Intro to Natural Language Processing

DistrictDataLabs

What is Language?

Or, why should we analyze it?

DistrictDataLabs

Crab

What does this mean?

DistrictDataLabs

/kræb/ **Crab**

Is the symbol representative of its meaning?

DistrictDataLabs

sound	symbol	sight
/kræb/	**Crab**	

Or is it just a mapping in a mental lexicon?

DistrictDataLabs

sound	symbol	sight
/kávouras/	**κάβουρας**	

These symbols are arbitrary

DistrictDataLabs

What is Language?

Linguistic symbols:

- Not acoustic “things”
- Not mental processes

Critical implications for:

- Literature
- Linguistics
- Computer Science
- Artificial Intelligence

DistrictDataLabs

What is Natural Language Processing?

The science that has been developed around the facts of language passed through three stages before finding its true and unique object. First something called "grammar" was studied. This study, initiated by the Greeks and continued mainly by the French, was based on logic. It lacked a scientific approach and was detached from language itself. Its only aim was to give rules for distinguishing between correct and incorrect forms; it was a normative discipline, far removed from actual observation, and its scope was limited.

-- Ferdinand de Saussure

DistrictDataLabs

What is Natural Language Processing?

The science that has been developed around the facts of language passed through three stages before finding its true and unique object. First something called "grammar" was studied. This study, initiated by the Greeks and continued mainly by the French, was based on logic. It lacked a scientific approach and was detached from language itself. Its only aim was to give rules for distinguishing between correct and incorrect forms; it was a normative discipline, far removed from actual observation, and its scope was limited.

-- Ferdinand de Saussure

DistrictDataLabs

Formal vs. Natural Languages

Formal Languages

- Strict, unchanging rules defined by grammars and parsed by regular expressions
- Generally application specific (chemistry, math)
- Literal: exactly what is said is meant.
- No ambiguity
- Parsable by regular expressions
- Inflexible: no new terms or meaning.

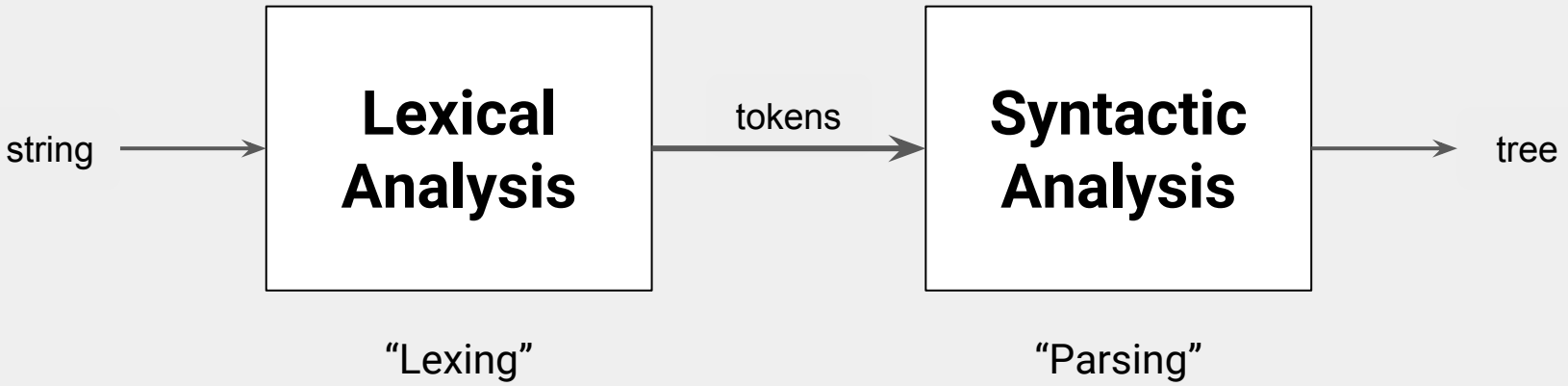
Natural Languages

- Flexible, evolving language that occurs naturally in human communication
- Unspecific and used in many domains and applications
- Redundant and verbose in order to make up for ambiguity
- Expressive
- Difficult to parse
- Very flexible even in narrow contexts

DistrictDataLabs

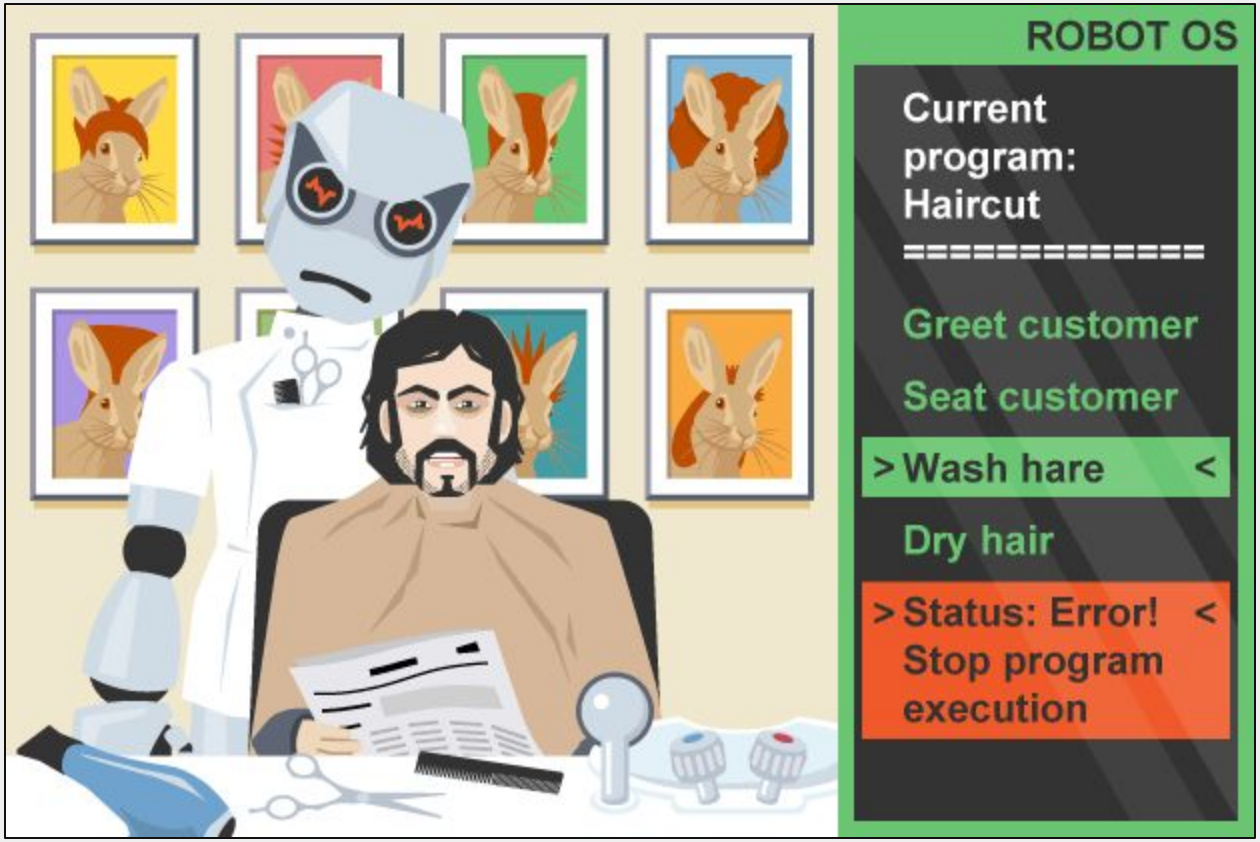
Computer science has traditionally focused on formal languages.

