

Sequencing Legal DNA: NLP for Law and Political Economy

2. Tokenization

Instructions before we begin:

- (1) Turn on video and set audio to mute
- (2) In Participants panel, set zoom name to "Full Name, School / Degree"
(ex: "Leon Smith, ETH Data Science Msc")
- (3) If this is your first lecture, say "hi" in the chat

Online Lecture Norms

Let's make the most of online learning!

- ▶ Live attendance at lectures is required.
- ▶ Keep video on if connection allows.
- ▶ Stay muted when not talking.
- ▶ To make questions or comments, use the “raise hand” function.

Homework

- ▶ First homework is due tomorrow by midnight.
- ▶ Submit on EduFlow (reachable from moodle, link will be on syllabus).

TA Session

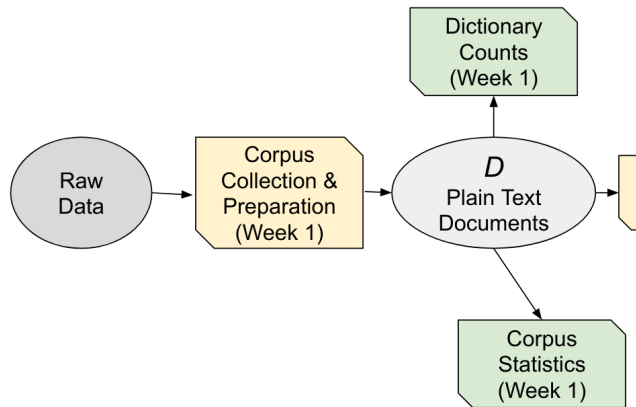
- ▶ Any feedback on the first TA session?
 - ▶ video is linked on syllabus.
- ▶ Second TA session is this Friday, 1230h-1330h
 - ▶ go over week 1 homework
 - ▶ go over week 2 notebook
 - ▶ can ask questions in advance using TA Q&A page (on syllabus).

Final Assignment Info

- ▶ For those not doing a project, there is a final assignment distributed a week or two after class ends.
 - ▶ Questions will be based on the slides and some new readings.
 - ▶ You will have three days to do it.
 - ▶ Will distribute practice questions beforehand.

<http://bit.ly/NLP-QA02>

Last Week



Practice with Dictionary Methods

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

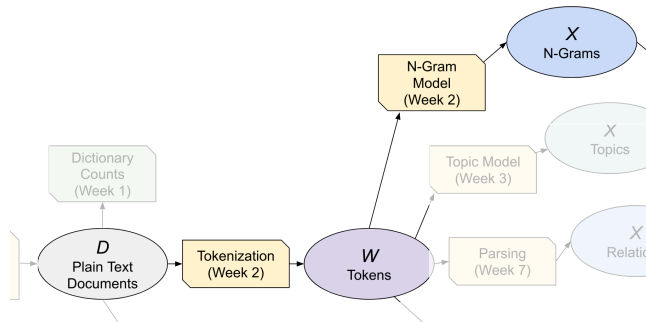
N-Grams

Parts of Speech

Applications

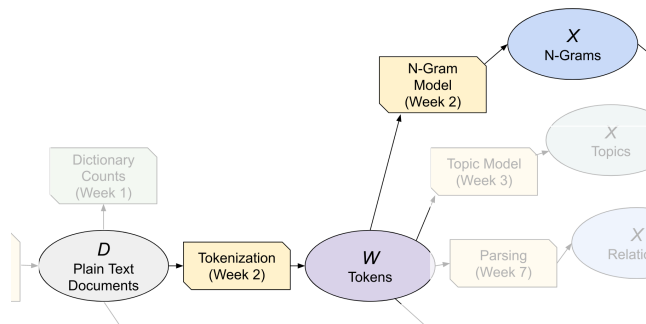
Appendix on Course Projects

Today



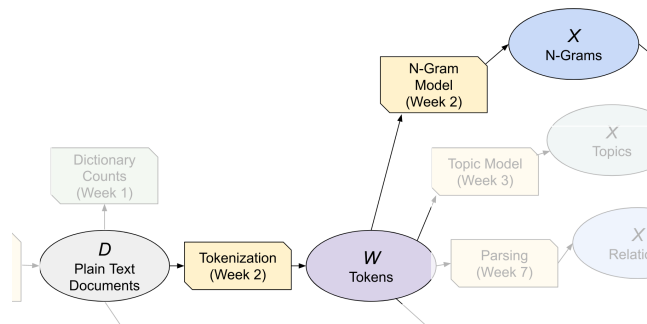
- Input:
 - A set of documents (e.g. text files), D .

Today



- ▶ Input:
 - ▶ A set of documents (e.g. text files), D .
- ▶ Output (tokens):
 - ▶ A sequence, W , containing a list of tokens – words or word pieces for use in natural language processing

Today



- ▶ Input:
 - ▶ A set of documents (e.g. text files), D .
- ▶ Output (tokens):
 - ▶ A sequence, W , containing a list of tokens – words or word pieces for use in natural language processing
- ▶ Output (n-grams):
 - ▶ A matrix, X , containing statistics about word/phrase frequencies in those documents.

Goals of Tokenization

To summarize: A major goal of tokenization is to produce features that are

- ▶ **predictive** in the learning task
- ▶ **interpretable** by human investigators
- ▶ **tractable** enough to be easy to work with

Goals of Tokenization

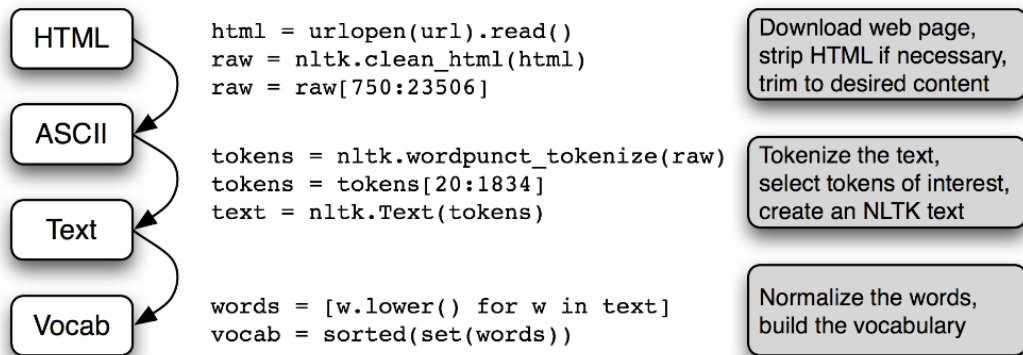
To summarize: A major goal of tokenization is to produce features that are

- ▶ **predictive** in the learning task
- ▶ **interpretable** by human investigators
- ▶ **tractable** enough to be easy to work with

Two broad approaches:

1. convert documents to vectors, usually frequency distributions over pre-processed n-grams.
2. convert documents to sequences of tokens, for inputs to sequential models.

