Semantic Annotation of Geospatial RESTful Services Using External Resources

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Abstract. RESTful services are increasingly gaining traction over WS-* ones. As with WS-* services, their semantic annotation can provide benefits in tasks related to their discovery, composition and mediation. In this paper we present an approach to automate the semantic annotation of RESTful services using a cross-domain ontology, two semantic resources like DBpedia and GeoNames, and additional external resources (suggestion and synonym services). We also present a preliminary evaluation in the geospatial domain that proves the feasibility of our approach in a domain where RESTful services are increasingly appearing and highlights that it is possible to carry out this semantic annotation with satisfactory results.

Keywords: REST, semantic annotation.

1 Introduction

In recent years, since the advent of Web 2.0 applications and given some of the limitations of "classical" Web services based on SOAP and WSDL, Representational State Transfer (REST) services have become an increasing phenomenon. Machine-oriented Web applications and APIs that are conformant to the REST architectural style [23], normally referred to as RESTful Web services, have started appearing mainly due to their relative simplicity and their natural suitability for the Web.

However, using RESTful services still requires much human intervention since the majority of their description pages are given in the form of unstructured text in a Web page (HTML), which contains a list of the available operations, their URIs and parameters (also called attributes), expected output, error messages, and a set of examples of their execution. This hampers the discovery, composition and mediation between services, which may be required in the development of simple and complex applications, and which are also important tasks in WS-* approaches.

Traditionally, semantic annotation approaches for services have focused on defining formalisms to describe services, and have been normally applied to WS-* service description formalisms and middleware. More recently, these (usually heavyweight) approaches have started to be adapted in a more lightweight manner for the semantic description of RESTful services [1, 5, 8]. However, most of the

processes related to the annotation of RESTful services (e.g., [2, 11]) still require a large amount of human intervention. First, humans have to understand the informal descriptions provided in the RESTful service description pages, and then the semantic annotation of RESTful services has to be automated as much as possible.

In this paper, we address these two main challenges by: (1) providing syntactic descriptions of RESTful services that allow their automatic registration and invocation, and (2) interpreting and enriching the RESTful services' parameters, by means of their semantic annotation.

The main contribution of our work is the proposal of an automatic approach for the semantic annotation of RESTful services using diverse types of resources: a cross-domain ontology, DBpedia (combined with GeoNames in the specific case of geospatial services), and diverse external services, such as suggestion and synonym services.

The remainder of this paper is structured as follows: Section 2 presents related work in the context of semantic annotation of WS-* services and RESTful services. Section 3 introduces our approach for the automatic annotation of RESTful services, including explanations on how we derive their syntactic description and semantic annotation. Section 4 presents the evaluation of our system in the geospatial domain. Finally, Section 5 presents some conclusions of this paper and identifies our future work.

2 Related work

Most research in the semantic annotation of RESTful services has focused on the definition of formal description languages for creating semantic annotations. The main proposed formalisms for describing these services are: the Web Application Description Language[1] (WADL) which describes RESTful services syntactically, MicroWSMO [3] which uses hREST (HTML for RESTful services) [3, 5], and SA-REST [2, 8] which uses SAWSDL [1] and RDFa[2] to describe service properties.

The work done in the state of the art on Semantic Web Services (SWS) addresses mainly SOAP/WSDL services, which are only focused on the syntax required for describing the exposed functionality (operations, input and output types). Considering this, in [19] the authors introduced an approach to annotate WADL documents linking them to ontologies. Among these approaches, some authors propose rather heavyweight approaches for semantic description, which are normally derived from Web Service (WS-*) semantic description frameworks like WSMO or OWL-S. An example is proposed in [10], which makes use of a specific selection of existing languages and protocols, reinforcing its feasibility. First, OWL-S is used as the base ontology for services, whereas WADL is used for syntactically describing them. Second, the HTTP protocol is used for transferring messages, defining the action to be executed, and also defining the execution scope. Finally, URI identifiers are responsible for specifying the service interface. Nevertheless, these languages are strongly influenced by existing traditional WS-* services.

