Classification of Semantic Similarity Technique between Word Pairs using Word Net

Atul Gupta, Krishan Kumar Goyal

Abstract: ***The concept of relevancy is a most blazing topic in information regaining process. In the last few years there is a drastically increase the digital data so there is a need to increase the accuracy of information regaining process .Semantic Similarity measure the similarity between word-pair by using WordNet as ontology.We have analyzed the different category of semantic similarity algorithm to compute semantic closeness between word-pair and evaluate its value by using WordNet.We have compared various algorithms on Miller- Charles data set of 30 word-pair is used to rank them category wise.***

Keywords**:** ***Semantic similarity, Semantic closeness, Word Net, Least common subsumer***

I. INTRODUCTION

We have a lots of difficulty on computing Semantic Similarity between a String of characters means a pair of words , a Similarity between two words(word1 and word2) or similarity between two sentences is a big problem in the Area of artificial intelligence,machine learning and natural language processing.

Variety of applications of Semantic similarity such as information retrieving from search engine, bio-medical sciences and other internet Application are available. The basic purpose to compute similarity between words and pair of sentences is always possible for a fixed domain , either from medical science domain e.g gene prioritization[1], Artificial intelligence ,machine learning ,Geo –Informatics,computational linguistics and NLP(Natural Language Processing).For Semantic similarity we used lexical database ,in lexical database words are connected for ex, Delhi →City→Capital→India.

All the above mentioned applications are very much depends on the domain so it require various different algorithm to calculate the semantic closeness between two words (word1 and word2) so that similarity score is high.Lexical database play a major role to compute the semantic closeness between words,words are arranged in hierarchical form.

Various Algorithms have been developed previously where Word-Net is used as lexical database or corpus,Word-Net was developed by Princeton University by psychology professor George A.Miller[2] in 1985.It groups English words into sets of synonyms called synsets.WordNet contains 1,55,327 words organized in 175979 synsets and total 207016 word-pair in compressed form.It includes a lexographic category of noun,verb,adjective and adverb but

ignores preposition,determiners and other functional words. There are various type of semantic relationship word-net have synonyms of word,antonyms of words,hyponymy of words and meronymy of words

Table 1: Types of semantic relationship inWord-Net (Corpus)

Semantic Relationship	Category	Words
Synonyms (similar words)	1. Noun 2. Verb, 3. Adjective 4. Adverb	word1=car and word2=vehicle word1=rise and word2=ascend word1=sad and word=unhappy word1=rapidly and word2=speedily
Antonyms (opposite words)	1. Verb 2. Noun 3. Adjective 4. Adverb	word1=rise and word2=fall word1=top and word2=bottom word1=wet and word2=dry word1=slowly and word2=rapidly
Hyponyms	Noun	Word1=plant and word2= tree
Meronyms (part of)	Noun	Word1=ship and word2=fleet

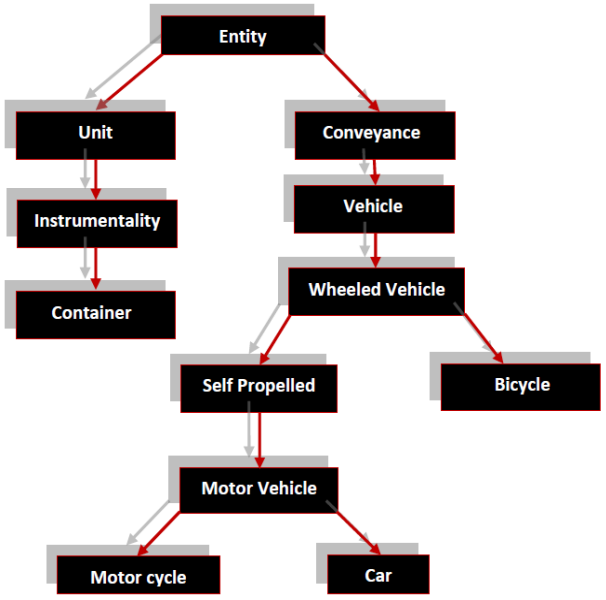

Fig 1. A Hierarchal structure of Word-Net
(IS-A relationship)

Previously related works are classified in various categories :

- Co-occurrence words method
- A lexical database similarity method
- Web search engine based method

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Co-occurrence of Word method used in Information retrieval(IR) systems[2].This method has a list of words each list of word have meaningful words, and query is considered as one document .

