On Lexicographical Networks

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1 Introduction

Lexical resources are important components of natural language processing (NLP) applications providing machine-readable knowledge for various tasks. One of the most popular examples of lexical resources are lexicons. Lexicons provide linguistic information about the vocabulary of a language and the semantic relationships between the words in a pair of languages. In addition to the lexicons, there are various other types of lexical resources, particularly those which are made by experts such as WordNet, VerbNet and FrameNet and, those which are collaboratively curated such as Wikipedia and Wiktionary.

The potential of lexical resources in improving language technology applications is not fully exploited yet. This is due to the complexity of the structure of such resources which generally contain heterogeneous and multi-lingual data. Therefore, linking concepts and words across resources, a task known as lexical resource alignment, remains a challenging task in NLP. Combining lexical resources not only improves word, knowledge and domain coverage, but also can enhance multilinguality.

The focus of the current study is on the structure of lexicons and their potential in addressing lexical alignment problem.

Figure 1: A set of dictionary entries (left) and the equivalent lexicographical network (right).

2 Objective

There are three main linking approaches applicable to e-lexicography: ontology alignment, schema matching and graph matching [1]. Despite the dependency of the two former ones on semantic relatedness, graph matching only relies on structural properties.
In this study, we analyze lexicographical networks based on basic graph notions. We define a lexicographical network as a network of two disjoint sets of vocabulary which are interconnected based on a sense relation. Analyzing the structure of such networks provide further information that may be of help in using alignment algorithms based on link prediction methods. Figure 1 illustrates a set of entries of a bilingual English-French dictionary and their lexicographical network schema.

3 Analysis notions

Throughout this study, we assume that graph $G = ((U, V), E, W)$ is unweighted, undirected, and bipartite. In other words, $U$ and $V$ are disjoint sets of vertices and the edge set $E \subseteq U \times V$ contains only edges between vertices in $U$ (source entries) and vertices in $V$ (target entries). We use similar notions to Latapy et al. [2] to define basic bipartite statistics.

Given a bipartite graph $G$, we denote the number of right and left nodes by $n_U = |U|$ and $n_V = |V|$. We also denote the number of links in the graph by $m = |E|$. The average degree of each set of vertices is defined as $k_U = \frac{m}{n_U}$ and $k_V = \frac{m}{n_V}$. Therefore, the average degree of the whole graph $G' = (U \cup V, E, W)$ can be calculated as $k = \frac{2m}{n_U + n_V} = \frac{n_U \times k_U + n_V \times k_V}{n_U + n_V}$. Finally, we define the number of existing links divided by the number of possible links as the bipartite density $\delta(G) = \frac{m}{n_U \times n_V}$.

In order to capture a notion of overlap, we also define clustering coefficient which measures the probability that two nodes are linked based on the common neighbors. Borgatti and Evrett [3] define the clustering coefficient in bipartite graphs as the following:

$$cc(u, v) = \frac{\sum_{v \in N(N(u))} cc(u, v)}{|N(N(u))|}$$

where $cc(u, v)$ measures the overlap between neighbourhoods of $u$ and $v$ and $N(u)$ refers to the neighbours of $u$. If there is no common neighbours between $u$ and $v$, then $cc(u, v) = 0$. If they have the same common neighbours, $cc(u, v) = 1$. Therefore, $cc(u, v)$ is defined as:

$$cc(u, v) = \frac{N(u) \cap N(v)}{N(u) \cup N(v)}$$

Finally, we define the average clustering coefficient in $U$ (or in $V$) as the average of $cc(u)$ (or $cc(v)$) over the whole number of nodes:

$$cc(U) = \frac{\sum_{u \in U} cc(u)}{|U|}$$

4 Experiments

We analyze the lexicographical network of the 10 largest multilingual dictionaries freely-accessible on FreeDict. The evaluation results of each network are shown in table 1.

Although the sizes of the dictionaries are not identical, their feature values seem to be uniformly varying in a specific range. The average degree $k$ changes in the range of $[1, 2]$ indicating one-to-many relations between source entries and target entries. A higher degree in each side of the network, i.e.,

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1This assumption may not be always correct as in a real-world dictionary an entry can refer to another entry in the same set, for instance, using see or cf. keywords.

