A Topic Modeling Approach for Web Service Annotation

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Abstract

1 Introduction

During last two decades we have been witnessing how the Web has evolved from being a text and image repository on its early stages, to provide a huge offer of both information-providing and world-altering services. The current Web has posed a paradigm that revolutionized the generation and consumption dynamics of this kind of resources, encouraging its users, not merely to consume these services, but also to build and publish them [1].

This dominant paradigm of the current Web, has inspired the conception of initiatives into other communities such as the Telco providers, which include the GSMA's One API [2], and the ECMA-348 [3] and ECMA-323 [4] standards. Such initiatives promote for network operators to expose their capabilities and information via Web service interfaces, easing this way for users (service designers and developers) to create and deploy new telecom services, with a reduced time-to-market and tailored to their specific needs.

Thus, the service offering inside the Web is diversifying and steadily growing, so it is necessary to provide the users with increasingly intelligent mechanisms for services search and retrieval, identifying in a truthful way the functionality

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provided by such resources while being able to deliver relevant services to the customer. The above has meant the transition from the traditional keyword-based or table-based search methods [5], to approaches supported on semantic Web technologies [6] which provide meaning for both the services specifications, and user queries, through a formal and machine-readable specification of knowledge (e.g. ontologies, taxonomies, lexical database and so on).

In practical terms, however, the actual implementation of semantic-based mechanisms for service retrieval has been restricted precisely due to the expensive procedure involved in the formal specification of services. Such a procedure comprises a regular, time-consuming task of semantic annotation, performed by hand by service developers, who additionally require specialized knowledge on models for semantic description of services (e.g. OWL, WSMO, RDF-S), as well as the aforementioned formal specifications of knowledge.

In order to overcome this limitation, currently some approaches are considered to tackle the problem of semantic service annotation, by applying knowledge discovery and emergent semantics techniques over a huge corpus of service descriptors, which in some cases already contains annotations made by consumers in a collaborative way. Those approaches however, has serious limitations in terms of the reliability of the users feedback they are built upon, which impacts the precision of search and selection tasks. Therefore it's considered necessary to develop mechanisms that enable the automation of semantic service annotation tasks.

This paper introduces our proposal for service annotation, based on processing existing web service documentation resources for extracting information regarding its offered capabilities. By uncover the hidden semantic structure of such information through statistical analysis techniques, we are able to associate meaningful annotations to the services operations, and to group those operations into non-exclusive semantic related categories.

Based on this approach we have build Topicalizer, a tool that allows the user to process a bunch of SOAP API descriptors (WSDL documents), in order to group the technical information they contain into semantic categories, and specifying such categorization as RDF statements stored in a Sesame triple-store, to which users may access and issue SPARQL queries.

2 Motivation and Background

Nowadays the amount of information and resources available on the Web is huge and ever increasing, so that it has exceeded our ability for locating and accessing the resources we need. This way, increasingly sophisticated computational tools are required for organizing, searching and understanding those resources, beyond the traditional information indexing and retrieval approaches.

Semantic annotation, is one of the core concepts of the current proposal. It aims to make explicit for machines, the meaning (the semantics) of content and resources available in large repositories of information. This latter constitutes one of the requirements to meet to finally materializing the Semantic Web. The semantic annotation procedure is commonly supported in formal representation of knowledge, as the aforementioned ontologies, and for services, consists in associating ontological entities to the terms defining the attributes of the service in its descriptor document [8], allowing for instance, for service search engines to effectively comprehend (on a semantic level) both the services functionality as the service's clients requests, enabling them to accurately respond to service inquiries.

Traditionally, this semantic annotation procedure must be performed by hand by service designers and developers or in a collaborative way by service users (conceiving a sort of folksonomy of services). In both cases, the large and growing amount of services, along with the lack of knowledge regarding semantic description methods for services and the scarceness of suitable domain ontologies, has overwhelmed the human ability for performing this semantic annotation task. Additionally, the human intervention in marking up the services descriptors with ontological entities involves a very expensive process in terms of time, effort and resources. In this regard, the focus of the present approach is on leveraging current techniques taken from the fields of machine learning, information retrieval and knowledge discovery, for automating the semantic annotation of web services. The next section will deal the revision of some previous works regarding the problem being tackled herein.