A vector is created for each query. The relevant document was fetched based on vector created for each query and vector created for document .The major drawback of this method the word ordering of the query/sentence is completely ignored, the context of the sentence is completely ignored for example if there is a word book, book may be the collection of pages or book might be reservation of seat ,so context of the sentence plays vital role .This method have following advantages :they matches document regardless of the size. It extracts important words from the document.

On using lexical database ,we compute similarity by predefined word hierarchy and relationship between words is determined by tree like structure[3].On comparing two words it take care of path between words and depth of the subsumer in the hierarchy.It also uses a word corpus to calculate the Information content of the word. While computing the similarity the subsumer pointing on the relative root node on comparison of two words. This method have some limitations: The nearest word meaning is not considered on calculating similarity while on calculating the similarity it take the best matching paired if the meaning of the word is totally different. Information content approaches differ from corpus to corpus that's means final result is different for every corpus.

Web search engine based method not essentially find the similarity between words as words having antonym that means opposite meaning most of the times occurs in same web pages hence it will influence the final similarity index results.Google similarity distance [4] uses this methodology.But this method doesn't consider the context of two words.

II. DEFINATION OF SIMILARITY

Semantic similarity measure include relationship between two words ($word1\ and\ word2$) , it only include *IS-A* relationship between two words.for e.g. bus is similar to an automobile,but bus is also similar to driver and road , but similarity value of bus-driver and bus-road is less than bus-automobile in a **IS-A** relationship on WordNet ontology.

Our instinctual about the similarity:

Instinctual 1: Similarity between $word1$ and $word2$ is depends on the commonness between $word1$ and $word2$ .The more the commonness between $word1$ and $word2$ so that more is the similarity.

Instinctual 2: Similarity between word1 and word2 is depends on the differentiation between word1 and word2.The more the differentiation between word1 and word2 so that less is the similarity.

Instinctual 3: The similarity between word1 and word2 is maximum if the two words are same, no matter what commonness they will share.

On finding the similarity between words our instinctual approach finds the commonness between words.There are various presumption of commonness

Presumption1: The commonness between word1 and word2 is find by

$$I\big(common(word1, word2)\big)$$

Where $common(word1, word2)$ is proposition that denote commonness between $word1$ and $word2$ where $I(x)$ contained the amount of Information in proposition x.For e.g. if word1 is mango and word2 is an papaya.The proposition find the commonness between word1 and $word2$ was " $fruit(word1)$ and $fruit(word2)$ " . *Cover and Thomas, 1991[5]* in information theory find the commonness between $word1$ and $word2$ is calculated by negative of logarithms of probability of words.

$$I\big(common(word1, word2)\big) = -\log P\big(fruit(word1) and\ fruit(word2)\big)$$

There is need to calculate differentiation between two words. If we know the commonness and differentiation between two words then its easy to say what word1 and word2 are, now we suppose:

Presumption 2: The differentiation between $word1$ and $word2$ is calculated by

$$I\big(description(word1, word2)\big) - I\big(common(word1, word2)\big)$$

Where $description(word1, word2)$ denotes the meaning of $word1$ and $word2$ .Instinctual 1 and 2 denotes similarity between words is depends on commonness and differentiation between words and that is one of the factor while calculating similarity.

III. OVERVIEW OF DIFFERENT METHOD AND TECHNIQUE USED TO COMPUTE SEMANTIC SIMILARITY MEASURE

On computing semantic similarity between two words/concepts(word1 and word2) we used word net as an ontology of English language which was developed by professor G.A Miller [2] and maintained by congnitive science laboratory at Princeton university. WordNet contain three databases one for noun,second for verb,and third for adjective and adverb.Strings of character that means words or say concepts was organized in the form of synsets(synonyms of words /concepts). The paper focused on a is-a relationship in noun concepts using WordNet as an ontology for semantic relevancy.WordNet contain several noun hierarchies path between word1 and word2 may not exits so there is root which subsumes all the noun hierarchy in the WordNet.

