

# Quantitative text analysis: descriptive statistical methods

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MY 459: Quantitative Text Analysis

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Course website: [lse-my459.github.io](https://lse-my459.github.io)

1. Overview and Fundamentals
2. Descriptive Statistical Methods for Text Analysis
3. Automated Dictionary Methods
4. Machine Learning for Texts
5. Supervised Scaling Models for Texts
6. *Reading Week*
7. Unsupervised Models for Scaling Texts
8. Similarity and Clustering Methods
9. Topic models
10. Word embeddings
11. Working with Social Media

# Outline for today

- ▶ Defining documents and features
- ▶ Strategies for feature weighting
- ▶ Strategies for feature selection
- ▶ Descriptive statistics for text

# Overview of text as data methods

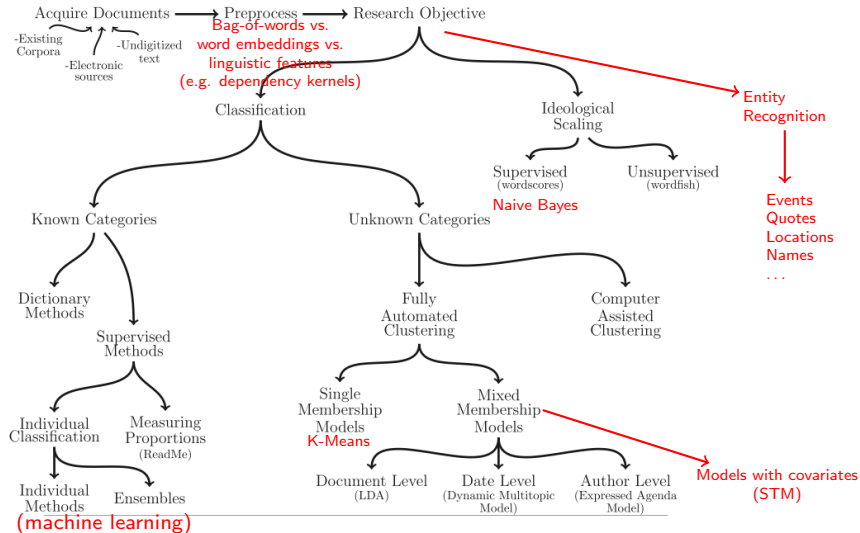


Fig. 1 in Grimmer and Stewart (2013)

# Review of basic concepts

(text) corpus a large and structured set of texts for analysis

document each of the units of the corpus

types for our purposes, a unique word

tokens any word – so token count is total words

e.g. A corpus is a set of documents.

This is the second document in the corpus.

is a corpus with 2 documents, where each document is a sentence. The first document has 6 types and 7 tokens. The second has 7 types and 8 tokens. (We ignore punctuation for now.)

# Review of basic concepts

**stems** words with suffixes removed (using set of rules)

**lemmas** canonical word form (the base form of a word that has the same meaning even when different suffixes or prefixes are attached)

---

<b>word</b>	win	winning	wins	won	winner
<b>stem</b>	win	win	win	won	winner
<b>lemma</b>	win	win	win	win	win

---

**keys** such as dictionary entries, where the user defines a set of equivalence classes that group different word types

**“key” words** Words selected because of special attributes, meanings, or rates of occurrence

**stop words** Words that are designated for exclusion from any analysis of a text

# Document Term Matrices Review

	As You Like It	Twelfth Night	Julius Caesar	Henry V
battle	1	0	7	13
good	14	80	62	89
fool	36	58	1	4
wit	20	15	2	3

- ▶ The document term matrix for four words in four Shakespeare plays.
- ▶ The red boxes show that each document is represented as a column vector of length four.
- ▶ Each document is represented by a vector of words
- ▶ Vectors are similar for the two comedies
- ▶ Both are different than the two historical plays
- ▶ Comedies have more fools and wit and fewer battles.

