A Language-Independent Approach to Keyphrase Extraction and Evaluation

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Abstract

We present Likey, a language-independent keyphrase extraction method based on statistical analysis and the use of a reference corpus. Likey has a very light-weight preprocessing phase and no parameters to be tuned. Thus, it is not restricted to any single language or language family. We test Likey having exactly the same configuration with 11 European languages. Furthermore, we present an automatic evaluation method based on Wikipedia intra-linking.

1 Introduction

Keyphrase generation is an approach to collect the main topics of a document into a list of phrases. The methods for automatic keyphrase generation can be divided into two groups: keyphrase assignment and keyphrase extraction (Frank et al., 1999). In keyphrase assignment, all potential keyphrases appear in a predefined vocabulary and the task is to classify documents to different keyphrase classes. In keyphrase extraction, keyphrases are supposed to be available in the processed documents themselves, and the aim is to extract these most meaningful words and phrases from the documents.

Most of the traditional methods for keyphrase extraction are highly dependent on the language used and the need for preprocessing is extensive, e.g. including part-of-speech tagging, stemming, and use of stop word lists and other language-dependent filters.

1.1 Related Work

In the statistical keyphrase extraction, many variations for term frequency counts have been proposed in the literature including relative frequencies (Damerau, 1993), collection frequency (Hulth, 2003), term frequency–inverse document frequency (tf.idf) (Salton and Buckley, 1988), among others. Additional features to frequency that have been experimented are e.g. relative position of the first occurrence of the term (Frank et al., 1999), importance of the sentence in which the term occurs (HaCohen-Kerner, 2003), and widely studied part-of-speech tag patterns, e.g. Hulth (2003). Matsuo and Ishizuka (2004) present keyword extraction method using word co-occurrence statistical information. Most of the presented methods need a reference corpus or a training corpus to produce keyphrases. The reference corpus acts as a sample of general language, whereas the training corpus is used to tune the parameters of the system.

Statistical keyphrase extraction methods without reference corpora have also been proposed, e.g. (Matsuo and Ishizuka, 2004; Bracewell et al., 2005). The later study is carried out for bilingual corpus.

1.2 Reference Corpora

The reference corpus of natural language processing systems acts as a sample of general language. The corpus should be as large as possible to get sufficiently many examples of language use. In our study, we used the Europarl corpus that consists of transcriptions of European Parliament speeches in eleven European languages, including four Romance languages (Spanish, French, Italian and Portuguese), five Germanic languages...
(Danish, German, English, Dutch and Swedish), Finnish and Greek (Koehn, 2005). The number of words in the corpora is between 23 million in Finnish and 38 million in French, while the number of word types differs from 98 thousand in English to 563 thousand in Finnish.

2 The Likey Method

We present a keyphrase extraction method Likey that is an extension of Damerau’s method (Honkela et al., 2007). In Damerau’s (1993) method, terms are ranked according to the likelihood ratio and the top \( m \) terms are used as index terms. Both single words and bigrams are considered to be terms. Likey produces keyphrases using relative ranks of \( n \)-gram frequencies. It is a simple language-independent method: The only language-specific component is a reference corpus in the corresponding language. Likey keyphrases may be single words as well as longer phrases.

The preprocessing phase of Likey consists of extraction of the main text body without captions of figures and tables, and removing special characters (except for some hyphens and commas). Numbers are replaced with \(<\text{NUM}>\) tags.

An integer rank value is assigned to each phrase according to its frequency of occurrence, where the most frequent phrase has rank value one and phrases with the same frequency are assigned the same rank. Rank values \( \text{rank}_a \) and \( \text{rank}_r \) are calculated from the text and the reference corpus, respectively, for each phrase. Rank order rank is calculated separately for each phrase length \( n \). Thus we get ranks from unity to \( \max_{\text{rank}} \) for each \( n \). This way \( n \)-gram frequencies for \( n \geq 2 \) are scaled to follow approximately the same distribution as 1-grams in the corpus. The ratio

\[
\text{ratio} = \frac{\text{rank}_a}{\text{rank}_r} \tag{1}
\]

of ranks is used to compare the phrases.

In highly inflective languages, such as Finnish, and languages with frequent word concatenation, such as German, many of the phrases occurring in the analysed document do not occur in the reference corpus. Thus, their ratio value is related to the maximum rank value, according to Eq. 2,

\[
\text{ratio} = \frac{\text{rank}_a}{\max_{\text{rank}} + 1} \tag{2}
\]

where \( \max_{\text{rank}} \) is the maximum rank in the reference corpus. The ratios are sorted in increasing order and the phrases with the lowest ratios are selected as the extracted keyphrases. Phrases occurring only once in the document cannot be selected as keyphrases.

3 Evaluation

The most straightforward way to evaluate the extracted keyphrases is to first decide which phrases are appropriate to the document and then calculate how many of the extracted keyphrases belong to the appropriate phrases set, e.g. by using precision and recall measures.

There are two widely used approaches for defining the appropriate phrases for a document. The first method is to use human evaluators for rating extracted keyphrases. The other approach is to analyse documents that have author-provided keyword lists. Each document has a list of keyphrases which are easy to accept to be correct. Anyway, automated keyphrase extraction methods are usually poor in predicting author-provided keyphrases since many of the provided phrases do not exist in the document at all but they are sort of super-concepts.