[1] http://www.w3.org/Submission/wadl/

[2] http://www.w3.org/TR/xhtml-rdfa-primer/

Other approaches are more lightweight, for instance, the proposals of [1, 2]. The authors advocate an integrated lightweight approach for formally describing semantic RESTful services. This approach is based on use of the hREST and MicroWSMO microformats, which enable the creation of machine-readable service descriptions and the addition of semantic annotations. Furthermore, the authors present SWEET, a tool which effectively supports users in creating semantic descriptions of RESTful services based on the aforementioned technologies. Unlike this work, our approach is based on an automatic semantic description of services. Once the semantics of the RESTful service is obtained, this could be represented in any of the existing semantic description approaches, such as hREST, MicroWSMO, etc.

Finally, another approach for service description that focuses on automation, and hence may be closer to our work, is presented in [17]. This approach classifies service datatypes using HTML treated Web form files as the Web service's parameters. In this approach Naïve Bayes is used to classify assigned semantic types to the input and output parameters.

3 An approach for the automatic semantic annotation of RESTful services

In this section, we present our approach, visualized in Figure 1, for automating the syntactic and semantic annotation of RESTful services. Our system consists of three main components, including invocation and registration, repository, and semantic annotation components, which are enriched by diverse external resources. Next, we briefly describe the different components, illustrating the descriptions with some sample services on the geospatial domain.

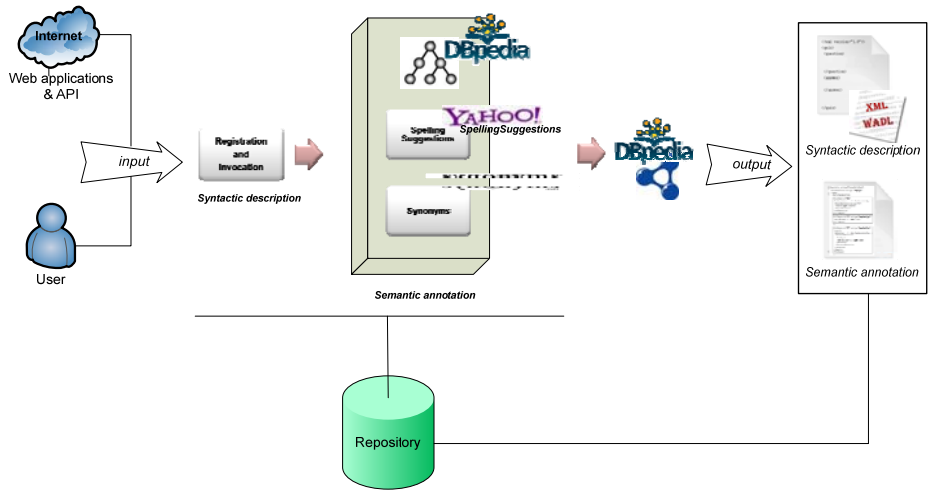

Figure 1. RESTful Service Semantic Annotation System

3.1 A sample set of RESTful services in the geospatial domain

Nowadays the largest online repository of information about Web 2.0 mashups and APIs is ProgrammableWeb.com. This aggregator site provides information on 4,884 mashups and 2,033 APIs that were registered between September 2005 and June 2010, as of the time of the writing of this paper. Mashups tagged as "mapping" represent a 34% of the 2,229 mashups that are listed, what represents the importance of geospatial information in the generation of these applications. With respect to APIs, GoogleMaps is the most used with a 43%, that is, this API is used on 1,983 mashups. These data show the importance of geospatial information in the context of the REST world. The following services are two representative RESTful services in the geospatial domain, taken from the aforementioned site:

- **Service 1**. http://ws.geonames.org/countryInfo?country=ES

  This service retrieves information related to a 'country'. More specifically, it returns information about the following parameters: 'capital', 'population', 'area' (km^2), and 'bounding box of mainland' (excluding offshore islands).

- **Service 2**. http://api.eventful.com/rest/venues/search?app_key=p4t8BFcLDtCzpxdS&location=Madrid

  This service retrieves information about places (venues). More specifically, it returns parameters like: 'city', 'venue_name', 'region_name', 'country_name', 'latitude', 'longitude', etc.

3.2 Syntactic Description: Invocation and Registration into the Repository

As aforementioned, RESTful services are normally described or registered in sites like *programmableWeb* by means of their URLs, plus some natural language descriptions and execution examples, if at all available. Hence, the first step in our system is to take as input the URL of an available RESTful service that is known by users (for instance, it has been discovered by a user by browsing this site, or it has been sent to the user by a friend).