## A potential recipe for preprocessing

1. Remove capitalization, punctuation
2. Segment into words, characters, morphemes
3. Discard Order ("Bag of Words" Assumption)
4. Discard stop words
5. Create Equivalence Class: stem, lemmatize, or synonym
6. Discard less useful features
7. Other reduction, specialization



## A Complete Example

"Political power grows out of the barrel of a gun" - Mao

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"Political power grows out of the barrel of a gun" - Mao

**Compound Words/Collocations:** With substantive justification, words can be combined or split to improve inference.

## A Complete Example

"Political power grows out of the barrel of a gun" - Mao

**Compound Words/Collocations:** An analyst may want to combine words into a single term that can be analyzed.

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"Political power grows out of the barrel of a gun" - Mao

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[Political], [power], [grows], [out], [of], [the], [barrel of a gun]

**Compound Words/Collocations:** An analyst may want to combine words into a single term that can be analyzed.

## A Complete Example

[Political], [power], [grows], [out], [of], [the], [barrel of a gun]

**Stopword Removal:** Removing terms that are not related to what the author is studying from the text.

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[Political], [power], [grows], [out], [of], [the], [barrel of a gun]

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**Stopword Removal:** Removing terms that are not related to what the author is studying from the text.



## A Complete Example

[Political], [power], [grows], [out], [barrel of a gun]

**Stemming:** Takes the ends off conjugated verbs or plural nouns, leaving just the "stem."

## A Complete Example

[Polit~~ical~~], [power], [grow~~s~~], [out], [barrel of a gun]

**Stemming:** Takes the ends off conjugated verbs or plural nouns, leaving just the "stem."

## A Complete Example

[Polit], [power], [grow], [out], [barrel of a gun]

**Stemming:** Takes the ends off conjugated verbs or plural nouns, leaving just the "stem."

## A Complete Example

Finally, we can turn tokens and documents into a "document-term matrix." Imagine we have a second document in addition to the Mao quote, "the political science students study politics", which tokenizes as follows.

**Document #1:** [polit], [power], [grow], [out], [barrel of a gun]

**Document #2:** [polit], [scien], [student], [studi], [polit]

## Output: Document Term Matrix

	Doc 1	Doc 2
power	1	0
grow	1	0
out	1	0
barrel of a gun	1	0
student	0	1
studi	0	1
polit	1	2
scien	0	1

## But raw frequency is a bad representation

- ▶ Frequency is clearly useful; if sugar appears a lot near apricot, that's useful information.
- ▶ But overly frequent words like “the”, “it”, or “they” are not very informative about content
- ▶ Some terms carry more information about contents
- ▶ Need a function that resolves this frequency paradox!

# Outline for today

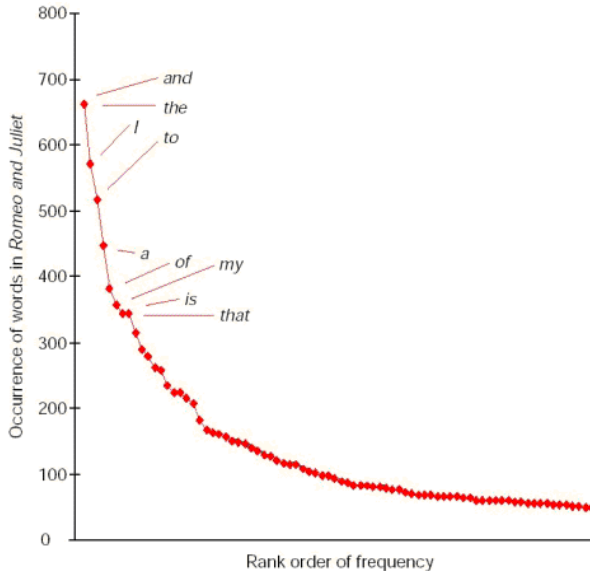
- ▶ Defining documents and features
- ▶ Strategies for feature weighting
- ▶ Strategies for feature selection
- ▶ Descriptive statistics for text

# Power-law/Zipf Distribution of Word Frequency

- ▶ Many words with a small frequency of occurrence
- ▶ A few words with a very large frequency
- ▶ High skew (asymmetry)
- ▶ Comparing to a normal distribution:
  - ▶ Many people with a medium height
  - ▶ Almost nobody with a very high or very low height
  - ▶ Height is symmetric

