Text Preprocessing in Python: Steps, Tools, and Examples

Data Monsters
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by Olga Davydova, Data Monsters

In this paper, we will talk about the basic steps of text preprocessing. These steps are needed for transferring text from human language to machine-readable format for further processing. We will also discuss text preprocessing tools.

After a text is obtained, we start with text normalization. Text normalization includes:

- converting all letters to lower or upper case
- converting numbers into words or removing numbers
- removing punctuations, accent marks and other diacritics
- removing white spaces
- expanding abbreviations

- removing stop words, sparse terms, and particular words
- text canonicalization

We will describe text normalization steps in detail below.

Convert text to lowercase

Example 1. Convert text to lowercase

Python code:

```
input_str = ”The 5 biggest countries by population in 2017 are
China, India, United States, Indonesia, and Brazil.”
input_str = input_str.lower()
print(input_str)
```

Output:

```
the 5 biggest countries by population in 2017 are china, india,
united states, indonesia, and brazil.
```

Remove numbers

Remove numbers if they are not relevant to your analyses. Usually, regular expressions are used to remove numbers.

Example 2. Numbers removing

Python code:

```
import re
input_str = ’Box A contains 3 red and 5 white balls, while Box B
contains 4 red and 2 blue balls.’
result = re.sub(r’\d+’, ‘’, input_str)
print(result)
```

Output:

```
Box A contains red and white balls, while Box B contains red and
blue balls.
```

Remove punctuation

The following code removes this set of symbols [!”#$%&’()*+,-./:;<=>?
@[\]^_`{|}~]:

Example 3. Punctuation removal

Python code:

```
import string
input_str = “This &is [an] example? {of} string. with.?
punctuation!!!!” # Sample string
result = input_str.translate(string.maketrans(“”,””),
string.punctuation)
print(result)
```

Output:

```
This is an example of string with punctuation
```

Remove whitespaces

To remove leading and ending spaces, you can use the *strip()* function:

Example 4. White spaces removal

Python code:

```
input_str = “ \t a string example\t “
input_str = input_str.strip()
input_str
```

Output:

```
'a string example'
```

Tokenization

Tokenization is the process of splitting the given text into smaller pieces called tokens. Words, numbers, punctuation marks, and others can be considered as tokens. In this table ("Tokenization" sheet) several tools for implementing tokenization are described.

Name	Developer, Initial release	Features	Programming languages	License	Project link
Natural Language Toolkit (NLTK)	The University of Pennsylvania, 2001	Mac/Unix/Windows support Contains many corpora, toy grammars, trained models, etc [1].	Python	Apache License Version 2.0.	http://www.nltk.org/index.html
TextBlob	Steven Loria, 2013	Splitting text into words and sentences WordNet integration [2]	Python	http://textblob.readthedocs.io/en/dev/license.html	http://textblob.readthedocs.io/en/dev/
Spacy	Explosion AI, 2016	Runs on Unix/Linux, MacOS/OS X, and Windows. Neural network models multi-language support [3]	Python	MIT License	https://spacy.io/
Gensim	RaRe Technologies, 2009	Can process large, web-scale corpora Runs on Linux, Windows and OS X Vector space modeling and topic modeling [4]	Python	GNU LGPLv2.1 license	https://radimrehurek.com/gensim/
Apache OpenNLP	Apache Software Foundation, 2004	Contains a large number of pre-built models for a variety of languages Includes annotated text resources [5]	Java	Apache License, Version 2.0	https://opennlp.apache.org/
OpenNMT	Yoon Kim, harvardnlp, 2016	Is a generic deep learning framework mainly specialized in sequence-to-sequence models Can be used either via command line applications, client-server, or libraries. [6] Has currently 3 main implementations (OpenNMT-lua, OpenNMT-py, OpenNMT-tf)	Python Lua	MIT License	http://opennmt.net/
General Architecture for Text Engineering (GATE)	GATE research team, University of Sheffield, 1995	Includes an information extraction system Multiple languages support Accepts input in various formats [7]	Java	the GNU licenses and other	https://gate.ac.uk/
Apache UIMA	IBM, Apache Software Foundation, 2006	Contains Addons and Sandbox Cross-platform REST requests support [8]	Java, C++	Apache License 2.0	https://uima.apache.org/
Memory-Based Shallow Parser (MBSP)	Vincent Van Asch, Tom De Smedt, 2010	Client-server architecture includes binaries (TiMBL, MBT and MBLEM) Precompiled for Mac OS X Cygwin usage for Windows [9]	Python	GPL	https://www.clips.uantwerpen.be/pages/MBSP#tokenizer
RapidMiner	RapidMiner, 2006	Unified platform Visual workflow design Breadth of functionality Broad connectivity [10]	RapidMiner provides a GUI to design and execute analytical workflows	AGPL	https://rapidminer.com/

