Incorporating WordNet in an Information Retrieval System

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Agenda

- Introduction
- Query Expansion
- WordNet
- Part-of-Speech Tagging
- Similarity Ranking Functions
- Experiments and Conclusions
- Demo

Introduction

- Project Goal
  - Implement query expansion in Yioop
  - Extend query rewriting mechanism in Yioop to use Wordnet
  - Implement Part-Of-Speech tagging
  - Implement a Similarity Ranking Function
  - Rewrite a result reordering algorithm to use WordNet Scores

Query Expansion

- Reformulating a seed query to improve retrieval performance in information retrieval operations[4]
- Different ways:
  - Finding synonyms of words Using WordNet
  - Techniques like spelling correction
  - Re-weighting the terms in the original query
- You would want a search for *computer,* then by query expansion we get
  - *Computing device*
  - *Information processing system*
  - *Data processor*

Manning, C. D., Raghavan, P., & Schütze, H. (2008). Introduction to information retrieval. *New York: Cambridge University Press.*

WordNet

- Founder – Dr. George A Miller, Princeton University[1]
- Awarded the Antonio Zampolli Prize
- A Large Lexical Database for English or an “Electronic Dictionary”
- Covers English Verbs, Nouns, Adverbs, Adjectives
- Used in Many Information Retrieval Systems
- Useful tool for Computational linguistic and natural language processing
- Applications
  - Produce a combination of dictionary and thesaurus
  - Support automatic text analysis and artificial intelligence applications

Princeton University "About WordNet." WordNet. Princeton University. 2010. <http://wordnet.princeton.edu>

WordNet

- Similar Applications
  - WordWeb, Artha, Moby thesaurus, openthesaurus etc.
- Large Database of English[1]

Part of speech	Unique String	Synset	Total Word-Sense pair
Noun	117798	82115	146312
Verb	11529	13767	25047
Adjective	21479	18156	30002
Adverb	4481	3621	5580
Total	155287	117659	206941

WordNet Database

- Database Information

Type of word	Files
Adjective	data.adj , index.adj
Adverb	data.adv , index.adv
Noun	data.noun , index.noun
Verb	data.verb , index.verb

- Exceptions
  - noun.exec
  - verb.exec
  - adj.exec
  - adv.exec

Data.verb

- *00048819 29 v 01 habit 0 002 @ 00047662 v 0000 + 03479089 n 0101 01 + 09 00 | put a habit on*
  - *synset_offset* - Current byte offset in the file (8 digit)
  - *lex_filenum – (2 digit)* lexicographer file name containing the synset
  - *ss_type – n,v,a,r*
  - *w_cnt – number of words in synset (2 digit HEX)*
  - *word – Actual search word*
  - *Lex_id – a hexadecimal digit appended to lexicographic file*
  - *P_cnt – count of pointers*
    - *Pointer_symbol – define a relationship with other words*
    - *Synset_offset*
    - *Part of speech*
    - *First 2 HEX digits for source and next 2 digits for target*
  - gloss – represented as vertical bar followed by text string. May contain 1 or more examples

Index.verb and noun.exec

- *body v 1 2 @ 1 0 02672913*
  - *lemma – lower case ASCII text of the word*
  - *pos – n v a r (part of speech)*
  - *synset_cnt – number of synsets that lemma is in*
  - *p_cnt – number of pointers*
  - *Pointer_symbol - @ for hypernym, ! For antonyms, etc. otherwise p_cnt is 0*
  - *Sense_count – number of senses*
  - *Tagsense-count – number of tags*
  - *Synset_offset – 8 digit offet used in data.pos*
- *corpora corpus*
  - *Irregular word*
  - *Base form of word*

Output of WordNet

- Input word - *fly*

The noun fly has 5 senses (first 4 from tagged texts)

1. (6) **fly** -- (two-winged insects characterized by active flight)
2. (1) tent-fly, rainfly, fly sheet, **fly**, tent flap -- (flap consisting of a piece of canvas that can be drawn back to provide entrance to a tent)
3. (1) **fly**, fly front -- (an opening in a garment that is closed by a zipper or by buttons concealed under a fold of cloth)
4. (1) **fly**, fly ball -- ((baseball) a hit that flies up in the air)
5. **fly** -- (fisherman's lure consisting of a fishhook decorated to look like an insect)

The verb fly has 14 senses (first 9 from tagged texts)

1. (33) **fly**, wing -- (travel through the air; be airborne; "Man cannot fly")
2. (9) **fly** -- (move quickly or suddenly; "He flew about the place")
3. (5) **fly**, aviate, pilot -- (fly a plane)
4. (3) **fly** -- (transport by aeroplane; "We fly flowers from the Caribbean to North America")
5. (2) **fly** -- (cause to fly or float; "fly a kite")
6. (2) **fly** -- (be dispersed or disseminated; "Rumors and accusations are flying")
7. (2) **fly** -- (change quickly from one emotional state to another; "fly into a rage")

