NgramQuery - Smart Information Extraction from Google N-gram using External Resources

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Abstract

This paper describes the implementation of a generalized query language on Google Ngram database. This language allows for very expressive queries that exploit semantic similarity acquired both from corpora (e.g. LSA) and from WordNet, and phonetic similarity available from the CMU Pronouncing Dictionary. It contains a large number of new operators, which combined in a proper query can help users to extract n-grams having similarly close syntactic and semantic relational properties. We also characterize the operators with respect to their corpus affiliation and their functionality. The query syntax is considered next given in terms of Backus-Naur rules followed by a few interesting examples of how the tool can be used. We also describe the command-line arguments the user could input comparing them with the ones for retrieving n-grams through the interface of Google Ngram database. Finally we discuss possible improvements on the extraction process and some relevant query completeness issues.

Keywords: N-grams, WordNet, Lexical Similarity

1. Introduction

In computational linguistics many tasks are properly dealt exploiting a combination of syntagmatic and domain features. Syntagmatic aspects are often managed by taking advantage of the analysis of large n-gram databases, while domain and ontological aspects are more properly modeled by semantic similarity spaces (e.g. latent semantic space) and lexical ontologies such as WordNet.

This paper describes the implementation of a generalized query language on Google Ngram database, whose expressiveness boosting is accomplished by plugging semantic similarity acquired both from corpora (e.g. LSA) and from WordNet, and phonetic similarity available from pronouncing dictionaries. It contains several different operators, which combined in a proper query can help users to extract n-grams having similarly close syntactic and semantic relational properties. We also characterize the operators with respect to their functionality, i.e. similarity, part-of-speech, syntactic and semantic operators.

The tool can be useful in a variety of tasks, ranging from specific lexicon extraction and lexical substitution task (McCarthy andNavigli, 2007) to the automatization of creative and figurative language processes (Strapparava et al., 2007; Stock et al., 2008; Veale, 2011) such as puns and portmanteau words generation, metaphors, hyperbolae and other rhetorical phenomena.

The paper is organized as follows. Section 2, briefly presents the notions of what we call The Core language and The Ngram-query language. Section 3, describes the operators we have implemented and it groups them into categories according to their functionality. In Section 4, we present how we can extract domain-specific concepts and how we can deal with orthographic and phonetic rhymes. Finally, in Section 5, we describe the expressiveness of the tool and some promising future directions.

2. Implementation

2.1. Preliminary notes

The starting point was the Google Web 1T 5-Grams database (Brants and Franz, 2006). This data set contains English word n-grams and their observed frequency counts. The length of the n-grams ranges from unigrams to five-grams. The n-gram counts were generated from approximately 1 trillion word tokens of text from publically accessible Web pages. For easily handling that huge dataset, we exploited Web1T5-Easy1, which is a collection of Perl scripts for indexing and querying the Google Web 1T 5-Grams database with the open-source database engine SQLite. The creation of our tool was inspired by the idea of combining different knowledge sources, in particular:

- Lexical concepts and their taxonomies, given by WordNet lexicon database. Besides all the relations present in WordNet, we embedded in the query language also the common similarity measures (Budanitsky and Hirst, 2006; Pedersen et al., 2004) such as Resnik, Lin, Jiang-Conrath, etc.
- Exploiting a specific version of LSA space (Deerwester et al., 1990) acquired from the full British National Corpus.
- The CMU Pronouncing Dictionary2, for dealing with assonances, partial homophones, etc.

Finally we designed a query language that is able to express these concepts according Google N-gram database. Information extraction from such a database using fixed external

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1http://cogsci.uni-osnabrueck.de/~korpora/ws/cgi-bin/Web1T5/Web1T5_freq.perl
2http://www.speech.cs.cmu.edu/cgi-bin/cmudict

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resources is a difficult task, especially with respect to efficiency and completeness. We will discuss some of these issues in the Section 5.

To give a flavor of the expressiveness, a possible query could be:

\[ \sim \# \text{food sandwich with cheese}\# \]

that retrieves the 4-grams, along with their frequencies, in which the first word is a hyponym of \textit{food} (i.e. the term \( \sim \# \text{food} \)), then \textit{‘sandwich with’} followed by one of the first 10 similar words to \textit{cheese} according to LSA (i.e. \#10). The most frequent 4-gram (with frequency 896) that satisfies the query is:

896 egg sandwich with tomato

2.2. Core language

Web1T5-Easy offers a quick and convenient way to build an interactive searchable version of the Web1T5 database, including a full collocation analysis and it provides five search terms, i.e. a literal term, a word set term, wildcard term (use of %), arbitrary word term (asterisk *) and skipped token term (question mark ?). They give to the user a simple extraction power. Nonetheless, they are quite useful and we built our extension on top of them. We call the set of queries constructed using these terms \textit{The Core-query language}.

