Semantic Annotation of Images Extracted from the Web using RDF Patterns and a Domain Ontology

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Abstract: Semantic annotation of web resources presents a point of interest for several research communities. The use of this technique improves the retrieval process because it allows one to pass from the traditional web to the semantic web. In this paper, we propose a new method for semantically annotating web images. The main originality of our approach lies in the use of RDF (Resource Description Framework) patterns in order to guide the annotation process with contextual factors of web images. Each pattern presents a group of information to instantiate from contextual factors related to the image to annotate. We compared the generated annotations with annotations made manually. The results we obtain are encouraging.

1 INTRODUCTION

The concept of the semantic web is the brainchild of Tim Berners-Lee (Cunningham et al., 2002), the original creator of the World Wide Web. The main idea behind this kind of web is to weave a web that not only links documents to each other but also that recognises the meaning of the information in those documents. The aim of Tim Berners-Lee was to transform the current web from a set of interconnected data by simples links semantically isolated into a huge mass of information linked in a semantic manner.

In other words, the semantic web consists in adding formal semantics to the web content in order to allow a more efficient access and management. This is possible thanks to the improvement of the capability of computers to manipulate data meaningfully by providing meaning into web resources[1]. In doing so, external software agents have to carry out complex tasks on behalf of a human user and to improve the degree of cooperation between humans and computers.

However, the transformation from traditional web to semantic web depends on the presence of a critical mass of metadata (Krestel et al., 2010) corresponding to web resources. The acquisition of these metadata is a major challenge for the semantic web community. As a solution, many manual tools ((Kahan and Koivunen, 2001), (McDowell et al., 2003), (Handschuh et al., 2001), (Bechhofer and Goble, 2001)), semi-automatic tools ((Cunningham et al., 2002), (Laclavik et al., 2009), (Vargas-Vera et al., 2002)) and automatic tools ((Popov et al., 2004), (Kogut and Holmes, 2001)) for semantic annotation have been developed.

In our case, we are interested in the semantic annotation of web images. With the presence of a huge number of web images, many approaches were developed. There are many approaches based on the image content (color, texture, etc.) in order to produce annotations and only a few works using the contextual factors of the image to annotate it without human intervention.

Our goal is to obtain a fully automatic approach for web images annotation based on contextual factors such as image caption, document title and surrounding text. The main idea is to generate an RDF [2] graph from each contextual factor. The elementary RDF graph (concerning one contextual factor) is composed of concepts and instances of concepts linked between them by semantic relations. After the generation of all elementary RDF graphs from all the contex-

[1]A web resource is an entity that can be described on the web. Each resource is identified by a unique URI (Uniform Resource Identifier).

[2]http://www.w3.org/tr/2004/rec-rdf-primer-20040210/

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tual factors, the next step consists in combining them into a global RDF graph which is considered as an image annotation.

The originality of our work is the use of a set of RDF patterns and a domain ontology in order to guide the step of annotation.

This paper is organised as follows: Section 2 reviews the related works. Section 3 details the approach we propose for the image annotation. In section 4, we present the domain ontology used in our work. Section 5 finally demonstrates the obtained results.

2 RELATED WORKS

2.1 Annotation Approaches for Images

We can classify the existing approaches into two categories: (1) Content-Based Image Annotation; and (2) Context-based Image Annotation.

Several works have studied Content-Based Image Annotation. Among these approaches, we find (Li and Wang, 2003) (Cusano et al., 2004), (Halaschekwiener et al., 2006), (Bellini et al., 2011), (Arndt et al., 2007). The main idea of this type of approaches is to associate a semantic description with the image in totality or to describe a specific region of the image. (Wang et al., 2007) shows a good classification of these different approaches. Using the content of the image for annotation purpose resolves, partially, the Semantic Gap Problem defined by (Smeulders et al., 2000).

Only a few works use contextual factors of the image in order to annotate it. Among these approaches, we find (Declerck et al., 2004). This approach was proposed in the project Esperonto. It was based on natural language techniques, ontologies and other knowledge bases.

The approach proposed in (Nguyen, 2007) used two contextual factors associated with web images. It exploited the caption and keywords associated with the image in order to construct a graph representing its semantics.