A large volume of literature is present to compute similarity in the field of semantic relevancy.we classified all the basic approaches into four major categories (a)The category based on Distance (b)The categories based on information content(c)The categories based on Features

A. Category Based on Distance

In this category we focused the distance between two words in the WordNet ontology.Here *Edge Counting* based methodology is used to compute the similarity between two words (word1 and word2).edge counting based semantic relevancy is based on the length of path between two words on the WordNet ontology to compute the semantic relevancy between two words.

Key characterstics of Distance based

a. It is one of the simplest techniques.It measure value which is based on path.

b. The similarity score measure by path length is not in normalized form the value is in discrete form.

c. The approach is based on data which is tagged and edges in the graph contain no wights.

Leacock-chodorow similarity measure: Leacock and chodorow[7] approach is based on the shortest path length between two noun in an IS-A relationship in WordNet ontology.Basically the shortest path is that in which there is lesser number of intermediate nodes.The value was scaled by depth D where depth is measured as length of longest distance from leaf node to root node of the word net hierarchy.The similarity relevance is defined as follows:

$$Sim(word1, word2) = -log[min(length(word1, word2))/(2 * D))]$$

Where min(length(word1,word2)) is the length of shortest path between two concepts where D is the maximum depth in the WordNet ontology.The approach focus on nodes rather than links.So Synet(synonym of words)are only one unit distance apart each other.

Key characteristics of Leacock and Chodorow

a. The Approach is very simple which is based by counting the number of edges between two words word1 and word2.
b. The Approach work on data which is tagged and depends on the quality of graph.
c. The cost is uniform and no cost is specified in the graph between two edges(on connection of two words).

Similarity based on Shortest path Measure: Shortest path measure[8] based similarity works on how close the similarity between two words.

$$Sim = 2 * M - L$$

Where M means the maximum path distance between two words in the WordNet ontology and L means the no of **IS-A** link between two words.This method also work on HAS-A link between two words.

Wu an Palmer similarity measure[9]: This method is also based on path length,method find the most specific common predecessor of two words in the IS-A relationship in WordNet ontology. The method work on the concept of intersection which is the most specific the two word have common that we called *LCS (Lowest Common Subsumer)*.The method work good in the verb ontology basically method work well in all part of speech where the words are arranged in hierarchical form.

$$Sim(word1, word2) = 2 * X3/X1 + X2 + 2 * X3$$

Where X_1 and X_2 is the number of *IS-A* node from word1 and word2 to most specific common parents and X_3 means the distance from the word to the root node in WordNet hierarchy.

Depth means the distance from the word to the root node in the WordNet hierarchy. Length is the number of node between two words.

In Fig2 word net fragment if we calculate the semantic relevance between word coast and word hill .The most common subsume of coast and hill is geologic formation value of X_3 is equal to 3 and value of X_1 is equal to 2 and X_2 is equal to2 so semantic relevance between word is calculated by:

$$Sim(coast, hill) = 2 * 3/2 + 2 + 2 * 3 = .60$$

Key characteristics ofWu an Palmer

a. The Approach is based on path length and depth of the word in the hierarchy of the WordNet.
b. It also work on least common subsumer so that *LCS* of two words(most specific common subsumer) of two words word1 and word2 in a directed Acyclic graph that both the words word1 and word2 are descedents.
c. The similarity score between two words word1 and word2 never becomes to 0.