DistrictDataLabs



Who has written a compiler or interpreter?

DistrictDataLabs



Syntax Errors are your friend! http://bbc.in/23pSPRq

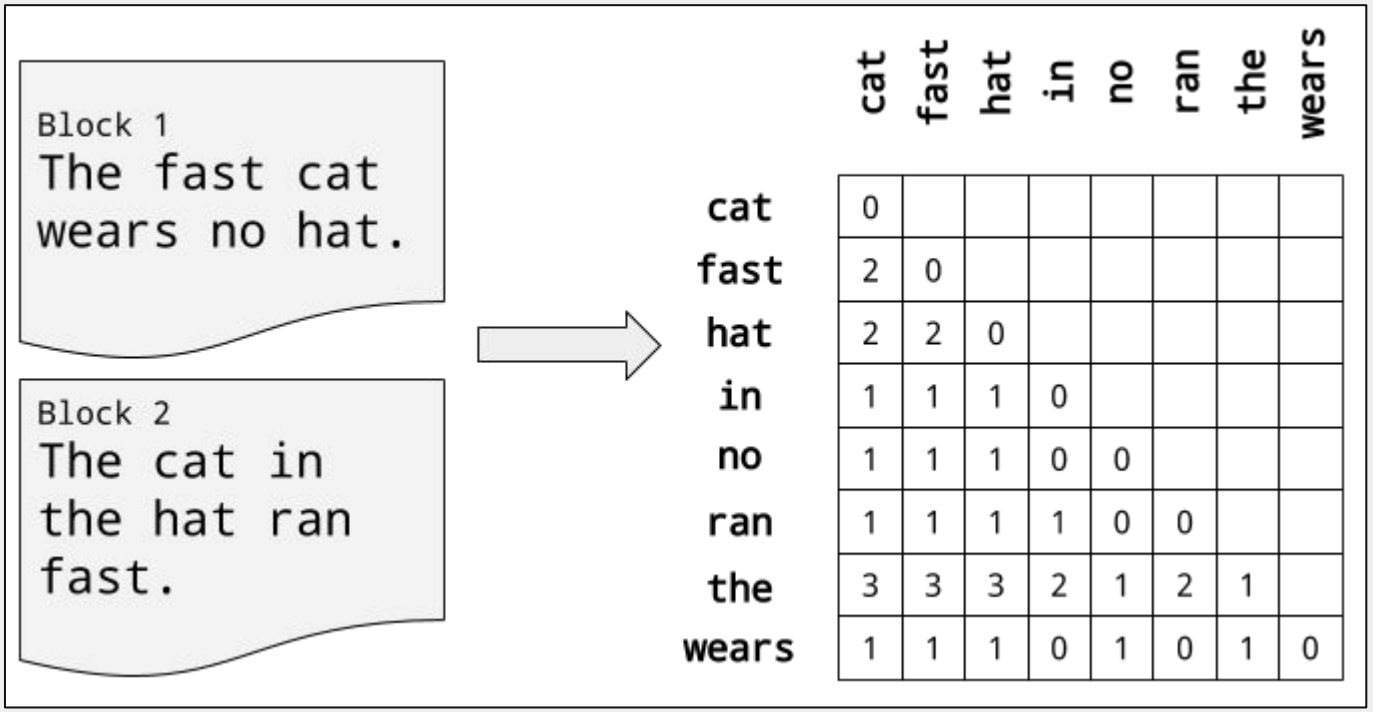
However, ambiguity is required for understanding when communicating between people with diverse experience.

DistrictDataLabs

Most of the time. http://bit.ly/1XlOtHv

Natural Language Processing requires flexibility, which generally comes from machine learning.

DistrictDataLabs



	cat	fast	hat	in	no	ran	the	wears
cat	0							
fast	2	0						
hat	2	2	0					
in	1	1	1	0				
no	1	1	1	0	0			
ran	1	1	1	1	0	0		
the	3	3	3	2	1	2	1	
wears	1	1	1	0	1	0	1	0

