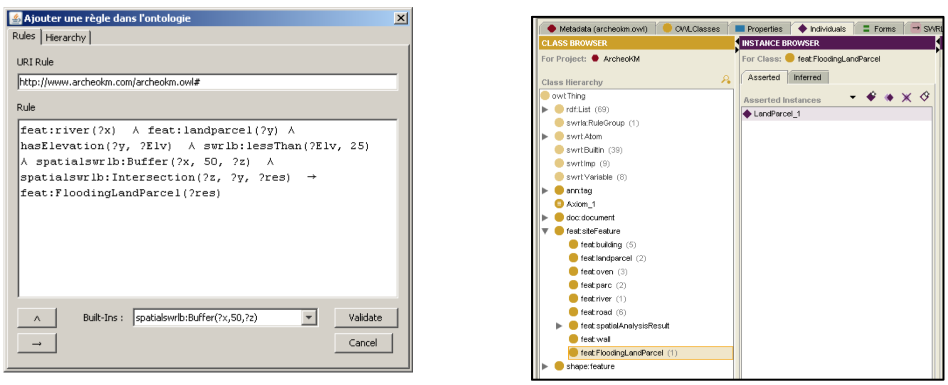

Figure 2: Execution and result of the rule

The figure 5 also shows the result. But currently it is possible to view the result in OWL editor like in Protégé. The integration of spatial components in *ArchaeoKM*is currently underway. After the complete integration, it would be possible to view results in working application. However, with this simple exhibition tool, it could be easily proved that the spatial analysis is possible through executing the spatial rule in proper sequence.

6. Conclusion

The paper demonstrates the working example of spatial integration in semantic web framework. Semantic web and its technologies are in the process of maturity and hence it is not possible to achieve this goal through the existing technologies within semantic web only. The paper demonstrates how the conventional database system could be utilized in order to perform spatial functions and operations and how the results from these operations can be populated in the knowledge base. As the technology shifts the individual components within it needs to be shifted as well. We are witnessing a shift in technology from database oriented Information Technology to Knowledge Management technology. Semantic web technology and its tools and techniques are contributing this shift in its own way. The spatial components that are represented through spatial extensions in database system need to be adjusted in the changing environment. We present an approach in which they could be adjusted. It has huge benefits to GIS technology as it would be possible to reason the data spatially through reasoning engines or infer spatial rules as presented here. A layer in GIS process can be proposed to represent knowledge which will allow efficient and fast processing of data.

7. References

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