2.3. Generalized language

We call \textit{The Ngram-query language} the extension of the basic query language. It contains a large number of new operators, with proper syntax and semantics. They allow the user to combine syntagmatic and domain operators within a single query and to retrieve resource-dependent n-grams in a fast and efficient manner.

3. Operators

In this section we present the operators implemented by dividing them into groups. This division was inspired by having different external corpora, i.e. WordNet lexicon database, a specific version of LSA space and the CMU Pronouncing Dictionary, on one hand and the operator functionality, i.e. pointer-concept, similarity and relatedness, part-of-speech, syntactic and phonetic operators, on the other.

3.1. WordNet

3.1.1. Relational operators

The organization of the lexical knowledge in the WordNet repository is represented by a variety of lexical and semantic relations. While lexical relations hold between word forms, the semantic relations hold between word meanings (i.e. synsets). We used pointers to represent the relations between the words in one synset and another. Lexical pointers relate specific word forms in the source and target synsets. Semantic pointers relate word meanings, and therefore pertain to all of the members in the source and target synsets. In addition, the repository files lexicographically correspond to one of the four syntactic categories, i.e. noun, verb, adjective and adverb.

In Table 1 the operators implemented for each of the WordNet categories are listed.

| Operator                | n | v | a | r |
|-------------------------|---|---|---|---|
| Antonym (!)             | + | + | + | + |
| Hypernym (@)            | + | + | - | - |
| Instance hypernym (@i)  | + | - | - | - |
| Hyponym (−)             | + | + | - | - |
| Instance hyponym (−i)   | + | - | - | - |
| Member holonym (#m)     | + | + | - | - |
| Substance holonym (#s)  | + | + | - | - |
| Part holonym (#p)       | + | + | - | - |
| Member meronym (%m)     | + | + | - | - |
| Substance meronym (%s)  | + | + | - | - |
| Part meronym (%p)       | + | + | - | - |
| Attribute (=)           | + | + | - | - |
| Derivationally related form (+) | + | + | - | - |
| Entailment (+)          | - | - | - | - |
| Cause (>)               | - | - | - | - |
| Also see (’)            | - | + | + | - |
| Verb group ($)          | - | + | + | - |
| Similar to ($)          | - | - | + | + |
| Participle of verb (<)  | - | + | - | + |
| Pertainym (‘)            | - | - | + | + |
| Derived from adjective (‘) | - | - | + | + |

Table 1: Pointer-concept operators. Abbreviation are as follows: \textit{n} (noun); \textit{v} (verb); \textit{a} (adjective); \textit{r} (adverb); + means the relation is present in WN, and — otherwise.

To clarify the use of the pointer operators we provide some examples. First, let us consider the query:

\[ \sim \# \text{food} \# \]

that retrieves the hyponyms of the noun \textit{food} for all of its senses. Some of the returned unigrams, along with their frequencies in the Google Web 1T5-gram database, are given below.

\[ \begin{align*}
  21757873 & \text{ dish } \\
  20962063 & \text{ milk } \\
  17654214 & \text{ meat } \\
  16705545 & \text{ cheese } \\
  16529672 & \text{ cake } \\
  15533365 & \text{ fiber } \\
  11444465 & \text{ beef } \\
  10977879 & \text{ juice } \\
  10888394 & \text{ eggs } \\
  9757346 & \text{ salmon } 
\end{align*} \]

Our second example aims at uncovering the expressiveness of the new language:

\[ \sim \# \text{query} \# \]

which extracts the hyponyms of the verb \textit{query}. Possible concepts with their frequencies are listed next.
3.1.2. Similarity operators

Exploiting the topology and the content of the WordNet repository it is possible to implement a variety of similarity and relatedness measures as operators in the extended language. The authors in (Pedersen et al., 2004) present a simple and useful Perl-implemented software package, Wordnet::Similarity, which can be used for retrieving information related with the degree of similarity and relatedness between two concepts either within a single part of speech or between different syntactic category spaces. In the former case they discuss 6 similarity measures, i.e. 3 LCS-based and 3 path-based, which are followed by a short presentation of 3 relatedness measures possibly crossing the boundaries of the part of speech spaces. We used the provided API to include all 9 measures as operators in the Ngram-query language. Furthermore, we added the possibility for the user to set a random measure, which chooses in a stochastic manner one of the other measures, and a similarity or relatedness threshold, i.e. if two concepts have measure value below this threshold they are discarded. Table 2 presents these operators together with their threshold.