A Standard Tokenization Pipeline



Source: NLTK Book, Chapter 3.

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

N-Grams

Parts of Speech

Applications

Appendix on Course Projects

Segmenting paragraphs/sentences

- ▶ Many tasks should be done on sentences, rather than corpora as a whole.
 - ▶ NLTK and spaCy do a good (but not perfect) job of splitting sentences, while accounting for periods on abbreviations, etc.
 - ▶ spaCy is slower but significantly better.

Segmenting paragraphs/sentences

- ▶ Many tasks should be done on sentences, rather than corpora as a whole.
 - ▶ NLTK and spaCy do a good (but not perfect) job of splitting sentences, while accounting for periods on abbreviations, etc.
 - ▶ spaCy is slower but significantly better.
- ▶ There isn't a grammar-based paragraph tokenizer.
 - ▶ most corpora have new paragraphs annotated.
 - ▶ or use line breaks.

Pre-processing

- ▶ An important piece of the “art” of text analysis is deciding what data to throw out.
 - ▶ Uninformative data add noise and reduce statistical precision.
 - ▶ They are also computationally costly.

Pre-processing

- ▶ An important piece of the “art” of text analysis is deciding what data to throw out.
 - ▶ Uninformative data add noise and reduce statistical precision.
 - ▶ They are also computationally costly.
- ▶ Pre-processing choices can affect down-stream results, especially in unsupervised learning tasks (Denny and Spirling 2017).
 - ▶ some features are more interpretable: “judge has” / “has discretion” vs “judge has discretion”.

Capitalization

- ▶ Removing capitalization is a standard corpus normalization technique
 - ▶ usually the capitalized/non-capitalized version of a word are equivalent – e.g. words showing up capitalized at beginning of sentence
 - ▶ → capitalization not informative.

Capitalization

- ▶ Removing capitalization is a standard corpus normalization technique
 - ▶ usually the capitalized/non-capitalized version of a word are equivalent – e.g. words showing up capitalized at beginning of sentence
 - ▶ → capitalization not informative.
- ▶ Also: what about “the first amendment” versus “the First Amendment”?

Capitalization

- ▶ Removing capitalization is a standard corpus normalization technique
 - ▶ usually the capitalized/non-capitalized version of a word are equivalent – e.g. words showing up capitalized at beginning of sentence
 - ▶ → capitalization not informative.
- ▶ Also: what about “the first amendment” versus “the First Amendment”?
 - ▶ Compromise: include capitalized version of words not at beginning of sentence.

Capitalization

- ▶ Removing capitalization is a standard corpus normalization technique
 - ▶ usually the capitalized/non-capitalized version of a word are equivalent – e.g. words showing up capitalized at beginning of sentence
 - ▶ → capitalization not informative.
- ▶ Also: what about “the first amendment” versus “the First Amendment”?
 - ▶ Compromise: include capitalized version of words not at beginning of sentence.
- ▶ For some tasks, capitalization is important
 - ▶ needed for sentence splitting, part-of-speech tagging, syntactic parsing, and semantic role labeling.

Capitalization

- ▶ Removing capitalization is a standard corpus normalization technique
 - ▶ usually the capitalized/non-capitalized version of a word are equivalent – e.g. words showing up capitalized at beginning of sentence
 - ▶ → capitalization not informative.
- ▶ Also: what about “the first amendment” versus “the First Amendment”?
 - ▶ Compromise: include capitalized version of words not at beginning of sentence.
- ▶ For some tasks, capitalization is important
 - ▶ needed for sentence splitting, part-of-speech tagging, syntactic parsing, and semantic role labeling.
 - ▶ For sequence data, e.g. language modeling – huggingface tokenizer takes out capitalization but then add a special “capitalized” token before the word.

Punctuation

Let's eat grandpa.
Let's eat, grandpa.

**correct punctuation can
save a person`s life.**

Source: Chris Bail text data slides.

Inclusion of punctuation depends on your task:

Let's eat grandpa.
Let's eat, grandpa.

**correct punctuation can
save a person's life.**

Source: Chris Bail text data slides.

Inclusion of punctuation depends on your task:

- ▶ if you are vectorizing the document as a bag of words or bag of n-grams, punctuation won't be needed.

Let's eat grandpa.
Let's eat, grandpa.

**correct punctuation can
save a person`s life.**

Source: Chris Bail text data slides.

Inclusion of punctuation depends on your task:

- ▶ if you are vectorizing the document as a bag of words or bag of n-grams, punctuation won't be needed.
- ▶ frequency of exclamation points “!” indicates emotion and question marks “?” indicates curiosity.

Let's eat grandpa.
Let's eat, grandpa.

**correct punctuation can
save a person's life.**

Source: Chris Bail text data slides.

Inclusion of punctuation depends on your task:

- ▶ if you are vectorizing the document as a bag of words or bag of n-grams, punctuation won't be needed.
- ▶ frequency of exclamation points “!” indicates emotion and question marks “?” indicates curiosity.
- ▶ like capitalization, punctuation is needed for annotations (sentence splitting, parts of speech, syntax, roles, etc)
 - ▶ also needed for language models.

Numbers

- ▶ for classification using bag of words:
 - ▶ can drop numbers, or replace with special characters

Numbers

- ▶ for classification using bag of words:
 - ▶ can drop numbers, or replace with special characters
- ▶ for language models:
 - ▶ just treat them like letters.
 - ▶ GPT-3 can solve math problems.