Language models are used for flexibility

DistrictDataLabs

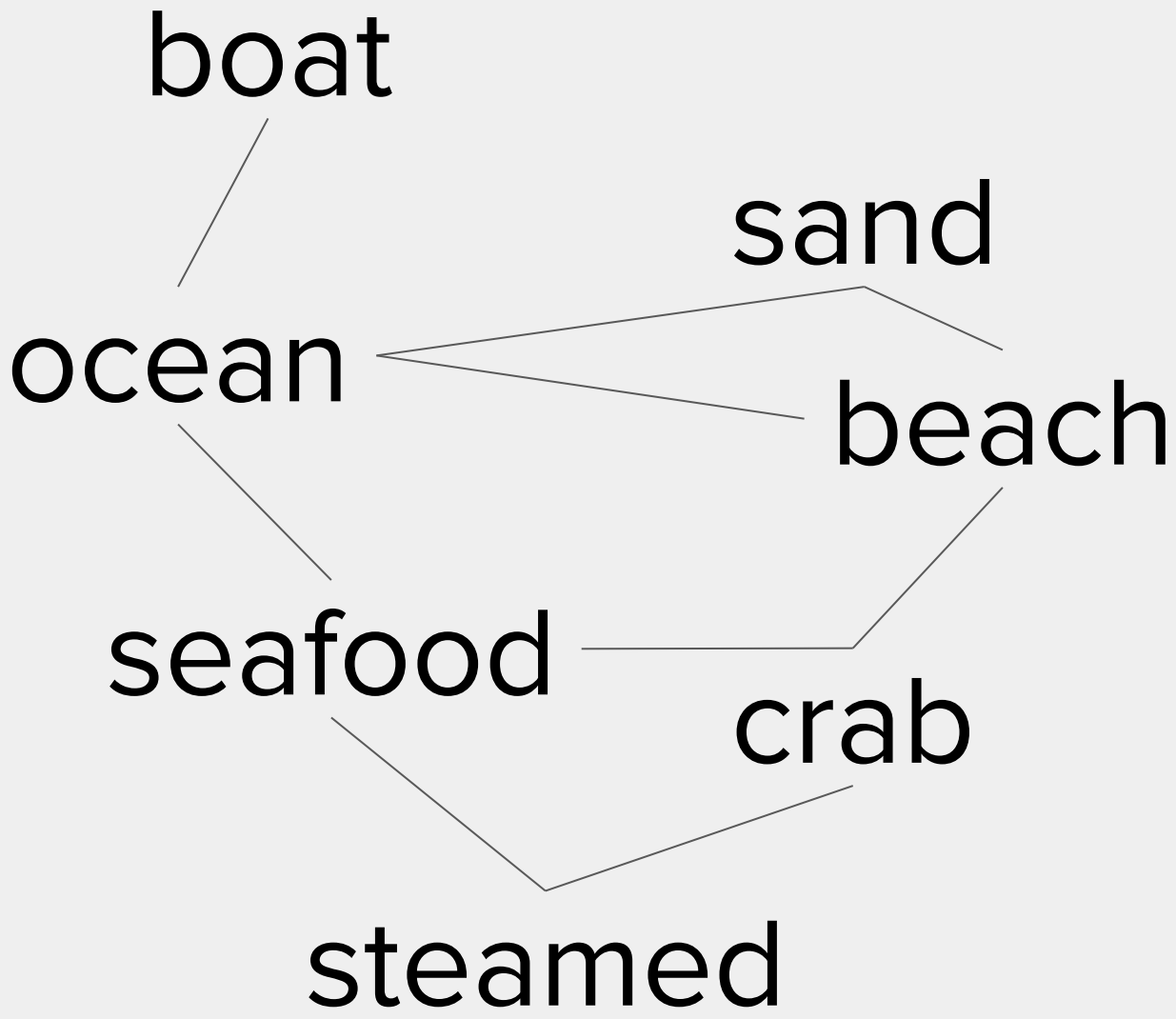
Intuition: Language is Predictable (if flexible)

"There was a ton of traffic on the beltway so I was _____."

"At beach we watched the _____."

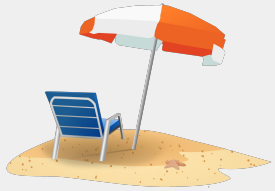
"Watch out for that _____!"

DistrictDataLabs



These models predict relationships between tokens.

DistrictDataLabs



But they can’t understand meaning (yet)

DistrictDataLabs

So please keep in mind:

Tokens != Words

- Substrings
- Only structural
- Data

```
“bearing”
“shouldn’t”
```

- Objects
- Contains a “sense”
- Meaning

```
to bear.verb-1
should.auxverb-3
not.adverb-1
```

The State of the Art

- Academic design for use alongside intelligent agents (AI discipline)
- Relies on formal models or representations of knowledge & language
- Models are adapted and augmented through probabilistic methods and machine learning.
- A small number of algorithms comprise the standard framework.

