Cross Comparison of Synonym Graphs in A Multi Linguistic Context

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Abstract—Language is one of the most important aspects of human cognition; it represents the way we think, act and communicate with each other. Each language has its own history, background, and form. A language represents a lot of important cultural aspects of the nation speaking it. Languages differ and so do cultures. In this paper we analyze cultural differences between East and West in a multi-linguistic context from a complex networks point of view. There has been considerable work on the topic of cultural differences by psychologist and sociologist. Also studies on complex networks that make use of WordNet have been done, but until now there is no previous work that uses WordNets from different Eastern and Western languages as complex lexical networks in order to obtain possible differences or similarities between the cultures using those respective languages. Our work aims to do this.

I. INTRODUCTION

Synonyms are a well-known and important part of a language. According to a definition by Leibniz, two concepts are synonymous if the substitution of one for another never changes the truth value of the sentence in which the substitution occurs. But such a pure synonymy either doesn’t exist at all, or is very rare. Instead a weakened version of this definition which considers synonyms as relative to the context in which they are used, applies in general, i.e. two concepts are synonyms in a context if the substitution of one for another does not change the truth value of the context [1].

People may use several words to express a certain concept, i.e. a concept can be represented by these several words known as synonyms. If the set of synonyms of a certain concept is large, we may well say that this concept is important to the people using it. When a synonym for a concept is created, it is not done simply for fun and is not cost free. Generally, people need to create it and when doing this, some cognitive processing is done by the brain. If people need to extend the synonym set of a concept, then this means that this specific concept is widely used and important to them. Since each nation has its own language, culture and way of living, the needs for synonyms of a certain concept may differ from one culture to the other according to the importance given to concepts by those cultures.

Thinking in this way, it could be possible to capture culture differences as well as similarities by examining synonym networks from different languages. Since East and West are considered to be two extremes of culture, it would be interesting and worth studying on different Eastern and Western languages. This was our motivation and aim at the start of our work.

There has been some previous work on the topic of linguistic networks. For example, Ferrer & Sole made use of the British National Corpus in constructing huge word networks in which the words are linked to each other if they are directly neighbors in a sentence [2]. They found that the network were scale free and showed small world properties. Motter constructed synonym networks by using an English thesaurus and found small-world characteristics [3]. Sigman & Cecchi used WordNet to analyze English nouns [4]. They analyzed the network by using the relationships between concepts, such as hyponymy, meronymy, holonymy, antonymy etc. They found that the presence of polysemy dramatically changes the compactness of the network. Steyvers & Tenenbaum made a study on three types of semantic networks: word associations, WordNet, and Roget’s Thesaurus [5]. They showed that these networks have a small-world structure and that the distributions of the number of connections follow power laws.

As far as we are concerned, no prior work has been done in analyzing the synonym graphs of different languages in attempt to find possible culture differences as well as similarities. In this aspect ours is a novice work.

Since the beginning of the work, we aimed at studying on four different languages, two eastern and two western ones, but we had the possibility to work only on English and Turkish, each of them being a representative of West and East respectively. Actually we are planning to extend the work to other languages such as: Italian, Hindi, Arabic and Hebrew, whose electronic resources we have recently obtained. One of the most important issues was the choice of the electronic resource. We decided to make use of WordNet facility whose English and Turkish versions were available to us.

The explanation of WordNet and the reason why we chose it will be given in the following section. The rest of the paper is organized as follows: Section 2 consists of a brief introduction to WordNet, in section 3 we explain how we constructed the synonym graphs, section 4 consists of the graph analysis results, in section 5 we give the drawn conclusions and at the end, the references used.

II. WORDNET

WordNet is an on-line lexical reference system whose design is based on psycholinguistic theories of human lexical
memory. English nouns, verbs, and adjectives are organized into synonym sets each representing one underlying lexical concept. Synonym sets are linked by different relations, such as antonymy, meronomy, hyponymy [1], [6]. Its development began in 1985 at Princeton University under the direction of George A. Miller. Several versions of it have been made available through the years. The most recent version for Windows is 2.1, but we used the version 2.0 for Windows, because that same version of the Turkish WordNet was available to us at the time. The English 2.0 version contains 125207 words and 99143 synonym sets. On the other hand, Turkish WordNet was developed at Sabancı University under the direction of Kemal Oflazer. It is part of the BalkaNet project and the current version contains 15491 words and 14796 synonym sets [7].