Drop Stopwords?

a	an	and	are	as	at	be	by	for	from
has	he	in	is	it	its	of	on	that	the
to	was	were	will	with					

Drop Stopwords?

a an and are as at be by for from
has he in is it its of on that the
to was were will with

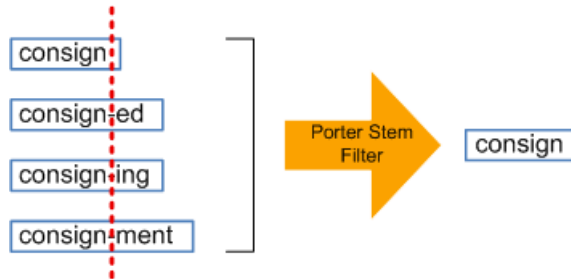
- ▶ What about “not guilty”?
- ▶ Legal “memes” often contain stopwords:
 - ▶ “beyond a reasonable doubt”
 - ▶ “with all deliberate speed”

Drop Stopwords?

a an and are as at be by for from
has he in is it its of on that the
to was were will with

- ▶ What about “not guilty”?
- ▶ Legal “memes” often contain stopwords:
 - ▶ “beyond a reasonable doubt”
 - ▶ “with all deliberate speed”
- ▶ can drop stopwords by themselves, but keep them as part of phrases.
- ▶ can filter out words and phrases using part-of-speech tags (later).

Stemming/lemmatizing



- ▶ Effective dimension reduction with little loss of information.
- ▶ Lemmatizer produces real words, but N-grams won't make grammatical sense
 - ▶ e.g., "judges have been ruling" would become "judge have be rule"

Tokens

The most basic unit of representation in a text.

- ▶ characters: can represent documents as sequence of individual letters {h,e,l,l,o,
,w,o,r,l,d}

Tokens

The most basic unit of representation in a text.

- ▶ characters: can represent documents as sequence of individual letters {h,e,l,l,o, ,w,o,r,l,d}
- ▶ words: split on white space {hello, world}

Tokens

The most basic unit of representation in a text.

- ▶ characters: can represent documents as sequence of individual letters {h,e,l,l,o, ,w,o,r,l,d}
- ▶ words: split on white space {hello, world}
- ▶ n-grams: learn a vocabulary of phrases and tokenize those: “ETH Zurich → ETH_Zurich”

Tokens

The most basic unit of representation in a text.

- ▶ characters: can represent documents as sequence of individual letters {h,e,l,l,o, ,w,o,r,l,d}
- ▶ words: split on white space {hello, world}
- ▶ n-grams: learn a vocabulary of phrases and tokenize those: “ETH Zurich → ETH_Zurich”
- ▶ what else?

Sub-Word Units

- ▶ The standard tokenization approach in deep learning (i.e. language models) uses sub-word information.
- ▶ Tokenizers like **SentencePiece** do tokenizing at the character level, with white space and punctuation treated equivalently to alphanumeric characters.
 - ▶ requires lots of data/compute but learns word endings etc
- ▶ We will come back to this starting week 5.

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

N-Grams

Parts of Speech

Applications

Appendix on Course Projects

Bag-of-words representation

Say we want to convert a corpus D to a matrix X :

- ▶ In the “bag-of-words” representation, a row of X is just the frequency distribution over words in the document corresponding to that row.

Counts and frequencies

- ▶ **Document counts:** number of documents where a token appears.
- ▶ **Term counts:** number of total appearances of a token in corpus.

Counts and frequencies

- ▶ **Document counts:** number of documents where a token appears.
- ▶ **Term counts:** number of total appearances of a token in corpus.
- ▶ **Term frequency:**

$$\text{Term Frequency of } w \text{ in document } k = \frac{\text{Count of } w \text{ in document } k}{\text{Total tokens in document } k}$$

Building a vocabulary

- ▶ An important featurization step is to build a vocabulary of words:
 - ▶ Compute document frequencies for all words
 - ▶ Inspect low-frequency words and determine a minimum document threshold.
 - ▶ e.g., 10 documents, or .25% of documents.

Building a vocabulary

- ▶ An important featurization step is to build a vocabulary of words:
 - ▶ Compute document frequencies for all words
 - ▶ Inspect low-frequency words and determine a minimum document threshold.
 - ▶ e.g., 10 documents, or .25% of documents.
- ▶ Can also impose more complex thresholds, e.g.:
 - ▶ appears twice in at least 20 documents
 - ▶ appears in at least 3 documents in at least 5 years

Building a vocabulary

- ▶ An important featurization step is to build a vocabulary of words:
 - ▶ Compute document frequencies for all words
 - ▶ Inspect low-frequency words and determine a minimum document threshold.
 - ▶ e.g., 10 documents, or .25% of documents.
- ▶ Can also impose more complex thresholds, e.g.:
 - ▶ appears twice in at least 20 documents
 - ▶ appears in at least 3 documents in at least 5 years
- ▶ Assign numerical identifiers to tokens to increase speed and reduce disk usage.

TF-IDF Weighting

- ▶ TF/IDF: “Term-Frequency / Inverse-Document-Frequency.”
- ▶ The formula for word w in document k :

$$\underbrace{\frac{\text{Count of } w \text{ in } k}{\text{Total word count of } k}}_{\text{Term Frequency}} \times \log\left(\underbrace{\frac{\text{Number of documents in } D}{\text{Count of documents containing } w}}_{\text{Inverse Document Frequency}}\right)$$

TF-IDF Weighting

- ▶ TF/IDF: “Term-Frequency / Inverse-Document-Frequency.”
- ▶ The formula for word w in document k :

$$\underbrace{\frac{\text{Count of } w \text{ in } k}{\text{Total word count of } k}}_{\text{Term Frequency}} \times \log\left(\underbrace{\frac{\text{Number of documents in } D}{\text{Count of documents containing } w}}_{\text{Inverse Document Frequency}}\right)$$

- ▶ The formula up-weights relatively rare words that do not appear in all documents.
 - ▶ These words are probably more distinctive of topics or differences between documents.
 - ▶ Example: A document contains 100 words, and the word appears 3 times in the document. The TF is .03. The corpus has 100 documents, and the word appears in 10 documents. the IDF is $\log(100/10) \approx 2.3$, so the TF-IDF for this document is $.03 \times 2.3 = .07$. Say the word appears in 90 out of 100 documents: Then the IDF is 0.105, with TF-IDF for this document equal to .003.