2https://freedict.org/
Table 1: Evaluation of lexicographical networks based on basic graph notions

<table>
<thead>
<tr>
<th>Language pairs</th>
<th>n_U</th>
<th>n_V</th>
<th>m</th>
<th>k_U</th>
<th>k_V</th>
<th>k</th>
<th>δ</th>
<th>ccc_U</th>
<th>ccc_V</th>
</tr>
</thead>
<tbody>
<tr>
<td>German-English</td>
<td>81540</td>
<td>92982</td>
<td>123490</td>
<td>1.51</td>
<td>1.32</td>
<td>1.41</td>
<td>1.62e-05</td>
<td>2.86e-23</td>
<td>0.0046</td>
</tr>
<tr>
<td>English-Arabic</td>
<td>87424</td>
<td>56410</td>
<td>89028</td>
<td>1.01</td>
<td>1.57</td>
<td>1.23</td>
<td>1.80e-05</td>
<td>0.0</td>
<td>0.0001</td>
</tr>
<tr>
<td>Dutch-English</td>
<td>22747</td>
<td>15412</td>
<td>45151</td>
<td>1.98</td>
<td>2.92</td>
<td>2.36</td>
<td>1.28e-04</td>
<td>7.57e-14</td>
<td>0.2094</td>
</tr>
<tr>
<td>Kurdish-German</td>
<td>10562</td>
<td>6974</td>
<td>10562</td>
<td>1.0</td>
<td>1.65</td>
<td>1.24</td>
<td>1.56e-04</td>
<td>0.0</td>
<td>0.0012</td>
</tr>
<tr>
<td>English-Hindi</td>
<td>22907</td>
<td>49534</td>
<td>55635</td>
<td>2.42</td>
<td>1.22</td>
<td>1.53</td>
<td>1.90e-05</td>
<td>2.09e-20</td>
<td>0.0001</td>
</tr>
<tr>
<td>Japanese-French</td>
<td>13233</td>
<td>17809</td>
<td>27692</td>
<td>2.09</td>
<td>1.54</td>
<td>1.78</td>
<td>1.17e-04</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Breton-French</td>
<td>23109</td>
<td>29141</td>
<td>42730</td>
<td>1.84</td>
<td>1.46</td>
<td>1.63</td>
<td>6.34e-05</td>
<td>6.44e-29</td>
<td>0.0168</td>
</tr>
<tr>
<td>Hungarian-English</td>
<td>139935</td>
<td>89679</td>
<td>254734</td>
<td>1.82</td>
<td>2.84</td>
<td>2.21</td>
<td>2.02e-05</td>
<td>1.54e-78</td>
<td>0.0143</td>
</tr>
<tr>
<td>Icelandic - English</td>
<td>8416</td>
<td>6405</td>
<td>8416</td>
<td>1.0</td>
<td>1.31</td>
<td>1.13</td>
<td>1.56e-04</td>
<td>1.32e-05</td>
<td>0.0344</td>
</tr>
<tr>
<td>Norwegian Nynorsk-Norwegian Bokmål</td>
<td>63509</td>
<td>62103</td>
<td>63509</td>
<td>1.0</td>
<td>1.02</td>
<td>1.01</td>
<td>1.61e-05</td>
<td>7.87e-06</td>
<td>0.9559</td>
</tr>
</tbody>
</table>

$k_U$ and $k_V$, shows a higher number of edges connected to the nodes. Norwegian Nynorsk-Norwegian Bokmål and Dutch-English present the lowest and the highest average degrees respectively. This range of degree is expected as in a lexicon, no entry is left without being matched.

In most of the cases, there is a remarkable difference between the clustering coefficients of $U$ and $V$. $cc_U$ tending to zero suggests the scarcity of entries with common neighbors in $U$. On the other hand, the clustering coefficient in $V$, $cc_V$, indicates a higher number of common neighbors. This metric in particularly interesting as it may be used as a heuristic in link discovery algorithms.

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References