B. Category based on Information content Similarity

Resnik Similarity Measure: Resnik[10] similarity measure works that semantic similarity calculation between two words is based on how much common information the word1 and word2 shared in between.If the common Information shared in between word1 and word2 is more, then there similarity value is high.The common information in between words word1 and word2 is calculated by most specific common subsumer of two words (concepts) in the WordNet ontology.

$$SimRESNIK = IC(lcs(word1, word2)$$

Information content of the word is compute by count the frequency of the word in the WordNet ontology and it is find by probability of occurrence an instance of that word.

$$IC = -log(p(c))$$

Key characteristics of Resnik's similarity

a. This method is based on Information content.The Information content is based on counting the frequency of occurrence of concepts/words on the Available corpus(WordNet).
b. This method can only be used on noun and verb part of speech in the WordNet ontology .The reason for using only these two part of speech because these part of speech are organized in the hierarchical manner.
c. The value of Resnik's similarity measure will always be greater than or equal to 0.
d. The Resnik similarity measure approach is also based on depth in the hierarchy of ontology.
e. The information content based approach give better result than path based approach.

Jiang and Conrath similarity measure

Jiang and Conrath[11] similarity works that semantic similarity between two words is based on Information content of most specific common subsumer ot two WordNet along with semantic distance between two words.

$$Distance_{jiang\ \&\ conrath} = IC(word1) + IC(word2) - 2 * IC(lcs(word1, word2))$$

$$Sim_{Jiang\ \&\ conrath} = 1/distance\ jiang\ \&\ conrath(word1, word2)$$

Where $Distance_{jiang\ \&\ conrath}$ calculate the dissimilarity between $word1$ and $word2$ .High value indicate lower similarity between $word1$ and $word2$ and low value indicate higher similarity between $word1$and $word2$.

Key characterstics of Jiang and Conrath similarity

a. Jiang & Conrath similarity measure is also based on Resnik based approach.
b.
c.
d.

e. The Sim_{JCn} score is based on commonness between words(word1 and word2) and the Information content of words(word1 and word2) which describe them completely.
f. There is need to handle the JCn value equal to zero scenario.
g. This is also refined version of path-based methodlogy which uses the concept of depth to calculate similarity.

Lin similarity measure

Lin[12] similarity measure works that semantic similarity between two words is based on how much the words (word1 and word2) share in common to the total amount of information contains by word1 and word2.It uses the concept of commonness of information between word1 and word2 and the information described by two words completely.

$$Sim_{Lin} = 2 * IC(lcs(word1, word2))/IC(word1) + IC(word2)$$

Key characterstics of Lin similarity

a. The Approach is based on commonness of Information between two words(word1 and word2) and the Information content of word1 and word2 describe the word completely.
b. This is refined version of path-based methods which uses Normalization and depth in the hierarchy of WordNet.
c. It depends on the structure of corpus(WordNet).
d. This methodology is better than various path based methodologies.

Commonness of the words is calculated by information content of most specific common ancestor of word1 and word2 and the total information content of word1 and word2.Lin calculated the value between 0 and 1 . 0 means two words (word1 and word2) are out of context and 1 means both the words (word1 and word2) are same that means word is compared by itself.

In the above WordNet fragment e if we calculate the semantic relevance between words, one of the word is coast and other word is hill.So semantic relevance between two words is calculated by the formula:

$$Similarity(word1, word2) = 2 * \log P\left(\frac{lcs(word1, word2)}{\log P(word1) + \log P(word2)}\right)$$

$$Similarity(coast, hill) = 2 * \frac{\log P(Geologic\ formation)}{\log P(coast) + \log P(hill)}$$

The value of the similarity is approximately equal to 0.592.

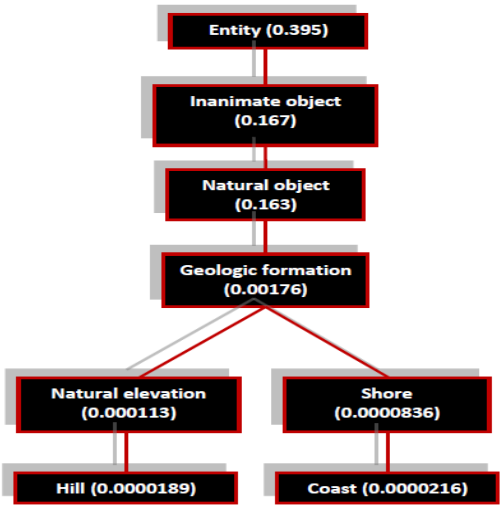

Fig 2. A small fragment of (Corpus WordNet)