2.2 SPARQL Query Generation using Patterns

Our work is inspired by the SWIP system presented in (Pradel et al., 2013). This system allows the translation of natural language queris into formal ones, expressed in SPARQL. The translation process is done thanks to the use of query patterns, each pattern representing a family of typical queries. After the selection of the pattern which is the best match to the natural language query, that pattern is modified in order to build the SPARQL query corresponding to the natural query. The formal definition of a pattern is given in (Pradel et al., 2012). An extension of that work has been presented in (Gillet, 2013). It allows the generation of SPARQL queries based on different ontologies of a same domain, thanks to ontology alignments.

Even if our goal is to annotate documents instead of querying them, we propose to use patterns in our work. These patterns are deeply inspired by the patterns defined in (Pradel et al., 2012), but they are used for multimedia document annotation purpose. The patterns are adapted in order to take into account the notions related to images. The details of our approach is presented in Section 3.

3 OUR APPROACH FOR IMAGE ANNOTATION

In this section, we present our approach aiming at annotating web images. Our idea is to use RDF patterns in order to guide the extraction of relevant information from contextual factors surrounding the image to be annotated.

Among these factors, we cite (1) the image caption; (2) the paragraph title; (3) the text around the image; (4) the hyperlinks between documents containing images (if they exist); (5) the image name (if it is significant) and (6) the table content if the images are grouped in this structure.

After the choice of the factors to be used, the next step is to apply, for each factor, a set of processings. The goal of this step is to instantiate the RDF patterns and to select the best instantiated pattern. More details about our approach can be found in (Jaouachi et al., 2013). Figure 1 shows an overview of the proposed approach.

In this paper, we will focus on the step of the definition, the instantiation and the use of RDF patterns.

A pattern is an RDF graph which represents a prototype regrouping information considered as important by the domain experts (the cinema in our case). Each pattern is built by focusing on a group of pieces of information related to the cinema field. Different relationships between various concepts forming the patterns are inspired from the “Movie ontology”.

In addition to these relations, we use two properties belonging to the foaf ontology (foaf:depiction and foaf:img) which allows us to express the relationship

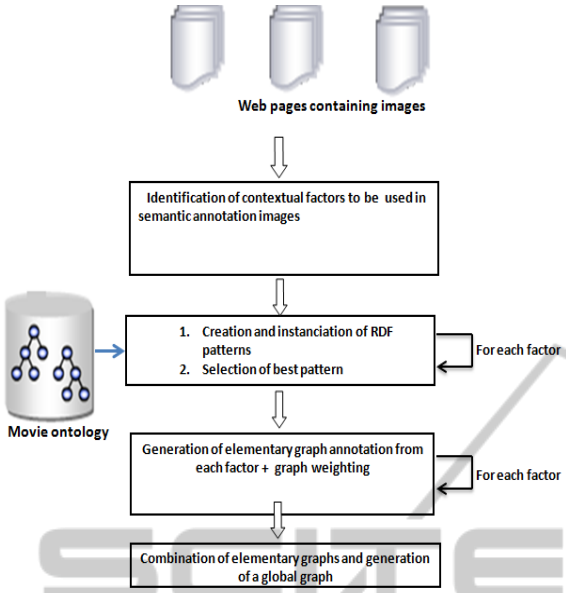


Figure 1: General approach overview.

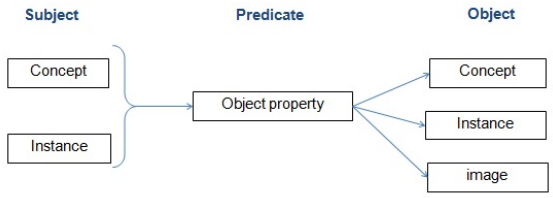


Figure 2: Triples constituting the graph patterns.

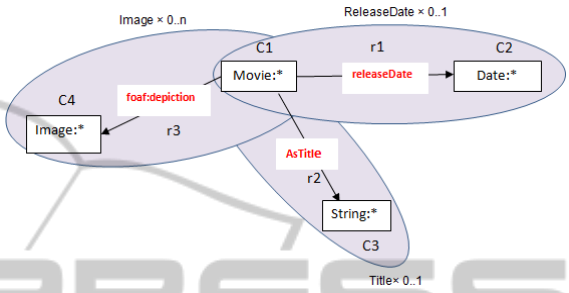


Figure 3: Example of a pattern used for the annotation.

between an element of the pattern (object or person respectively) and the related image.