Tokenization tools

Remove stop words

"Stop words" are the most common words in a language like "the", "a", "on", "is", "all". These words do not carry important meaning and are usually removed from texts. It is possible to remove stop words using Natural Language Toolkit (NLTK), a suite of libraries and programs for symbolic and statistical natural language processing.

Example 7. Stop words removal

Code:

```
input_str = "NLTK is a leading platform for building Python programs
to work with human language data."
stop_words = set(stopwords.words('english'))
from nltk.tokenize import word_tokenize
tokens = word_tokenize(input_str)
```

```
result = [i for i in tokens if not i in stop_words]
print (result)
```

Output:

```
['NLTK', 'leading', 'platform', 'building', 'Python', 'programs',
'work', 'human', 'language', 'data', '.']
```

A scikit-learn tool also provides a stop words list:

```
from sklearn.feature_extraction.stop_words import ENGLISH_STOP_WORDS
```

It's also possible to use spaCy, a free open-source library:

```
from spacy.lang.en.stop_words import STOP_WORDS
```

Remove sparse terms and particular words

In some cases, it's necessary to remove sparse terms or particular words from texts. This task can be done using stop words removal techniques considering that any group of words can be chosen as the stop words.

Stemming

Stemming is a process of reducing words to their word stem, base or root form (for example, books — book, looked — look). The main two algorithms are Porter stemming algorithm (removes common morphological and inflexional endings from words [14]) and Lancaster stemming algorithm (a more aggressive stemming algorithm). In the "Stemming" sheet of the table some stemmers are described.

Name	Developer, Initial release	Features	Programming languages	License	Project link
Natural Language Toolkit (NLTK)	The University of Pennsylvania, 2001	Includes Porter stemmer, Snowball stemmer, and Lancaster stemmer Contains a stemmer that uses regular expressions to identify morphological affixes multiple languages support [15]	Python	Apache License Version 2.0.	http://www.nltk.org/api/nltk.stem.html
Snowball	Martin Porter, 2002	Multiple languages support Small string processing language designed for creating stemming algorithms [16]	Java Python Wrappers are provided	the 3-clause BSD License	https://snowballstem.org/
PyStemmer	Richard Boulton, 2006	Efficient algorithms for calculating a "stemmed" form of a word Provides algorithms for several (mainly European) languages Porter stemming algorithm for English [17]	MPython	MIT license	https://github.com/snowballstem/pystemmer
Hunspell stemmer	lopusz	Polish language support Dictionary-based stemming [18]	Java	Apache License, Version 2.0	https://www.elastic.co/guide/en/elasticsearch/guide/current/hunspell.html
	The Stanford Natural Language				https://github.com/stanfordnlp/CoreNLP/blob/master/src/edu/stanford/

CoreNLP Stemmer	The Stanford Natural Language Processing Group, 2010	A special class Stemmer was created	Java	GNU General Public License	https://github.com/stanfordnlp/CoreNLP/blob/master/src/edu/stanford/nlp/process/Stemmer.java
Apache Lucene	Apache Software Foundation, 1999	Scalable, high-performance indexing Powerful, accurate and efficient search algorithms cross-platform solution [19]	Java ported to Object Pascal, Perl, C#, C++, Python, Ruby and PHP	Apache License, Version 2.0	https://lucene.apache.org/
DKPro Core	The Ubiquitous Knowledge Processing Lab (UKP) at the Technische Universität Darmstadt, 2009	Various models covering different languages accompany the components Supports various data formats Easy integration into Python projects [20]	Java Groovy Python	Apache Software License (ASL) version 2	https://dkpro.github.io/dkpro-core/