Output From Command Line

- Input word – *fly (wn <search_word> -over)*

```
Overview of noun fly

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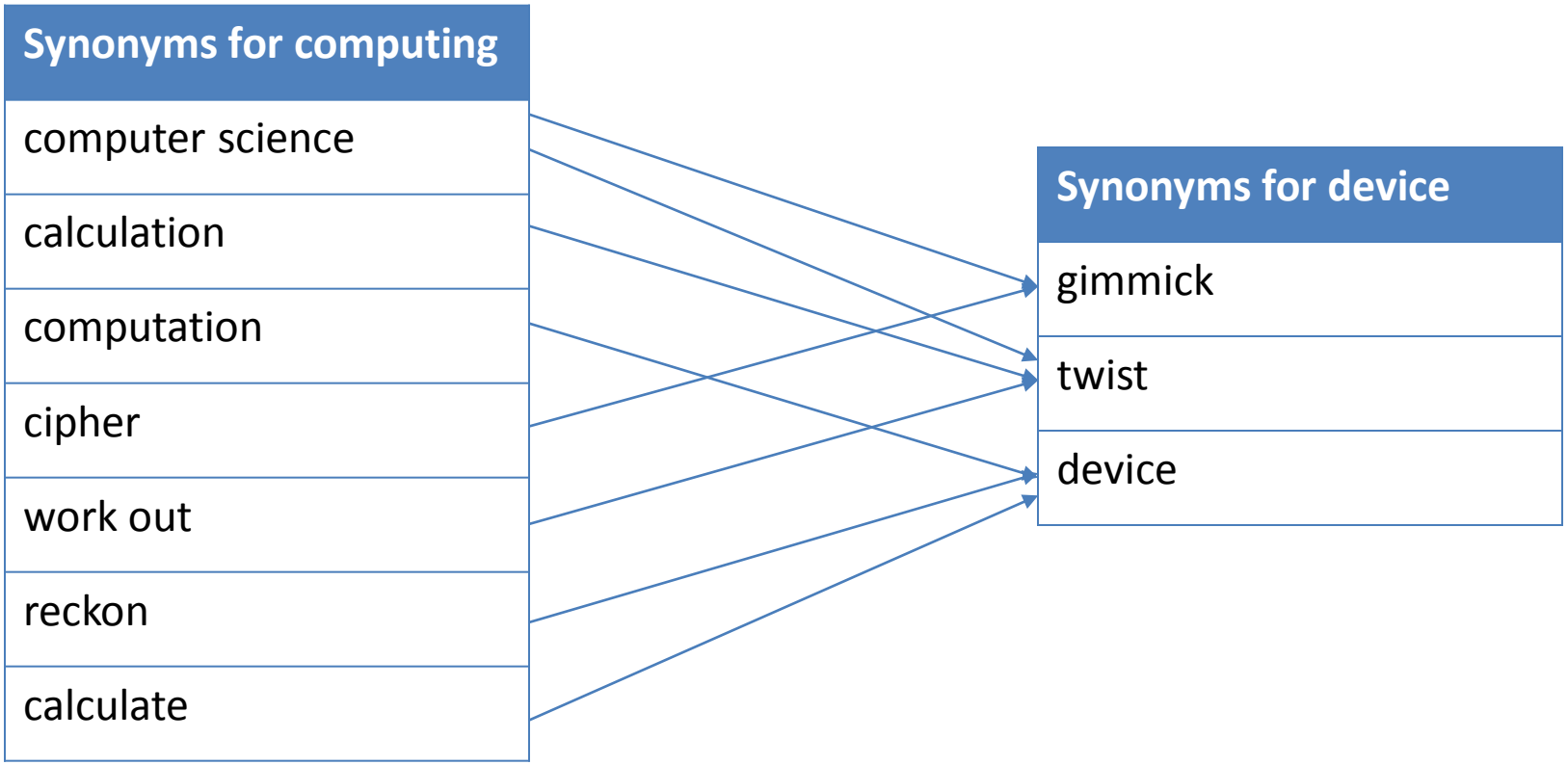
Query Expansion Example

- Consider an input query- computing device



Query Expansion Example

- Total possible combinations for *computing device – 21*

Combinations for computing device			
computer science gimmick	computer science twist	computer science device	calculation gimmick
calculation twist	calculation device	computation gimmick	computation twist
computation device	cipher gimmick	cipher twist	cipher device
work out gimmick	work out twist	work out device	reckon gimmick
reckon twist	reckon device	calculate gimmick	calculate twist
calculate device			

Part Of Speech Tagging

- Process of marking up or tagging a word based on definition and context
- Also called as POS tagging / POST
- Decided by its relationship with adjacent word
- Two approaches
  - Rule based
  - stochastic

Part-of-speech tagging. (n.d.). Wikipedia. Retrieved December10, 2013, from http://en.wikipedia.org/wiki/Part-of-speech_tagging

Part-of-Speech Tagging continued..

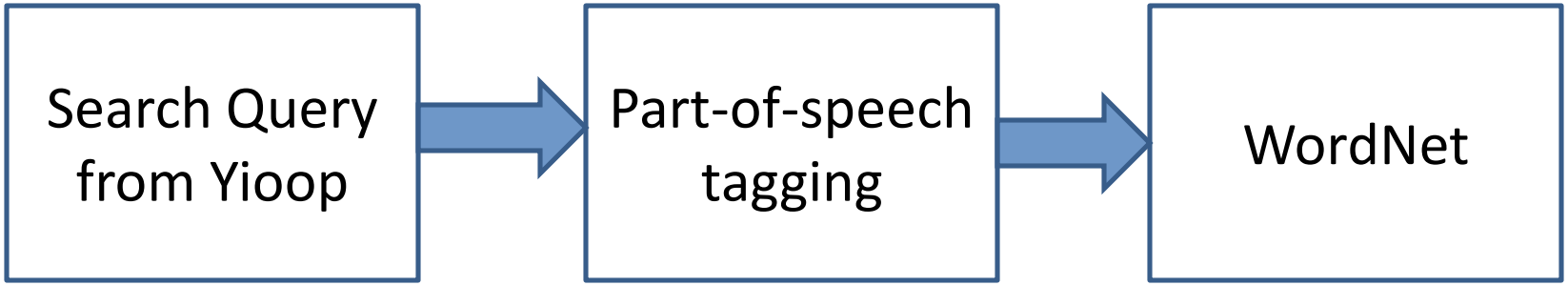
- Rule based POST is Oldest approach
- Use of Hand Written Rules and Dictionary
- Difficult to automate the process
- Easy way to use corpus containing manual tagging and linguistic rules
- Bigger lexicon, more processing time

Part-of-Speech Tagging continued..

- Word ends with ‘ed’ is past participate, ‘ly’ is adverb
- Use of Brill tagger
- Common Tags are
  - NN - Singular or mass Noun