In our system, the user adds the URLs of different services as a starting point, with the objective of obtaining automatically information related to each of the corresponding RESTful services. Once URLs have been added, our system invokes the RESTful service with a sample of parameters, obtained from the examples that are normally provided together with the URL (if this information is not available, our system cannot continue), and analyzes the response to obtain a basic syntactic description of a parameter set, which is used like inputs and outputs.

In this process our system uses the Service Data Object[3] (SDO) API to perform the invocation of the RESTful service and determine whether it is available or not. SDO is a specification for a programming model that unifies data programming across data source types and provides robust support for common application patterns in a disconnected way [22]. The invocation process is performed as follows: first, it takes

[3] http://www.oasis-opencsa.org/sdo

the input parameters and their values, which are given to the service as part of a URL. Then, the system invokes the service that translates our "RESTful service call" into a query to a specific service, including the URL and related parameters.

The service invocation of a specific RESTful service may return diverse formats, such as HTML, JSON, XML, etc. In our work we use any of these formats, although for presentation purposes in this paper we will show how we handle the XML responses. The results of a sample invocation of the services that we presented in section 3.1 are showed in Table 1.

Table 1. XML response of two sample RESTful services

Service 1	Service 2
<geonames> <country> <countryCode>ES</countryCode> **<countryName>Spain</countryName>** <isoNumeric>724</isoNumeric> <isoAlpha3>ESP</isoAlpha3> <fipsCode>SP</fipsCode> <continent>EU</continent> <capital>Madrid</capital> <areaInSqKm>504782.0</areaInSqKm> <population>40491000</population> <currencyCode>EUR</currencyCode> <languages>es-ES,ca,gl,eu</languages> <geonameId>2510769</geonameId> <bBoxWest>-18.169641494751</bBoxWest <bBoxNorth>43.791725</bBoxNorth> <bBoxEast>4.3153896</bBoxEast> <bBoxSouth>27.6388</bBoxSouth> </country> </geonames>	<venue id="V0-001-000154997-6"> <url>http://eventful.com/madrid/venues/la-ancha-/V0-001-000154997-6</url> **<country_name>Spain</country_name>** <name>La Ancha</name> <venue_name>La Ancha</venue_name> <description></description> <venue_type>Restaurant</venue_type> <address></address> <city_name>Madrid</city_name> <region_name></region_name> <region_abbr></region_abbr> <postal_code></postal_code> <country_abbr2>ES</country_abbr2> <country_abbr>ESP</country_abbr> <longitude>-3.68333</longitude> <latitude>40.4</latitude> <geocode_type>City Based GeoCodes</geocode_type> <owner>frankg</owner> <timezone></timezone> <created></created> <event_count>0</event_count> <trackback_count>0</trackback_count> <comment_count>0</comment_count> <link_count>0</link_count> <image></image> </venue> <venue id="V0-001-000154998-5">

These XML responses are processed using SDO, which enables to navigate through the XML and extract output parameters of each service. The result of this invocation process is then a syntactic definition of RESTful services in XML, which can be expressed in description languages like WADL or stored into a relational model. Table 2 shows the different output parameters of each service, where we can observe by manual inspection that there is some similarity between diverse parameters (e.g., `countryName` and `country_name`) and that they return similar values (Spain). However, these parameters are written differently.

The output parameters are registered and stored into a repository. This repository is implemented as a database that is specifically designed to store syntactic descriptions

of RESTful services. We selected this storage model in order to increase efficiency in the recovery of the RESTful services.

Table 2. Syntactic description of our two sample RESTful services.

Service 1:
countryInfo($country,bBoxSouth,isoNumeric,continent,fipsCode,areaInSqKm,languages,isoAlpha3,countryCode,bBoxNorth,population,bBoxWest,currencyCode,bBoxEast,capital,geonameId,countryName)
Service 2:
rest/venues/search($location,$app_key,id,link_count,page_count,longitude,trackback_count,version,venue_type,owner,url,country_name,event_count,total_items,city_name,address,name,latitude,page_number,postal_code,country_abbr,first_item,page_items,last_item,page_size,country_abbr2,comment_count,geocode_type,search_time,venue_name)

3.3 Semantic annotation

Some of the difficulties that arise in the semantic annotation of RESTful services are briefly described in [1, 11]. In order to cope with them, we rely on techniques and processes that permit: a) semantic annotation using only the syntactic description of the services and their input/output parameters, or b) semantic annotation by identifying a set of example values that allow the automatic invocation of the service.