Stemming tools

Example 8. Stemming using NLTK:

Code:

```
from nltk.stem import PorterStemmer
from nltk.tokenize import word_tokenize
stemmer= PorterStemmer()
input_str=”There are several types of stemming algorithms.”
input_str=word_tokenize(input_str)
for word in input_str:
    print(stemmer.stem(word))
```

Output:

```
There are sever type of stem algorithm.
```

Lemmatization

The aim of lemmatization, like stemming, is to reduce inflectional forms to a common base form. As opposed to stemming, lemmatization does not simply chop off inflections. Instead it uses lexical knowledge bases to get the correct base forms of words.

Lemmatization tools are presented libraries described above: NLTK (WordNet Lemmatizer), spaCy, TextBlob, Pattern, gensim, Stanford CoreNLP, Memory-Based Shallow Parser (MBSP), Apache OpenNLP, Apache Lucene, General Architecture for Text Engineering (GATE), Illinois Lemmatizer, and DKPro Core.

Example 9. Lemmatization using NLTK:

Code:

```
from nltk.stem import WordNetLemmatizer
from nltk.tokenize import word_tokenize
lemmatizer=WordNetLemmatizer()
input_str="been had done languages cities mice"
input_str=word_tokenize(input_str)
for word in input_str:
    print(lemmatizer.lemmatize(word))
```

Output:

```
be have do language city mouse
```

Part of speech tagging (POS)

Part-of-speech tagging aims to assign parts of speech to each word of a given text (such as nouns, verbs, adjectives, and others) based on its definition and its context. There are many tools containing POS taggers including NLTK, spaCy, TextBlob, Pattern, Stanford CoreNLP, Memory-Based Shallow Parser (MBSP), Apache OpenNLP, Apache Lucene, General Architecture for Text Engineering (GATE), FreeLing, Illinois Part of Speech Tagger, and DKPro Core.

Example 10. Part-of-speech tagging using TextBlob:

Code:

```
input_str="Parts of speech examples: an article, to write,
interesting, easily, and, of"
from textblob import TextBlob
result = TextBlob(input_str)
print(result.tags)
```

Output:

```
[('Parts', u'NNS'), ('of', u'IN'), ('speech', u'NN'), ('examples',
u'NNS'), ('an', u'DT'), ('article', u'NN'), ('to', u'TO'), ('write',
u'VB'), ('interesting', u'VBG'), ('easily', u'RB'), ('and', u'CC'),
('of', u'IN')]
```

Chunking (shallow parsing)

Chunking is a natural language process that identifies constituent parts of sentences (nouns, verbs, adjectives, etc.) and links them to higher order units that have discrete grammatical meanings (noun groups or phrases, verb groups, etc.) [23]. Chunking tools: NLTK, TreeTagger chunker, Apache OpenNLP, General Architecture for Text Engineering (GATE), FreeLing.

Example 11. Chunking using NLTK:

The first step is to determine the part of speech for each word:

Code:

```
input_str=”A black television and a white stove were bought for the
new apartment of John.”
from textblob import TextBlob
result = TextBlob(input_str)
print(result.tags)
```

Output:

```
[(‘A’, u’DT’), (‘black’, u’JJ’), (‘television’, u’NN’), (‘and’,
u’CC’), (‘a’, u’DT’), (‘white’, u’JJ’), (‘stove’, u’NN’), (‘were’,
u’VBD’), (‘bought’, u’VBN’), (‘for’, u’IN’), (‘the’, u’DT’), (‘new’,
u’JJ’), (‘apartment’, u’NN’), (‘of’, u’IN’), (‘John’, u’NNP’)]
```

The second step is chunking:

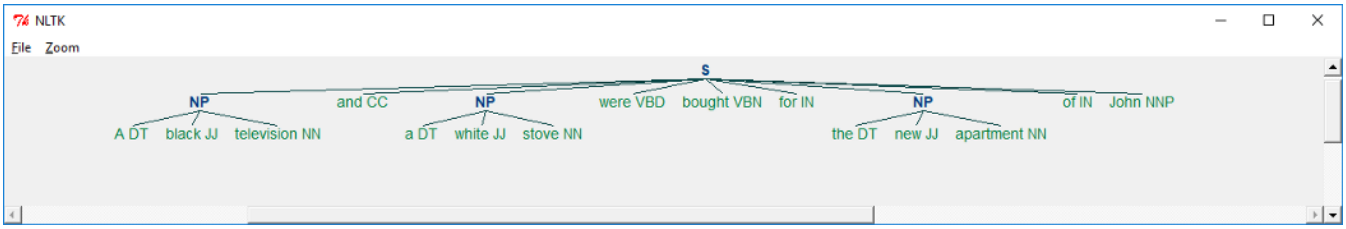
Code:

```
reg_exp = “NP: {<DT>?<JJ>*<NN>}”
rp = nltk.RegexpParser(reg_exp)
result = rp.parse(result.tags)
print(result)
```

Output:

```
(S (NP A/DT black/JJ television/NN) and/CC (NP a/DT white/JJ
stove/NN) were/VBD bought/VBN for/IN (NP the/DT new/JJ apartment/NN)
of/IN John/NNP)
```

It's also possible to draw the sentence tree structure using code `result.draw()`



Named entity recognition

Named-entity recognition (NER) aims to find named entities in text and classify them into pre-defined categories (names of persons, locations, organizations, times, etc.).

Named-entity recognition tools: NLTK, spaCy, General Architecture for Text Engineering (GATE) — ANNIE, Apache OpenNLP, Stanford CoreNLP, DKPro Core, MITIE, Watson Natural Language Understanding, TextRazor, FreeLing are described in the "NER" sheet of the table.

Name	Developer, Initial release	Features	Programming languages	License	Project link
Baleen	Defence Science and Technology Laboratory (Dstl), 2014	Works with unstructured and semi-structured data sources Includes a built-in server [25]	Java	Apache License 2.0	https://github.com/dstl/baleen
CogComp NER Tagger (Illinois Named Entity Tagger)	L. Ratinov, D. Roth, Cognitive Computation Group, 2009	Tags plain text with named entities 4-label type set (people / organizations / locations / miscellaneous) 18-label type set (based on the OntoNotes corpus) [26]	Java	Licensing Agreement	https://github.com/CogComp/cogcomp-nlp/tree/master/ner
Minimal Named-Entity Recognizer (MER)	LaSIGE, Faculdade de Ciências, Universidade de Lisboa, Portugal, 2017	Returns the list of terms recognized in the text, including their exact location (annotations) Only requires a lexicon (text file) with the list of terms representing the entities of interest RESTful Web service [27]	GNU awk	-	https://github.com/lasigeBioTM/MER
ParallelDots	ParallelDots	Uses deep learning technology to determine representations of character groupings Discovers the most relevant entities in textual content Accurate, real-time, customizable [28] demo	excel add-in AI APIs	Pricing	https://www.paralleldots.com/named-entity-recognition
Open Calais	Thomson Reuters Corporation	Extracts entities (companies, people, places, products, etc.), relationships, facts, events, topics. [29]	API	Terms of Service	http://www.opencalais.com/about-open-calais/
LingPipe	Breck Baldwin, 1999	Finds the names of people, organizations, or locations Source code and unit tests Multi-lingual, multi-domain, multi-genre models [30]	Java	License Matrix	http://alias-i.com/lingpipe/index.html
Named Entity Recognition Tool	Guillaume Lample, Miguel Ballesteros, Sandeep Subramanian, Kazuya Kawakami, Chris Dyer, 2016	A neural architecture state-of-the-art performance in NER on the 4 CoNLL datasets (English, Spanish, German and Dutch) without resorting to any language-specific knowledge or resources such as gazetteers [31]	Python	Apache License 2.0	https://github.com/glample/tagger