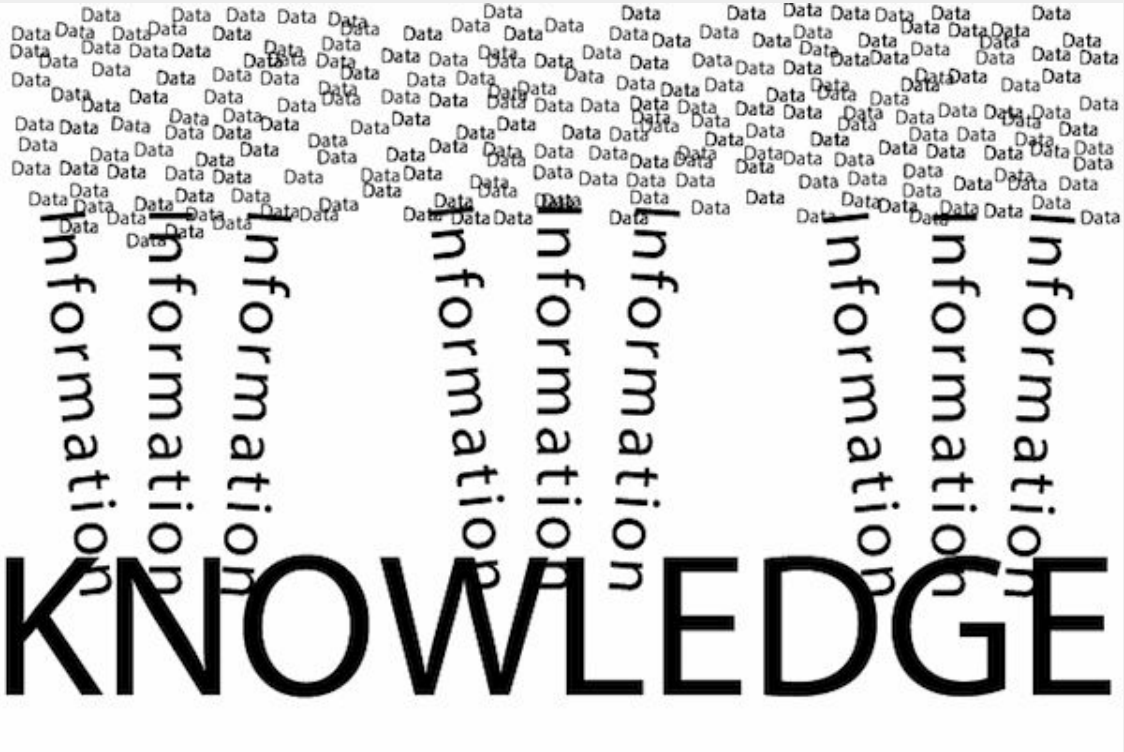
DistrictDataLabs

Traditional NLP Applications

- Summarization
- Reference Resolution
- Machine Translation
- Language Generation
- Language Understanding
- Document Classification
- Author Identification
- Part of Speech Tagging
- Question Answering
- Information Extraction
- Information Retrieval
- Speech Recognition
- Sense Disambiguation
- Topic Recognition
- Relationship Detection
- Named Entity Recognition

DistrictDataLabs

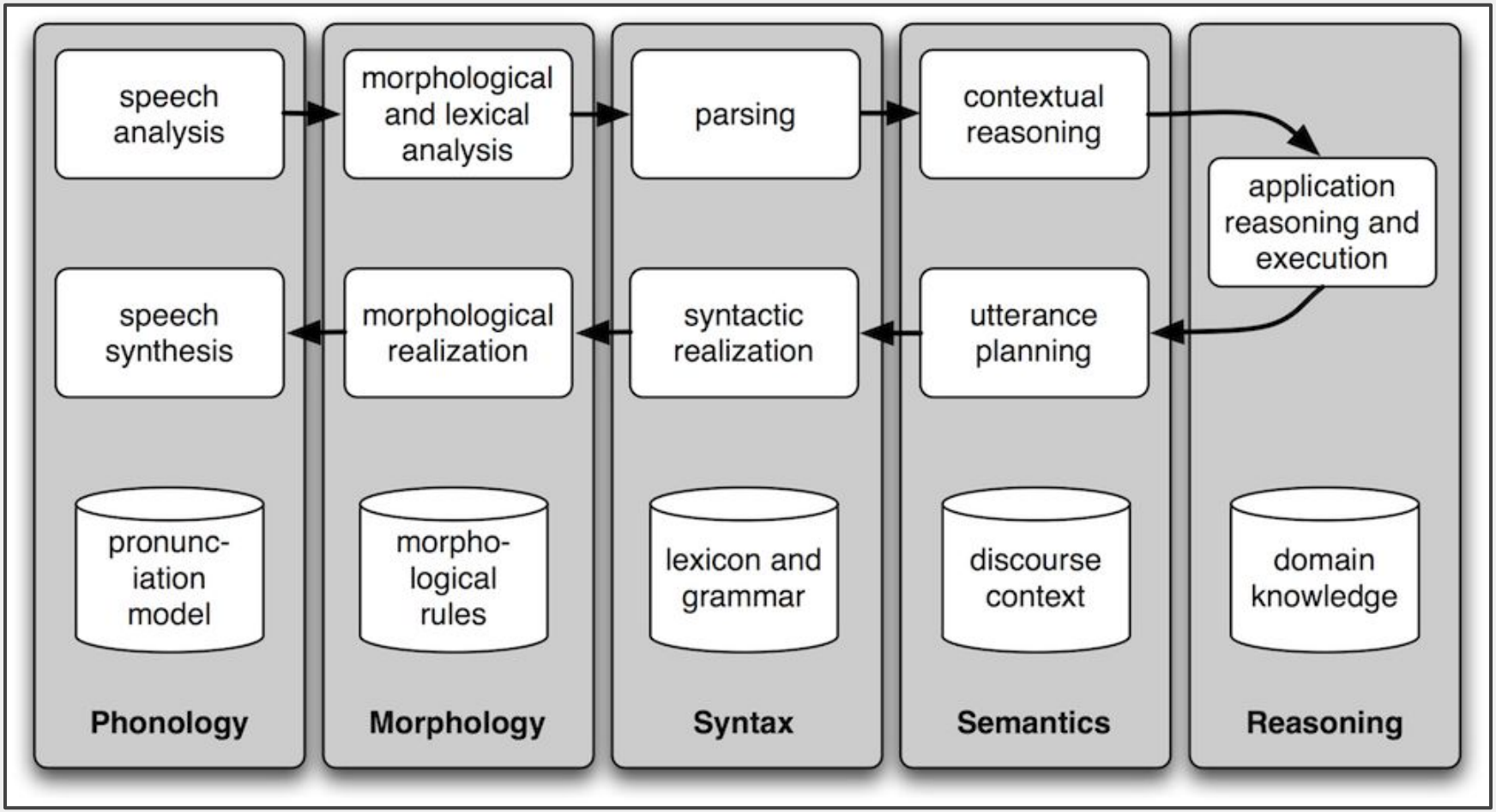
What is Required?



Domain Knowledge

A Corpus in the Domain

DistrictDataLabs



The NLP Pipeline

DistrictDataLabs

Morphology

The study of the forms of things, words in particular.