At this stage of the work, we were concerned only with synonymy relationship, the one that really characterizes WordNet. WordNet consists of sets of synonymous words called synsets. The words inside a synset are synonyms of each other in a symmetric manner, i.e. if word \(X\) is synonym of word \(Y\), then \(Y\) is synonym of \(X\) as well. A concept (word meaning) can be represented by the words inside its respective synonym set used to express it. For example two meanings of board can be represented unambiguously by these synonym sets: \{board, plank\} and \{board, comittee\}. In addition each synonym set is accompanied by a definition of the underlying concept, an example of its usage in a sentence or expression, the domain to which it belongs, for example the domain of the concept organism is biology. Its lexical and computational features make WordNet an efficient and widely used tool for Natural Language Processing.

III. GRAPH CONSTRUCTION

We made use of WordNet as a lexical resource in order to construct our complex networks in both languages. The resulting networks showed to be scale free, have a small worlds structure and follow power law [13]. First of all, we assigned a unique ID to each word available in WordNet and stored them in the appropriate tables of our database. We treated each word as a vertex (node) of the network and every synonymous relationship between two words as an edge. For example, if there is a synonymous relationship between the words hard and difficult, then there is an edge from hard to difficult as well as from difficult to hard.

Consider a synonym set \(A\) consisting of the words \(a\), \(b\), \(c\), \(d\), then we construct twelve edges representing the symmetric synonymous relationship between every word pair as shown in Figure 1. The number of edges \(E\), resulting from the words in a synonym set could be expressed as:

\[
E = 2 \times \left( \frac{V}{2} \right)
\]

(1)

where \(V\) is the number of words (vertices) of the synonym set. In this way, our graphs are directed, preserving the symmetric synonymous relationship between any two words.

For every pair of synonymous words there are two cases: either corresponding meanings (named as sense in WordNet) of the words are synonymous or non-corresponding ones are. Consider this example taken from the English WordNet: the first sense (meaning) of the word barely is synonymous to the first sense of the word hardly, but the third sense of word cut is synonymous to the fourth sense of the word shortened. We don’t distinguish between corresponding or non corresponding senses of synonymous words when we analyze the networks, i.e. we don’t do any sense filtering during graph analysis at this stage of the work. We keep the information that a certain sense of a certain word is synonymous to a certain sense of another word in the database but we don’t show this specifically in our network. Whenever there is a clique i.e. a fully connected component in the graph, resulting from nodes linked by single edges, then this means that the nodes of this component take place in the same synonym set and share the same concept (word meaning).

Often it is possible to go from one word to another one of a different meaning through a path in the network. Consider the graph in Figure 2 which results from two synonym sets. Let synonym set \(A = \{a, b, c, d\}\) and set \(B = \{a, c, e\}\). In set \(A\) the synonymous relationships with respect to the senses of the words are as follows: the first sense of \(a\), the third sense of \(b\), the second sense of \(c\) and the fourth sense of \(d\) are synonymous to each other. On the other hand, the synonymous relationships with respect to the senses of the words in set \(B\) are: the third sense of \(a\), the first sense of
TABLE I
BASIC NETWORK PROPERTIES

| Property                        | English | Turkish |
|---------------------------------|---------|---------|
| The number of words             | 125207  | 15491   |
| The number of edges             | 271895  | 18047   |
| Diameter                        | 30 (between elating and well timed) | 32 (between çoğalmak and yol katetmek) |
| Average distance among reachable pairs | 23924  | 17807   |

c and the fifth sense of e are synonymous to each other. In Figure 2 set A is represented by the fully connected component (clique) consisting of the nodes a, b, c, d and set B is represented by the clique consisting of the nodes a, c, e. The concepts (word meanings) expressed by these two synonym sets are different but there exist paths from one set to the other for example: d-a-e, c-e-b etc.

IV. ANALYSIS RESULTS

After constructing our complex networks, we began to analyze them on basis of graph theory criteria. We made use of Pajek software for network analysis [8]. First we looked at some basic network properties, which we briefly show by Table I:

![English Degree Distribution](image1.png)

Fig. 3. English Degree Distribution

![English Degree Distribution LOG-LOG](image2.png)

Fig. 4. English Degree Distribution LOG-LOG

We also examined the degree distribution in both networks and constructed the respective normal and log-log graphs. The normal graphs have a hyperbolic shape and the log-log graphs show that the data follows power law. It can be seen that the graphs for English have a clearer shape and display the data behavior better than the graphs for Turkish. This happens because the data in English WordNet is much more abundant than that in Turkish one, but still the graphs for both languages are rather similar to each other in shape and behaviour.

