Improved Chinese Language Processing for an Open Source Search Engine

Forrest Sun
Agenda

• Introduction
  • Background of Yioop
  • Background of Natural Language Processing

• Design and Implementation
  • Chinese Text Segmentation
  • Chinese Part-of-Speech Tagging
  • Chinese Named Entity Recognition
  • Chinese Question Answering System

• Test and Result

• Conclusion
Background of Yioop

• An open source Search Engine written in PHP
• Provides features:
  • Search Results
    • Crawling, Indexing, Retrieving web pages
  • Media Servers
    • News, Video streaming
  • Social
    • Groups, Blogs, Wikis
  • Websites
    • Build websites, Wikis, RSS, JSON service
  • Monetization
    • Ads, etc.
Search in a Search Engine

- [www.worldwidewebsize.com](http://www.worldwidewebsize.com) shows:
  - There are at least 5.7 billion pages (Wednesday, 06 May, 2020) on internet.

- Impossible to search all pages after user enter the keywords

- Searching “San Jose State University” in Google:
  - About 303,000,000 results (1.14 seconds)
Inverted Index

• Also referred to as a postings file or inverted file
• A database index storing a mapping from content, such as words or numbers, to its locations in a table, or in a document or a set of documents
• Forward index: document->term vs. Inverted index: term-> document

<table>
<thead>
<tr>
<th>Document</th>
<th>Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document 1</td>
<td>the, cow, says, moo</td>
</tr>
<tr>
<td>Document 2</td>
<td>the, cat, and, the, hat</td>
</tr>
<tr>
<td>Document 3</td>
<td>the, dish, ran, away, with, the, spoon</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Word</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>cow</td>
<td>Document 2, Document 3, Document 4</td>
</tr>
<tr>
<td>says</td>
<td>Document 5</td>
</tr>
<tr>
<td>moo</td>
<td>Document 7</td>
</tr>
</tbody>
</table>
Leonard Bloomfield introduced the concept of "Minimal Free Forms" in 1928. Words are thought of as the smallest meaningful unit of speech that can stand by themselves.
Introduction of Natural Language Processing

• How Computer analyzes large amounts of natural language data
• A subfield of linguistics, computer science, information engineering, and artificial intelligence
• Has a wide range of research tasks and sub-tasks:
  • Syntax
    • Part-of-speech tagging, Stemming, Word segmentation
  • Semantics
    • Machine translation, Named entity recognition, Optical character recognition (OCR)
  • Speech
    • Speech recognition, Text-to-speech
What is the problem in Chinese Language or some Asian Languages when indexing?

• No delimiter between words
  • English
    • Hello World
  • Chinese
    • 你好 世界
  • Japanese
    • こんにちは 世界

• Not meaningful to index characters instead of words
• Need help from Natural Language Processing
Chinese Text Segmentation

• Is it easy? No! It’s very Ambiguous
  • 黑夜总会过去，光明才是永恒
  • Black Night eventually will be over, light is eternal

• Google translate:
  • 黑夜总会过去，光明才是永恒
  • The nightclub is over, the light is eternity

• Nightclub is a sensitive word in Weibo (Chinese social network) so this post is against law.
What about Human?

• Ambiguous segmentation in Chinese People: Very Common
  • 草帽路飞说要当上海贼王 (Wrong: Shanghai Thief King)
  • 草帽路飞说要当上海贼王 (Correct: Pirate King)
  • Luffy says he will become the Pirate King

• 全国性交易 Nationwide transaction
• 全国性交易 Sex transaction in nation
Some Chinese Text Segment Techniques

• Pure statistic based
• Pure dictionary based
• Statistic and dictionary based
• Machine Learning
  • Maximum Entropy
  • Conditional Random Field
Pure statistic based

• Mutual information
  • Frequency between adjacent chars

• Association measures
  • More measures amount a window of chars

• Non-segmented text
Pure dictionary based

• Greedy Algorithm
• Forward Maximum Matching (FMM)
• Backward Maximum Matching (BMM)
• Yioop can use BMM

• Disadvantages:
  • Ambiguous
  • Cannot segment new words

• Advantages:
  • Fast
  • Standard Accuracy
Statistic and dictionary based

• Use frequency and weight of words
• Newly Implemented in Yioop

• Advantages:
  • Better Accuracy
  • Not too slow
  • No training time (all needs to is to count the words)

• Disadvantages:
  • Cannot segment new words
  • Less accuracy compare to Machine Learning
Machine Learning

- Maximum Entropy
- Conditional Random Field
- Long Short-Term Memory
- B stands for beginning of the word and E otherwise
  - Ex. 计(B)算(E)机(E)是(B)人(B)类(E)的(B)伟(B)大(E)发(B)明(E)。
- Use Features:
  - Chars around chars, tags around the chars, combination of chars, etc.
Machine Learning. count.

• Advantages:
  • Very Accurate
  • Can segment new words

• Disadvantages:
  • Slow
  • Needs a lot of memory
  • High storage space for weights
  • Long training time
Question Answering

• Return answers directly without going into the documents
Question Answering

• Knowledge-based
  • Gramma Parser
    • Semantic Triple (triplet): subject–predicate–object
    • Part-of-speech tagging (POS)
  • Named Entity Recognition
    • Location, person name, organization name
    • Ex. San Jose State University

• Information retrieval-based
  • Named Entity Recognition
  • Question detection
  • Searching and ranking documents
  • Ranking paragraphs and answering extraction
POS tagging

• Rule-based
  • Ripple down rule

• Machine Learning
  • Maximum Entropy
  • Conditional Random Field
  • Features:
    • Words surrounded
    • Tags surrounded
Named Entity Recognition

• What / who is the main target in the content?
  • Person
    • Forrest Sun, Dr. Pollett
  • Location
    • California, San Jose
  • Organization
    • San Jose State University