Consider pluralization for English:

- Orthographic Rules: puppy → puppies
- Morphological Rules: goose → geese or fish

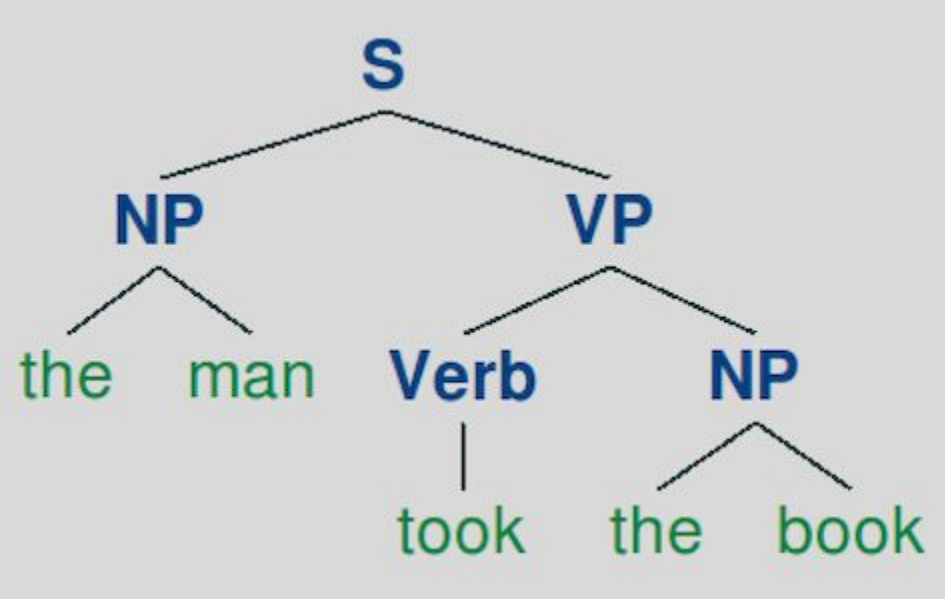
Major parsing tasks:

stemming, lemmatization and tokenization.

DistrictDataLabs

Syntax

The study of the rules for the formation of sentences.



Major tasks:

chunking, parsing, feature parsing, grammars

DistrictDataLabs

Semantics

The study of meaning.

- I see what I eat.
- I eat what I see.
- He poached salmon.

Major Tasks

Frame extraction, creation of TMRs

DistrictDataLabs

“The man hit the building with the baseball bat”

```
{
    "subject": {"text": "the man", "sense": human-agent},
    "predicate": {"text": "hit", "sense": strike-physical-force},
    "object": {"text": "the building", "sense": habitable-structure},
    "instrument": {"text": "with the baseball bat" "sense": sports-equipment}
}
```

Thematic Meaning Representation

DistrictDataLabs

Recent NLP Applications

- Yelp Insights
- Winning Jeopardy! IBM Watson
- Computer assisted medical coding (3M Health Information Systems)
- Geoparsing -- CALVIN (built by Charlie Greenbacker)
- Author Identification (classification/clustering)
- Sentiment Analysis (RTNNs, classification)
- Language Detection
- Event Detection
- Google Knowledge Graph
- Named Entity Recognition and Classification
- Machine Translation

DistrictDataLabs

Applications are BIG data

- Examples are easier to create than rules.
- Rules and logic miss frequency and language dynamics
- More data is better for machine learning, relevance is in the long tail
- Knowledge engineering is not scalable
- Computational linguistics methodologies are stochastic

DistrictDataLabs

The Natural Language Toolkit (NLTK)

DistrictDataLabs

What is NLTK?

- Python interface to over 50 corpora and lexical resources
- Focus on Machine Learning with specific domain knowledge
- Free and Open Source
- Numpy and Scipy under the hood
- Fast and Formal

DistrictDataLabs

What is NLTK?

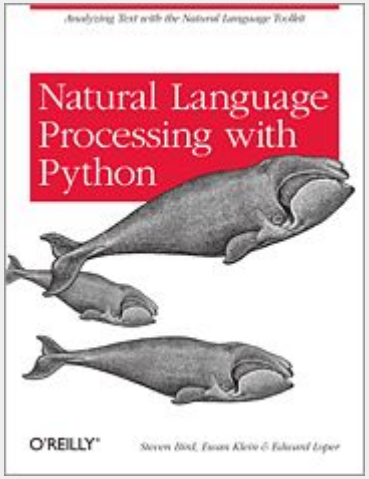
Suite of libraries for a variety of academic text processing tasks:

- tokenization, stemming, tagging,
- chunking, parsing, classification,
- language modeling, logical semantics

Pedagogical resources for teaching NLP theory in Python ...

DistrictDataLabs

Who Wrote NLTK?



Steven Bird

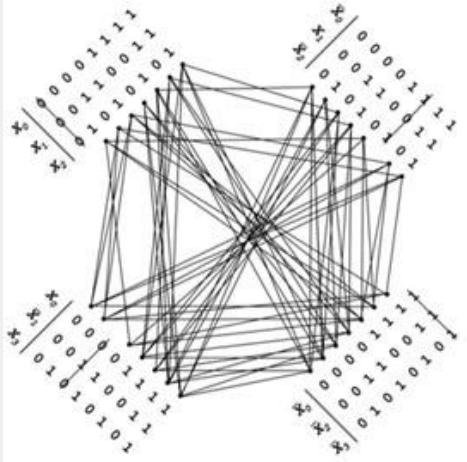
Associate Professor
University of Melbourne
Senior Research Associate, LDC

Ewan Klein

Professor of Language Technology
University of Edinburgh.

DistrictDataLabs

Batteries Included



NLTK = Corpora + Algorithms
Ready for Research!

DistrictDataLabs

What is NLTK not?

- Production ready out of the box*
- Lightweight
- Generally applicable
- Magic

*There are actually a few things that are production ready right out of the box.

DistrictDataLabs

The Good

- Preprocessing
  - segmentation, tokenization, PoS tagging
- Word level processing
  - WordNet, Lemmatization, Stemming, NGram
- Utilities
  - Tree, FreqDist, ConditionalFreqDist
  - Streaming CorpusReader objects
- Classification
  - Maximum Entropy, Naive Bayes, Decision Tree
  - Chunking, Named Entity Recognition
- Parsers Galore!
- Languages Galore!

DistrictDataLabs

The Bad

- Syntactic Parsing
  - No included grammar (not a black box)
- Feature/Dependency Parsing
  - No included feature grammar
- The sem package
  - Toy only (lambda-calculus & first order logic)
- Lots of extra stuff
  - papers, chat programs, alignments, etc.

DistrictDataLabs

Other Python NLP Libraries

- TextBlob
- SpaCy
- Scikit-Learn
- Pattern
- gensim
- MITIE
- guess_language
- Python wrapper for Stanford CoreNLP
- Python wrapper for Berkeley Parser
- readability-lxml
- BeautifulSoup

DistrictDataLabs

NLTK Demo

Working with Text

- Working with Included Corpora
- Segmentation
- Tokenization
- Tagging
- A Parsing Exercise
- Named Entity Recognition

Machine Learning on Text

DistrictDataLabs

Machine learning uses instances (examples) of data to fit a parameterized model which is used to make predictions concerning new instances.