| Operator          | acr | t   | sim | rel |
|-------------------|-----|-----|-----|-----|
| Resnik            | res | ≥ 1.37 | +  | -   |
| Lin               | lin | [0, 1] | +  | -   |
| Jiang & Conrath   | jcn | ≥ 0  | +  | -   |
| Leac. & Chod.     | lch | [0, 3.68] | + | -   |
| Wu & Palmer       | wup | [0, 1] | +  | -   |
| Measure path      | path | (0, 1) | +  | -   |
| Hirst & St-Onge   | hso | [0, 16] | - | +   |
| Baner. & Peder.   | lesk | ≥ 1  | -  | +   |
| Patwardhan        | vector | [0, 1] | - | +   |
| Random            | random | above | + | +   |

Table 2: WordNet measures operators. Abbreviation are as follows: acr (similarity measure acronym); t (threshold range); sim (similarity); rel (relatedness).

We embedded the LSA similarity into the query syntax in two settings: a threshold for the number of similar words, and a threshold for the cosine value between words. The user has the freedom to insert them individually or together within a single query term. As an example, the query

```
vehicle#L#0.7
```

gives the concepts which are similar to the noun `vehicle` and have cosine value greater or equal than 0.7. The second example generalizes the settings by specifying the number of the required LSA terms within the query in addition to their cosine. It retrieves the similar terms of `food` with cosine value at least 0.6 among the first 15 most similar terms.

```
food#L#15#0.6
```

3.2. LSA

In addition to similarity measures obtained using lexical resources such as WordNet, we intended to exploit in the query language also a corpus-based semantic similarity mechanism. As a corpus-based measure of semantic similarity we exploited latent semantic analysis (LSA) proposed by (Landauer et al., 1998). In LSA, term co-occurrences in a corpus are captured by means of a dimensionality reduction operation by a singular value decomposition (SVD) on the term-by-document matrix representing the corpus. For the implementation reported in this paper, we run the SVD operation on the full British National Corpus, using 400 dimensions. Then for each word in the corpus, we cached the first hundred most similar words to that word, with the respective cosine values.

3.3. Phonetic dictionary

The Carnegie Mellon University Pronouncing Dictionary is a machine-readable pronunciation dictionary, which contains over a hundred twenty-five thousand words and their translations. The last is built on top of the phoneme domain, which currently contain 39 phonemes, for which the vowels may carry a flag indicating their lexical stress, i.e. 0 for no stress, 1 for primary stress and 2 for secondary stress. We
implemented a single operator, which allows us to retrieve words with similar phonemic beginnings, endings or both. Its acronym is $\%$ and it is applied in a manner similar to the orthographic substring matching $\&$ operator in The Core-query language, i.e. $\&$ or $\&$. In Table 3 a comparison between the two operators is given.

| Operator | acr | begin | middle | end |
|----------|-----|-------|--------|-----|
| Orthographic Phonetic | $\%$ | +     | +      | +   |
| $\&$     | +   | -     | +      | +   |

Table 3: Syntactic and phonetic operators. Operator applicability: begin (at the beginning of a word); middle (within a word); end (at the end of a word)

The orthographic operator can be applied multiple times within a word, while the phonetic one can only be applied either at the beginning or the end of a word (or both). The following two examples clarify the use of the two operators. They also show how the user can use the word set term (i.e. asking for two different n-grams in the same query).

$\%quer\%, %ide$

181971412 article
54080132 vehicle
31295263 query
... 8329460 particle
7821136 albuquerque
6939347 chronicle
... 661990 konqueror
563796 follicle
439169 ventricle
...

We can see that $\%$ can be applied more than one times within a string. This is not the case with the operator $\&$ as shown next. Recall, when $\&$ operator is applied to a string then an overlapping between the given string and the words in the phonetic dictionary is performed and the positive matches are returned as part of the results to the query.

$\&fore$

5933321709 for
277552584 before
129170208 four
2380057 fore
542725 heretofore
...

3.4. Query syntax

In this subsection we give a formalization of the query syntax in The Ngram-query language in terms of Backus-Naur grammar rules.