  - NNS - Plural Noun
  - JJ – Adjective
  - IN- Preposition
- Use of Linguistic feature of word
  - *We~NN systematically~AV analyze~NN the~DT performance~NN of~IN these~DT techniques~NN versus~IN existing~VB search~NN results~NN*

Implementation of Part-Of-Speech-Tagger for WordNet

- Placed between Yioop and WordNet Layer



- Experimented Part-of-Speech Tagging
  - During Crawl Time
  - During Query Time

Part Of Speech Tagging

- Consider input – running dog
- After Part-Of-Speech Tagging
  - running~VB dog~NN
- Get WordNet Result for word *running*
  - Noun has 5 senses
  - Verb has 41 senses
  - Adjective has 7 senses
- Total we have 52 senses

Part Of Speech Tagging

- For running, VB is part-of-speech.
- Get verb senses from WordNet search result

The verb run has 41 senses (first 29 from tagged texts)

1. (106) **run** -- (move fast by using one's feet, with one foot off the ground at any given time; "Don't run--you'll be out of breath"; "The children ran to the store")
2. (38) scat, **run**, scarper, turn tail, lam, run away, hightail it, bunk, head for the hills, take to the woods, escape, fly the coop, break away -- (flee; take to one's heels; cut and run; "If you see this man, run!"; "The burglars escaped before the police showed up")
3. (21) **run**, go, pass, lead, extend -- (stretch out over a distance, space, time, or scope; run or extend between two points or beyond a certain point; "Service runs all the way to Cranbury"; "His knowledge doesn't go very far"; "My memory extends back to my fourth year of life"; "The facts extend beyond a consideration of her personal assets")