Other Transformations

- ▶ Kelly et al (2019) suggest that including indicators for whether a phrase appears in a document (rather than the count) is often independently predictive.

Other Transformations

- ▶ Kelly et al (2019) suggest that including indicators for whether a phrase appears in a document (rather than the count) is often independently predictive.
- ▶ Could add log counts, quadratics in counts, etc.
- ▶ Could also add pairwise interactions between word counts/frequencies.

Other Transformations

- ▶ Kelly et al (2019) suggest that including indicators for whether a phrase appears in a document (rather than the count) is often independently predictive.
- ▶ Could add log counts, quadratics in counts, etc.
- ▶ Could also add pairwise interactions between word counts/frequencies.
- ▶ These often are not done much because of the dimensionality problem.

Other Transformations

- ▶ Kelly et al (2019) suggest that including indicators for whether a phrase appears in a document (rather than the count) is often independently predictive.
- ▶ Could add log counts, quadratics in counts, etc.
- ▶ Could also add pairwise interactions between word counts/frequencies.
- ▶ These often are not done much because of the dimensionality problem.
 - ▶ could use feature selection or principal components to deal with that.

Other Transformations

- ▶ Kelly et al (2019) suggest that including indicators for whether a phrase appears in a document (rather than the count) is often independently predictive.
- ▶ Could add log counts, quadratics in counts, etc.
- ▶ Could also add pairwise interactions between word counts/frequencies.
- ▶ These often are not done much because of the dimensionality problem.
 - ▶ could use feature selection or principal components to deal with that.
 - ▶ for machine learning, could use SVM with a polynomial kernel.

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

N-Grams

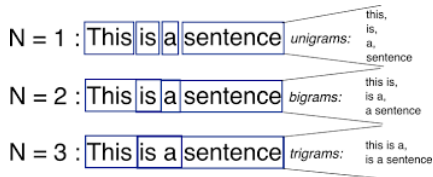
Parts of Speech

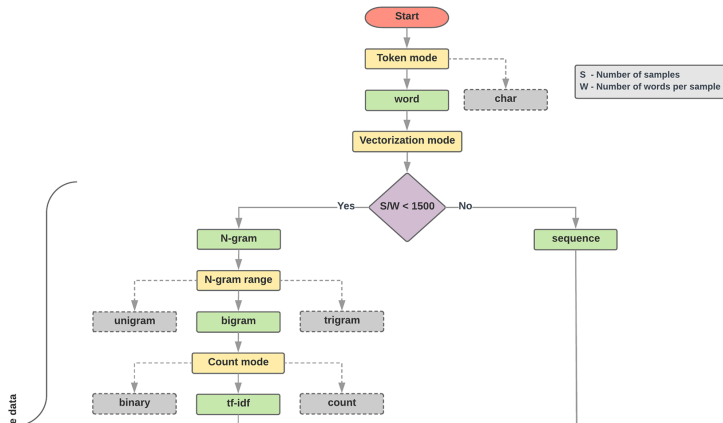
Applications

Appendix on Course Projects

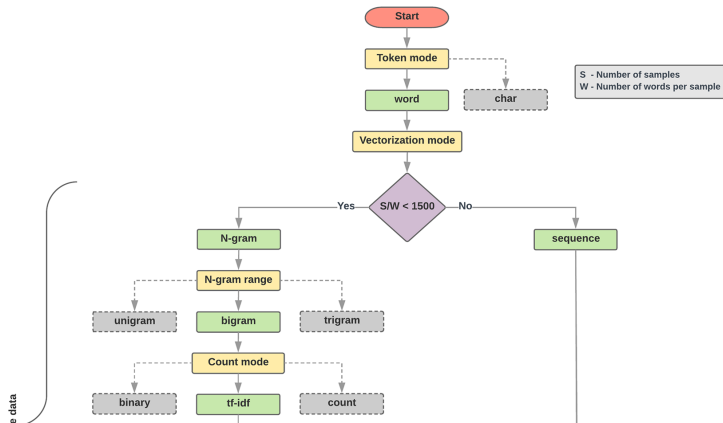
What are N-grams

- ▶ N-grams are phrases, sequences of words up to length N .
 - ▶ bigrams, trigrams, quadgrams, etc.





- ▶ Google Developers recommend **tf-idf-weighted bigrams** as a baseline specification for text classification tasks.
 - ▶ ideal for fewer, longer documents.



- ▶ Google Developers recommend **tf-idf-weighted bigrams** as a baseline specification for text classification tasks.
 - ▶ ideal for fewer, longer documents.
- ▶ With more numerous, shorter documents (rows / doclength > 1500), better to use an embedded sequence (starting Week 5).

N-grams and high dimensionality

- ▶ N-grams will blow up your feature space:
 - ▶ filtering out uninformative n-grams is necessary.

N-grams and high dimensionality

- ▶ N-grams will blow up your feature space:
 - ▶ filtering out uninformative n-grams is necessary.
- ▶ Google Developers say that a feature space with $P = 20,000$ will work well for descriptive and prediction tasks.
 - ▶ I have gotten good performance with 10K or even 2K features.
 - ▶ For supervised learning tasks, a decent baseline is to build a vocabulary of 60K, then use feature selection to get down to 10K.

Feature selection using univariate comparisons

- ▶ χ^2 is a very fast feature selection routine for classification tasks
 - ▶ features must be non-negative
 - ▶ works on sparse matrices
 - ▶ works on multi-class problems

Feature selection using univariate comparisons

- ▶ χ^2 is a very fast feature selection routine for classification tasks
 - ▶ features must be non-negative
 - ▶ works on sparse matrices
 - ▶ works on multi-class problems
- ▶ With negative predictors:
 - ▶ use `f_classif`.

Feature selection using univariate comparisons

- ▶ χ^2 is a very fast feature selection routine for classification tasks
 - ▶ features must be non-negative
 - ▶ works on sparse matrices
 - ▶ works on multi-class problems
- ▶ With negative predictors:
 - ▶ use `f_classif`.
- ▶ For regression tasks:
 - ▶ use `f_regression` or OLS coefficients.