• Encoding
  • IO encoding
  • IOB encoding

<table>
<thead>
<tr>
<th>Entity</th>
<th>IO encoding</th>
<th>IOB encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forrest</td>
<td>PER</td>
<td>B-PER</td>
</tr>
<tr>
<td>lived</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>in</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Shanghai</td>
<td>LOC</td>
<td>B-LOC</td>
</tr>
<tr>
<td>Mainland</td>
<td>LOC</td>
<td>B-LOC</td>
</tr>
<tr>
<td>Of</td>
<td>LOC</td>
<td>I-LOC</td>
</tr>
<tr>
<td>China</td>
<td>LOC</td>
<td>I-LOC</td>
</tr>
</tbody>
</table>
Implementation Details

• Chinese Word Segmentation
• POS tagging
• Named Entity Recognition
• Question Answering
Chinese Word Segmentation

• Use statistic and dictionary-based approach
  • Not too hard to implement
  • Faster than Machine Learning
  • Light in storing weight files
  • Good Accuracy

• Trie Array
  • Good for finding words one char by one char
  • Extremely flexible
  • Consume huge memory when it is very deep
    Especially in Dynamic languages such as PHP
Chinese Words Segmentation cout.

• Frequency (f)
  • How frequent the words appear in the training data

• Probability based on frequency
  • We have a string of characters $C_1C_2C_3$, where both $C_1C_2$ and $C_2C_3$ can be a word
    • $P_1 = \text{Frequency}(C_1C_2) \times \text{Frequency}(C_3)$
    • $P_2 = \text{Frequency}(C_1) \times \text{Frequency}(C_2C_3)$
    • $P_3 = \text{Frequency}(C_1) \times \text{Frequency}(C_2) \times \text{Frequency}(C_3)$
    • Compare and pick the highest choice

• $\max \prod \text{frequency}$

• If we have a long string, P might underflow because each frequency is a very low number
Chinese words segmentation cout.

• Weight:
  • $C = -\log(frequency)$
  • $\min \sum C$

• Viterbi algorithm / Dynamic programming find the sum

• Enhancement on Memory, caching
  • Trie array consumes too much memory in PHP (about 8 times higher than in C)
  • Caused by the depth of the Array
  • Caching only words in use and throw away outdated
  • 80/20 rule, Pareto principle
## Chinese Segmentation Result

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Stochastic Segmentation (ours)</th>
<th>Reverse Max Match</th>
<th>Neural with Multi-Criteria Learning (Current Highest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS</td>
<td>94.3%</td>
<td>89.42%</td>
<td>96.6%</td>
</tr>
<tr>
<td>PKU</td>
<td>86.8%</td>
<td>83.10%</td>
<td>96.6%</td>
</tr>
</tbody>
</table>
Segmentation time vs. memory

Memory usage vs running time

- Blue line: peak memory usage (MB)
- Orange line: running time (s)
Maximum Entropy Model / Multinomial logistic regression

• Use logistic regression
• Many classifiers instead of just one
• Can have many features
• Select the one with highest Probability

\[
\Pr(Y_i = 1) = \frac{e^{\theta_1 x_i}}{1 + \sum_{k=1}^{K-1} e^{\theta_k x_i}} \\
\Pr(Y_i = 2) = \frac{e^{\theta_2 x_i}}{1 + \sum_{k=1}^{K-1} e^{\theta_k x_i}} \\
\cdots \\
\Pr(Y_i = K-1) = \frac{e^{\theta_{K-1} x_i}}{1 + \sum_{k=1}^{K-1} e^{\theta_k x_i}}
\]
Maximum Entropy Model count.

\[ p'(h, t) = w_0 + \sum_{j=1}^{k} w_j f_j^{(h, t)} \]

- \( h \) is the contexts
- \( t \) is tag
- \( f \) is indicator function
- \( w \) is the weight to be trained
- \( k \) is the number of the indicator functions

\[ s = \text{sigmoid}(p') = \frac{1}{1 + e^{-p'}} \]

- Loss function: \(-(y \log(s) + (1-y)\log(1-s))\)
POS Tagging

• Maximum Entropy Model
• Features:
  • Current word
  • 2 words before current word
  • 2 words after current word
  • 2 tags before current word
POS tagging result

- **Data:** Chinese Three Bank
- **30% for training**
- **10% for testing**
- **Accuracy:** 92.5%
Named Entity Recognition

• Maximum Entropy Model

• Features:
  • Current character
  • 2 characters before current character
  • 2 characters after current character
  • 2 tags before current character
Named Entity Recognition Result

- MSRA dataset
  - With its own Training / Test dataset
  - 83.6%
Question Answering System

• Chinese syntax
  • Subject predicate object
  • Very flexible compare to English
  • Lots of particle words. Usually has no meaning. Used for tense
    • 的, 地, 得, 了, 着

• One sentence consists of many sub-sentences.
  • Sub-sentence does not necessarily contain subject
    • 珠穆朗玛峰是喜马拉雅山脉的主峰，同时是世界海拔最高的山峰，位于中国与尼泊
      尔边境线上。
    • Mount Qomolangma is the main peak of the Himalayas, at the same time is the highest
      mountain in the world, is located on the border between China and Nepal.
Chinese syntax Parser result

• The subject, predicate and object are parsed
Conclusion

• Implemented and improved many features in Yioop
  • Chinese Segmentation
  • POS tagging
  • NER
  • QA

• Many different approaches are used in this project
  • Rule based
  • Statistics based
  • Machines learning
Future work

• Compare to latest techniques in Natural language processing, the accuracy in my project is not great.
• Needs more machines learning library support for NLP.
• Question Answering System can have IR-based feature.