The starting point of the semantic annotation process is the list of syntactic parameters obtained previously. Once the RESTful service is syntactically described with all its identified input and output parameters, we proceed into its semantic annotation. We follow a heuristic approach that combines a number of external services and semantic resources to propose annotations for the parameters as shown in Figure 2. Next, we describe the main components of the semantic annotation.

3.3.1 A model for describing RESTful services

In order to describe semantically these services we define a model to show relationships of different parameters with diverse resources used in the semantic annotation process. Some of the elements of this model are domain-independent, while others are related to the geospatial domain, which is the domain where we have performed our experiments in order to evaluate the feasibility of our approach.

This model (Figure 3) defines the following components:

- `Parameter`. This class provides a list of all parameters (inputs and outputs) collected from different services. Likewise, we search for additional information for each parameter, such as suggestions and synonyms, for enriching the initial description of parameters. The relation `hasCollection` relates `Parameter` with `DBpediaOntology`. This relation has a cardinality of 1 in the `Parameter` end, and 0..* in the `DBpediaOntology`.

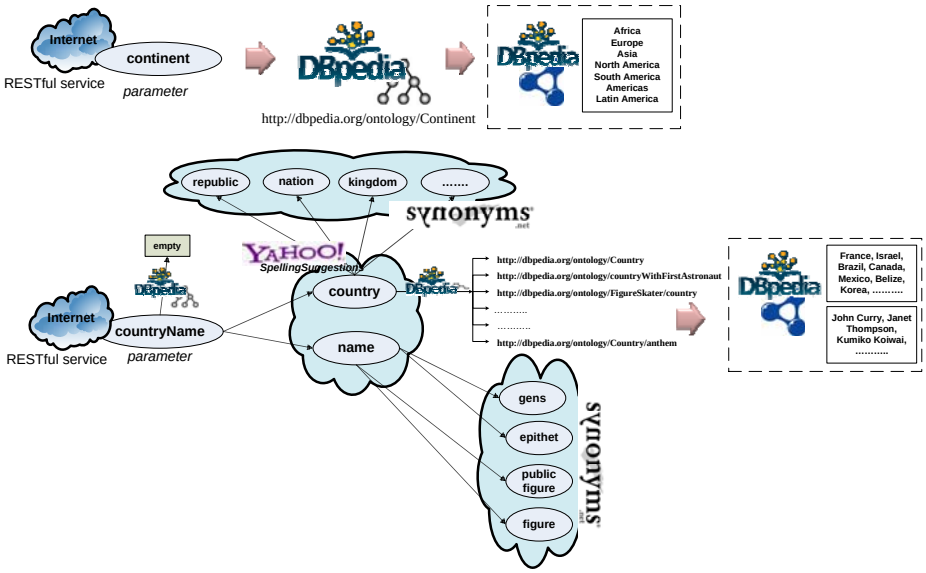

Figure 2. Semantic annotation process

- `DBpediaOntology`. This class contains classes and properties of the DBpedia ontology related to the parameters of each service. This class is related to the classes `DBpediaInstance` and `GeonamesInstance` by means of the relation `hasCollection`. This relation has a cardinality of 1 in the `DBpediaOntology` end, and 0..* in the `DBpediaInstance` and `GeonamesInstance`.
- `DBpediaInstance`. This class collects values from the DBpedia SPARQL Endpoint, where a parameter may have one o more associated resources.
- `GeonamesInstance`. This class collects geospatial information related to latitude, longitude, and bounding box parameters from a local GeoNames[4] SPARQL Endpoint.

The information related to each parameter of the RESTful service (semantic annotations) is stored only once in the system repository. By doing this, we avoid to duplicate information related to the same parameters, storing annotations independently of services and increasing the efficiency of our system.