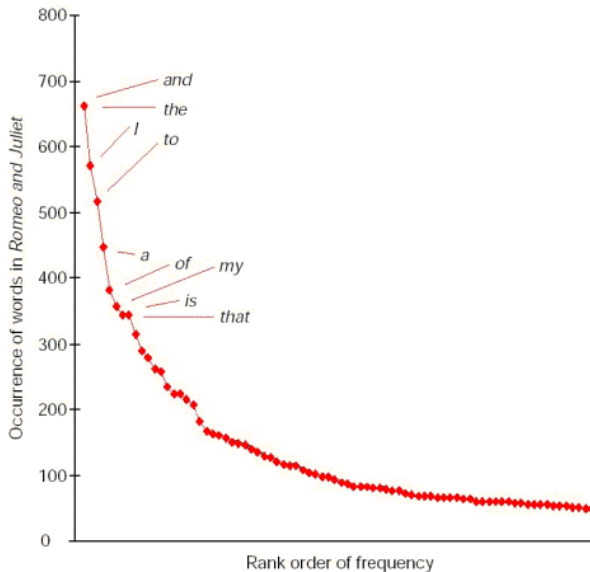


# Power-law/Zipf Distribution of Word Frequency



**Question:** Where are the most informative words on this plot?

# Power-law/Zipf Distribution of Word Frequency



**Question:** How might we address the problem of highly weighted non-informative tokens?

# Power-law/Zipf Distribution of Word Frequency

1. What do we mean by feature selection?
2. What do we mean by feature weighting?

# Weighting strategies for feature counting

**term frequency** Some approaches trim very low-frequency words.  
Rationale: get rid of rare words that expand the feature matrix but matter little to substantive analysis

**document frequency** Could eliminate words appearing in few documents

**inverse document frequency** Conversely, could weight words more that appear in the most documents

*tf-idf* a combination of term frequency and inverse document frequency, common method for feature weighting

# Term Frequency (tf)

- ▶ A term is more important if it occurs more frequently in a document
- ▶ tf: term frequency. frequency count (usually log-transformed):

$$\text{tf}_{t,d} = \begin{cases} 1 + \log(\text{count}(t, d)) & \text{if } \text{count}(t, d) > 0 \\ 0 & \text{otherwise} \end{cases}$$

# Inverse Document Frequency (idf)

- ▶ A term is more discriminative if it occurs only in fewer documents. Why this is true?

$$idf_i = \log \left( \frac{N}{df_i} \right)$$

- ▶  $N$  is the total number of documents in the collection
- ▶  $df_i$  is the number of documents in the collection that contain the word  $i$
- ▶ Note that IDF is document independent while TF is document dependent!
- ▶ Words like "the" or "and" have a very low idf

## Strategies for feature *weighting*: tf-idf

- ▶  $tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{k,j}}$  where  $n_{i,j}$  is number of occurrences of term  $t_i$  in document  $d_j$ ,  $k$  is total number of terms in document  $d_j$
- ▶  $idf_i = \ln \frac{|D|}{|\{d_j : t_i \in d_j\}|}$   
where
  - ▶  $|D|$  is the total number of documents in the set
  - ▶  $|\{d_j : t_i \in d_j\}|$  is the number of documents where the term  $t_i$  appears (i.e.  $n_{i,j} \neq 0$ )
- ▶  $tf-idf_i = tf_{i,j} \cdot idf_i$

## Computation of tf-idf: Example

Example: We have 100 political party manifestos, each with 1000 words. The first document contains 16 instances of the word “environment”; 40 of the manifestos contain the word “environment”.