3 Related Work

This section explores some approaches that deal with semantic annotation, not only for web services, but also for content and other kinds of web resources.

In [9, 10, 11] the authors explore alternative approaches for semantic annotation of available services and resources in the Web. Such an approach consists of recognizing the information constructs from collaborative tagging systems (folksonomies) as specifications of shared knowledge, which can be suitable for semantically annotating service interfaces, dispensing with the use of ontologies. The main goal of these proposals, however, is to assist the process of semantic enrichment, still requiring human intervention (developers, users, providers, etcetera) for fulfilling the complete process.

The authors of [12] and [13] address two works regarding to semantic annotation of folksonomies, for various kinds of online available resources. In contrast to aforementioned works, the proposals of Angeletou in [12] and the one described by Siorpaes in [13] argue that it is required to formalize the knowledge generated within folksonomies, by using ontologies, in order to overcome their limitations in terms of organizing, searching and retrieving resources based on tags.

The work of Angeletou differs from the current proposal, as long as the former is focused on an image folksonomy. In turn, the project addressed in [13], although it takes into account the services as part of its working resources, its scope is limited to promote collaborative tagging thereof. Furthermore, the development of that project is still in an early stage, so the results from its implementation are not yet conclusive.

The approaches outlined in [14, 15, 16, 17] pose the use of techniques of machine learning such as Formal Concept Analysis (FCA) and most recently Relational Concept Analysis (RCA), for extracting and representing the knowledge covered by documental corpus, as conceptual hierarchies or taxonomies. This way, the approaches described in these works are suitable for composing formal models of knowledge, such as core ontologies, avoiding the intervention of domain experts. However, none of the aforesaid proposals had considered the automation of such a process.

From observations made on related proposals, the present work aims to automate the process of semantic annotation of web services descriptors, through an approach that combines techniques of text mining, unsupervised machine learning (FCA) and others taken from the Information Retrieval field (Latent Dirichlet Allocation–LDA and Nearest/Normalized Similarity Score–NSS) for enabling automatic and incremental generation of formal models of knowledge from service descriptors. Such models are meant to be used in annotating and categorizing services, through a platform that implements the above techniques.

Next section will address the description of our proposal, by outlining the architecture of the platform for automatic semantic annotation of service descriptors.

4 Proposal

A research conducted by Maleshkova et al. [18] reports that, despite the apparent spreading of RESTful services in the Web, there are actually few services that supports all the tenets and constraints of REST. The authors of this study have analyzed by hand 222 web APIs, randomly chosen from the Programmable Web API directory5 . The results that arose from their analysis, evidence that only 32% of services could be considered—at least approximately—REST services (i.e., services from levels two and three in the Richardson maturity model), while the remaining 68% was RPC and hybrid services (i.e., services from levels zero and one, according to the same model).

The study of Maleshkova also states that service development is driven by the particular criteria of its creators, rather than well-established standards and rules. Similarly, service documentation (specially REST service documentation) is not supported on interface description languages such as WSDL, but it is provided as HTML documents, which have no regular or standard structure. Therefore, the use of web services requires a cumbersome manual process which additionally hinders the execution of discovery, composition and invocation procedures. In this regard, some initiatives have been fostered, seeking the definition of standard formats for describing REST services. That is the case of WADL (Web Application Description Language) [19], a language intended for specifying HTTP-based web services and applications.

A WADL descriptor (or contract) is a document that specifies the set resources hosted by a service, as well as their associated URI templates, the HTTP methods the service supports and the representations it is able to receive and deliver. Just like WSDL, WADL enables automatic building of services clients, making them easier to consume and accessible to developers. Nonetheless, WADL descriptors merely describe the static view of services and applications, neglecting the user-resources interaction dynamics, which is better specified by hypermedia and media types. Consequently, as stated in [20], this kind of descriptor is suitable only for CRUD-like REST services (Level two services) whose functionality is limited to manipulate records from a data set.