Definition

Our definition of a pattern is inspired from (Pradel et al., 2013).

A pattern p is composed of 5 elements (G, Q, SP, Img, S):

- G is a connected RDF graph which describes the general structure of the pattern to be instantiated. Such a graph is composed of triples according to the structure presented in Figure 2. This structure is formed by a subject (which can be a concept or an instance of a concept), a predicate and an object (which can be a concept or an instance of a concept or an image);
- Q is a subset of elements of G, these elements are considered to be characteristics of the pattern. Such an element can be a class or an object property or an image of G;
- SP is the set of sub-patterns sp of p;
- Img is the set of distinct images called qualifying images present in the pattern. An image can illustrate an element of the pattern;
- S is a description of the meaning of the pattern in natural language.

Example

Figure 3 shows an example of an RDF pattern used for the step of annotation. It is composed of three sub-patterns which are [Movie,releaseDate,Date], [Movie,AsTitle,String] and [Movie,foaf:depection,Image]. All of them are optional because they can remain uninstantiated.

Sub-patterns [Movie,releaseDate,Date] and [Movie,AsTitle,String] are not repeatable and have as cardinalities *ReleaseDate*0..1* and *Title*0..1* respectively with 0 is the minimal cardinality and 1 is the maximum cardinality. Indeed, a movie has one title and one release date.

However, the sub-pattern [Movie,foaf:depiction,Image] is repeatable and has as cardinality *image*0..n*, n being the maximum cardinality.

3.1 RDF Pattern Definition

In order to annotate web images, we define some RDF patterns. Each pattern represents a prototype of a group of information related to the domain studied. In our case, we used six patterns considered as important by the experts of the domain. Each pattern is centered around a vertex which is the Movie concept and formed by a set of sub-patterns.

A sub-pattern can be defined as a simple triple with the subject which is an instance of the Movie concept (eg. triple [Movie:*,hasSoundmix,SoundMix:*] with Movie:* is a vertex of the pattern) or a set of triples whith one of them which is linked at the vertex of the pattern (eg. triples [Movie:*,hasComposer,Musical_Artist:*] and [Musical_Artist:*,foaf:img,image:*]) . The figure 4 reinforces the two definitions.

In order to define formally a pattern, we need three type of vocabularies:

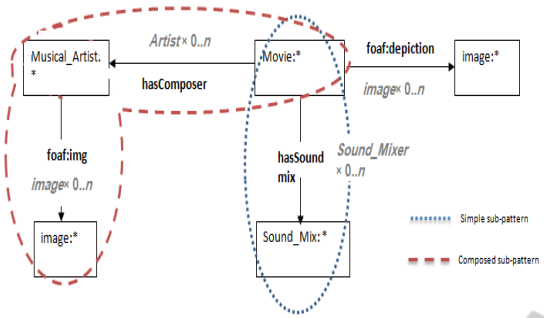


Figure 4: Examples of sub-patterns.

- The first vocabulary allows the description of the patterns in general. Indeed, we use the *patters ontology* [3] proposed in (Pradel et al., 2013). This ontology defines the grammar allowing the representation of patterns.
- The second vocabulary is the vocabulary of the domain addressed in the context of the image. It is necessary to associate each element or relationship of a pattern with a concept or a relationship belonging to the domain ontology used for the evaluation. In our case, we use the domain ontology named Movie ontology which will be presented in section 4. We use properties of this ontology to link the various properties used in the construction of the RDF patterns. For example, we have exploited the properties ***releaseDate*** from the Movie ontology to specify the predicate between Movie concept and Date concept and consequently to construct a sub-pattern of the pattern shown in figure 3.
- The third vocabulary is necessary to describe all the elements of the RDF patterns in relation to images. Indeed, by this vocabulary, we link an image to the appropriate element of the pattern. In our case, we use two properties from the foaf project: *foaf:depiction* and *foaf:img*.The first property represents a relationship between a thing and an image that depicts it, and the second property relates a Person to an image that represents him/her.

