Unstructured Data

Professor Widom's Instructional Odyssey

www.professorwidom.org

Stanford University

Google

INSTABASE

Google Cloud Platform

Association for Computing Machinery

Very Large Data Bases Endowment Inc.

amazon web services™

Data Tools and Techniques

- Basic Data Manipulation and Analysis
  - Performing well-defined computations or asking well-defined questions ("queries")
- Data Mining
  - Looking for patterns in data
- Machine Learning
  - Using data to make inferences or predictions
- Data Visualization
  - Graphical depiction of data
- Data Collection and Preparation

Over "unstructured" data (text, images, video)

Analyzing Text

- Much of the world's data is in the form of free-text
- Different sizes of text elements
  - Small – tweets
  - Medium – emails, product reviews
  - Large – documents
  - Very large – books
- Different sizes of text corpuses
  - Ultimate text corpus: the web

Types of Text Processing

1. Search "Text analytics", "Text mining"
   - For specific words, phrases, patterns
   - Find common patterns, phrase completions
2. Understand "Natural language processing/understanding"
   - Parts of speech, parse trees
   - Entity recognition – people, places, organizations
   - Disambiguation - "ford", "jaguar"
   - Sentiment analysis - happy, sad, angry, …

Applications of Text Analytics / NLP

- Search engines
- Spam classification
- News feed management
- Document summarization
- Language translation
- Speech-to-text
- Generative AI
- Many, many more …

"Information Retrieval"

- Long-standing subfield of computer science
  Since the 1950's!
- Goal: retrieve information (typically text) that matches a search (typically words or phrases)
  1. Text corpus usually too large to scan
  2. Return most relevant answers first

Seem familiar?

- Some techniques and tools
  - Inverted indices
  - N-grams
  - TF-IDF
  - Regular expressions

Inverted Indices

Goal: Find all documents in a corpus containing a specific word (e.g., web search)

- Impossible to scan all documents for the word
- Scan the corpus in advance to build an "inverted index"; keep it up-to-date as content changes

Word	Document IDs
the	1, 2, 3, 5, 7, 8, 9, …
quick	2, 5, 7, 13, …
brown	1, 2, 7, 16, 17, …
fox	7, 9, 11, 13, …
jumped	3, 4, 6, 7, …
…	…

N-grams

Goal: Find all documents in a corpus containing a specific *phrase* (e.g., web search)

- Cannot create inverted index for all phrases
- Create indexes of "n-grams" – phrases of length n

3-gram	Document IDs
the quick brown	2, 7, 15, 23, …
fox jumped over	7, 23, 35 …
the lazy dog	23, 35, 87, 88, …
over the lazy	5, 9, 23, 88, …
…	…

- Note: index on previous slide was 1-grams
- Also helps with longer phrases

N-grams

N-gram frequency counts – typically over entire text corpus or language, useful for:

- Search auto-completion, spelling correction
- Summarization
- Speech recognition, machine translation, generative AI

3-gram	Frequency
quick brown fox	1500
quick brown dog	800
…	…
the lazy dog	2500
the lazy person	50
…	…

TF-IDF

Goal: estimate how important a given keyword is to a document (e.g., for keyword search ranking)

1. Use word frequency in the document:

   "tree" occurs very frequently

   "cheetah" occurs much less frequently

   - "tree" is an important word, "cheetah" less so

2. Incorporate word specialization:

   TF-IDF = Term Frequency / Document Frequency

   (IDF = "Inverse Document Frequency")

TF-IDF

TF-IDF = Term Frequency / Document Frequency

Term frequency: # occurrences in document

Document frequency: # documents with at least one occurrence

- Ex: "tree" occurs 50 times in document, occurs in 1000 documents in corpus: TF-IDF = .05
- Ex: "cheetah" occurs 10 times in document, occurs in 30 documents in corpus: TF-IDF = .33

Words with very high document and term frequency are typically "stopwords" (*and*, *at*, *but*, *if*, *that*, *the*, …), often excluded from text analysis

Regular Expressions

Goal: Search for text that matches a certain pattern

Sample of regular expression constructs:

regular expression	matches
.	any single character
exp ?	zero or one instances of *exp*
exp *	zero or more instances of *exp*
exp +	one or more instances of *exp*
(exp_1 | exp_2)	either exp_1 or exp_2