- ▶ The *term frequency* is  $16/1000 = 0.016$
- ▶ The *inverse document frequency* is  $100/40 = 2.5$ , or  $\ln(2.5) = 0.916$
- ▶ The *tf-idf* will then be  $0.016 * 0.916 = 0.0147$
- ▶ If the word had only appeared in 15 of the 100 manifestos, then the *tf-idf* would be 0.0304 (three times higher).
- ▶ A high weight in tf-idf is reached by a high term frequency (in the given document) and a low document frequency of the term in the whole collection of documents; hence the **weights hence tend to filter out common terms**



# Tf-idf Weighted Document Term Matrix

	<b>As You Like It</b>	<b>Twelfth Night</b>	<b>Julius Caesar</b>	<b>Henry V</b>
<b>battle</b>	0.074	0	0.22	0.28
<b>good</b>	0	0	0	0
<b>fool</b>	0.019	0.021	0.0036	0.0083
<b>wit</b>	0.049	0.044	0.018	0.022

- ▶ A tf-idf weighted document term matrix for four words in four Shakespeare plays, using the counts from the earlier document term matrix
- ▶ The idf weighting has eliminated the importance of the ubiquitous word good and vastly reduced the impact of the almost-ubiquitous word fool.

## Other weighting schemes

- ▶ Okapi BM25 (based on tf-idf)
- ▶ the SMART weighting scheme (Salton 1991, Salton et al):  
The first letter in each triplet specifies the term frequency component of the weighting, the second the document frequency component, and the third the form of normalization used (not shown). Example: *lnn* means log-weighted term frequency, no idf, no normalization

Term frequency		Document frequency	
n (natural)	$tf_{t,d}$	n (no)	1
l (logarithm)	$1 + \log(tf_{t,d})$	t (idf)	$\log \frac{N}{df_t}$
a (augmented)	$0.5 + \frac{0.5 \times tf_{t,d}}{\max_t(tf_{t,d})}$	p (prob idf)	$\max\{0, \log \frac{N - df_t}{df_t}\}$
b (boolean)	$\begin{cases} 1 & \text{if } tf_{t,d} > 0 \\ 0 & \text{otherwise} \end{cases}$		
L (log ave)	$\frac{1 + \log(tf_{t,d})}{1 + \log(\text{ave}_{t \in d}(tf_{t,d}))}$		

- ▶ Note: Mostly used in information retrieval, although some use in machine learning

## Other weighting schemes: Okapi BM25

$$\text{score}(D, Q) = \sum_{i=1}^n \text{IDF}(q_i) \cdot \frac{f(q_i, D) \cdot (k_1 + 1)}{f(q_i, D) + k_1 \cdot \left(1 - b + b \cdot \frac{|D|}{\text{avgdl}}\right)},$$

- ▶ Used in information retrieval (e.g. ranking searches in a search engine given a query  $q$ )
- ▶ BM25 and other similar term-weighting methods were core components of most early search engines
- ▶  $f(q_i, D)$  is the document frequency of the query term
- ▶  $q_i$  is the keyword (each word in the search)
- ▶  $k_1, b$  are free parameters

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# Review of Feature Selection Approaches

Equivalence classes: stems, or lemmas

Parts of speech: part of speech tags

Purposive selection: dictionary, or keywords

Purposive removal: stopwords

# Selecting more than words: collocations

collocations **bigrams**, or **trigrams** e.g. *capital gains tax*

how to detect: pairs occurring more than by chance, by measures of  $\chi^2$  or *mutual information* measures

example:

Summary Judgment	Silver Rudolph	Sheila Foster
prima facie	COLLECTED WORKS	Strict Scrutiny
Jim Crow	waiting lists	Trail Transp
stare decisis	Academic Freedom	Van Alstyne
Church Missouri	General Bldg	Writings Fehrenbacher
Gerhard Casper	Goodwin Liu	boot camp
Juan Williams	Kurland Gerhard	dated April
LANDMARK BRIEFS	Lee Appearance	extracurricular activities
Lutheran Church	Missouri Synod	financial aid
Narrowly Tailored	Planned Parenthood	scored sections

Table 5: Bigrams detected using the mutual information measure.

