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Volume 1, No. 2, September 2010
Journal of Global Research in Computer Science
ISSN-2229-371X
RESEARCH PAPER
Available Online at www.jgrcs.info

# Spatial Rules through Spatial Rule built-ins in SWRL

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***Abstract*:** The paper presents a method to include spatial rule within rule languages like SWRL to infer spatial rules within semantic web framework. The concept presented here could benefit both geospatial community as they benefit using the adjusted knowledge base to infer spatial rule and semantic web community as the inclusion of spatial data in its framework adds value to the technology. The methods presented here is suitable to be implemented in other tools and techniques within semantic web technology.

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

## INTRODUCTION

Internet has refashioned the concept of information and has been the biggest repository of information. The volume of information is ever-growing and thus is the necessity in maintaining them. It has now become almost impossible to use the conventional human intelligence to manage the information hosted by Internet sites. It is thus inevitable for a radical shift in technology to manage them. The inclusion of machine interpretable technology co-working with human has been proposed by Tim-Berners Lee as the next generation web in his paper [3] and coined it as "*Semantic Web*". The idea was to give information well defined meaning which enables machine to work together with human. Knowledge is considered as the foremost theme to manage these information and this close association of knowledge technology in semantic web technology has provided platform for developments in knowledge management systems [12].

We are witnessing the change in technology and with this shift, every components of previous technology need to be shifted too. Previously we have seen that when technology shifted from file based system to database oriented Information system, the geospatial community readily embraced the shift. And now is the time to embrace the new technology of ontology based knowledge system which semantic web is a part. Unfortunately, the full potentiality of the technology is yet to be realized. Today most of the researches in geo-ontology are driven by data integration and data interoperability concerns. Though these researches yield highest degree of successes, they have not used the full potentiality of the knowledge technology in semantic web [7].

This paper discusses the integration of geospatial data into the semantic web technology in terms of tools and techniques based on knowledge processing and managing.

This paper is arranged in the following manner. Section 2 discusses the case study of this research work. Section 3 discusses the underlying concept and methodology behind the research. And finally chapter 4 concludes with the discussion on the results.

### *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 a scenario. This concept could be easily be applied to 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. *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 [6].

## *BACKGROUND CONCEPT AND METHODOLOGY*

The spatial technology has benefited immensely from the development in database system. Today every database system is hooked up with spatial extension to carry out spatial operations. We benefited from an open database system in PostgreSQL and its spatial extension PostGIS. The spatial operations and functions in a database system can be classified into four broader categories: *GeoQueries*, *GeoMeasurement*, *GeoProcessing* and *GeoRelationships.* We will discuss the last two categories in this paper for the spatial integration as they cover majority of the operations. *GeoProcessing* functions are functions which return geometries when executed. Spatial functions as *Buffer*, *Union*, *Difference* and *Union* lie under this category. In contrast the *GeoRelationship* functions return the status of the spatial relationship between two objects. Operations as *Touch*, *Within*, *Overlap*, *Contain* are the examples of such functions. Both these categories are integrated as built-ins in semantic web but are handled in two distinct approaches.

Spatial components are integrated as built-ins within the semantic web tools. Ontology represented through OWL [1, 2, 5] 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.

### *Ontological Adjustment*

The linkage of the real world objects to their spatial properties must be exploited in order to use them for coming up with proper association of spatial technology within knowledge base. This paper discusses an approach of mapping the classes representing real world to those accommodated spatial components through certain strictly defined relationships within domain ontology. This paper uses the domain ontology described in *ArchaeoKM* [8, 9, 10] 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.

As stated previously, the two categories of spatial functions need to be accommodated within the domain ontology in their own unique approach. Let us begin with the accommodation process of *GeoProcessing* functions. They return geometries and these geometries need to be stored in some method for further calculations. They are stored as classes in the OWL files. Furthermore, these classes are related to the classes representing real world objects through the respective object properties. For example there should be a class *Buffer* which should relate to class representing real world object through the object property *hasBuffer.* The *GeoRelationship* functions return the status of relationships. They can thus be directly included through object properties in the OWL files. For example, the spatial function *touch* should be represented through *hasTouch* object property within the OWL file. This is shown in figure 1.

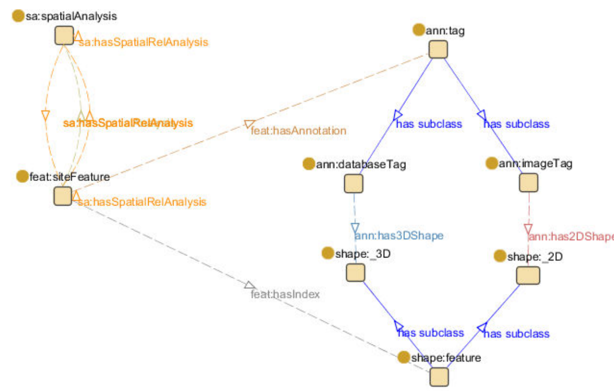


**Figure 1:** Classes and Relationships for the ontology adjustment process

This ontological settlement is then exploited by tools and techniques of semantic web technologies to perform their task. We would be focusing on the inference capability of semantic web technology through rules to execute spatial rule through this settlement but other tools and techniques like reasoning engines and SPARQL [11] can also benefit from this adjustment. 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). It could be seen that new components *sa*:*spatialAnalysis* and *sa:hasSpatialRelAnalysis* have been injected in the domain ontology of *ArchaeoKM*. They basically represent the generalized class of classes representing *GeoProcessing* functions and generalized object property of object properties representing the *GeoRelationship* functions and the ones mapping the classes with *sa*:*spatialAnalysis* to the classes containing real world objects, *feat*:*siteFeature* in this case. For detail on other components one could read [8, 10].

### *SWRL Built-ins*

The spatial functions are included within SWRL rules are spatial built-ins. 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)*.

### *Translation Engine*

The major responsibility of Translation Engine is to break down the SWRL statement and parse the spatial components for execution of spatial functions in the database system. It then enriches the results of the operation in to the knowledge base. Now since the knowledge base is enriched and the spatial SWRL is transformed to standard SWRL, the engine runs the rules with the help of standard rule engines as *Racer, Jess* or *Pellet*.

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)*

## …AND FINALLY

The integration process in realized through a tool which is 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.

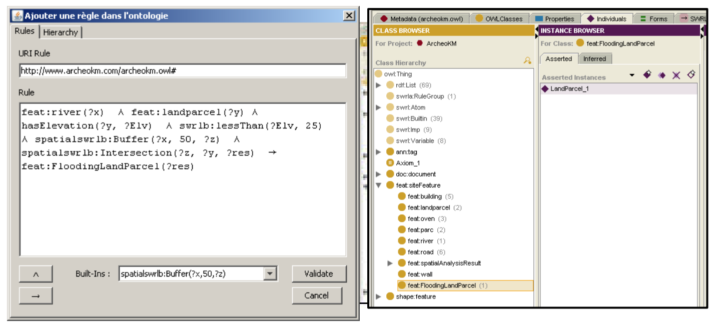


**Figure 2:** Execution and result of the rule

The figure 2 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.

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. We present an approach in which spatial components can be adjusted within semantic web framework. It has huge implications to GIS technology as it would be possible to reason the data spatially through reasoning engines or infer spatial rules as presented here providing tremendous boost to spatial analysis process.

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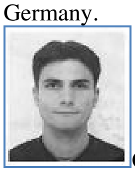
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