  To conclude, this step allows us to obtain several patterns that have to be instantiated based on any document related to the domain (cinema in our case).

Example

Figure 5 shows an example of RDF pattern according to the formal definition and uses the three vocabularies mentioned above.

[3]http://swip.univ-tlse2.fr/SwipWebClient/welcome.html

```
prefixes
    www:            "http://www.movieontology.org/2009/11/09/"
    movieontology:  "http://www.movieontology.org/2009/10/01/movieontology.owl#"
    page:           "http://dbpedia.org/page/"
    ontology:       "http://dbpedia.org/ontology/"
    foaf:           "http://xmlns.com/foaf/0.1/"
end prefixes

pattern movie_location_country

       [ 1_www:Movie    2_movieontology:hasFilmLocation
3_page:Place;
         3               4_foaf:depiction                    5_foaf:Image;
    ]location:0..1/5
       [ 1               6_movieontology:hasReleasingCountry
7_ontology:Country;
         3               8_foaf:depiction                    9_foaf:Image;
    ]country:0..1/9

    sentence
       -1- -location-[" located in "-3-" which has picture "-5-] -country-["
released in "-7-" which has picture "-9-]
    end sentence
end pattern
```

Figure 5: Examples of pattern presented in formal definition.

This pattern is composed of two sub-patterns: location and country. The three numbers after the name of each sub-pattern are respectively : the minimal cardinality, the maximal cardinality and the identifying of the element in order to instantiate the concerned pattern.

3.2 Instanciation of RDF Patterns

The purpose of defining and using RDF patterns is to guide the annotation procedure. We are not willing to extract all the pieces of information contained in a document but only to extract the pieces of information which allow the instantiation of the patterns.

For example, by using the pattern shown in figure 3, we want to extract triples from a document that can be instance of one of the three sub-patterns. In other words, we look for the date of the Movie, its title and its images.

This is possible by the following steps that will be repeated as many times as the number of sub-patterns:

- The first step consists in identifying the predicate of the sub-pattern. This step is based on the application of extraction rules that will be described in section 5.1.

- Once found, the second step consists in identifying the subject and the predicate related by the identified relationship. This step is based on the identification of instances forming two approximates of the identified relationship.

- The third step consists in linking the web image to the appropriate element of the pattern. This step is based on the analysis of the image caption, if there is any indication in the text describing the instance of

the concept concerned by the image.

We present in figure 7 the instantiation of the pattern shown in figure 3 by using the text and the image.

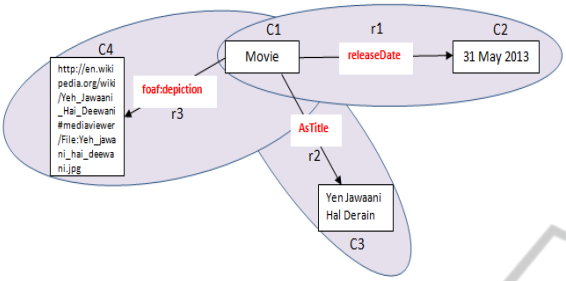


Figure 6: Instantiation of the pattern presented in figure 3.

3.3 Selecting the Best Instantiated Patterns to Represent the Text

The purpose of using patterns is to generate an RDF annotation for the web document containing the image. Our strategy is to instantiate patterns and then to choose the best instantiated pattern.

In order to rank the instantiated patterns, we focus on a set of criteria such as recall, precision, number of correct extracted triples, number of automatic extracted triples. It is possible to use the three first criteria only if we have a manual annotation as reference. However the last criteria is independent of manual annotation.

In this paper, we present the results based on the number of automatic extracted triples. The results using this criteria are presented in section 5. As a reference, we will compare the results obtained by using our approach with manual ranking.

4 THE MOVIE ONTOLOGY

Like in most research domains, there are ontologies which are used in order to represent, share and reuse knowledge. Ontologies contain an effective structure of the domain knowledge which improves the efficiency of the retrieval system. The semantic web techniques and technologies provide a manner to construct and use web resources by attaching semantic information to them.