[4] http://www.geonames.org/

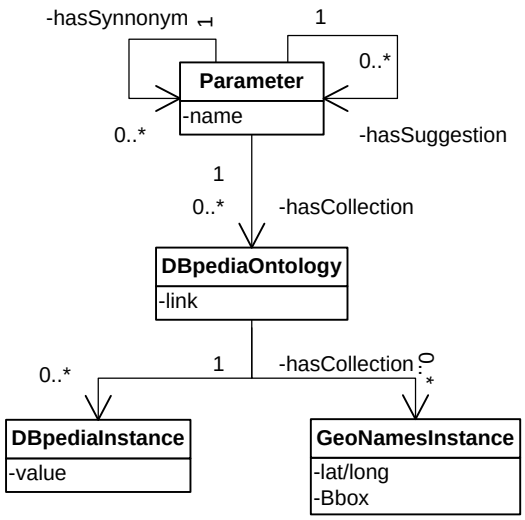

Figure 3. Model for the description of RESTful services

3.3.1 Using semantic sources in the annotation process

At this stage, the list of syntactic parameters obtained previously is used to query the DBpedia and GeoNames SPARQL Endpoints (the latter is only used in the case of the geospatial domain) and retrieve associated results for each parameter, as follows:

- First, the system retrieves all the classes from the DBpedia ontology whose names have an exact match with each parameter of the RESTful service. If the system obtains correspondences from the matching process, it uses these DBpedia concepts individually to retrieve samples (concept instances) from the DBpedia SPARQL Endpoint. Likewise, when a parameter matches an ontology class related to some geospatial information; such as latitude, longitude, or bounding box, our system retrieves samples from the GeoNames SPARQL Endpoint. The resulting information (RDF) is suggested automatically to the system and registered as a possible value for the corresponding parameter. When a parameter matches more than once in the DBpedia ontology, our system only considers concepts that have information (instances), and automatically discards those ontology concepts without instances.
- Next, the system tries to find correspondences between parameters of the RESTful service and DBpedia properties. If the system obtains some correspondences, it uses these DBpedia properties individually to retrieve information of the DBpedia or GeoNames SPARQL Endpoint, as described above. Furthermore, this information is registered as a possible correct value for the corresponding parameter.
- Finally, with the obtained classes and properties, the system calls the DBpedia and GeoNames SPARQL Endpoints to retrieve values (instances) for those classes and properties, so that now we have possible values for them.

3.3.2 Enriching the semantic annotations

Since we request exact matches with DBpedia (and GeoNames) classes and properties, our system does not establish correspondences with ontology classes or properties for all parameters of the RESTful service, since there are many lexical and syntactic variations that the parameter names may have, and because in some cases the information that is being requested may not be available in any of the external sources that are consulted. In order to annotate semantically the parameters that did not match any DBpedia resource, we use additional external services to enrich the results. Below we describe the main characteristics of the external services that are considered in the system.

Spelling Suggestion Services

Web search engines (e.g. Google, Yahoo, and Microsoft) usually try to detect and solve users' writing mistakes. Suggestions services, also called "Did You Mean", are spelling algorithms which aim at solving these spelling mistakes. For example, when a user writes 'countryName' these algorithms suggest 'country' and 'name' separately.

In our system we use the Yahoo Boss service[5] to retrieve suggestions about the parameters that we have obtained in the previous steps and for which we have not obtained any candidate in our semantic resources. Thus, for each parameter that the system did not find a correspondence with classes or properties in DBPedia (nor GeoNames), this service is invocated for obtaining a list of suggestions to query DBpedia (and GeoNames) again. The output is registered and stored into the repository. Following the previous example, the parameter 'countryName' is not found in the DBpedia ontology. Nevertheless, the added service allows separating this parameter in 'country' and 'name', and then it calls to the DBpedia SPARQL Endpoint for obtaining results.

Use of Synonyms

This external service[6] is incorporated into the system to retrieve possible synonyms for a certain parameter. This service tries to improve the semantic annotation process when our system does not offer results for the previous steps, that is, when we still have parameters in a RESTful service without any potential annotations.

As an example, we may have a parameter called 'address'. The invocation process uses the synonyms service to retrieve a set of synonyms of 'address' such as *extension*, *reference*, *mention*, *citation*, *denotation*, *destination*, *source*, *cite*, *acknowledgment*, and so on. These outputs are registered and stored into the repository, and then, the service calls to the DBpedia (and GeoNames) SPARQL Endpoints for results.