DistrictDataLabs

In text analysis, what are the instances?

DistrictDataLabs

Instances = Documents

(no matter their size)

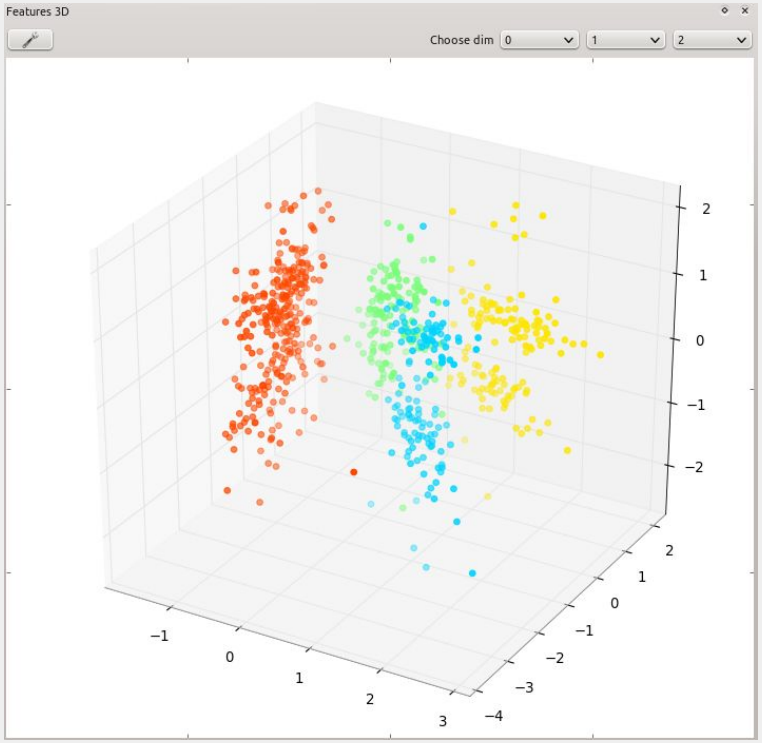
DistrictDataLabs

A corpus is a collection of documents to learn about.

(labeled or unlabeled)

DistrictDataLabs

Features describe instances in a way that machines can learn on by putting them into feature space.



DistrictDataLabs

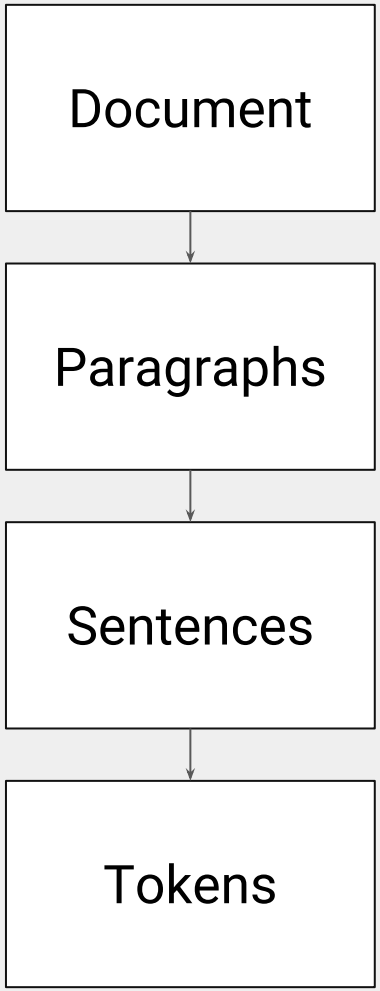
Document Features

Document level features

- Metadata: title, author
- Paragraphs
- Sentence construction

Word level features

- Vocabulary
- Form (capitalization)
- Frequency



DistrictDataLabs

Vector Encoding

- Basic representation of documents: a vector whose length is equal to the vocabulary of the entire corpus.
- Word positions in the vector are based on lexicographic order.

The elephant sneezed at the sight of potatoes.

Bats can see via echolocation. See the bat sight sneeze!

Wondering, she opened the door to the studio.

DistrictDataLabs

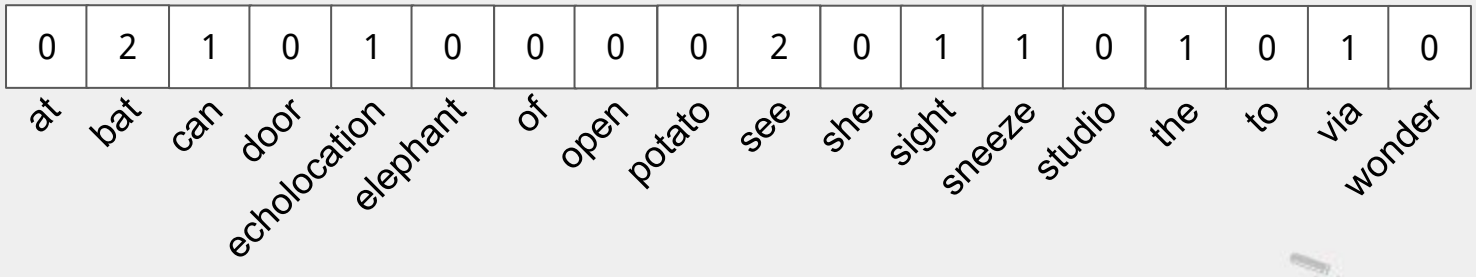
Bag of Words: Token Frequency

- One of the simplest models: compute the frequency of words in the document and use those numbers as the vector encoding.

The elephant sneezed at the sight of potatoes.

Bats can see via echolocation. See the bat sight sneeze!

Wondering, she opened the door to the studio.