In our work, we are interested in improving the management of multimedia information by means of knowledge representation, indexing and retrieval. Among the multimedia entertainment, cinema stands a good position so that we are interested, especially, in the cinema domain.

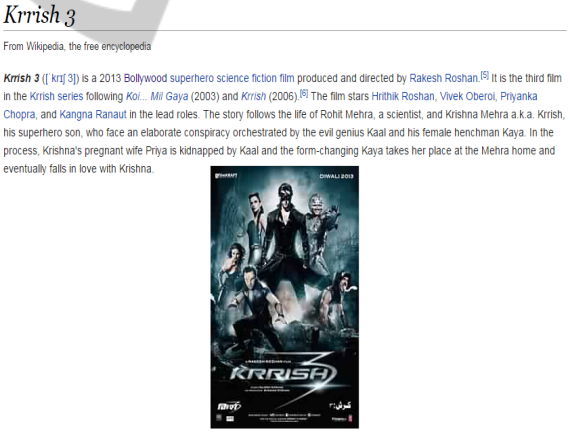
In the literature, there is an ontology of the cinema field which describes movie scenes. It is called "Movie ontology"[4] and it is developed by the Department of Informatics at the University of Zurich. This ontology contains concept hierarchies for movie categorisation, instances of concepts and relations between concepts.

It contains distinct concepts like Award, Certification, Film, Person (Actor, Actress, Writer, Producer, etc.).

5 EXPERIMENTATIONS AND EVALUATION

In order to validate our proposition, we used a corpus composed of 10 Wikipedia pages related to the cinema domain, written in English language and containing images. The choice of these pages was arbitrary. In our experiments, we have used only the surrounding text of images in order to instantiate six patterns.

As a reference, we annotated the corpus manually and we generated the RDF graph corresponding to the semantic annotation of each image. Figure 7 shows an example of a web image and its surrounding text.


Krrish 3

From Wikipedia, the free encyclopedia

Krrish 3 ([krɪʃ 3]) is a 2013 Bollywood superhero science fiction film produced and directed by Rakesh Roshan.[5] It is the third film in the Krrish series following *Koi... Mil Gaya* (2003) and *Krrish* (2006).[6] The film stars Hrithik Roshan, Vivek Oberoi, Priyanka Chopra, and Kangna Ranaut in the lead roles. The story follows the life of Rohit Mehra, a scientist, and Krishna Mehra a.k.a. Krrish, his superhero son, who face an elaborate conspiracy orchestrated by the evil genius Kaal and his female henchman Kaya. In the process, Krishna's pregnant wife Priya is kidnapped by Kaal and the form-changing Kaya takes her place at the Mehra home and eventually falls in love with Krishna.

Figure 7: Example of image used for the evaluation.

5.1 Extraction Rules for Semantic Relation Detection

In order to instantiate the RDF patterns, we use the NLP (Natural Language Processing) tools, GATE platform (Cunningham et al., 2002), Porter stemmer (Porter, 1997) and our own extensions dedicated to determinate the semantic relations for different patterns.

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

In this step, we used JAPE language (Cunningham et al., 2002). It is a language based on regular expressions. Using extraction rules, we try to detect an instance of the Movie ontology relations (adapted as a predicate for RDF pattern) and to detect instances of concepts linked by this relationship.

Such a rule represents a set of phases, each of which consists of a set of pattern/action rules. It has always two sides: Left (LHS:Left-Hand Side) and Right(RHS:Rigth-Hand Side). The LHS of the rule contains the identified annotation pattern that may contain regular expressions and the RHS outlines the action to be taken on the detected pattern and consists of annotation manipulation statements. The example below (figure 8) shows a grammar which allows the detection of instances of the semantic relation ”isAwardedWith”.

```
Rule:isAwardedwith

(
( (
 {Token.stem == "receiv"})


 ({Lookup.majorType == number} {SpaceToken})?
 ({Token.category == NP} {SpaceToken})?
 ({Token.category == NP}{SpaceToken})?

 ({Token.stem == "award"})?
)
|
(
  {Token.lemma == "win"}
 )

(
  {Token.lemma == "earn"}
 )
)

:is_Awarded_with -->
:is_Awarded_with.RelationShip = {kind = "is_Awarded_with", rule=isAwardedwith}
```

Figure 8: Rule example of JAPE grammar.