NER Tools

Example 12. Named-entity recognition using NLTK:

Code:

```
from nltk import word_tokenize, pos_tag, ne_chunk
input_str = "Bill works for Apple so he went to Boston for a
conference."
print ne_chunk(pos_tag(word_tokenize(input_str)))
```

Output:

```
(S (PERSON Bill/NNP) works/VBZ for/IN Apple/NNP so/IN he/PRP
went/VBD to/TO (GPE Boston/NNP) for/IN a/DT conference/NN ./.)
```

Coreference resolution (anaphora resolution)

Pronouns and other referring expressions should be connected to the right individuals. Coreference resolution finds the mentions in a text that refer to the same real-world entity. For example, in the sentence, "Andrew said he would buy a car" the pronoun "he" refers to the same person, namely to "Andrew". Coreference resolution tools: Stanford CoreNLP, spaCy, Open Calais, Apache OpenNLP are described in the "Coreference resolution" sheet of the table.

Name	Developer, Initial release	Features	Programming languages	License	Project link
Beautiful Anaphora Resolution Toolkit (BART)	Massimo Poesio, Simone Ponzetto, Yannick Versley, Johns Hopkins Summer Workshop, 2007	Incorporates a variety of machine learning approaches Uses several machine learning toolkits Exports the result as inline XML [36]	REST-based web service	Apache license v2.0	http://www.bart-coref.org/
JavaRAP	Long Qiu, 2004	Resolves third person pronouns, lexical anaphors, Identifies pleonastic pronouns Output format: anaphor - antecedent pairs; text with in-place substitutions Accuracy: 57.9% (MUC6) around 1,500 words per second [37]	Java	-	https://wing.comp.nus.edu.sg/~qiu/NLPTools/JavaRAP.html
A General Tool for Anaphora Resolution - GuiTAR	University of Essex, 2007	Takes as an input a MAS-XML compliant file and adds new markup holding anaphoric information (elements). Evaluation module is also included [38]	Java	GPL License	http://cswww.essex.ac.uk/Research/nle/GuiTAR/
Reconcile	Cornell University, The University of Utah, Lawrence Livermore National Labs, 2009	Runs on common data sets or unlabeled texts Utilizes supervised machine learning classifiers from the Weka toolkit, the Berkeley Parser and Stanford Named Entity Recognition system. MUC Score (MUC-6): recall 67.23; precision 65.54; F-measure 66.38 [39]	Java	GPL License	https://www.cs.utah.edu/nlp/reconcile/
ARKref	Brendan O'Connor, Michael Heilman, 2009	Deterministic, rule-based system Uses syntactic information from a constituent parser, and semantic information from an entity recognition component Precision: 0.657617, recall: 0.552433, f1: 0.600454 [40]	Java	GPL, MIT	http://www.cs.cmu.edu/~ark/ARKref/
Illinois Coreference Package	Dan Roth, Eric Bengtson, 2008	Coreference related features: Gender and number match, WordNet relations including synonym, hypernym, antonym, and ACE entity types (person, organization, and geopolitical entity) Features anaphoricity classifier [41]	Java	-	https://cogcomp.org/page/software_view/Coref
Neural coref	Hugging Face, 2017	Uses neural nets and spaCy Adds various speakers in the conversation when computing the features and resolving the coreferences [42] Online demo	Python	MIT License	https://github.com/huggingface/neuralcoref

Coreference resolution tools

An example of coreference resolution using xrenner can be found here.

Collocation extraction

Collocations are word combinations occurring together more often than would be expected by chance. Collocation examples are “break the rules,” “free time,” “draw a conclusion,” “keep in mind,” “get ready,” and so on.