C. Category based on Features

Tversky's similarity measure: Tversky's[13] semantic relevancy calculate the similarity between two words(word1 and word2) .It uses the complete description of the words to whom we measure the similarity so that each word have some features which are common to words and some features which are unique .If the word1 and word2 have common features that means similarity is increased but if the word have some unique feature that means similarity is decreased. Similarity between two words (word1 and word2) depends upon common feature of two words, the features which is present in word1 but not in word2 and the features which is present in word2 but not word1.

$$Sim_{Tvr's} = a.G(x(word1) \cap x(word2)) - b.G\left(\frac{x(word1)}{x(word2)}\right) - c.G\left(\frac{x(word1)}{x(word2)}\right)$$

Where,

$x(word1)/x(word2)$ features present in word1 but not word2, $x(word1)/x(word2)$ features present in word2 but not word1, $x(word1) \cap x(word2)$ features common in both the words.

Piarro(P&S) similarity measure: Piarro semantic similarity algorithm is based on Tversky's similarity algorithm.It explore the tversky's methodology into the information content domain.Here function G(x(word1)intersection x(word2)) is same as $IC(lcs(word1, word2))$, $x(word1)/x(word2)$ is same as $IC(word1) - IC(lcs(word1, word2))$ and $x(word2)/x(word1)$ is same as $IC(word2) - IC(lcs(word1, word2))$.

$$Sim_{\text{Piarro}} = \begin{cases} 3 * \text{IC}(\text{lcs}(\text{word1}, \text{word2})) - \text{IC}(\text{word1}) - \text{IC}(\text{word2}) & \text{if (word1! = word2)} \\ 1 & \text{if (word1 = word2)} \end{cases}$$

$lcs(word1, word2)$ is the longest common subsumer between word1 and word2 and $IC(lcs(word1, word2))$ denotes the information content value of that subsume but the value is depends on the corpus used. $IC(word1)$ is the information content value of word1 and $IC(word2)$ is the information content value of $word2$.

IV. COMPARISON BETWEEN DIFFERENT SEMANTIC SIMILARITY MEASURE TECHNIQUES

On Comparing the five techniques in Table-1 Leacock-chodorow and Wu an Palmer(distance based), Resnik's , Lin and Jiang and Conrath (Information content based) we find that semantic similarity or semantic closeness is based on synonymy of the words. Rubenstein& Goodenough[15] calculate semantic judgment on the 51 human based subjects from 65 word pair.The word pair rating from (0.0 to 4.0) that means highly related to semantic unrelated words.Miller & Charles[2] select 30 word pair from 65 word pair of Rubenstein& Goodenough[15] ,Miller rate 10 word pair into the high level of similarity (3.0 to 4.0), 10 word pair into intermediate level(1.0 to 3.0) and 10 word pair into the low level of similarity(0.0 to 1.0).We have take Miller and Charles data set of 30 word-pair to compute semantic similarity.