[5] http://developer.yahoo.com/search/boss/boss_guide/Spelling_Suggest.html
[6] http://www.synonyms.net/

3.4 Checking the semantic annotation of RESTful services

In order to check the collected sample individuals and initial semantic annotations of the previous process, our system invocates the RESTful service that was already registered in the repository (as we describe in Section 3.2) and validates the input and output parameters.

For the validation of the **input parameters**, our system selects, for each parameter, a random subset of the example instances (of classes and/or properties) coming from the DBpedia (and GeoNames) ontology that we have obtained and registered before. Next, it makes several invocations of the RESTful service iterating over these registered values. The system does not check this with all the possible combination of collected instances for all parameters for two reasons: first, because of the combinatorial explosion that may be produced in such a case, and second because many RESTful services have invocation limitations.

If the service returns results from the invocation, then the service is deemed as executable, and the corresponding annotations are marked as valid. If a service cannot be invoked successfully, the service is classified as non-executable and is automatically discarded from the list of services that can be automatically annotated.

For the validation of the **output parameters**, our system only takes into account executions with the correct inputs from the input sets that have been considered before. Next, the system compares the outputs obtained after execution with the information already stored in the repository due to the initial retrieval processes done before with DBPedia (and GeoNames), and external utility services. If the output can be matched, our system considers the output annotation as valid.

Finally, the correspondences that have been established between the different parameters of the RESTful service and the DBpedia (and GeoNames) ontology are registered and stored in the repository, so that they can be used later. In such a way, the RESTful service is annotated semantically and it will allow generating semantic descriptions or annotations of any of the types that were identified in the related work section (WADL, hREST, etc.). Table 3 provides an abbreviated form of this description for our exemplar service 1.

Table 3. Semantic annotation of a RESTful service

($country,bBoxSouth,isoNumeric,http://dbpedia.org/ontology/Continent,fipsCode,http://dbpedia.org/property/areaMetroKm,languages,isoAlpha3,http://dbpedia.org/ontology/country,bBoxNorth,http://dbpedia.org/ontology/populationDensity,bBoxWest,http://dbpedia.org/ontology/Currency,bBoxEast,http://dbpedia.org/ontology/capitalgeonameId,http://dbpedia.org/ontology/country)

4 Experimental results

In order to make an evaluation of our approach in the geospatial domain we have used 45 different RESTful services found in http://www.programmableweb.com/, which we have selected randomly from those that were available and could be characterized to contain geospatial information by a manual lookup. The list of these services can be found in our experiment website[7]. The syntactic registration of all these services in the system, by means of introducing the list of their URLs, has produced a complete list of 226 different parameters (considering both inputs and outputs), without duplications.

This analysis follows the three steps described in our semantic annotation process. First, our system identifies correctly 54 of 226 parameters by calling directly the DBpedia and GeoNames ontologies. Second, the system uses initial parameters plus the suggestion service and calls the DBpedia and GeoNames ontologies. In this case, it identifies 75 correspondences and adds 76 parameters to the initial ones. Third, the system uses the initial parameters plus the synonyms service, and calls the DBpedia and GeoNames ontologies. It identifies 161 correspondences and incorporates 848 additional parameters into the system. Finally, the system combines all the resources that result of the enrichment process and calls again the DBpedia and GeoNames ontologies. Here it identifies 193 correspondences and adds 886 more parameters. A detailed view of these results is shown in Table 4.

Attributes	**Total**	**Additional parameters**	**Matches** (*DBpedia and GeoNames ontologies*)
Initial parameters	226	-	54
Parameters + Suggestions	302	76	75
Parameters + Synonyms	1074	848	161
Parameters + Suggestions + Synonyms	1112	886	193

Table 4. Enriching initial parameters with external resources

With respect to the validation of input parameters (see Table 5), our system recognizes 120 inputs of the initial list, of which 80 parameters can be annotated automatically. Some of the parameters are not considered for this validation, concretely 28 parameters, since they are related to service identifiers (for instance, `userID`, `api_key`, etc.) and our system takes them out automatically from the service registration process[8].