Name	Developer, Initial release	Features	Programming languages	License	Project link
TermeX	Text Analysis and Knowledge Engineering Lab, University of Zagreb, 2009	UTF-8 formatted input text uses 14 association measures Processes of n-grams up to length four Hand selection of candidate n-grams for terminology lexica Windows and Linux support Fast and memory efficient processing of large corpora [47]	Front end GUI	Freely available for research purposes upon request.	http://ktlab.fer.hr/termex/
Collocate	Athelstan	Uses statistical analyses (t-score, log likelihood, Mutual Information) and frequency information to present a list of candidate collocations Searches for a word (phrase) within a set span (e.g. 4 words). Produces an n-gram list Extracts collocations using thresholds and either mutual information [48]	Application	Educational Price. Single user: $45 Site license (2-year, 15 users) $395	https://www.athel.com/colloc.html
CollTerm	Faculty of Humanities and Social Sciences at University of Zagreb; Research Institute for Artificial Intelligence at Romanian Academy	Results based on five different co-occurrence measures for multiword units (i.e. collocations) or distributional differences from large representative corpus by application of the TF-IDF measurement on single word units Language independent [49]	Python	ApacheLicense 2.0	https://github.com/accurat-toolkit/CollTerm
Collocation Extractor	Dan Ștefănescu, 2012	Collocation words features in this approach: – the distance between them is relatively constant; – they appear together more often than expected by chance (Log-Likelihood) Language independent output annotation format: Text output with one collocation per line and annotations separated by tab [50]	Application	Restrictions: Inform Licensor, No User Nature: Academic,	http://metashare.ilsp.gr:8080/repository/browse/collocation-extractor/7a2432acdc7311e5aa0b00237df3e35819ec25a2cee244cd8782b24eddcad3c8/

Collocation extraction tools

Example 13. Collocation extraction using ICE [51]

Code:

```
input=[“he and Chazz duel with all keys on the line.”]
from ICE import CollocationExtractor
extractor = CollocationExtractor.with_collocation_pipeline(“T1” ,
bing_key = “Temp”,pos_check = False)
print(extractor.get_collocations_of_length(input, length = 3))
```

Output:

```
[“on the line”]
```

Relationship extraction

Relationship extraction allows obtaining structured information from unstructured sources such as raw text. Strictly stated, it is identifying relations (e.g., acquisition, spouse, employment) among named entities (e.g., people, organizations, locations).

For example, from the sentence “Mark and Emily married yesterday,” we can extract the information that Mark is Emily’s husband.

Name	Developer, Initial release	Features	Programming languages	License	Project link
ReVerb	University of Washington's Turing Center	Automatically identifies and extracts binary relationships from English sentences Designed for Web-scale information extraction where the target relations cannot be specified in advance and speed is important. Inputs raw text Outputs (argument1, relation phrase, argument2) triples [53]	Java	ReVerb Software License Agreement	http://reverb.cs.washington.edu/
EXEMPLAR	University of Alberta, 2013	Able to identify instances of any relation described in the text Extracts relations with two or more arguments Role of an argument can be SUBJ (subject), DOBJ (direct object) and POBJ (prepositional object) [54]	Java	GNU General Public License v3.0	https://github.com/U-Alberta/exemplar
Toolkit for Exploring Text for Relation Extraction (TETRE)	Alisson Oldoni, 2017	Accepts raw text as an input Optimized for the task of information extraction in a corpus composed of academic papers Does data transformation, parsing, wraps tasks of third-party binaries Outputs the relations in HTML and JSON [55]	Command line tool	MIT License	https://github.com/aoldoni/tetre
TextRazor	TextRazor, 2011	Uses state-of-the-art NLP and AI techniques Processes thousands of words per second per core Allows user to add product names, people, companies, custom classification rules and advanced linguistic patterns [56]	Python PHP Java REST API	Pricing	https://www.textrazor.com/
Information Extraction in Python (IEPY)	Machinalis, 2014	Tries to predict relations using information provided by the user Aimed to perform Information Extraction (IE) on a large dataset created for scientific experiments with new IE algorithms Configured with convenient defaults [57]	Python	BSD 3-Clause "New" or "Revised" License	https://github.com/machinalis/iepy

An example of relationship extraction using NLTK can be found here.