So far, WADL has been poorly adopted as description language for REST services. Instead other studies have been conducted for defining service descriptors that include semantic metadata, which aim to enable the automatic discovery and composition of services. Semantic annotations make it possible for intelligent agents to understand the services functionality, and establishing service relationships at the semantic level (e.g., similarity, partial matching, and membership [21]).

In this regard the academic community has came up with proposals like hRESTS [22]—an HTML-based description microformat that allows specifying the services functional attributes, like its operations, inputs and outputs—, along with its extensions SA-REST [23] and MicroWSMO [24], which enable the semantic annotation of hREST descriptors.

Another approach to REST API description is RESTdesc, proposed by Verborgh et al. in [25,26,27]. RESTdesc provides a functionality-centered format for semantic description of REST services, as well as an automatic discovery mechanism based on inference with logic rules specifying the capabilities of these resources.

According to the authors of RESTdesc, the approach they propose is supported on well known technologies such as HTTP and RDF/Notation3 [28] and is grounded on the hypermedia and Linked Data [29] concepts, from which defines and leverages relationships between different services specifications, enabling intelligent agents to automatically discover and compose services.

Finally, the approach addressed by Saquicela et al. in [30], introduces a proposal for semantic description of REST services which allows their storage and invocation, as well as an automatic technique for semantic annotation of service parameters, supported on the DBpedia ontology[31] and external resources such as suggestion and synonyms services. Since, in general terms, there is a sort of barrier regarding the adoption of new formats for specifying the web service semantics, the proposal conceived under my master's degree work entitled "Automated semantic annotation of services on the Web", intends to use the information currently available in service description documents—i.e., WSDL interfaces for SOAP services and HTML documents for XML-RPC and REST services—in order to abstract a knowledge representation based on the content of such documentation, from which it would be possible to establish semantic similarity relations between services. This proposal is founded on three main processes:

1. Extraction of technical information related to service functionality.

2. Analysis of the extracted information for identifying conceptual categories the services they comprise.

3. Deriving a taxonomy from the categories obtained in process (2).

4.1 Analysis of Web Service documentation sources

As evidenced in the study by Maleshkova et al. [18], web service documentation is often limited by the content that API developers provide on their websites. SOAP services are a special case, whose main descriptor is a WSDL document, which defines an abstract service interface (information regarding operations, messages and types) and concrete details about transport and location of the service. Following subsections deal with the description of mechanisms for extraction of technical information regarding service functionality, from various documentation sources: WSDL descriptors for SOAP services, and HTML pages for XML-RPC and REST services.

4.1.1 SOAP Services

WSDL is an XML standard format for Web service description [32]. A WSDL document describes service interface abstractly and provides concrete technical details about service operation. This may be visualized in figure 1, which shows the structure of a WSDL descriptor.

The diagram of figure 1, shows the separation between service's abstract description and concrete details. The later refer to element that specify service endpoints, and communication and transport protocols used for message exchange. These concrete details are required for service invocation, however they provide little information about service functionality, this is why descriptor analysis focuses on the components of the abstract description of the service interface, namely:

- *Types (schema, element, complexElement, sequence)*: define the data types composing the messages exchanged in service invocation.

- *Message* : represents an abstract definition of data transmitted when invoking a particular service operation.

- *PortType*: it is defined as a grouping of abstract service operations along with their associated messages.

- *Operation*: abstracts service functional units. This descriptor element is associated with a set of input/output messages.