De-Meaning or Residualizing Variables

- ▶ For `f_classif` and `f_regression`, can de-mean predictors by groups, for example by year or location.
 - ▶ purges correlated information and can help model generalize to new years/locations.
 - ▶ for regression, can also de-mean the outcome.

De-Meaning or Residualizing Variables

- ▶ For `f_classif` and `f_regression`, can de-mean predictors by groups, for example by year or location.
 - ▶ purges correlated information and can help model generalize to new years/locations.
 - ▶ for regression, can also de-mean the outcome.
- ▶ What if you want to de-mean by both year and location?
 - ▶ → take residuals from OLS regression of each variable (outcome and predictor) on the category dummies.

De-Meaning or Residualizing Variables

- ▶ For `f_classif` and `f_regression`, can de-mean predictors by groups, for example by year or location.
 - ▶ purges correlated information and can help model generalize to new years/locations.
 - ▶ for regression, can also de-mean the outcome.
- ▶ What if you want to de-mean by both year and location?
 - ▶ → take residuals from OLS regression of each variable (outcome and predictor) on the category dummies.
- ▶ That is:
 - ▶ regress $Y_i = FE_1 + FE_2 + \epsilon_i$ and $x_i^w = FE_1 + FE_2 + \epsilon_i, \forall w$,
 - ▶ take residuals $\tilde{Y}_i = Y_i - \hat{Y}_i$ and $\tilde{x}_i^w = x_i^w - \hat{x}_i^w$

De-Meaning or Residualizing Variables

- ▶ For `f_classif` and `f_regression`, can de-mean predictors by groups, for example by year or location.
 - ▶ purges correlated information and can help model generalize to new years/locations.
 - ▶ for regression, can also de-mean the outcome.
- ▶ What if you want to de-mean by both year and location?
 - ▶ → take residuals from OLS regression of each variable (outcome and predictor) on the category dummies.
- ▶ That is:
 - ▶ regress $Y_i = FE_1 + FE_2 + \epsilon_i$ and $x_i^w = FE_1 + FE_2 + \epsilon_i, \forall w$,
 - ▶ take residuals $\tilde{Y}_i = Y_i - \hat{Y}_i$ and $\tilde{x}_i^w = x_i^w - \hat{x}_i^w$
- ▶ Then use residuals as variables, in feature selection step or in machine learning task.

Hashing Vectorizer

- ▶ A very different approach to tokenizing documents:
 - ▶ rather than make a one-to-one lookup for each n-gram, put n-grams through a hashing function that takes an arbitrary string and outputs an integer in some range (e.g. 1 to 10,000).

Traditional Vocabulary Construction

the	→	5
cats	→	6
and	→	7
dogs	→	8

Hashing Trick

the	hash →	19322
cats	hash →	67
and	hash →	31011
dogs	hash →	67

Hashing Vectorizer

- ▶ A very different approach to tokenizing documents:

- ▶ rather than make a one-to-one lookup for each n-gram, put n-grams through a hashing function that takes an arbitrary string and outputs an integer in some range (e.g. 1 to 10,000).

Traditional Vocabulary Construction

the	→	5
cats	→	6
and	→	7
dogs	→	8

Hashing Trick

the	hash →	19322
cats	hash →	67
and	hash →	31011
dogs	hash →	67

- ▶ Pros:

- ▶ can have arbitrarily small feature space
- ▶ handles out-of-vocabulary words – any word or n-gram gets assigned to an arbitrary integer based on the hash function.

Hashing Vectorizer

- ▶ A very different approach to tokenizing documents:

- ▶ rather than make a one-to-one lookup for each n-gram, put n-grams through a hashing function that takes an arbitrary string and outputs an integer in some range (e.g. 1 to 10,000).

Traditional Vocabulary Construction

the	→	5
cats	→	6
and	→	7
dogs	→	8

Hashing Trick

the	hash →	19322
cats	hash →	67
and	hash →	31011
dogs	hash →	67

- ▶ Pros:
 - ▶ can have arbitrarily small feature space
 - ▶ handles out-of-vocabulary words – any word or n-gram gets assigned to an arbitrary integer based on the hash function.
- ▶ Cons:
 - ▶ harder to interpret features
 - ▶ at least not directly – but the eli5 implementation keeps track of the mapping
 - ▶ will have collisions – n-grams will randomly be paired with each other in the feature map.
 - ▶ usually innocuous, but could sum outputs of two hashing functions to minimize this.

Collocations are Familiar N-grams

- ▶ Conceptually, the goal of including n-grams is to featurize **collocations**:
 - ▶ Non-compositional: the meaning is not the sum of the parts
(kick+the+bucket \neq "kick the bucket")

Collocations are Familiar N-grams

- ▶ Conceptually, the goal of including n-grams is to featurize **collocations**:
 - ▶ Non-compositional: the meaning is not the sum of the parts
(kick+the+bucket \neq "kick the bucket")
 - ▶ Non-substitutable: cannot substitute components with synonyms ("fast food" \neq "quick food")

Collocations are Familiar N-grams

- ▶ Conceptually, the goal of including n-grams is to featurize **collocations**:
 - ▶ Non-compositional: the meaning is not the sum of the parts (kick+the+bucket \neq "kick the bucket")
 - ▶ Non-substitutable: cannot substitute components with synonyms ("fast food" \neq "quick food")
 - ▶ Non-modifiable: cannot modify with additional words or grammar: (e.g., "kick around the bucket", "kick the buckets")

Point-wise mutual information

- ▶ A metric for identifying collocations is point-wise mutual information:

$$\begin{aligned}\text{PMI}(w_1, w_2) &= \frac{\text{Pr}(w_1_w_2)}{\text{Pr}(w_1)\text{Pr}(w_2)} \\ &= \frac{\text{Prob. of collocation, actual}}{\text{Prob. of collocation, if independent}}\end{aligned}$$

where w_1 and w_2 are words in the vocabulary, and w_1, w_2 is the N-gram $w_1_w_2$.