DistrictDataLabs

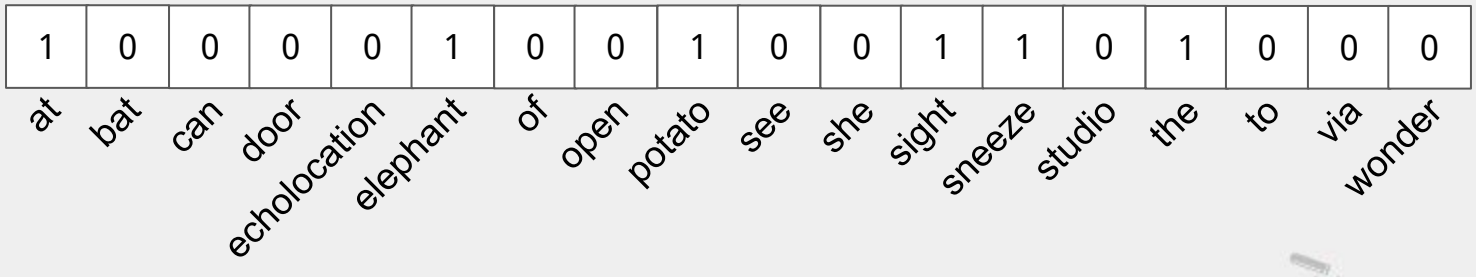
One Hot Encoding

- The feature vector encodes the vocabulary of the document.
- All words are equally distant, so must reduce word forms.
- Usually used for artificial neural network models.

The elephant sneezed at the sight of potatoes.

Bats can see via echolocation. See the bat sight sneeze!

Wondering, she opened the door to the studio.



DistrictDataLabs

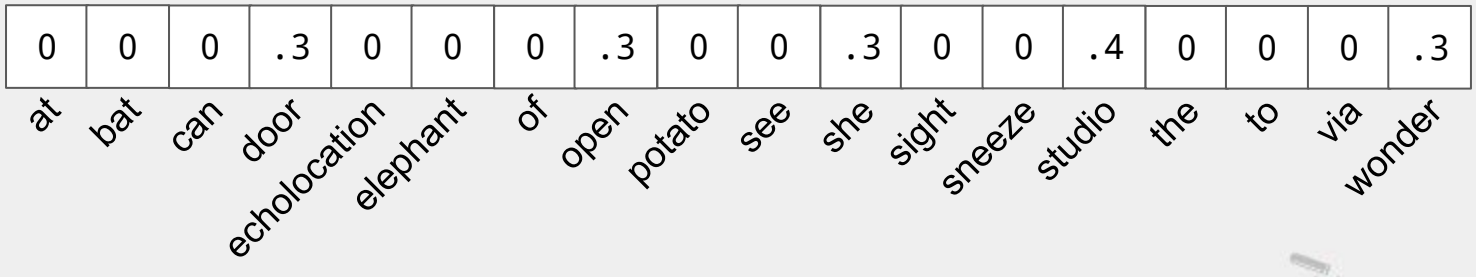
TF-IDF Encoding

- Highlight terms that are very relevant to a document relative to the rest of the corpus by computing the term frequency times the inverse document frequency of the term.

The elephant sneezed at the sight of potatoes.

Bats can see via echolocation. See the bat sight sneeze!

Wondering, she opened the door to the studio.



DistrictDataLabs

Pros and Cons of Vector Encoding

Pros

- Machine learning requires a vector anyway.
- Can embed complex representations like TF-IDF into the vector form.
- Drives towards token-concept mapping without rules.

Cons

- The vectors have lots of columns (high dimension)
- Word order, grammar, and other structural features are natively lost.
- Difficult to add knowledge to learning process.

DistrictDataLabs

In the end, much of the work for language aware applications comes from domain specific feature analysis; not just simple vectorization.

DistrictDataLabs

Classification and Clustering

Classification

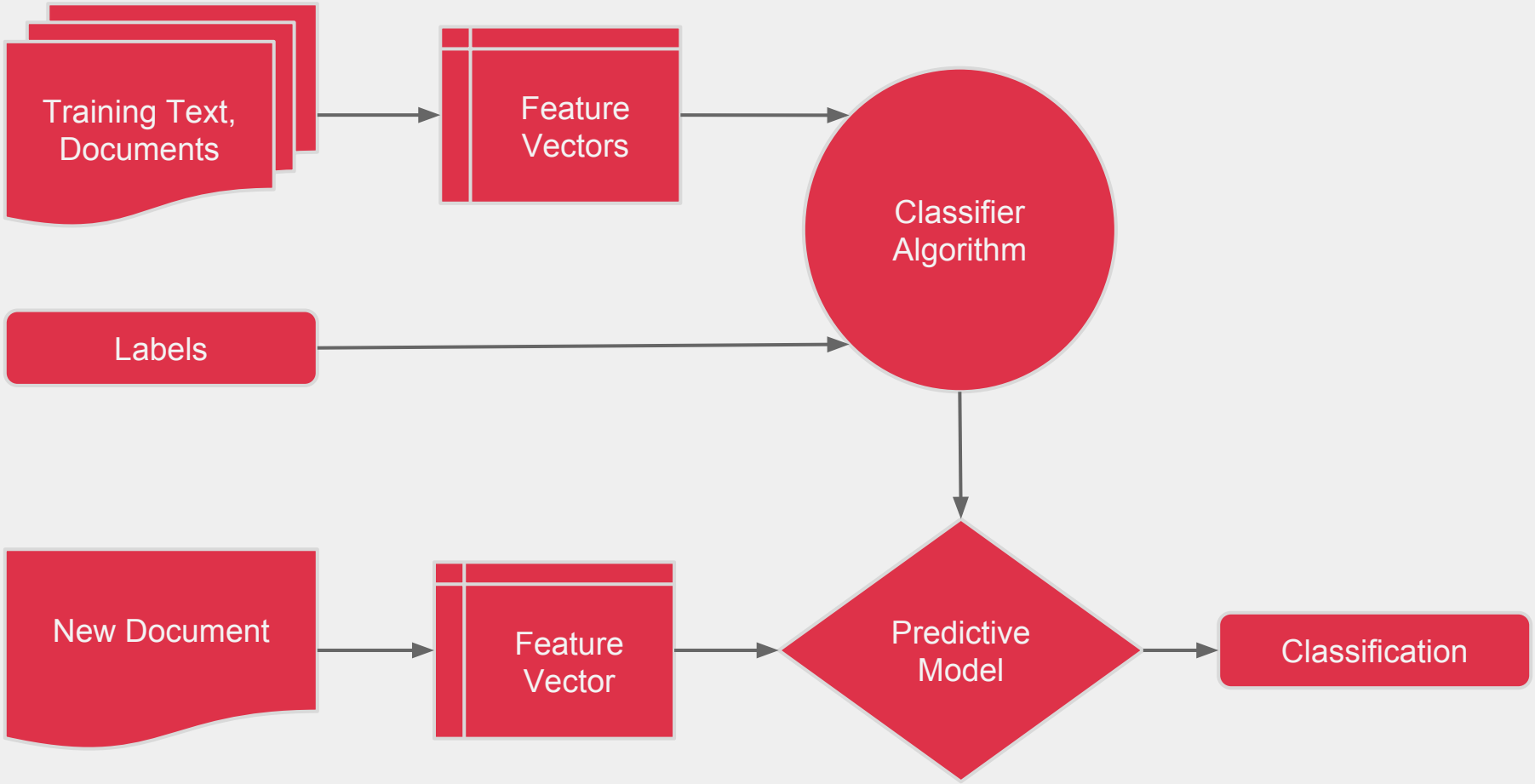
- Supervised ML
- Requires pre-labeled corpus of documents
- Sentiment Analysis
- Models:
  - Naive Bayes
  - Maximum Entropy