4. (20) operate, **run** -- (direct or control; projects, businesses, etc.; "She is running a relief operation in the Sudan")

- Out of 52, we will work on 41 senses
- Improved Processing, execution Speed

How to Extract Similar Words?

- We have Similar words, exact meaning and usage of similar words in sentence

  (106) run -- (move fast by using one's feet, with one foot off the ground at any given time; "*Don't run you'll be out of breath*"; "*The children ran to the store*")
- Use of Similarity Ranking Functions
- Methods to find similarity between two sentences
- We used Cosine Similarity Ranking, Intersection Ranking, Okapi BM25 ranking

Cosine Similarity Ranking

- Measure of Similarity between two vectors of an inner space product
- Independent of magnitude of vectors
- Should be in positive space
- Term Frequency (TF)

$$TF = \log(f_{t,d}) + 1 \quad if\ f_{t,d} > 0\ \&\ 0\ otherwise$$

- IDF (Inverse Document Frequency)

$$IDF = \log\left(\frac{N}{N_t}\right)$$

Büttcher, S., Clarke, C. L., & Cormack, G. V. (2010). Information retrieval: implementing and evaluating search engines. Cambridge, Mass.: MIT Press

Cosine Similarity Ranking

- Given two $|V|$ dimensional vectors as *x* , for query and *y* for document
  - $\vec{x} = (x_1, x_2, x_3, x_4, \dots\dots, x_{|v|})$
  - $\vec{y} = (y_1, y_2, y_3, y_4, \dots\dots, y_{|v|})$
- Dot product of x and y is given as

$$\vec{x}.\vec{y} = \sum_{i-1}^{|v|} x_i.y_i$$

Cosine Similarity Ranking

- Geometric meaning is

$$\vec{x}.\,\vec{y} = |\vec{x}||\vec{y}|\cos\theta$$