Point-wise mutual information

- ▶ A metric for identifying collocations is point-wise mutual information:

$$\begin{aligned}\text{PMI}(w_1, w_2) &= \frac{\Pr(w_1_w_2)}{\Pr(w_1)\Pr(w_2)} \\ &= \frac{\text{Prob. of collocation, actual}}{\text{Prob. of collocation, if independent}}\end{aligned}$$

where w_1 and w_2 are words in the vocabulary, and w_1, w_2 is the N-gram $w_1_w_2$.

- ▶ ranks words by how often they collocate, relative to how often they occur apart.

Point-wise mutual information

- ▶ A metric for identifying collocations is point-wise mutual information:

$$\begin{aligned}\text{PMI}(w_1, w_2) &= \frac{\text{Pr}(w_1_w_2)}{\text{Pr}(w_1)\text{Pr}(w_2)} \\ &= \frac{\text{Prob. of collocation, actual}}{\text{Prob. of collocation, if independent}}\end{aligned}$$

where w_1 and w_2 are words in the vocabulary, and w_1, w_2 is the N-gram $w_1_w_2$.

- ▶ ranks words by how often they collocate, relative to how often they occur apart.
- ▶ Warning: Rare words that appear together once or twice will have high PMI.
 - ▶ Address this with minimum frequency thresholds.

Geometric Mean: Normalized PMI for $N \geq 2$

- ▶ PMI can be generalized to arbitrary N as the geometric mean of the probabilities:

$$\frac{\Pr(w_1, \dots, w_N)}{\prod_{i=1}^N \sqrt[N]{\Pr(w_i)}}$$

Geometric Mean: Normalized PMI for $N \geq 2$

- ▶ PMI can be generalized to arbitrary N as the geometric mean of the probabilities:

$$\frac{\Pr(w_1, \dots, w_N)}{\prod_{i=1}^N \sqrt[N]{\Pr(w_i)}}$$

- ▶ E.g., for trigrams:

$$\frac{\Pr(w_1, w_2, w_3)}{\sqrt[3]{\Pr(w_1)\Pr(w_2)\Pr(w_3)}}$$

Geometric Mean: Normalized PMI for $N \geq 2$

- ▶ PMI can be generalized to arbitrary N as the geometric mean of the probabilities:

$$\frac{\Pr(w_1, \dots, w_N)}{\prod_{i=1}^N \sqrt[N]{\Pr(w_i)}}$$

- ▶ E.g., for trigrams:

$$\frac{\Pr(w_1, w_2, w_3)}{\sqrt[3]{\Pr(w_1)\Pr(w_2)\Pr(w_3)}}$$

- ▶ The n -root normalizer is not necessary (it does not change the ranking), but makes scores for bigrams/trigrams/quadrgrams/etc. more comparable.

Phrase Dictionaries

- ▶ WordNet has some phrases as single entities.
- ▶ The Paraphrase Database 2.0 (PPDB, paraphrase.org/#/download) has a large database of equivalent/related words/phrases.
- ▶ Could take wikipedia article names as lists of multi-word expressions.
- ▶ In law, could use legal dictionaries (e.g., “first amendment”, “beyond a reasonable doubt”).

Named Entity Recognition

- ▶ refers to the task of identifying named entities such as “ETH Zurich” and “Marie Curie”, which can be used as tokens.

[**PER** John Smith] , president of [**ORG** McCormik Industries] visited his niece [**PER** Paris]
in [**LOC** Milan], reporters say .

Named Entity Recognition

- refers to the task of identifying named entities such as “ETH Zurich” and “Marie Curie”, which can be used as tokens.

[**PER** John Smith] , president of [**ORG** McCormik Industries] visited his niece [**PER** Paris] in [**LOC** Milan], reporters say .

TYPES OF NER

Type	Tag	Sample Categories	Example sentences
People	PER	people, characters	Turing is a giant of computer science.
Organization	ORG	companies, sports teams	The IPCC warned about the cyclone.
Location	LOC	regions, mountains, seas	The Mt. Sanitas loop is in Sunshine Canyon .
Geo-Political Entity	GPE	countries, states, provinces	Palo Alto is raising the fees for parking.
Facility	FAC	bridges, buildings, airports	Consider the Golden Gate Bridge .
Vehicles	VEH	planes, trains, automobiles	It was a classic Ford Falcon .

Figure 18.1 A list of generic named entity types with the kinds of entities they refer to.

- Blackstone has a trained legal NER system in spaCy (for UK law).

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

N-Grams

Parts of Speech

Applications

Appendix on Course Projects

Parts of speech tags

- ▶ Parts of speech (POS) tags provide useful word categories corresponding to their functions in sentences:
 - ▶ Eight main parts of speech: verb (VB), noun (NN), pronoun (PR), adjective (JJ), adverb (RB), determinant (DT), preposition (IN), conjunction (CC).
 - ▶ The Penn TreeBank POS tag set (used in many applications) has 36 tags:
https://www.ling.upenn.edu/courses/Fall_2003/ling001/penn_treebank_pos.html

Parts of speech tags

- ▶ Parts of speech (POS) tags provide useful word categories corresponding to their functions in sentences:
 - ▶ Eight main parts of speech: verb (VB), noun (NN), pronoun (PR), adjective (JJ), adverb (RB), determinant (DT), preposition (IN), conjunction (CC).
 - ▶ The Penn TreeBank POS tag set (used in many applications) has 36 tags:
https://www.ling.upenn.edu/courses/Fall_2003/ling001/penn_treebank_pos.html
- ▶ Parts of speech vary in their informativeness for various functions:
 - ▶ For categorizing topics, nouns are usually most important
 - ▶ For sentiment, adjectives are usually most important.

Parts of speech as features

- ▶ Can produce n-grams from parts of speech tags:
 - ▶ counts over NV, VN, AN, etc.

Parts of speech as features

- ▶ Can produce n-grams from parts of speech tags:
 - ▶ counts over NV, VN, AN, etc.
- ▶ POS n-gram frequencies are good stylistic features for authorship detection.
 - ▶ not biased by topics/content
 - ▶ for function words, can use the word itself rather than the POS tag.