Clustering

- Unsupervised ML
- Groups similar documents together.
- Topic Modeling
- Models:
  - LDA
  - NNMF

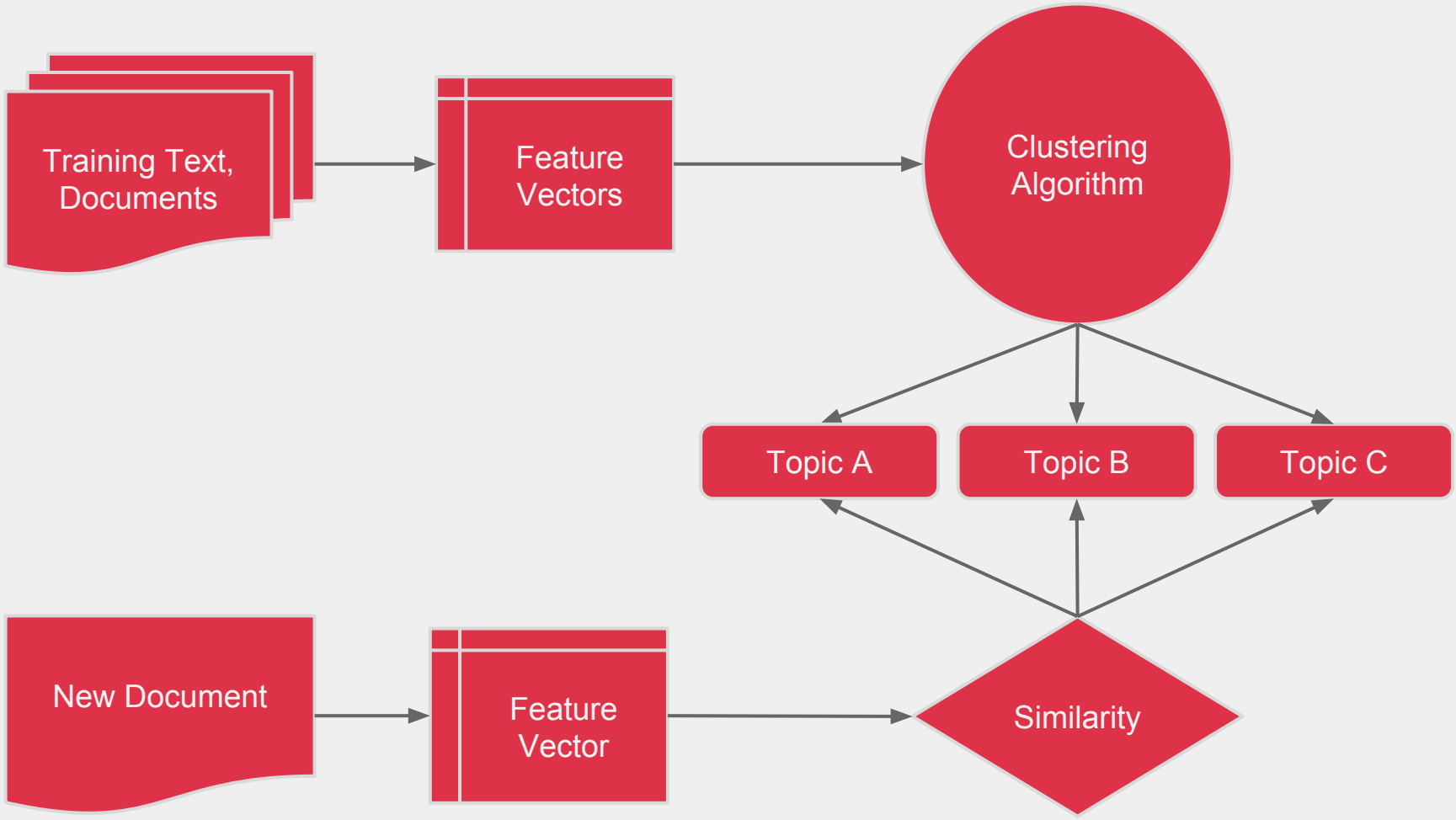
DistrictDataLabs

Classification Pipeline



DistrictDataLabs

Topic Modeling Pipeline



DistrictDataLabs

These two fundamental techniques are the basis of most NLP.

It’s all about designing the problem correctly.

DistrictDataLabs

Consider an automatic question answering system: how might you architect the application?

DistrictDataLabs

Production Grade NLP

NLTK
TextBlob

- Access to LDA model
- Good TF-IDF Modeling
- Use word2vec

- Text processing
- Lexical resources
- Access to WordNet

- More model families
- Faster implementations
- Pipelines for NLP

Our Task

Build a system that ingests raw language data and transforms it into a suitable representation for creating revolutionary applications.

DistrictDataLabs

Workshop

Building language aware data products

- Reading corpora for analysis
- Feature Extraction
- Document Classification
- Topic Modeling (Clustering)