- The length of the vector $|\vec{v}| = \sqrt{\sum_{i=1}^{|V|} v_i^2}$
- To calculate the angle

$$\cos\theta = \frac{\sum_{\mathrm{i}-1}^{\mathrm{V}} \mathrm{x_i} \cdot \mathrm{y_i}}{\sqrt{\sum_{i=1}^{|V|} x^2}\sqrt{\sum_{i=1}^{|V|} y^2}}$$

- Two vectors are collinear if $\theta = 0°, \cos\theta = 1$
- Two vectors are orthogonal if $\theta = 90°, \cos\theta = 0$

Cosine Similarity Ranking

- Consider a query vector $\overrightarrow{q}$ and document vector $\overrightarrow{d}$, then the similarity is defined as the cosine of the angle between them

$$sim(\overrightarrow{d}, \overrightarrow{q}) = \frac{\overrightarrow{d}}{|\overrightarrow{d}|} \cdot \frac{\overrightarrow{q}}{|\overrightarrow{q}|}$$

Intersection Ranking

- Split both sentences into array of words known as *tokens*
- Get common tokens between two sentences
- Intersection Ranking computed as follows:

$$f(s_1, s_2) = \frac{|\{w|w\ in\ s_1 \& w\ in\ s_2\}|}{(|s_1| + |s_2|)/2}$$

$|s_1|\ and\ |s_2|\ is\ the\ length\ of\ documents\ s_1\ and\ s_2\ respectively$

Index Manager in Yioop

- Contains inverted index
- Provides mapping between terms and their locations
- Two main components
  - Dictionary – terms in the vocabulary
  - Posting list – position of term in collection
- Example:
  - Device -> (1,2207), (20,4678), …… , (22,127838)
  - Engineering -> (2,36374), (9,667778)

Counts from Index Manager

Expanded Query	Count
Computer science device	43
Cipher device	32
Work out device	30
Computational device	10
.	.
.	.
.	.

Okapi BM25

- Retrieval function for Bag-of-words