Constructing “Memes” with POS

- ▶ A: Adjective, N: Noun, V: Verb, P: Preposition, D: Determinant, C: Conjunction.
- ▶ 2-grams: AN, NN, VN, VV, NV, VP.
 - ▶ tax credit, magistrate judge
- ▶ 3-grams: NNN, AAN, ANN, NAN, NPN, VAN, VNN, AVN, VVN, VPN, ANV, NVV, VDN, VVV, NNV, VVP, VAV, VVN, NCN, VCV, ACA, PAN.
 - ▶ armed and dangerous, stating the obvious

Constructing “Mememes” with POS

- ▶ A: Adjective, N: Noun, V: Verb, P: Preposition, D: Determinant, C: Conjunction.
- ▶ 2-grams: AN, NN, VN, VV, NV, VP.
 - ▶ tax credit, magistrate judge
- ▶ 3-grams: NNN, AAN, ANN, NAN, NPN, VAN, VNN, AVN, VVN, VPN, ANV, NVV, VDN, VVV, NNV, VVP, VAV, VVN, NCN, VCV, ACA, PAN.
 - ▶ armed and dangerous, stating the obvious
- ▶ 4-grams: NCVN, ANNN, NNNN, NPNN, AANN, ANNN, ANPN, NNPN, NPAN, ACAN, NCNN, NNCN, ANCN, NCAN, PDAN, PNPV, VDNN, VDAN, VVDN.
 - ▶ Beyond a reasonable doubt (preposition, article, adjective, noun)
 - ▶ Earned income tax credit (adjective, noun, noun, noun)

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

N-Grams

Parts of Speech

Applications

Appendix on Course Projects

Ranking Partisan language:

Monroe et al (2009)

- ▶ This paper systematically explores a number of methods for identifying words that are distinctive of groups of speakers
 - ▶ in this case, whether U.S. congressmen are Republicans or Democrats.

Ranking Partisan language:

Monroe et al (2009)

- ▶ This paper systematically explores a number of methods for identifying words that are distinctive of groups of speakers
 - ▶ in this case, whether U.S. congressmen are Republicans or Democrats.
- ▶ First, they separate speeches by topic using latent dirichlet allocation (next lecture).
 - ▶ they then test a number of methods for ranking partisanship of words.

Relative Frequency of Words

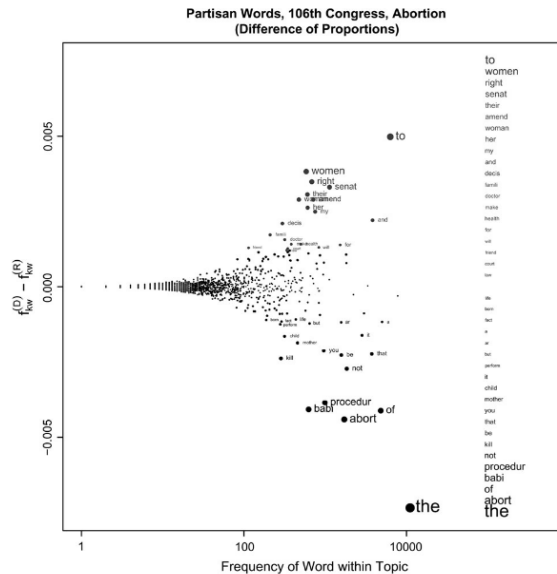


Fig. 1 Feature evaluation and selection using $f_{kw}^{(D)} - f_{kw}^{(R)}$. Plot size is proportional to evaluation weight, $|f_{kw}^{(D)} - f_{kw}^{(R)}|$. The top 20 Democratic and Republican words are labeled and listed in rank order to the right. The results are almost identical for two other measures discussed in the text: unlogged $tf.idf$ and frequency-weighted WordScores.

Log Odds Ratio Between Groups

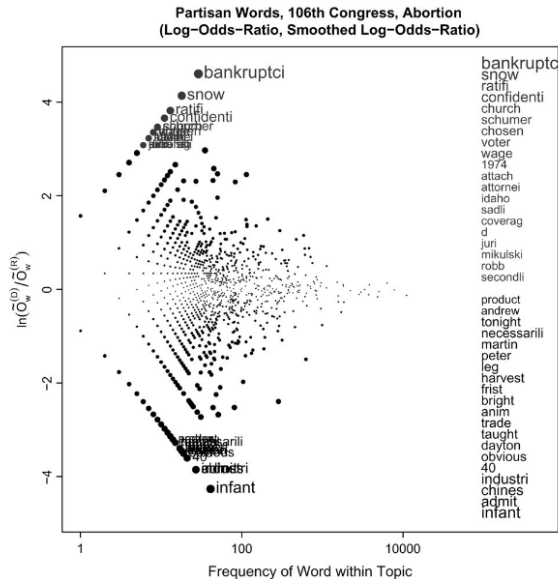


Fig. 2 Feature evaluation and selection using $\hat{\delta}_{kw}^{(D-R)}$. Plot size is proportional to evaluation weight, $|\hat{\delta}_{kw}^{(D-R)}|$. Top 20 Democratic and Republican words are labeled and listed in rank order. The results are identical to another measure discussed in the text: the log-odds-ratio with uninformative Dirichlet prior.

Bayesian Multinomial Model

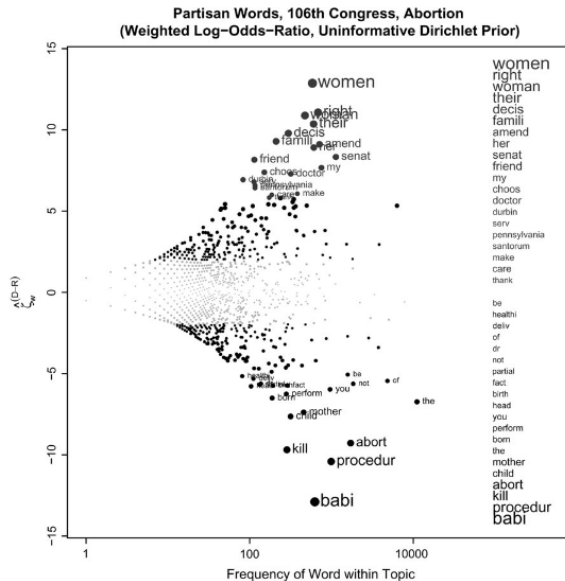


Fig. 4 Feature evaluation and selection using $\frac{\hat{s}_{kw}^{(D-R)}}{s_{kw}}$. Plot size is proportional to evaluation weight, $\left| \frac{\hat{s}_{kw}^{(D-R)}}{s_{kw}} \right|$; those with $\left| \frac{\hat{s}_{kw}^{(D-R)}}{s_{kw}} \right| < 1.96$ are gray. The top 20 Democratic and Republican words are labeled and listed in rank order to the right.