One aspect of our system is that we cannot always guarantee the success of the system, because in some cases the system cannot find any correspondence between the service parameters and the concepts or properties of the DBpedia or GeoNames ontologies. This is common, for instance, when parameter names are described by

[7] http://castor.dia.fi.upm.es/ev/RESTfulservice.html

[8] This was not described in the process described in section 3 since we did not consider it relevant for the description of the whole process.

only one letter (e.g., `s`, `l` or `q`) and hence they are not sufficiently descriptive for our automated approach to find any correspondence. In our evaluation, we had 12 of this type of parameters. In these cases the parameters should be shown to users for a manual description of them.

In summary, for 39 of the 45 initial geospatial RESTful services we have obtained correct input parameter associations, and only in six cases we could not find any correspondence.

RESTful Service	Input parameters	Not considered	Annotated parameters	Not found parameters	Service validation
*Source*1	3	2	1	0	✓
*Source*2	7	2	5	0	✓
*Source*3	6	2	4	0	✓
*Source*4	5	2	3	0	✓
*Source*5	4	2	2	0	✓
*Source*6	3	2	1	0	✓
*Source*7	4	2	2	0	✓
*Source*8	4	1	3	0	✓
*Source*9	2	1	1	0	✓
*Source*10	2	1	1	0	✓
*Source*11	3	1	2	0	✓
*Source*12	4	0	4	0	✓
*Source*13	3	0	3	0	✓
*Source*14	1	0	1	0	✓
*Source*15	2	0	2	0	✓
*Source*16	2	0	2	0	✓
*Source*17	2	0	2	0	✓
*Source*18	3	0	3	0	✓
*Source*19	2	0	2	0	✓
*Source*20	2	0	2	0	✓
*Source*21	3	0	3	0	✓
*Source*22	2	0	2	0	✓
*Source*23	2	0	2	0	✓
*Source*24	2	0	2	0	✓
*Source*25	1	0	1	0	✓
*Source*26	2	0	2	0	✓
*Source*27	2	0	2	0	✓
*Source*28	4	0	4	0	✓
*Source*29	1	0	1	0	✓
*Source*30	1	0	1	0	✓
*Source*31	2	1	1	0	✓
*Source*32	2	0	2	0	✓
*Source*33	1	0	0	1	×
*Source*34	2	0	2	0	✓
*Source*35	3	1	2	0	✓
*Source*36	4	1	3	0	✓
*Source*37	1	0	1	1	×
*Source*38	1	0	1	1	×
*Source*39	2	1	1	0	✓
*Source*40	2	1	1	0	✓
*Source*41	2	1	1	0	✓
*Source*42	2	1	1	0	✓
*Source*43	4	1	0	3	×
*Source*44	4	1	0	3	×
*Source*45	4	1	0	3	×
Total	**120**	**28**	**80**	**12**	

Table 5. Results of the input parameters validation

Besides the previous parameters that were described with one letter, we have discovered with our evaluation that some other parameters are useless in terms of semantic annotation processes, since they refer to the navigation process through the RESTful service results. This is the case, for example, of parameters like: *page*, *total*, *hits*, etc. We are planning to discard these types of input parameters in the future.