- Rank a set of documents depending upon appearance of query terms in each document
- Independent of relative proximity of query words in document
- Two Important factors : TF, IDF

Okapi BM25

- Term Frequency (TF) is calculated as

$$TF_{BM25} = \frac{f_{t,d}.(k_1 + 1)}{f_{t,d} + k_1.\left((1 - b) + b.\left(\frac{l_d}{l_{avg}}\right)\right)}$$

- The Inverse Document Frequency (IDF) is calculated as

$$IDF(t) = \log\left(\frac{N}{N_t}\right)$$

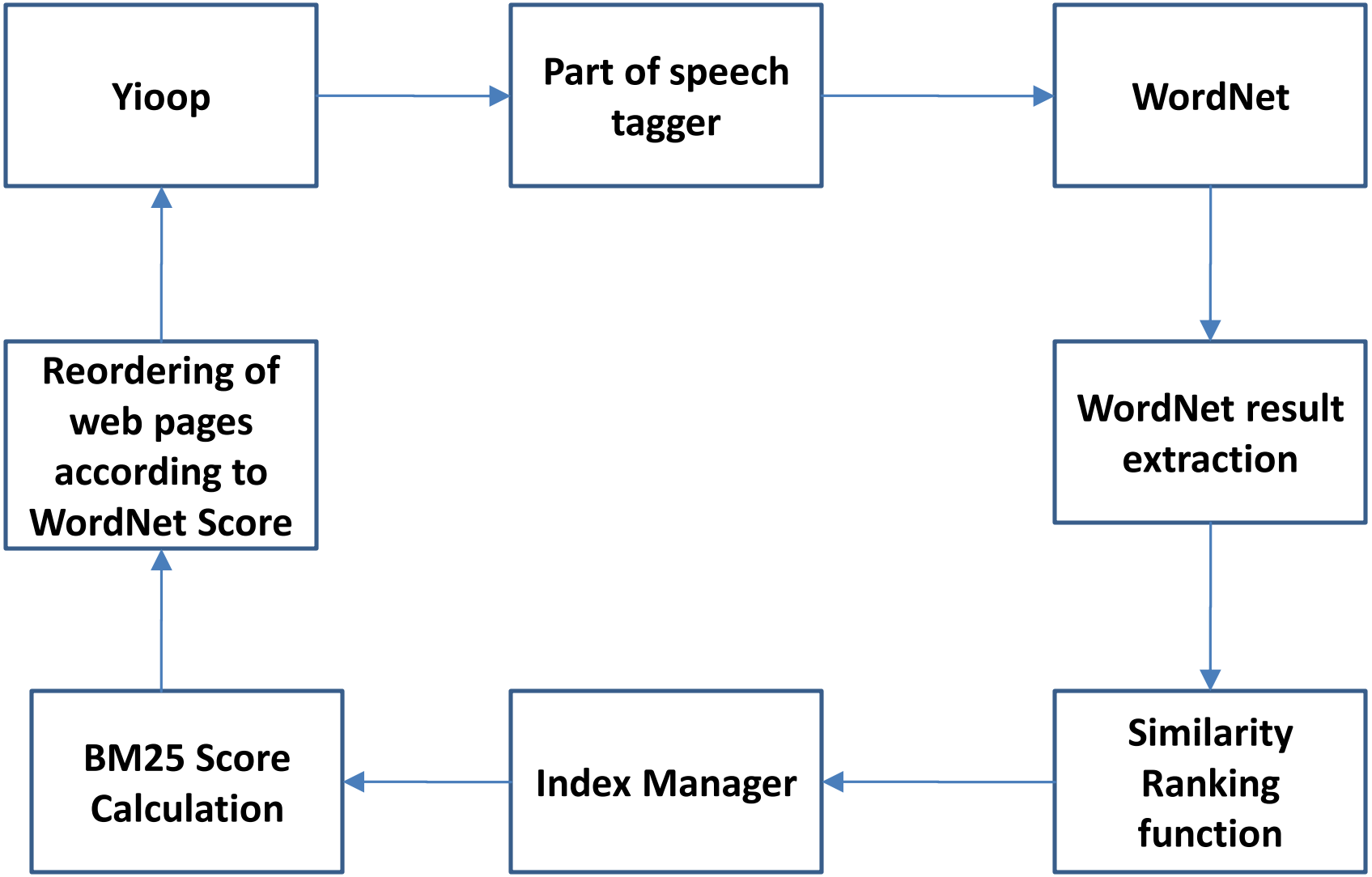
- The BM25 scoring function is defined as

$$Score_{BM25}(q, d) = \sum_{t \in q} IDF(t).TF_{BM25}(t, d)$$

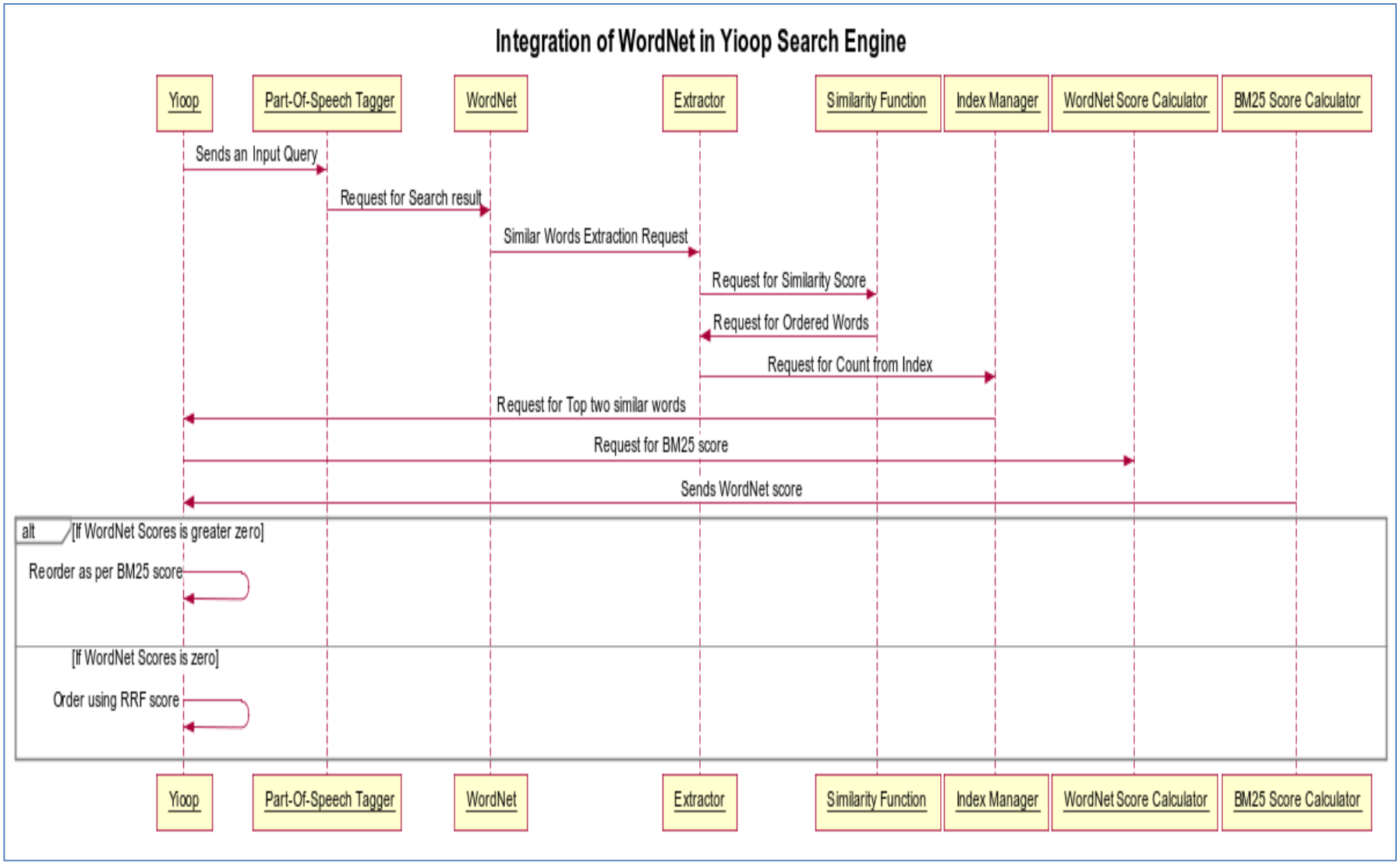
Usage of Similarity Ranking Algorithms

- To extract exact similar words from WordNet
- To sort search results after query expansion

Design & Implementation



Sequence Diagram



Experiments

- Used three datasets as follows:

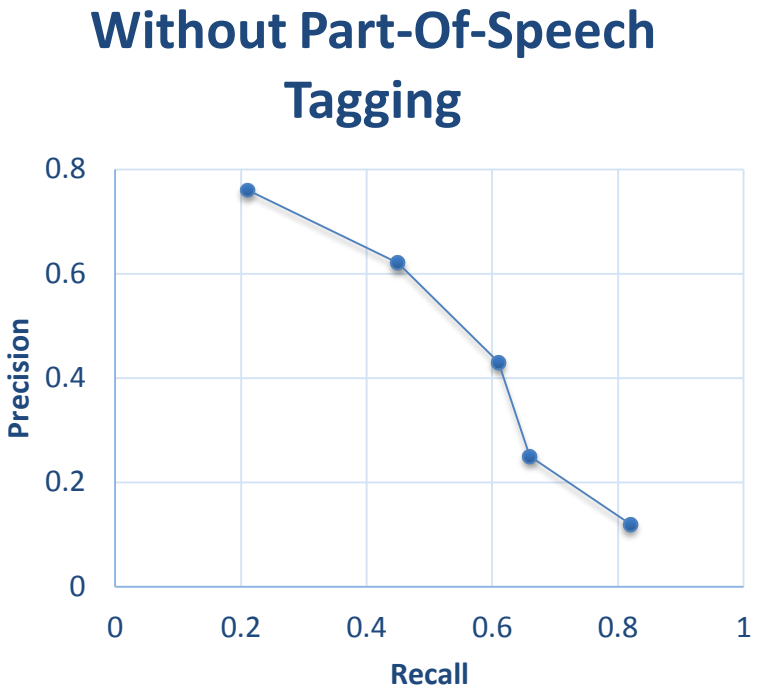
Name of Dataset	Number of crawled pages
SJSU CS	18156
Wikipedia dataset	100,000
dmoz dataset	972800

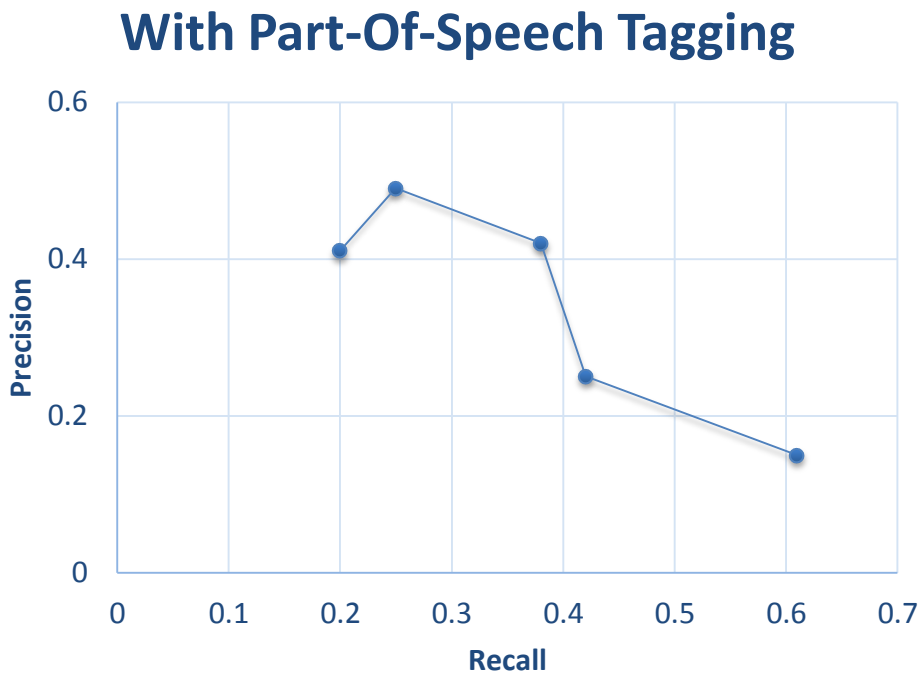
- Effectiveness of retrieved method is measured by the relevance provided by human assessment
- Two important aspects: Recall & Precision

Recall and Precision

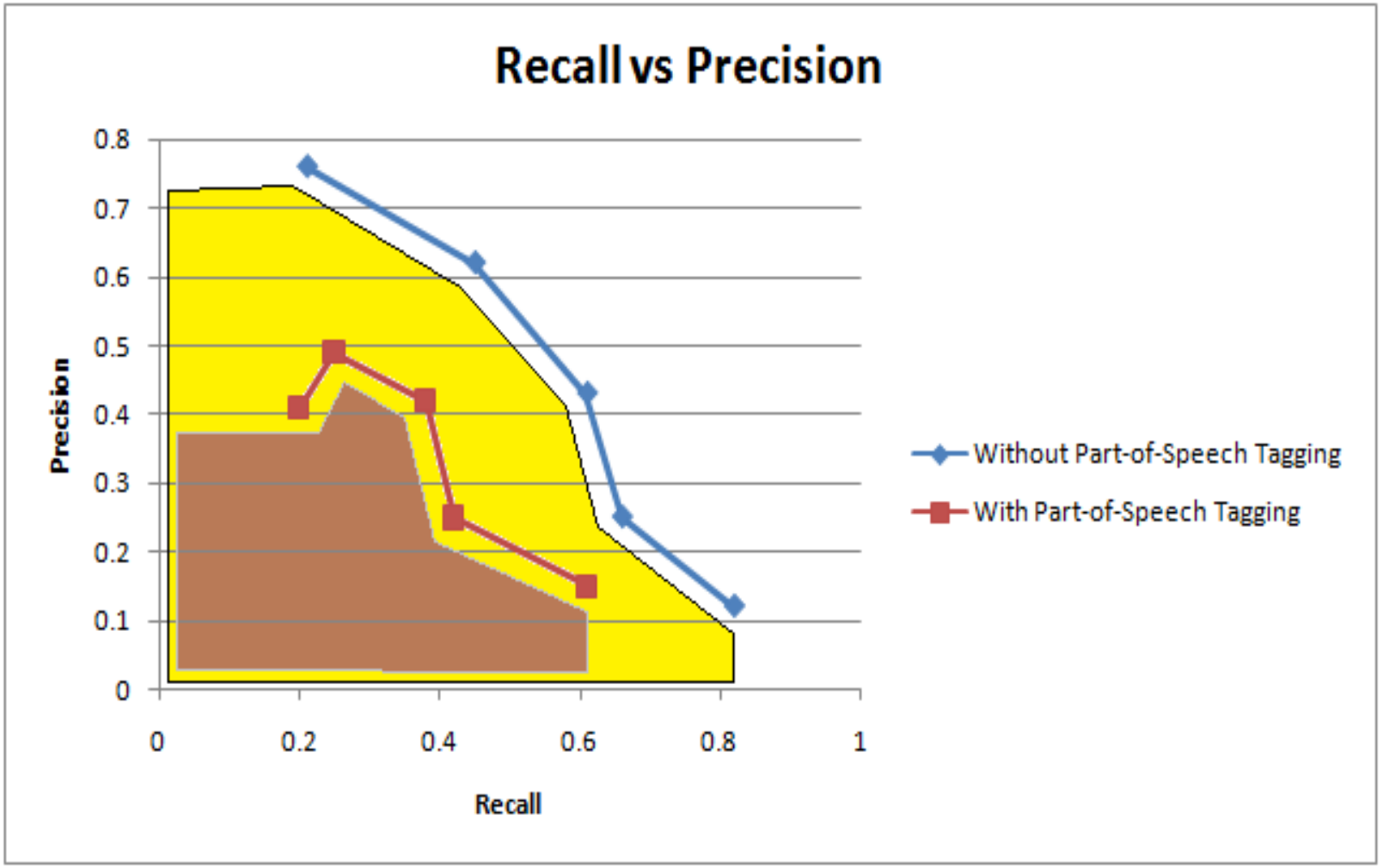
- Recall – the fraction of relevant documents which appears in result set
- Precision - the fraction of result set which is relevant
- Experimented Part Of Speech Tagging
  - During Crawl time and Query Time
  - During Query Time

Experimentation with Part Of Speech Tagging During Crawl



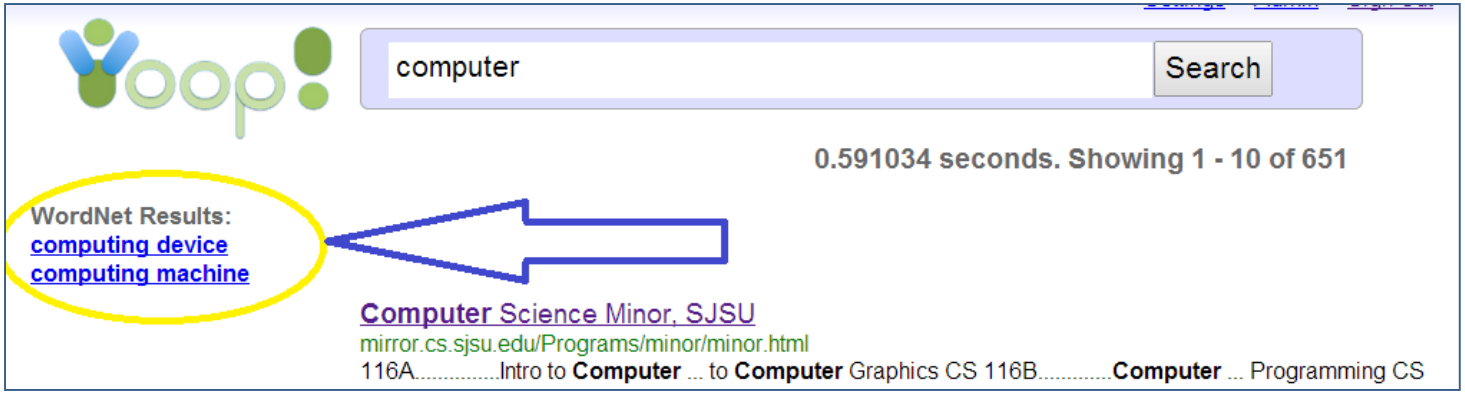


Experiment on Part Of Speech Tagging