Additionally, WSDL allows natural language description for some of the service interface elements, including: service, binding, portType, operation, message and types. Such a description is provided by service developers and is enclosed within a special tag called documentation. As argued by Falleri in [8], typically there is some redundancy in the information contained in certain

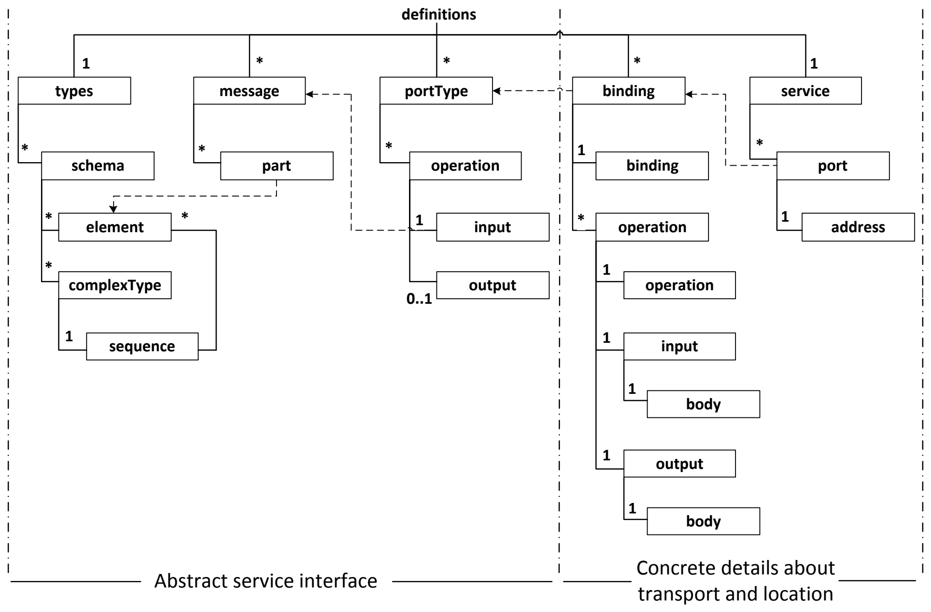


Figure 1: Structure of WSDL descriptor.

elements of service interface. Thus, for instance, terms defining ports, bindings and portTypes are frequently the same used for describing the service element; likewise terms defining input/output messages, are slight variations of the term specifying their associated operation. In consequence, it was decided that information extraction from service descriptor only takes the content of service, operation and types elements into account, including their natural language descriptions (when available). This way, it is possible to obtain a simplified model of the information the service interface contains, considering the three mentioned elements. This model is shown in figure 2.

In the model above, *DataElement* and *ComplexDataElement* elements represent *simple* and *complex types* (*types*) respectively, which compose the message exchanged when invoking a service operation. Typically the terms used in defining such elements of the WSDL descriptor follow naming conventions commonly adopted by programmer, e.g. using `CamelCase` compound words for identifying operations, types and services. Similarly, sometimes documentation tags contain HTML encoded data. Therefore it is necessary to get the content into a proper format to enable further processing. This involves the use of text mining techniques such as *tokenization*,*POS (Part-of-speech) tagging* and *spell checking* whose description is addressed in section **??**.

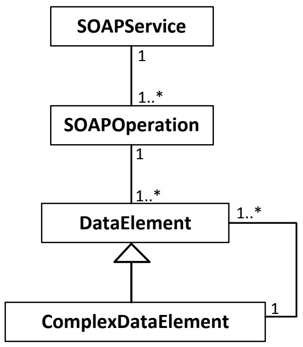


Figure 2: Simple model for describing SOAP Services.

4.1.2 XML-RPC and REST Services

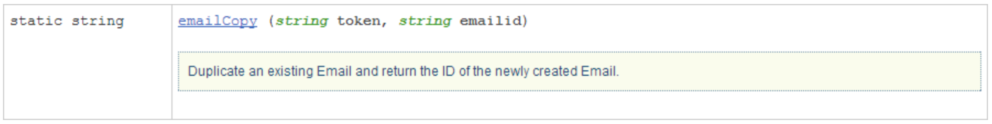
As it was mentioned at the beginning of section 4.1, Web service documentation—except for SOAP services—doesn't meet any standard format. XML-RPC and REST services, are commonly described by HTML pages, which provide information regarding service functionality and endpoints [1]. Usually the content of such pages doesn't follow a formal structure, making it difficult to extract relevant information in an automated way. There are some initiatives, including *ProgrammableWeb* and *APIhub* [2], which promotes the creation of centralized API directories, where service documentation is uniformly stored, by following a regularstructure. However, a major issue regarding these initiatives is that documentation must be registered manually, so more often than not the information provided either contains errors (typos, broken links) or is outdated.