Summary

In this post, we talked about text preprocessing and described its main steps including normalization, tokenization, stemming, lemmatization, chunking, part of speech tagging, named-entity recognition, coreference resolution, collocation extraction, and relationship extraction. We also discussed text preprocessing tools and examples. A comparative table was created.

After the text preprocessing is done, the result may be used for more complicated NLP tasks, for example, machine translation or natural language generation.

Resources:

1. http://www.nltk.org/index.html
2. http://textblob.readthedocs.io/en/dev/
3. https://spacy.io/usage/facts-figures
4. https://radimrehurek.com/gensim/index.html
5. https://opennlp.apache.org/

6. http://opennmt.net/
7. https://gate.ac.uk/
8. https://uima.apache.org/
9. https://www.clips.uantwerpen.be/pages/MBSP#tokenizer
10. https://rapidminer.com/
11. http://mallet.cs.umass.edu/
12. https://www.clips.uantwerpen.be/pages/pattern
13. https://nlp.stanford.edu/software/tokenizer.html#About
14. https://tartarus.org/martin/PorterStemmer/
15. http://www.nltk.org/api/nltk.stem.html
16. https://snowballstem.org/
17. https://pypi.python.org/pypi/PyStemmer/1.0.1
18. https://www.elastic.co/guide/en/elasticsearch/guide/current/hunspell.html
19. https://lucene.apache.org/core/
20. https://dkpro.github.io/dkpro-core/
21. http://ucrel.lancs.ac.uk/claws/
22. http://www.cis.uni-muenchen.de/~schmid/tools/TreeTagger/
23. https://en.wikipedia.org/wiki/Shallow_parsing
24. https://cogcomp.org/page/software_view/Chunker
25. https://github.com/dstl/baleen
26. https://github.com/CogComp/cogcomp-nlp/tree/master/ner
27. https://github.com/lasigeBioTM/MER
28. https://blog.paralleldots.com/product/dig-relevant-text-elements-entity-extraction-api/

29. http://www.opencalais.com/about-open-calais/

30. http://alias-i.com/lingpipe/index.html

31. https://github.com/glample/tagger

32. http://minorthird.sourceforge.net/old/doc/

33. https://www.ibm.com/support/knowledgecenter/en/SS8NLW_10.0.0/com.ibm.watson.wex.aac.doc/aac-tasystemt.html

34. https://www.poolparty.biz/

35. https://www.basistech.com/text-analytics/rosette/entity-extractor/

36. http://www.bart-coref.org/index.html

37. https://wing.comp.nus.edu.sg/~qiu/NLPTools/JavaRAP.html

38. http://cswww.essex.ac.uk/Research/nle/GuiTAR/

39. https://www.cs.utah.edu/nlp/reconcile/

40. https://github.com/brendano/arkref

41. https://cogcomp.org/page/software_view/Coref

42. https://medium.com/huggingface/state-of-the-art-neural-coreference-resolution-for-chatbots-3302365dcf30

43. https://github.com/smartschat/cort

44. http://www.hlt.utdallas.edu/~altaf/cherrypicker/

45. http://nlp.lsi.upc.edu/freeling/

46. https://corpling.uis.georgetown.edu/xrenner/#

47. http://takelab.fer.hr/termex_s/

48. https://www.athel.com/colloc.html

49. http://linghub.lider-project.eu/metashare/a89c02f4663d11e28a985ef2e4e6c59e76428bf02e394229a70428f25a839f75

50. http://ws.racai.ro:9191/narratives/batch2/Colloc.pdf

51. http://www.aclweb.org/anthology/E17-3027

52. https://metacpan.org/pod/Text::NSP

53. https://github.com/knowitall/reverb

54. https://github.com/U-Alberta/exemplar

55. https://github.com/aoldoni/tetre

56. https://www.textrazor.com/technology

57. https://github.com/machinalis/iepy

58. https://www.ibm.com/watson/developercloud/natural-language-understanding/api/v1/#relations

59. https://github.com/mit-nlp/MITIE

NLP Named Entity Recognition Text Mining Python Nltk