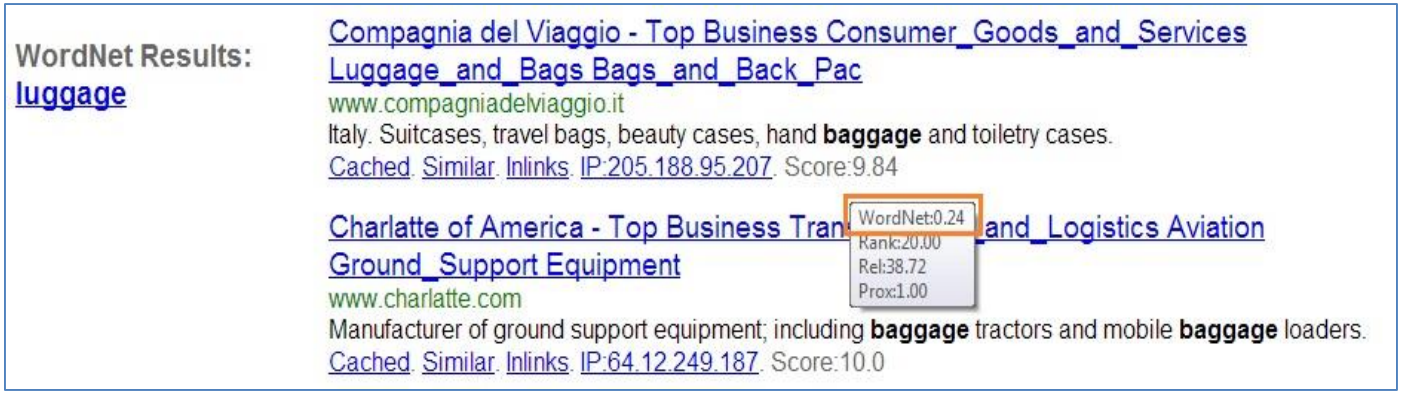


Screen Shots

- WordNet Results



- WordNet Score



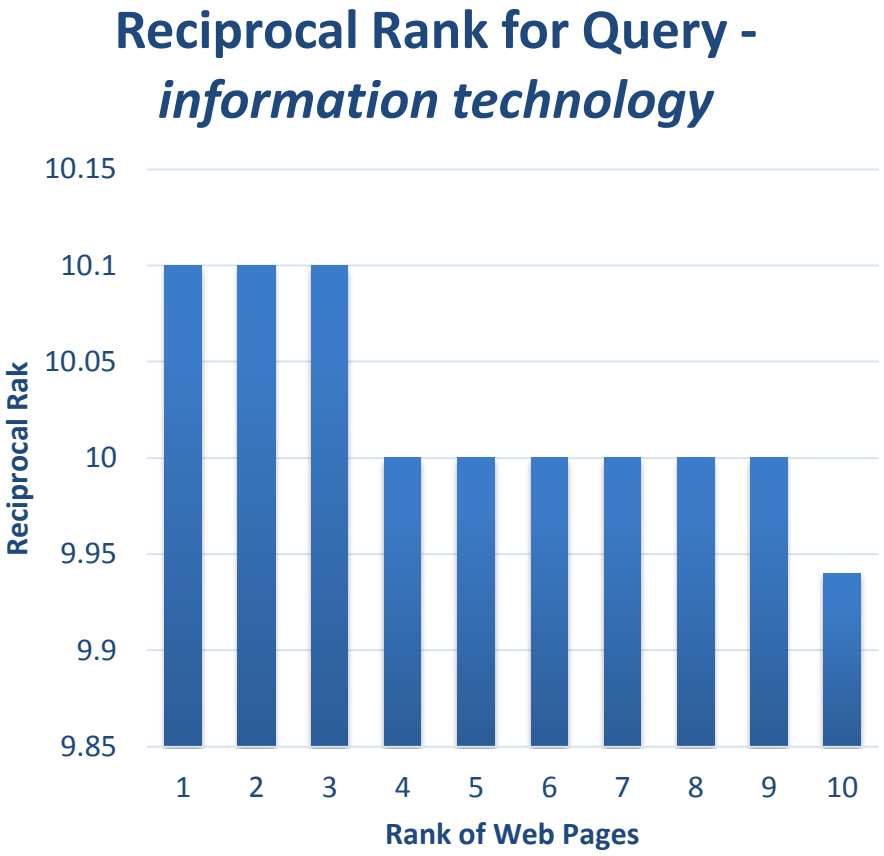
Important Findings

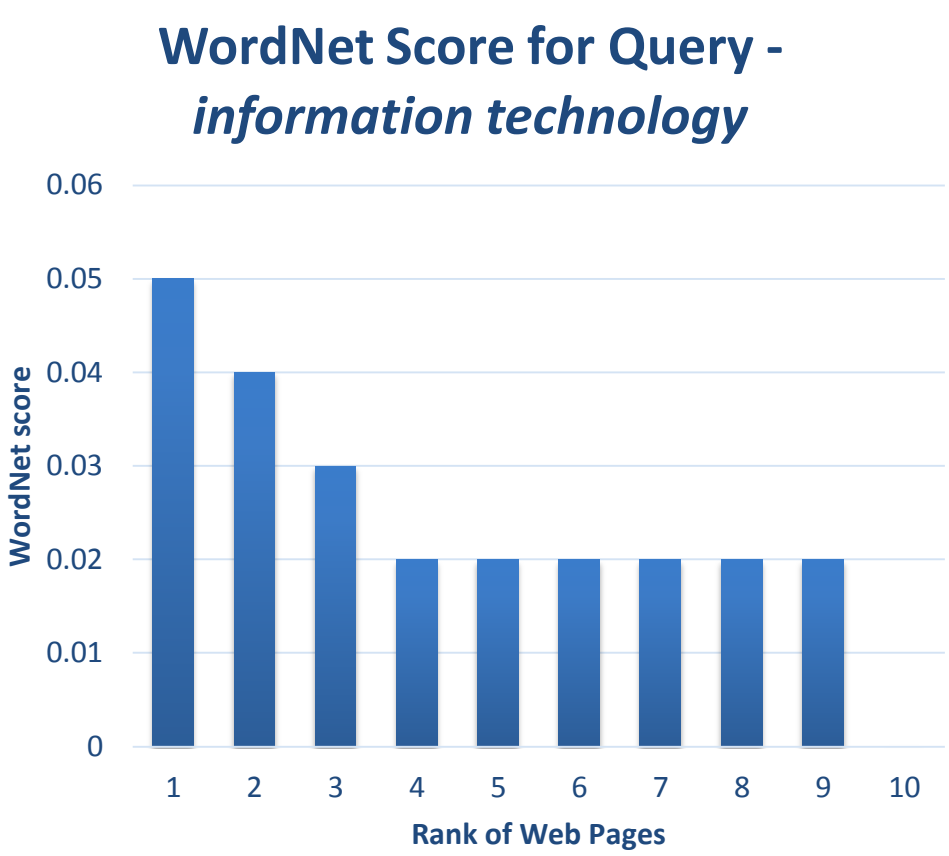
- Recall increases, precision decreases and vice-versa
- Number of URLs visited
  - Using Part-of-speech tagging during crawl time = 660 / hour
  - Not Using Part-of-speech tagging during crawl time = 800 / hour

Important Findings

- In absence of WordNet score, search results will sort by RRF (Reciprocal Rank Fusion)
- RRF is addition of Doc Rank score, Relevance score and Proximity score after normalization
- Sorted search results are more relevant as per order.
- Top two WordNet words are shown on Search Result window.

Comparison with WordNet score and RRF





Search Results

Website	WordNet Rank	RRF Rank
Intelligroup, Inc. - Top Business Information_Technology Consulting	1	3
David Christie and Associates Pty Ltd - Top Business Information_TechnologyEmployment Recruitment_	2	6
The Campus Computing Project - Top Reference Education Colleges_and_Universities North_America Unit	3	10
The International Foundation for Information Technology (IF4IT) - Top BusinessInformation_Technolo	4	8
Information Technology and Business Teachers of Ireland - Top Regional Europe Ireland Education	5	2
N. Voustros Information Technology Services - Top Regional Europe Greece Prefectures Ioannina Busin	6	5
Recruiter Solutions International - Top Business Employment Recruitment_and_Staffing Recruiters	7	9
Estonian Association of Information Technology and Telecommunications - ITL - Top Regional Europe	8	7