May be composed for arbitrarily complex expressions

Regular Expressions

regular expression	matches
.	any single character
exp ?	zero or one instances of *exp*
exp *	zero or more instances of *exp*
exp +	one or more instances of *exp*
exp_1 | exp_2	either exp_1 or exp_2

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Precision and Recall

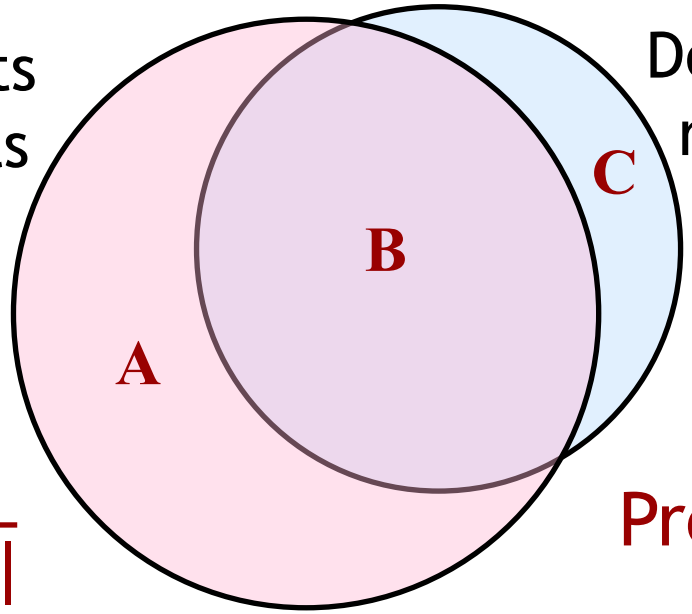
Measures of correctness or quality of results:

- Basic data analysis → expect the correct answer
- Data mining → results based on support and confidence thresholds
- Machine learning → accuracy of predicted values or labels (average error, percent correct)
- Text and image analysis → precision and recall

Precision and Recall

- Example
  - Search for documents about cats
  - Assume "ground truth" – every document is either about cats or it's not
- *Precision:* Fraction of returned documents that are actually about cats
- *Recall:* Fraction of documents about cats in the corpus that are returned by the search

Precision and Recall



$$\text{Recall} = \frac{|B|}{|A + B|}$$

$$\text{Precision} = \frac{|B|}{|B + C|}$$

- Return one correct document → 100% precision
- Return all documents → 100% recall
- ➢ Challenge is to achieve high values for both
- More complex when results are ranked

Hands-On Text Analysis

- Dataset
  - Wine descriptions (200, 10K)
- Python packages
  - Regular expressions (re)
  - Natural Language Toolkit (nltk)
- Text-scanning style only – no indices

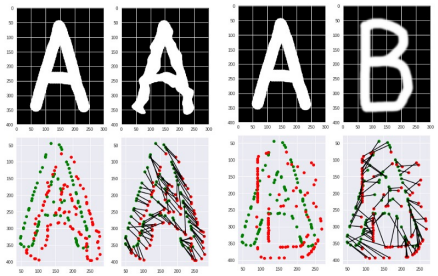
Image Analysis

- Find images in a corpus based on specification
  - E.g., color, shape, object, focus
- Rank images based on specification
- Classify or label images

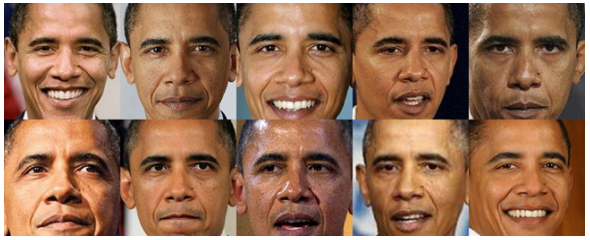
Image Analysis: Progression

First approach
- human labeling

Second approach
- shape recognition



Third approach
- machine learning



Video Analysis

- Video = series of images + audio stream
- Video search can take different forms
  - Like image search (colors, shapes, objects) but with added time element
  - Like text search over audio stream
  - Combine the two

  Find all videos with people in more than 50% of the frames and occurrences of both "Stanford" and "MIT" in the audio track

Hands-on Image Analysis

- Dataset
  - 206 country flags



- Simple image-by-image color analysis
  - All images are a grid of pixels - e.g., 200 x 200
  - Each pixel is one color
  - Color represented as RGB [0-255,0-255,0-255]
- Python package
  - Python Imaging Library (PIL)
  - Newer version "Pillow"

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