Given this limitation, it was decided to deal with documentation that developers provide on API websites. This way, we apply on each HTML page an analysis that involves identifying recurring patterns (which depends on the service type, either XML-RPC or REST) and document segmentation for extracting relevant information regarding service functionality. This analysis is supported on the approach of Ly et al. formulated in [7].

Analysis of XML-RPC service documentation Similar to SOAP services, an XML-RPC service defines a set of operations or procedures that clients can invoke remotely. The documentation of this kind of services, deals with the operations they expose, the arguments they require for their invocation, and usually specifies the service endpoint (URI) and the HTTP method used for communication.

[1]For example: (XML-RPC) ,http://www.benchmarkemail.com/API/Library (REST) https://dev.twitter.com/docs/api/1.1

[2]Available at: http://www.apihub.com/



static string emailCopy (string token, string emailid)

Duplicate an existing Email and return the ID of the newly created Email.

Figure 3: Operation description block - XML-RPC service. Source: http://www.benchmarkemail.com/API/Library

The description of operations within the same XML-RPC service documentation tends to share similar structure and content. Thus, for example, operation identifiers are usually defined by terms in `CamelCase` notation, composed of a verb and a noun (e. g., *getWeather*). Also, given that this kind of documentation is intended for humans, its content is articulated with recurrent visual clues that help identify operation description blocks within the HTML page: e.g., operation identifiers may be enclosed in `<h3>` tags and their natural language descriptions in `<p>` tags. Then, it is possible to use those local patterns present in each of the service documentation pages, for extracting the information blocks regarding service operations.

Prior to the extraction of operation description blocks, a preprocessing step is required for getting rid of images, scripts, malformed tags and formatting tags (`<b>`, `<strong>`, `<i>`, etc.) from HTML documentation pages.

Then the operation description blocks are extracted, by following the steps below:

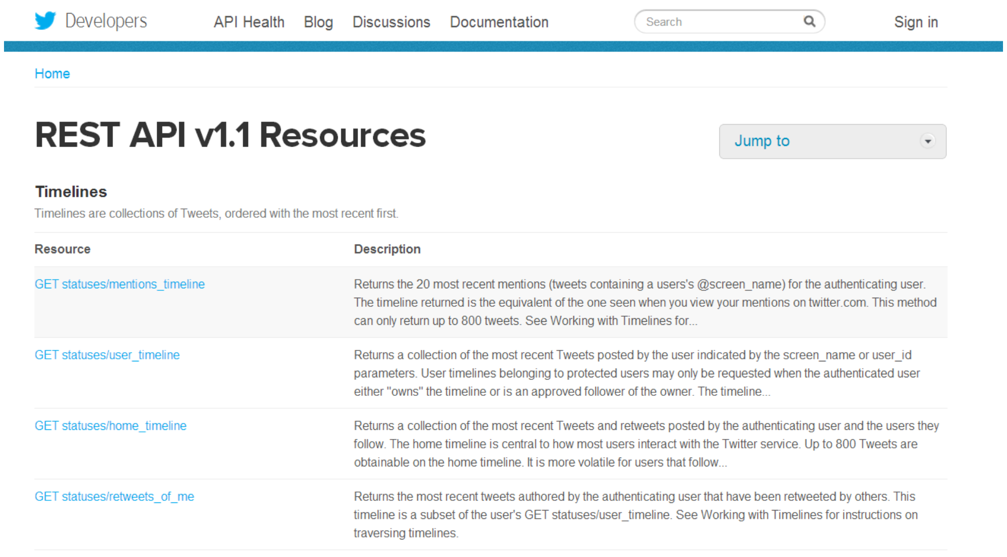
1. Extraction of `CamelCase` terms composed of a verb and a noun (which make up the set of candidate operations identifiers), while keeping track of the HTML tag that encloses them.