RESTful Service	Parameters	Not found parameters	Found parameters	Not annotated parameters	Annotated parameters	Right parameters	Precision	Recall
*Source*1	12	5	7	1	6	4	0,86	0,67
*Source*2	12	5	7	1	6	4	0,86	0,67
*Source*3	12	5	7	1	6	4	0,86	0,67
*Source*4	12	5	7	1	6	4	0,86	0,67
*Source*5	12	5	7	1	6	4	0,86	0,67
*Source*6	12	5	7	1	6	4	0,86	0,67
*Source*7	12	5	7	1	6	4	0,86	0,67
*Source*8	4	4	0	0	0	0	0,00	0,00
*Source*9	33	13	20	10	10	8	0,50	0,80
*Source*10	19	5	14	6	8	7	0,57	0,88
*Source*11	3	1	2	0	2	2	1,00	1,00
*Source*12	8	4	4	0	4	3	1,00	0,75
*Source*13	3	0	3	1	2	2	0,67	1,00
*Source*14	16	4	12	6	6	5	0,50	0,83
*Source*15	5	2	3	1	2	2	0,67	1,00
*Source*16	8	3	5	1	4	4	0,80	1,00
*Source*17	8	3	5	1	4	4	0,80	1,00
*Source*18	12	5	7	3	4	4	0,57	1,00
*Source*19	4	2	2	1	1	1	0,50	1,00
*Source*20	16	6	10	2	8	5	0,80	0,63
*Source*21	12	2	10	4	6	5	0,60	0,83
*Source*22	12	6	6	2	4	3	0,67	0,75
*Source*23	7	3	4	2	2	2	0,50	1,00
*Source*24	1	0	1	0	1	1	1,00	1,00
*Source*25	11	7	4	1	3	2	0,75	0,67
*Source*26	10	6	4	2	2	2	0,50	1,00
*Source*27	9	3	6	2	4	3	0,67	0,75
*Source*28	12	4	8	1	7	5	0,88	0,71
*Source*29	13	4	9	1	8	4	0,89	0,50
*Source*30	4	1	3	0	3	1	1,00	0,33
*Source*31	15	6	9	4	5	4	0,56	0,80
*Source*32	7	7	0	0	0	0	0,00	0,00
*Source*33	7	7	0	0	0	0	0,00	0,00
*Source*34	3	2	1	1	0	0	0,00	0,00
*Source*35	20	12	8	1	7	5	0,88	0,71
*Source*36	20	12	8	1	7	1	0,88	0,14
*Source*37	15	11	4	4	0	0	0,00	0,00
*Source*38	6	4	2	2	0	0	0,00	0,00
*Source*39	7	5	2	1	1	1	0,50	1,00
*Source*40	12	9	3	1	2	1	0,67	0,50
*Source*41	7	5	2	1	1	0	0,50	0,00
*Source*42	6	4	2	2	0	0	0,00	0,00
*Source*43	29	11	18	7	11	5	0,61	0,45
*Source*44	16	9	7	1	6	3	0,86	0,50
*Source*45	16	9	7	1	6	3	0,86	0,50
Total	**500**	**236**	**264**	**81**	**183**	**126**	**0,69**	**0,69**

Table 6. Results of the output parameters validation

With respect to the validation of output parameters (see Table 6), our system recognizes 500 outputs that belong to the 39 services whose input parameters have been validated. This total of output parameters is divided into 264 whose correspondences can be found and 236 whose correspondences cannot be found.

While in the context of the input parameters we are interested in determining whether we can call the service or not, in the case of output parameters, we are interested in the precision and recall metrics of the annotation process. Hence, we have generated a gold standard with the studied services in order to assign manually the annotations that have to be produced for all output parameters of these services, and we have performed an evaluation of the results obtained from the system for the parameters that are found. Regarding the parameters that are found, our system annotates 183 of them automatically, from which 126 parameters are annotated correctly according to the gold standard, while 81 parameters are not annotated. This provides us with an average value for precision and recall equal to 0.69 for both metrics.

To the best of our knowledge, there are no available results from existing research works to compare our results against. Likewise, these preliminary results prove the feasibility of our system and highlight that itis possible to carry out an automatic semantic annotation of RESTful services.

5 Conclusions and Future Work

In this paper we have proposed an approach to perform an automatic semantic annotation process of RESTful services. This process is implemented in a system that takes into account the DBpedia ontology and its SPARQL Endpoint, for general annotation, and GeoNames and its SPARQL Endpoint for geospatial specific results, as well as different external resources such as synonyms and suggestion services. We use combinations of these resources to discover meanings for each of the parameters of the RESTful services that a user may select and perform semantic annotations of them.

To illustrate our work and guide the explanations of the proposed semantic annotation process we have used two exemplary RESTful services related to the geospatial domain. Besides, we have presented some preliminary experimental results that prove the feasibility of our approach, at least in the geospatial domain, and show that it is possible to carry out a semantic annotation of RESTful services automatically, again at least in this domain.

Future work will focus on the development of a GUI that will ease the introduction of existing services by users for their semantic annotation, probably incorporated in any existing RESTful semantic annotation tool/utility suite. Furthermore, we also plan to make improvements to the proposed system, related to the matching process and the use of similarity metrics, so as to improve the results that have been demonstrated in our evaluation. In the same sense, we also aim at improving in the SPARQL queries to DBpedia and other semantic resources that may be associated or not to a specific domain to better explore the knowledge of this resource in the annotation

process, and optimize the use of suggestion and synonyms services. Finally, we will incorporate ontology domains in the semantic process for taking advantage of specific domain characteristics.

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