Another criterion on which we investigated the networks was the number of synonyms of the words i.e. their degrees. Table II displays the first twenty words with the largest number of synonyms for both languages. As mentioned, since the beginning of the study our main interest was on the words with large synonym number as it may show that the concepts represented by those words and their synonyms are important to the culture of the nation(s) speaking the language(s) under consideration. Although when asked, the first word(s) to come to mind would generally be nouns, most of the results for English are verbs (although the noun version of most of them exists, verb version is considerably more dominant) as table II shows. The results for Turkish are slightly different, although the number of verbs is large, it still doesn’t exceed that of nouns.

As mentioned, studies on cultural differences between East and West have been widely made since this is an interesting and challenging issue. A distinguished work on this field would be that of Richard E. Nisbett in Michigan University [11], [12]. After one of his brilliant Chinese students claimed that the main difference between them was the fact that he (the student) saw the world as a circle while the professor as a line, the famous professor started a series of studies named as "the nature of thought". During this study a lot of questions
TABLE II
TOP 20 WORDS WITH LARGEST NUMBER OF SYNONYMS

| English Concept | Number of Synonym | Turkish Concept | Number of Synonym |
|-----------------|------------------|-----------------|------------------|
| break           | 98               | düşcstdintek      | 17               |
| pass            | 86               | tutmak          | 20               |
| hold            | 72               | tip             | 17               |
| check           | 72               | yer             | 16               |
| get             | 70               | istemek         | 14               |
| make            | 69               | olmak           | 14               |
| take            | 69               | karşıtmak       | 13               |
| run             | 67               | geçmişmek       | 13               |
| line            | 66               | kafa            | 12               |
| cut             | 66               | acap            | 12               |
| deal            | 64               | çevirmek        | 12               |
| light           | 60               | ayak            | 12               |
| see             | 59               | iş               | 11               |
| set             | 57               | gelişme         | 11               |
| spoil           | 55               | ilgi            | 11               |
| cast            | 55               | destek          | 11               |
| beat            | 54               | hareket         | 10               |
| mark            | 54               | birey           | 10               |
| go              | 54               | yaratmak        | 10               |

raised, among which: "Why do Western children learn nouns more easily than verbs, while the contrary holds for Eastern children, i.e. they learn verbs more easily than nouns?". When we observed the results of Table II, we noticed two things related to the above case: the word line is among the words with the largest synonym number for English and this is an interesting result considering the claim of the Chinese student which in turn motivated Nisbett for his famous work.

Also, the dominant number of verbs with the largest number of synonyms may be an answer to the above question about Western and Eastern children from a different point of view: since the verbs have a lot of synonyms, it would be more difficult for a child to learn and remember them. Of course this is only one explanation to such a wide and complex issue, there may exist more, depending on different points of view. If we observe carefully the table, we could also see some other interesting results for both languages. Consider the English words (verb version): get, take, cut, deal, set, beat, mark, and hold. They may express different characteristics or attributes of Western culture:

set: the dominant meaning of this verb is that of giving a value, attribute, state, quality, cost, etc. to something in attempt to fix and make it distinct from something else. In a way, it shows importance given to objects when providing them with a value of any kind.

mark: the dominant meaning of this verb is that of making something distinct, generally by providing it with a feature that makes it distinguishable from the context or environment it is found. From this point of view, this verb also shows importance given to objects in attempting to make them distinct from the rest.

According to the work on culture and point of view, by Nisbett and Masuda, Westerners tend to give the main importance to objects rather than the environment, field or context while Eastern Asians are inclined to focus on the field, environment or context rather than the objects. We notice that the above explanations of the verbs set and mark support the above result by pointing out the importance given to objects, a characteristic of Westerners [11].

beat: this verb dominantly expresses ambition to succeed, to win, to be superior, one of the main features of capitalism which was born and is best applied in West.

get, take: both of these verbs mainly express the ambition to be in possession of, to obtain, to try to have something, again one of the features of capitalism, i.e. of West.

deal: this verb dominantly expresses the ability to agree on, to succeed in managing or arranging something. This verb has a wide use in the fields of business and politics; two areas in which West leads.

hold: this verb is used to express possession of something, again a well-known feature of West.