# Identifying collocations

- ▶ Does a given word occur next to another given word with a higher relative frequency than other words?
- ▶ If so, then it is a candidate for a collocation
- ▶ We can detect these using measures of association, such as a likelihood ratio, to detect word pairs that occur with greater than chance frequency, compared to an independence model
- ▶ The key is to distinguish “true collocations” from uninteresting word pairs/triplets/etc, such as “of the”

# Example

$C(w^1 w^2)$	$w^1$	$w^2$
80871	of	the
58841	in	the
26430	to	the
21842	on	the
21839	for	the
18568	and	the
16121	that	the
15630	at	the
15494	to	be
13899	in	a
13689	of	a
13361	by	the
13183	with	the
12622	from	the
11428	New	York
10007	he	said
9775	as	a
9231	is	a
8753	has	been
8573	for	a

**Table 5.1** Finding Collocations: Raw Frequency.  $C(\cdot)$  is the frequency of something in the corpus.

(from Manning and Schütze, *FSNLP*, Ch 5)



# Example

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## Example (filtered)

Some parts of speech indicate a collocation is less interesting.

Frequency	Word 1	Word 2	Part-of-speech pattern
11487	New	York	A N
7261	United	States	A N
5412	Los	Angeles	N N
3301	last	year	A N
3191	Saudi	Arabia	N N
2699	last	week	A N
2514	vice	president	A N
2378	Persian	Gulf	A N
2161	San	Francisco	N N
2106	President	Bush	N N
2001	Middle	East	A N
1942	Saddam	Hussein	N N
1867	Soviet	Union	A N
1850	White	House	A N
1633	United	Nations	A N
1337	York	City	N N
1328	oil	prices	N N
1210	next	year	A N
1074	chief	executive	A N
1073	real	estate	A N

**Table 1.5** Frequent bigrams after filtering. The most frequent bigrams in the *New York Times* after applying a part-of-speech filter.

(from Manning and Schütze, *FSNLP*, Ch 5)

## Contingency tables for bigrams

Tabulate every token against every other token as pairs, and compute for each token:

	token2	$\neg$ token2	Totals
token1	$n_{11}$	$n_{12}$	$n_{1p}$
$\neg$ token1	$n_{21}$	$n_{22}$	$n_{2p}$
Totals	$n_{p1}$	$n_{p2}$	$n_{pp}$

Then compute the “independence” model:

$$Pr(\text{token1}, \text{token2}) = Pr(\text{token1})Pr(\text{token2})$$

## Statistical association measures

where  $m_{ij}$  represents the cell frequency expected according to independence:

$G^2$  likelihood ratio statistic, computed as:

$$2 * \sum_i \sum_j (n_{ij} * \log \frac{n_{ij}}{m_{ij}}) \quad (1)$$

$\chi^2$  Pearson's  $\chi^2$  statistic, computed as:

$$\sum_i \sum_j \frac{(n_{ij} - m_{ij})^2}{m_{ij}} \quad (2)$$

**pmi** point-wise mutual information score, computed as  
 $\log n_{11} / m_{11}$

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## Simple descriptive table about texts: Describe your data!

Speaker	Party	Tokens	Types
Brian Cowen	FF	5,842	1,466
Brian Lenihan	FF	7,737	1,644
Ciaran Cuffe	Green	1,141	421
John Gormley (Edited)	Green	919	361
John Gormley (Full)	Green	2,998	868
Eamon Ryan	Green	1,513	481
Richard Bruton	FG	4,043	947
Enda Kenny	FG	3,863	1,055
Kieran O'Donnell	FG	2,054	609
Joan Burton	LAB	5,728	1,471
Eamon Gilmore	LAB	3,780	1,082
Michael Higgins	LAB	1,139	437
Ruairi Quinn	LAB	1,182	413
Arthur Morgan	SF	6,448	1,452
Caoimhghin O'Caolain	SF	3,629	1,035
All Texts		49,019	4,840
<i>Min</i>		919	361
<i>Max</i>		7,737	1,644
<i>Median</i>		3,704	991

# Quantities for describing texts

**Length** in characters, words, lines, sentences, paragraphs, pages, sections, chapters, etc.

**Readability statistics** Use a combination of syllables and sentence length to indicate “readability” in terms of complexity