Bayesian Multinomial Model, LaPlace Prior

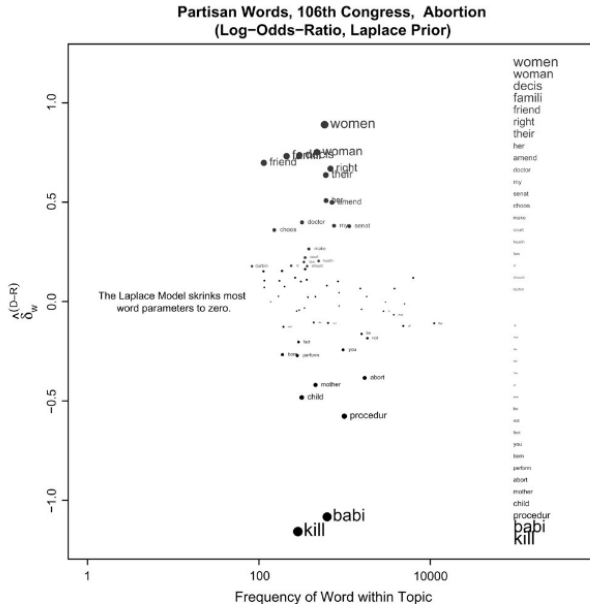


Fig. 6 Feature evaluation and selection using $\hat{\delta}_{kw}^{(D-R)}$. Plot size is proportional to evaluation weight, $\hat{\delta}_{kw}^{(D-R)}$. The top 20 Democratic and Republican words are labeled and listed in rank order to the right.

Tokenization: Overview

Pre-Processing Text

Counts and Frequencies

N-Grams

Parts of Speech

Applications

Appendix on Course Projects

Course Project Logistics

<https://bit.ly/NLP-proj>

- ▶ If you are signed up for the credits, the focus of your work in this course should be on the project.
 - ▶ Can be done individually or in small groups (up to 4 students).
 - ▶ Do an original analysis using methods learned in the course, and write a paper about it.

Course Project Logistics

<https://bit.ly/NLP-proj>

- ▶ If you are signed up for the credits, the focus of your work in this course should be on the project.
 - ▶ Can be done individually or in small groups (up to 4 students).
 - ▶ Do an original analysis using methods learned in the course, and write a paper about it.
- ▶ Deliverables:
 - ▶ description of topic (March 29th, 10% of grade)
 - ▶ proposal/outline (April 26th, 10% of grade)
 - ▶ Poster/presentation session (some time in May, 10% of grade).
 - ▶ Rough draft with data/methods/results (July 15th, 20% of grade)
 - ▶ Final draft (September 1st, 50% of grade)

Previous Year's Projects (1)

Previous Year's Projects (1)

- ▶ One of the groups began building a legal research application for Swiss lawyers:
 - ▶ see <https://deepjudge.ai/>
 - ▶ feature-rich legal search engine, one some VC funding

Previous Year's Projects (1)

- ▶ One of the groups began building a legal research application for Swiss lawyers:
 - ▶ see <https://deepjudge.ai/>
 - ▶ feature-rich legal search engine, one some VC funding
- ▶ Another group partnered with a local company to build out environmental-regulation analytics
 - ▶ won an Innosuisse grant.

Previous Year's Projects (1)

- ▶ One of the groups began building a legal research application for Swiss lawyers:
 - ▶ see <https://deepjudge.ai/>
 - ▶ feature-rich legal search engine, one some VC funding
- ▶ Another group partnered with a local company to build out environmental-regulation analytics
 - ▶ won an Innosuisse grant.
- ▶ *Note: These projects were above expectation.*

Previous Year's Projects (2)

Three projects have been published:

1. “Legal language modeling with transformers” (Lazar Peric, Stefan Mijic, Dominik Stammbach, Elliott Ash), *Proceedings of ASAIL* (2020).
2. “Entropy in Legal Language” (Roland Friedrich, Mauro Luzzatto, and Elliott Ash), *NLLP @ KDD* (2020).
3. “Towards Automated Anamnesis Summarization: BERT-based Models for Symptom Extraction” (Anton Schäfer, Nils Blach, Oliver Rausch, Maximilian Warm, Nils Krüger), *Machine Learning for Health at NeurIPS* (2020).

Previous Year's Projects (2)

Three projects have been published:

1. “Legal language modeling with transformers” (Lazar Peric, Stefan Mijic, Dominik Stammbach, Elliott Ash), *Proceedings of ASAIL* (2020).
2. “Entropy in Legal Language” (Roland Friedrich, Mauro Luzzatto, and Elliott Ash), *NLLP @ KDD* (2020).
3. “Towards Automated Anamnesis Summarization: BERT-based Models for Symptom Extraction” (Anton Schäfer, Nils Blach, Oliver Rausch, Maximilian Warm, Nils Krüger), *Machine Learning for Health at NeurIPS* (2020).

One more is under review at ACL:

- “MemSum: Extractive Summarization using Multi-step Episodic Markov Decision Processes” (Nianlong Gu, Elliott Ash, Richard Hahnloser).

Previous Year's Projects (3)

A number of other projects that are likely to get published:

- ▶ “Kwame: A Bilingual AI Teaching Assistant for Online SuaCode Courses” (George Boateng 2020)
- ▶ a partisan tweet generator that responds in the style of a Republican or Democrat.
- ▶ an analysis of bias towards immigrants in the early 1900s using old newspapers.
- ▶ a causal analysis using deep instrumental variables of what arguments in judicial opinions increase citations
- ▶ a partisan question answering system that answers questions with a partisan slant.
- ▶ an audio analysis of european central bank speech recordings.

New Project Ideas

- ▶ We have a list of potential project ideas, please email Claudia for access after registering for the course project credits.