2. Identify the most commonly used tag (*elected tag*) for the operation identifiers found in the first step.

3. Finally, out of all the operation identifiers found in step #1, only retain identifiers within *elected tags*. The page is then segmented according to the scope of the tags enclosing each of the chosen operation identifiers.

By following the above procedure, it is possible to identify and extract the textual data from operation description blocks, such as that illustrated in Figure 3.

Analysis of REST APIs documentation REST services operate according to the principles and constraints addressed in section **??**. While nowadays there is a seemingly increasing adoption of this architectural style for building web services, actually only a few of them support all the guidelines that REST defines. In terms of the Richardson's maturity model explained in section **??**, most of the existing REST services are in fact *level one* services (URI supported), while few of them qualify as *level two* (URI & HTTP supported) and *level three* (RESTFul: URI, HTTP & Hypermedia supported) services.



REST API v1.1 Resources

Timelines

Timelines are collections of Tweets, ordered with the most recent first.

Resource	Description
GET statuses/mentions_timeline	Returns the 20 most recent mentions (tweets containing a users's @screen_name) for the authenticating user. The timeline returned is the equivalent of the one seen when you view your mentions on twitter.com. This method can only return up to 800 tweets. See Working with Timelines for...
GET statuses/user_timeline	Returns a collection of the most recent Tweets posted by the user indicated by the screen_name or user_id parameters. User timelines belonging to protected users may only be requested when the authenticated user either "owns" the timeline or is an approved follower of the owner. The timeline...
GET statuses/home_timeline	Returns a collection of the most recent Tweets and retweets posted by the authenticating user and the users they follow. The home timeline is central to how most users interact with the Twitter service. Up to 800 Tweets are obtainable on the home timeline. It is more volatile for users that follow...
GET statuses/retweets_of_me	Returns the most recent tweets authored by the authenticating user that have been retweeted by others. This timeline is a subset of the user's GET statuses/user_timeline. See Working with Timelines for instructions on traversing timelines.

Figure 4: Documentation of the Twitter REST API. Source: https://dev.twitter.com/docs/api/1.1

Documentation of this kind of services, provided as HTML pages, is focused on the concept of resources and the parameters used for identifying them, which are encoded into URI templates (e.g., `/{resource}/{property}/`). In addition, this documentation specifies the allowed HTTP methods (`GET`, `POST`, `PUT`, `DELETE`, etcetera) for each of the resources hosted by the service. See for example the documentation available on the website of the twitter API for developers shown in Figure 4.

This way, the analysis of REST services documentation focuses on detection and extraction of resources description blocks, which contain URI templates, HTTP methods and usually a description in natural language. Since REST API developers tend to adopt a recurring pattern for documenting the service resources, it is possible to perform a segmentation procedure on the HTML content, in order to extract the mentioned description blocks.

Such a procedure starts from the analysis of the HTML DOM tree to perform the steps listed below:

1. Segment the HTML document into blocks containing URIs and HTTP methods.

2. Compute the similarity between the blocks found in step #1, and retain those having the same structure.

3. Extract the information of each resource, contained within the blocks identified in the previous step: resource URI, supported methods and descrip-

tion in natural language.

For conducting the second step of the previous procedure, the authors of [7] rely on the concepts of *entropy* and *node internal structure*. Entropy is a measure that quantifies local patterns present in segments of the HTML document, so that a high entropy suggests an irregular structure, while a low entropy denotes a substantial similarity. The internal structure of a node from the HTML DOM tree, consists in the concatenation of the tags that make up such node, so for example, given the following page segment `<div><a><span>link</span></a><p>text</p></div>`, the internal structure of the `div` node is: `<div><a><span><p>`.