3.1 Multilingual Approach

In our framework, there are keyphrases in 11 languages to be evaluated. Due to many problems related to human evaluation in such a context, we needed a new way of evaluating the results of our language-independent keyphrase extraction method. We took our evaluation data from Wikipedia, a free multilingual online encyclopedia.\(^1\) We present a novel way to use Wikipedia articles in evaluation of a multilingual keyphrase extraction method. Wikipedia corpus has lately been used as a resource for automatic keyword extraction for English (Mihalcea and Csomai, 2007) as well as to many other tasks.

We suppose that those articles which are linked from the article at hand and which link back to the article, are potential keyphrases of the article. For example, a Wikipedia article about some concept may link to its higher-level concept. Likewise, the higher-level concept may list all concepts including to the group.

3.2 Evaluation Data

Finding Wikipedia articles of adequate extent in all the languages is quite challenging, basically due

\(^1\)http://wikipedia.org
to generally quite short articles in Greek, Finnish and Danish. We gathered 10 articles that have sufficient amount of content in each of the 11 Europarl languages. These 110 selected Wikipedia articles were collected in March 2008 and their English names are Beer, Cell (biology), Che Guevara, Leonardo da Vinci, Linux, Paul the Apostle, Sun, Thailand, Vietnam War, and Wolfgang Amadeus Mozart.

The average lengths of articles in Finnish, Dutch and Swedish are between 2 000 words, the lengths of articles in Portuguese, Greek and Danish are around 3 000 words and the rest are between 5 000 and 7 000 words. The normalised lengths would switch the order of the languages slightly.

Among the 67 links extracted from the English Wikipedia article Cell include phrases such as adenosine triphosphate, amino acid, anabolism, archaea, bacteria, binary fission, cell envelope, cell membrane, and cell nucleus. The extracted links serve as evaluation keyphrases for the article.

4 Results

In our study, we extracted keyphrases of length $n = 1 \ldots 4$ words. Longer phrases than four words did not occur in the keyphrase list in our preliminary tests. As a baseline, the state-of-the-art keyphrase extraction method tf.idf keyphrases were extracted from the same material. Tf.idf (Salton and Buckley, 1988) is another simple and non-parameterized language-independent method that can be used for keyphrase extraction. For tf.idf we split the Europarl reference corpora in 'documents' of 100 sentences and used the same preprocessing that for Likey. To remove uninteresting tf.idf-produced phrases like of the cell, a Likey-like post processing was tried, and it gave slightly better results. Thus the post processing is used for all the reported results of tf.idf.

Generally, Likey produces longer phrases than tf.idf. Each keyphrase list characterises the topic quite well, and most of the extracted keyphrases recur in every language. Both methods extracted a French word re that is frequently used in the article as an acronym for r´eticulum endoplasmique. The same word in Dutch is extracted by tf.idf in a form endoplasmatisch reticulum er.

We compared our Likey keyphrase extraction method to the baseline method tf.idf by calculating precision and recall measures according to the Wikipedia-based evaluation keyphrases for both methods. We extracted 60 keyphrases from each document for the first evaluation round and the number of keyphrases available in the evaluation keyphrase list for the document for the second evaluation round. Precision and recall values of both Likey and tf.idf evaluated with Wikipedia intra-links are comparatively low (Table 1) but one has to take into account the nature of the evaluation set with notably varying number of 'correct keyphrases'.

| Method         | 60 keyphrases | $N$ keyphrases |
|----------------|---------------|----------------|
|                | Prec. | Recall | Prec. | Recall |
| Likey          | 0.1475 | 0.2470 | 0.1795 | 0.1795 |
| tf.idf         | 0.1225 | 0.2203 | 0.1375 | 0.1375 |
| tf.idf + p     | 0.1343 | 0.2341 | 0.1622 | 0.1622 |

Table 1: Average precisions and recalls for Likey, tf.idf and tf.idf with post processing (p). $N$ keyphrases refers to the amount of evaluation keyphrases available for each article.

The obtained precisions and recalls of the first evaluation differed significantly between languages. In Figure 1, the precision and recall of Likey and tf.idf with post processing for each language is given. Within the 11 European languages, English and German performed best according to the precision (Likey: 23.0% and 22.8%, respectively), but not that well according to the recall, where best performed Dutch and Greek (Likey: 33.4% and 31.8%, respectively).

5 Conclusions and Discussion

In this paper, we have introduced Likey, a statistical keyphrase extraction method that is able to analyse texts independently of the language in question. In the experiments, we have focused on European languages among which Greek and Finnish differ considerably from Romance and Germanic languages. Regardless of these differences, the method gave comparable results for each language.

The method enables independence from the language being analysed. It is possible to extract keyphrases from text in previously unknown language provided that a suitable reference corpus is available. The method includes only lightweight preprocessing, and no auxiliary language-dependent methods such as part-of-speech tagging are required. No particular param-
eter tuning is needed either. A web-based demonstration of Likey is available at http://cog.hut.fi/likeydemo/ as well as more detailed information on the method. The system highlights keyphrases of a document written in one of eleven languages.

Future research includes an extension of Likey in which unsupervised detection of morphologically motivated intra-word boundaries (Creutz, 2006) is used. This extension could also handle languages that have no white space between words. We also plan to apply the method within statistical machine translation. A methodological comparison of keyphrase-based dimension reduction and e.g. PCA will also be conducted.

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