**Vocabulary diversity** (At its simplest) involves measuring a *type-to-token ratio* (TTR) where unique words are types and the total words are tokens

**Word (relative) frequency** counts or proportions of words

# Lexical Diversity

- ▶ Basic measure is the **TTR**: Type-to-Token ratio
- ▶ Problem: This is very sensitive to overall document length, as shorter texts may exhibit fewer word repetitions
- ▶ Special problem: length may relate to the introduction of additional subjects, which will also increase richness



# Lexical Diversity: Alternatives to TTRs

$$\text{TTR} \quad \frac{\text{total types}}{\text{total tokens}}$$

$$\text{Guiraud} \quad \frac{\text{total types}}{\sqrt{\text{total tokens}}}$$

D (Malvern et al 2004) Randomly sample a fixed number of tokens and count those

MTLD “the mean length of sequential word strings in a text that maintain a given TTR value” (McCarthy and Jarvis, 2010) – fixes the TTR at 0.72 and counts the length of the text required to achieve it

# Vocabulary diversity and corpus length

- In natural language text, the rate at which new types appear is very high at first, but diminishes with added tokens

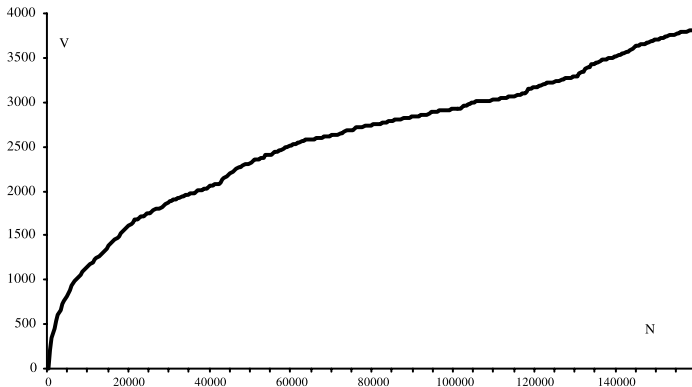


Fig. 1. Chart of vocabulary growth in the tragedies of Racine (chronological order, 500 token intervals).

# Complexity and Readability

- ▶ Use a combination of syllables and sentence length to indicate “readability” in terms of complexity
- ▶ Common in educational research, but could also be used to describe textual complexity
- ▶ Most use some sort of sample
- ▶ No natural scale, so most are calibrated in terms of some interpretable metric

# Flesch-Kincaid readability index

- F-K is a modification of the original **Flesch Reading Ease Index**:

$$206.835 - 1.015 \left( \frac{\text{total words}}{\text{total sentences}} \right) - 84.6 \left( \frac{\text{total syllables}}{\text{total words}} \right)$$

**Interpretation:** 0-30: university level; 60-70: understandable by 13-15 year olds; and 90-100 easily understood by an 11-year old student.

- **Flesch-Kincaid** rescales to the US educational grade levels (1-12):

$$0.39 \left( \frac{\text{total words}}{\text{total sentences}} \right) + 11.8 \left( \frac{\text{total syllables}}{\text{total words}} \right) - 15.59$$

# Exploring Texts: Key Words in Context

**KWIC** *Key words in context* Refers to the most common format for concordance lines. A KWIC index is formed by sorting and aligning the matching words within a corpus:

## **lime (14)**

79[C.10] 4 /Which was builded of **lime** and sand;/Until they came to  
247A.6 4 /That was well biggit with **lime** and stane.  
303A.1 2 bower./Well built wi **lime** and stane./And Willie came  
247A.9 2 /That was well biggit wi **lime** and stane./Nor has he stoln  
305A.2 1 a castell biggit with **lime** and stane./O gin it stands not  
305A.71 2 is my awin./I biggit it wi **lime** and stane./The Tinnies and  
79[C.10] 6 /Which was builded with **lime** and stone.  
305A.30 1 a prittie castell of **lime** and stone./O gif it stands not  
108.15 2 /Which was made both of **lime** and stone./Shee tooke him by  
175A.33 2 castle then./Was made of **lime** and stone./The vttermost  
178[H.2] 2 near by./Well built with **lime** and stone./There is a lady  
178F.18 2 built with stone and **lime**!/But far mair pittie on Lady  
178G.35 2 was biggit wi stane and **lime**!/But far mair pity o Lady  
2D.16 1 big a cart o stane and **lime**./Gar Robin Redbreast trail it