In the figure 8, we find an example of a rule that is labeled **isAwardedWith**. ”Token.stem” corresponds to the lemmatised form of the word, ”Token.category” corresponds to the grammatical category of the word, ”Token.Kind” design the kind of word. It means the word represents a number or a simple word or a punctuation. ”Lookup.majortype” means that the word is considered as the default concept. ”Lookup.minortype” corresponds to the specific categories of the word. "|" means that there are many alternatives. "-->" is the boundary of the LHS rule.

Our relation will be part of the annotation properties that can be seen in GATE. This is possible using :is_Awarded_with.RelationShip = kind = ”is_Awarded_with”, rule=isAwardedwith.

5.2 Results

In order to choose the best pattern to be considered as the basis for the annotation of the image, we did a ranking according to the number of extracted triples.

Table 1 and table 2 present the results for the image shown in Figure 7 using our approach firstly, and the result of the manual classification secondly.

Table 1: Automatic ranking of patterns corresponding to image 7.

Rank	Patterns Ranking	Number of automatic triple
1	pattern 2	7
2	pattern 4	6
3	pattern 1,pattern 6	4
4	pattern 3,pattern 5	0

Table 2: Manual RDF patterns classification.

Rank	Patterns Ranking	Number of manual triple
1	pattern 2	6
2	pattern 6	4
3	pattern1	3
4	pattern 3,pattern 4	1

We note that for this document, we obtained the same best rated pattern (pattern 2 is the highest rated pattern obtained by our approach and by a manual approach).

We note that the number of triples in a pattern can influence the final ranking. Indeed, the pattern 2 (the best ranked pattern) contains the highest number of triples. In addition, the presence of the generic triples having a maximum cardinality equal to n, can affect scheduling. For example, we can instantiate the generic triple [Movie: * hasActor, Actor *] repeatedly since a film can have the participation of several actors.

We repeated the same work for the ten web documents used for the evaluation.

In order to evaluate the quality of the annotation for the test collection, we used the following measure:

$$QA = \frac{Nr.of well annotated documents}{Total number of documents} \quad (1)$$

with QA is the quality of the annotation.

We consider a well-annotated document if it is annotated by P_i ($i \in [1..6]$ with 6 is the number of pattern used) having the first place automatically and the first place manually (the same P_i).

We also calculate QA where P_i obtains the second rank automatically.

Table 3 presents the results on the entire collection.

Obtained results are encouraging. Indeed, having high rates for the two best patterns (compared to manual annotation) shows the importance of our work.

Table 3: Quality of annotation.

Automatic Rank of P_i	QA
1	0.44
2	0.55

We succeeded to associate eighteen images to different elements of patterns that can be illustrated by a picture.

The success of these association shows the interest of our approach to annotate text and image at a time.

Choosing the number of extracted triples as criterion of classification is not arbitrary. In fact, it is impossible to use precision and recall as criterion of selection because it is not possible to obtain manual annotation for every test.

However, we note that the use of this criterion (number of extracted triples) has the disadvantage of promoting the pattern with the greatest number of sub-patterns or with a maximum cardinality greater than 1 (repeatable sub-patterns).

To overcome this problem, we plan to propose a new ranking function in our future work.

6 CONCLUSION

The potential of the semantic web to resolve information retrieval problems is tremendous. Based on semantic annotation techniques, adding formal semantics to the web content is vital to improve information indexing and retrieval.

In our case, our goal is to improve web images retrieval. To achieve this aim, we propose an automatic approach to semantically annotate images through their context. Indeed, we use contextual factors such as the caption of the image, the surrounding text, etc. in order to instantiate RDF patterns.

In this paper, we focused on the process of instantiation of RDF patterns using a domain ontology and patterns of extraction written in Jape language and the exploitation of instantiated patterns in order to choose the suitable annotation.

Preliminary results are encouraged to automate and use a bigger cinema corpus.

Working with all image contextual factors represents our next step. The aim of this step is to instantiate RDF patterns from each factor and to generate a global annotation.

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