International Federation for Information Technology and Tourism	9	1
ADEC Distance Education Consortium	10	4

Conclusion

- Query expansion helped to improved search results.
- Part-of-speech tagger helps efficient implementation.
- Similarity Ranking algorithms helped to retrieve exact words from WordNet.
- WordNet feature works for Windows, Linux, Mac.
- Part of speech tagging during crawl time is not efficient, so used only during crawl time.
- Throughput time is increased by 0.2 seconds and deviation of 0.3 seconds
- WordNet works only for English language.

Future Scope

- Yioop is multi-language search engine
- Implement query expansion with other languages as well.
- WordNet Feature is flexible enough to adopt new English dictionary.
- WordNet has many other feature, we can use one of them as improvement in search engine feature.

References

1. Princeton University "About WordNet." WordNet. Princeton University. 2010. *http://wordnet.princeton.edu*

2. Büttcher, S., Clarke, C. L., & Cormack, G. V. (2010). *Information retrieval: implementing and evaluating search engines. Cambridge, Mass.: MIT Press*

3. George A. Miller (1995). *WordNet: A Lexical Database for English Communications of the ACM Vol. 38, No. 11: 39-41*

4. Manning, C. D., Raghavan, P., &Schütze, H. (2008). *Introduction to information retrieval. New York: Cambridge University Press.*

5. Pollett, C. (2010, August). Open Source Search Engine Software - Seekquarry: Home. Retrieved November12, 2013, from *https://seekquarry.com/?c=main&p=documentation*

Thank You