# Irish Budget Speeches KIWC in quanteda

```
R Console

> data(iebudgets)
> iebudgets2010 <- subset(iebudgets, year==2010)
> kwic(iebudgets2010, "christmas", regex=TRUE)
```

	preword	word	postword
[2010_BUDGET_02_Richard_Bruton_FG.txt, 628]	and to see out this	Christmas	in the hope of something
[2010_BUDGET_03_Joan_Burton_LAB.txt, 371]	to suggest titles for a	Christmas	hit single. Fianna Fáil's hit
[2010_BUDGET_03_Joan_Burton_LAB.txt, 379]	Fianna Fáil's hit single for	Christmas	will be, "I saw NAMA
[2010_BUDGET_03_Joan_Burton_LAB.txt, 922]	women will say goodbye after	Christmas	because they must take the
[2010_BUDGET_03_Joan_Burton_LAB.txt, 1518]	in single golf clubs this	Christmas	With a possible election next
[2010_BUDGET_03_Joan_Burton_LAB.txt, 1726]	Community faking its message this	Christmas?	Is the Society of St.
[2010_BUDGET_03_Joan_Burton_LAB.txt, 3159]	bags. In previous years at	Christmas	time people were laden down
[2010_BUDGET_04_Arthur_Morgan_SF.txt, 346]	€204 per week or the	Christmas	bonus. Of course, that is
[2010_BUDGET_04_Arthur_Morgan_SF.txt, 3239]	to social welfare payments this	Christmas	The loss of the Christmas
[2010_BUDGET_04_Arthur_Morgan_SF.txt, 3244]	Christmas. The loss of the	Christmas	bonus, a double payment which
[2010_BUDGET_04_Arthur_Morgan_SF.txt, 3272]	streets on Santa presents and	Christmas	food. The Government's Scrooge measures
[2010_BUDGET_04_Arthur_Morgan_SF.txt, 5899]	their jobs, who face this	Christmas	in debt, in poverty and
[2010_BUDGET_06_Enda_Kenny_FG.txt, 2629]	to implement the reduction before	Christmas	I do not know whether
[2010_BUDGET_07_Kieran_ODonnell_FG.txt, 1365]	from the change in the	Christmas	period. We suggested that the
[2010_BUDGET_08_Eamon_Gilmore_LAB.txt, 550]	cut of €641, including the	Christmas	payment. A couple on invalidity
[2010_BUDGET_08_Eamon_Gilmore_LAB.txt, 638]	are on social welfare, the	Christmas	payment is gone. Earnest lectures
[2010_BUDGET_08_Eamon_Gilmore_LAB.txt, 998]	of emigration. Once again this	Christmas	we will witness the scenes
[2010_BUDGET_13_Ciaran_Cuffe_Green.txt, 911]	noted recently that over the	Christmas	recess work will be done
[2010_BUDGET_14_Caoimhghin_OCaolain_SF.txt, 148]	will all be over by	Christmas	If it is the last

```
>
```

## Wrapping up...

Before this week's seminar:

- ▶ Bring a laptop!
- ▶ Create a GitHub account
- ▶ Install R (from <https://www.r-project.org/>)
- ▶ Install RStudio Desktop (from <https://www.rstudio.com/products/rstudio-desktop/>)
- ▶ Install GitHub Desktop (from <https://desktop.github.com/>)

## Discussion Questions

- ▶ What does tf-idf have to do with Zipf's law?
- ▶ Should we always weight our features? Why/Why not?
- ▶ What is a test of independence? How does this help us detect true collocations?
- ▶ Why would we want to detect true collocations rather than simply include all bigrams in our dfm?
- ▶ How might we apply lexical diversity measures to a social science problem?