Table-1: Ratingof Various Semantic Similarity Techniques

Sl. No	Word-Pair	Human Judgement	Leacock & Chodorow (distance based)	Wu and Palmer (distance based)	Resnik (Information content based)	Lin (Information content based)	Jiang and Conrath (Information content based)
1.	Word1=*Car*,Word2=*Automobile*	3.921	3.580	1.0	0.67	1.0	1.0
3.	Word1=*journey*, Word2=*voyage*	3.842	2.892	0.92	0.65	0.84	0.87
4.	Word1=*boy*, Word2=*lad*	3.761	2.892	0.93	0.76	0.86	0.88
5.	Word1=*coast*, Word2=*shore*	3.710	2.892	0.92	0.77	0.98	0.98
6.	Word1=*asylum*, Word2=*madhouse*	3.610	2.890	0.94	0.93	0.96	0.96
7.	Word1=*magician*, Word2=*wizard*	3.521	3.580	1.0	0.79	1.0	1.0
8.	Word1=*midday*, Word2=*noon*	3.420	3.510	1.0	1.0	1.0	1.0
9.	Word1=furnace, Word2=stove	3.110	1.510	0.46	0.18	0.22	0.38
10.	Word1=*food*, Word2=*fruit*	3.080	1.510	0.22	0.05	0.12	0.62
11.	Word1=*bird*, Word2=*cock*	3.050	2.820	0.94	0.40	0.59	0.73
12.	Word1=*bird*, Word2=*crane*	2.970	2.191	0.84	0.40	0.59	0.73
13.	Word1=*tool*, Word2=*implement*	2.950	2.891	0.90	0.41	0.92	0.96
14.	Word1=*brother*, Word2=*monk*	2.821	2.810	0.94	0.82	0.90	0.91
15.	Word1=*brother*, Word2=*lad*	1.660	1.971	0.71	0.18	0.20	0.27
16.	Word1=*crane*, Word2=*implement*	1.680	1.971	0.66	0.23	0.36	0.59
17.	Word1=*journey*, Word2=*car*	1.160	0.870	0.0	0.0	0.0	0.33
18.	Word1=*monk*, Word2=*oracle*	1.110	1.510	0.58	0.18	0.21	0.34
19.	Word1=*cementry*,Word2=*woodland*	0.950	1.280	0.18	0.05	0.06	0.19
20.	Word1=*food*, Word2=*rooster*	0.891	0.940	0.13	0.05	0.08	0.40
21.	Word1=*coast*, Word2=*hill*	0.870	1.971	0.66	0.49	0.63	0.71
22.	Word1=*forest*, Word2=*graveyard*	0.840	1.281	0.18	0.05	0.06	0.19
23.	Word1=*shore*, Word2=*woodland*	0.630	1.791	0.44	0.08	0.10	0.30
24.	Word1=*monk*, Word2=*slave*	0.550	1.971	0.71	0.18	0.23	0.38
25.	Word1=*coast*, Word2=*forest*	0.421	1.630	0.40	0.08	0.10	0.28
26.	Word1=*lad*, Word2=*wizard*	0.420	1.970	0.71	0.18	0.21	0.31
27.	Word1=*cord*, Word2=*smile*	0.130	1.011	0.14	0.17	0.18	0.20
28.	Word1=*glass*, Word2=*magician*	0.110	1.28	0.30	0.08	0.10	0.3
29.	Word1=*rooster*, Word2=*voyage*	0.081	0.582	0.0	0.0	0.0	0.07
30.	Word1=*noon*, Word2=*string*	0.081	1.090	0.0	0.0	0.0	0.17

V. RESULT ANDDISCUSSION

After implemented of various distance based approaches and Information based approaches, Information content approach (JCn) is better than all the approaches.

Table-2: Correlation of Semantic Similarity Techniques

Semantic Similarity Measure Techniques	*Correlation of the similarities*
Human Judgement	1.000
Leacock & Chodorow (distance based)	0.828
Wu and Palmer (distance based)	0.763
Resnik (Information content based)	0.803
Lin (Information content based)	0.844
Jiang and Conrath (Information content based)	0.890

From Table-2 it was observed that the correlation of JCn is better than distance based as well as rest of information content based approaches.JCn approach is based onResnik's approach. The Sim_{JCn} score is based on commonness between words ($word1\ and\ word2$) and the Information content of words($word1\ and\ word2$) which describe them completely.The correlation of JCn after testing on Miller and Charles data set of 30 word pair is 0.890.

VI. CONCLUSION

Similarity is one of the important and neededconcepts in the area of genes prioritization,artificial intelligence and machine learning.Semantic similarity between word-pair($word1\ and\ word2$) is determined by various

distance based approach, Information content approach and feature based approach by using ontology of particular domain.Basically all the works done in the past calculate semantic similarity in noun *IS-A* relationship using WordNet as ontology.Our future work to develop the algorithm which consider the depth factor, semantic similarity increase as we go down in WordNet hierarchy and decrease as we go up in the WordNet hierarchy.

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