This way, the entropy measure estimates the similarity between the document segments found in step #1, which is subsequently used for obtaining the set of resources descriptor blocks included in the service documentation.

4.1.3 Service documentation pre-processing

Often, the information that developers provide in service descriptors follows naming conventions commonly used in programming languages, in particular they use compound words such as *helloword*, *hello_world* or *helloWord* for identifying operations, resources and parameters. Also, it might be possible for descriptions in natural language to include content encoded into HTML or XML tags, which are used for formatting the text or providing structure to it.

A requirement for further analyze the information extracted from service documentation (see end of section **??**) consists in processing such information and turning it into plain text, which involves splitting compound words and getting rid of HTML or XML tags. To this end it has been decided to use certain text mining techniques, including *tokenization*, *spell checking* and *POS tagging*, whose description is addressed below.

Tokenization This is a procedure that allows breaking a sequence of characters up into its composing tokens. The information extracted from service descriptors is subject to this process to generate the list of terms included within identifiers of operation, resources and types, as well as the text of descriptions in natural language. So, for example the list of tokens contained in the sequence "*getWeatherByCity*" is: {"*get*", "*Weather*" "*By*", "*City*"}. In the previous example, the method for breaking the compound term up relies on detecting transition from lowercase to uppercase along the sequence. However, there are some cases where this procedure is not that straightforward: e.g., the sequence "*getweatherbycity*" doesn't use letter case for telling tokens apart. In these special cases a spell checking technique is used, as outlined next.

Spell checking It is clear for a human that strings "*homeaddress*" and "*home address*" contain the same information. However for machines those are two different sequences of characters and there is no trivial way for it to tell that they are equivalent strings. This turns out to be a common problem in Information Retrieval [8] known as *compound splitting*. For tackling this compound

Table 1: Trie-based compound splitting for "*homeaddress*".

homeaddress				
iteration	*1st segment*	*Does it exist in Trie?*	*2nd segment*	*Does it exist in Trie?*
0	*h*	✓	*omeaddress*	X
1	*ho*	X	*meaddress*	X
2	*hom*	✓	*eaddress*	X
3	*home*	✓	*address*	✓

splitting problem, we use a mechanism based on term look up over a tree-like data structure called *Trie* [9] which in this particular case encodes the terms from the *words* dictionary [3], included in Unix-like operating systems. This data structure usually supports spell checking and autocomplete software, used in search engines and some other web and mobile applications.

Trie-based search is similar to the way we look up words in a dictionary, i.e. by using prefixes. For extracting the terms that make up a compound word an iterative procedure is conducted: (1) It divides the sequence of characters into segments with different length; (2) it look up each of the segments in the Trie. This process continues until all the segments obtained in step #1 match terms included in the dictionary. Table 1, shows this procedure applied on the sequence "*homeaddress*".

Part-of-speech (POS) tagging This technique, is used for detecting candidate operations described in the documentation of XML-RPC services. According to the analysis outlined in section **??**, the operations hosted by this kind of services, are frequently identified by `CamelCase` terms joining at least a verb and a noun (e. g., *getWeather*). POS tagging allows specifying the *lexical category* (verb, noun, pronoun, adverb, etcetera) corresponding to each term in a text or sentence. This way it is possible to filter out the compound words included in XML-RPC service documentation and extracting the set of candidate operations. The POS tagging technique used in our case is the one conceived by Toutanova, outlined in [10] and developed inside The *Stanford Natural Language Processing Group*.

By applying the techniques explained above on the documentation of Web services, the noise involved in the statistical analysis intended to identify groups of similar services is reduced. As defined at the end of section **??**, this analysis is the second of the key processes that comprise the approach documented herein. The description of this second process is addressed in the section below.

[3]Example available at: http://www.cs.duke.edu/∼ola/ap/linuxwords

5 Experimentation

6 Discussion and Conclusions

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