Now let us consider the results for Turkish: the first place of the list is occupied by the verb düşcstdintmek, the English correspondent of which is think. This is an interesting result from a cognitive point of view since thinking is closely related to brain, but it also may be interpreted as a tendency of Turkish people (Easterners) towards meditation, a kind of deep thinking. A similarity with the English results would be the presence of tutmak, the English correspondent of which is hold (discussed above). Another one we notice would be that of the presence of the verbs make and yaratmak (create, make, invent) among the results for both languages. Generally Westerners are considered as more innovative, creative and courageous in inventing new things, but the presence of yaratmak may show that this concept is important to Turkish people as well. The words ilgi (interest, involvement) and destek (support) may be interpreted from an emotional point of view as a tendency of Turkish people towards helping, supporting, paying attention to somebody. Other interesting words such as iş (work) and gelişme (progress) may be considered to express will for work and progress of Turkish people, while such features are usually attributed to Western people.

We made use of the online dictionaries in order to give objective definitions and explanations. Online Cambridge Dictionary was used for English [9] and Zargan for Turkish [10].

Another analysis we performed was that of finding the center words of both networks. To achieve this, we analyzed the largest island of the English network (the others are very small compared to it) and the three largest island of the Turkish network whose sizes are closed and comparable to each other. In Table III we show the first five

| English Concept | Average Distance |
|-----------------|------------------|
| get             | 4.84             |
| make            | 4.85             |
| go              | 4.88             |
| take            | 4.91             |
| run             | 4.92             |

TABLE III
CENTER WORDS IN ENGLISH (26095 WORDS IN ISLAND)
center words for each island in both networks. The average distance is calculated by the following formula:

\[ x_j = \frac{\sum_{i=1}^{n} (i \times N(i))}{m} \]

(2)

where \( x_j \) is the average distance for a node \( j \) with respect to all of its neighbours, \( i \) is the the number of hops, \( n \) is the diameter of island, \( N(i) \) is the number of nodes at \( i \)th hop, and \( m \) is the total number of nodes in the island.

As it can be seen from the tables, all of the English center words take place in Table II and this is important for us. Center words are important to a network and the fact that they are among the ones with largest synonym number emphasizes the importance of these words from our point of view also. Now consider the Turkish center words. In the first island (Table IV), we see that center words are verbs. The verb \( \text{olmak} \) which is the most central word of the island appears in Table II as well.

In the second island (Table V), only nouns are present. The word \( \text{iş} \) is also present in Table II. In the third island (Table VI), we can see that the word \( \text{ilgi} \) is also present in Table II.

In Figure 8 and Figure 7, we give the results of another network analysis, graph reduction. We used Pajek to perform this analysis based on the following criteria: for English the words which have more than 48 synonyms and for Turkish the ones that have more than 10 synonyms should survive the graph reduction. The survivor words are the same with those in Table II as it is obviously expected. Also, we can notice that the reduced graph for English preserves in great part the connectivity, while the one for Turkish doesn’t. This happens because of the great difference in network sizes, i.e. English network is huge compared to the Turkish one.

V. CONCLUSIONS

In this work we compared the synonym networks of English, a Western language, and Turkish, an Eastern one in an attempt to find possible cultural differences or similarities between the two extremes, East and West. We made use of a well-known lexical database, WordNet to construct the complex networks for both languages. As expected, these networks are free-scale, obey to Power Law and show small world effects. Previous work on linguistic networks in several aspects has been made, but we took the challenge of comparing Eastern and Western cultures by analyzing the synonym networks of two representative languages. Synonyms are an important part of a language and the need to invent new one(s) for a certain concept may differ from one culture to another, according to the importance given to that concept by those cultures. We simulated the networks on different graph theory criteria such as: degree distribution, finding center words, words with the largest degree (synonym number) and graph reduction. We obtained interesting results for both languages, especially with some English verbs and interesting words in Turkish (see Analysis Results). Most of these interesting words were found to be center words a well, emphasizing in this way their importance from both
the network and our point of view. Cultural differences is a well-known and wide topic on which several work from psychologists and sociologists has been done; we approached this matter by a different and new point of view. As future work, we plan to extend our study to four other languages: Italian, Hindi, Arabic and Hebrew, the WordNet license of which we have recently obtained. In this way, the comparison would be done from a wider and more consistent perspective. We also plan to add meaning filtering to the network analysis and to include also the various relationships between synonym sets in WordNets, such as hyponymy, meronomy, antonomy, etc. in the networks.

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