3.4.1. Grammar

Note that we have a natural restriction on the length of the query imposed by the fact that Google Ngram database contains up to five grams.

A query is composed of terms. The terms, in particular, can be simple words or a combination of words and operators. We clear the details with the following rules presenting the syntax of the different kinds of terms.

\[
\langle \text{term} \rangle ::= \langle \text{term}_0 \rangle \mid \langle \text{term}_1 \rangle \mid \langle \text{term}_2 \rangle \mid \langle \text{term}_3 \rangle
\]

\[
\langle \text{term}_0 \rangle ::= \langle \text{expr} \rangle
\]

\[
\langle \text{expr} \rangle ::= \langle \text{word} \rangle \mid \langle \%\text{-string} \rangle \mid \langle \&\text{-string} \rangle
\mid \langle \text{string-L} \rangle \mid \langle \text{expr}\rangle \langle \text{expr}\rangle \ldots
\]

\[
\langle \%\text{-string} \rangle ::= \langle \%\&\text{within\_concept} \rangle
\]

\[
\langle \text{string-L} \rangle ::= \langle \text{string}_L \rangle
\]

Examples of possible expressions are: ‘house’, ‘%ing’, ‘£ture’, ‘ref£’, ‘data, roof, ref£, %mics, ad%nt%, £ics’.

\[
\langle \text{term}_1 \rangle ::= \langle \_p\_c\rangle \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle
\mid \langle \text{term}_0 \rangle \langle \text{L} \rangle \langle \text{sim} \rangle \langle \text{freq} \rangle
\]

\[
\langle \_p\_c\rangle ::= \text{pointer\_concept}
\]

\[
\langle \text{pos} \rangle ::= n \mid v \mid a \mid r
\]

\[
\langle \text{s}_n \rangle ::= \text{sense\_number}
\]

\[
\langle \text{L} \rangle ::= \text{letter\_L}
\]

\[
\langle \text{sim} \rangle ::= \text{number\_similar\_words}
\]

\[
\langle \text{freq} \rangle ::= \text{frequency\_threshold}
\]

In the terms, following the first case of this pattern, part-of-speech ($\langle \text{pos} \rangle$) and the sense number ($\langle \text{s}_n \rangle$) settings can be omitted. Instead their defaults values are used, i.e. noun and all senses, respectively. In the second case at least one setting must be specified, i.e. either the number of similar concepts or the cosine threshold. Note that the number of similar words should be less than one hundred, a constraint imposed by the specificity of the LSA matrix we used (see Section 3.2.). The following examples give some possible terms according to the above pattern, i.e. ‘@#fast#a#2’, ‘concept#L#10#0.7’, ‘data#L#0.3’, ‘term#1’.

\[
\langle \text{term}_2 \rangle ::= \langle \_p\_c\rangle \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle
\]

\[
\langle \text{term}_3 \rangle ::= \langle \text{term}_0 \rangle \langle \text{L} \rangle \langle \text{sim} \rangle \langle \text{freq} \rangle \langle \text{concept} \rangle
\]

\[
\langle \text{term}_4 \rangle ::= \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle \langle \text{W} \rangle \langle \text{type} \rangle \langle \text{freq} \rangle \langle \text{s}_n \rangle
\]

\[
\langle \text{term}_5 \rangle ::= \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle \langle \text{W} \rangle \langle \text{type} \rangle \langle \text{freq} \rangle \langle \text{s}_n \rangle
\]

\[
\langle \text{term}_6 \rangle ::= \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle \langle \text{W} \rangle \langle \text{type} \rangle \langle \text{freq} \rangle \langle \text{s}_n \rangle
\]

\[
\langle \text{term}_7 \rangle ::= \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle \langle \text{W} \rangle \langle \text{type} \rangle \langle \text{freq} \rangle \langle \text{s}_n \rangle
\]

\[
\langle \text{term}_8 \rangle ::= \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle \langle \text{W} \rangle \langle \text{type} \rangle \langle \text{freq} \rangle \langle \text{s}_n \rangle
\]

\[
\langle \text{term}_9 \rangle ::= \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle \text{s}_n \rangle \langle \text{W} \rangle \langle \text{type} \rangle \langle \text{freq} \rangle \langle \text{s}_n \rangle
\]
For instance, Google Ngram database, i.e. to the way people use them. The query:

\[
\langle W \rangle := \text{letter}_W \\
\langle \text{type} \rangle := \text{Wordnet\_similarity\_measure} \\
\langle C \rangle := \text{letter}_C \\
\langle \text{term}_3 \rangle := \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle s_n \rangle \langle L \rangle \langle \text{sim} \rangle \langle freq \rangle \\
\# \langle W \rangle \langle \text{type} \rangle \langle freq \rangle \langle s_n \rangle \langle C \rangle \langle \text{concept} \rangle \\
| \langle p_c \rangle \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle s_n \rangle \langle L \rangle \langle \text{sim} \rangle \langle freq \rangle \\
\# \langle C \rangle \langle \text{concept} \rangle \\
| \langle p_c \rangle \langle \text{term}_0 \rangle \langle \text{pos} \rangle \langle s_n \rangle \\
\# \langle W \rangle \langle \text{type} \rangle \langle freq \rangle \langle s_n \rangle \langle C \rangle \langle \text{concept} \rangle \\
\]

3.4.2. Command Line
The user can use the query language using the terminal interface. A possible query is

\texttt{perl NgramQuery.perl -o -l 50 -f 1000 -d 3 \sim \#food’}

First the query retrieves the hyponyms of \texttt{\‘food’}, which are down to the third level in the corresponding \texttt{isa} hierarchy of WordNet, then the first 50 unigrams with frequency at least 1000 are proposed.

4. Examples
This section shows some examples on how to use the tool and how it is possible to combine different resources within a query.

4.1. Example 1: Automated creation of fast-food menu
The query:

\texttt{\sim \#food,drink sandwich,pizza,pasta,salad\#L\#10}

will retrieve bigrams, along with their frequencies, in which the first component is an hyponym of the word \texttt{food} or \texttt{drink} and the second one is a word within the first 10 LSA most similar words to \texttt{either sandwich,pizza,pasta} or \texttt{salad}. In such a way we can retrieve all the combinations not only correct with respect to the WordNet ontology and LSA similarity, but also reasonable with respect to Google Ngram database, i.e. to the way people use them. For instance, \texttt{eggburger, tomatoesalad, cheesespaghetti, etc.} are foods people used to eat, while \texttt{chocolate gringer, sugarsalad} are not.

4.2. Example 2: Interesting activities
The query:

\texttt{interesting \%ing
#n\#1\#W \#res\#2.1\#1\#C\#activity}

retrieves all bigrams in which the first word is interesting followed by a word, ending in \texttt{ing}, which has to be a noun and its first sense in WordNet has to be similar, according to Resnik similarity measure with threshold $\geq 2.1$, to the first sense of \texttt{activity}. The first two results are:

\texttt{3679 interesting shopping}  
\texttt{2409 interesting training}  
\texttt{...}

5. Future work and discussion
In the first example above the reader can observe that the query contains two terms and the results are bigrams. What about multiple-word concepts such as \texttt{modern} and \texttt{state-of-the-art}? The user might want to retrieve \texttt{state-of-the-art} technique when input the query \texttt{Q = \sim \#modern approach\#L\#20}. We will address such a situation as a future improvement.

An important issue is the trade-off between the expressiveness of the query language and the complexity of the retrieval. Imagine the user wants to retrieve 4-grams by entering the following query, \texttt{Q = fast\#a\#L\#10 old\#a\#1\#L\#10\#W\#lin\#0.2\#C\#archaic \&\#cheap\#L\#0.8 vehicle\#L\#10}. How complex is answering to this query? A complete freedom in combining operators leads quickly to computational tractability problems. At present this issue is addressed by relying on user awareness of keeping the queries sensible. We are planning to implement a preventive analysis of the query, providing the user with precise help for faster and more reliable retrieving.

6. Conclusions
We developed a generalized query language on Google Ngram database, whose expressiveness is boosted by plugging semantic similarity acquired both from corpora (e.g. LSA) and from WordNet, and phonetic similarity available from pronouncing dictionaries, in particular \texttt{CMU Pronouncing Dictionary}. The language implements a large number of new operators, each one of them with different meaning and purpose. We summarized them and clarified their syntax through usage examples. Then, we presented the syntax of the new language and discussed the settings involved. We think that this tool will be helpful in many tasks some of which are specific lexicon extraction, creative language combinations, and generation of language variations.

Acknowledgements
Martin Aleksandrov was partially supported by the European Master Program in Computational Logic (EMCL). Carla Strapparava was partially supported by a Google Research Award.

Finally, we would like to thank Marco Guerini and Gözde Özbal for many useful and valuable discussions.

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