

Intelligent Data Analysis 2020

Lecture 2

Statistical Analysis of Texts

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Objectives

- Understand different approaches to text-based IR
 - Explicit knowledge vs data
- “Bundles of words” approaches
- Introduction to zipf.c
- Statistical analysis of word occurrence in text
- Zipf’s Law
- Examples

Example Text

“There was no possibility of taking a walk that day. We had been wandering, indeed, in the leafless shrubbery an hour in the morning; but since dinner (Mrs. Reed, when there was no company, dined early) the cold winter wind had brought with it clouds so sombre, and a rain so penetrating, that further out-door exercise was now out of the question.”

keywords

Charlotte Brontë, “Jane Eyre”, first paragraph

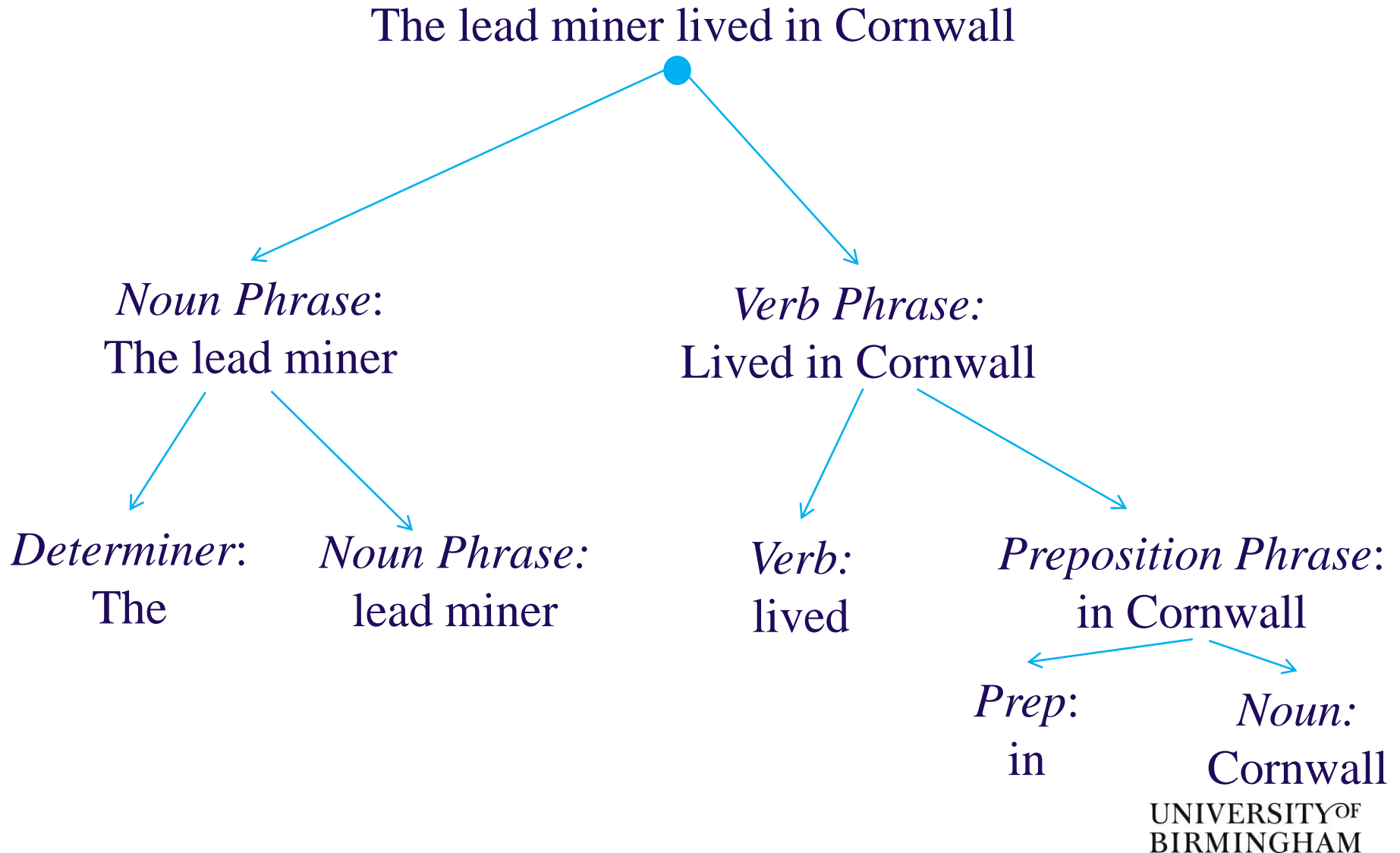
Jane Eyre extract

- What is it **about**?
- How do you know?
- What is your 'strategy' for understanding what a text is **about**?
- What are the **component** topics?
 - Exercise (walk, wandering, exercise)
 - Gardens (shrubbery)
 - Weather (cold, winter, wind, clouds, rain)

Structure in text

- Words
 - **Keywords** (some words are more important than others)
 - *Cold, Walk* and *Shrubbery* are important
 - *There, and* and *that* are not
- Sentences (Grammar / Syntax)
 - Word sequence structure helps us to understand and to remove ambiguity
 - ‘Parts of speech’
 - *The lead miner lived in Cornwall*
 - *Keep that dog on a lead!*
 - *He won the lead role in the new film*
roles

Example



Knowledge vs. Data (1)

- Knowledge (Rationalism):
 - Try to copy human language processing *emulation*
- Two questions:
 - Do we understand sufficiently well how we do it?
 - Is our knowledge ‘computationally useful’? I.e. is our knowledge sufficiently ‘solid’ to support algorithms and computer programs?
- These are topics in Natural Language Processing (NLP) and Computational Linguistics

Available knowledge

- Word inventories
 - Electronic dictionaries
- Word forms (noun, verb etc)
 - Available in electronic dictionaries
- Word meanings
 - Expressed in terms of predicate logic (properties)
- Grammar / syntax
 - Grammatical rules
- Parsers
 - Apply grammatical rules to a word sequence to determine if it is grammatical and, if so, its grammatical structure

Natural Language Processing

- Use word sense and meaning plus grammatical structure to infer ‘meaning’
- Several problems
 - Grammar may be too accommodating – accept non-grammatical sentences
 - Grammar may be too restrictive – reject valid sentences
 - The number of interpretations of a simple sentence may be huge (“I saw the man on the hill with the telescope”)
- Language is dynamic and changing

Knowledge vs. Data (2)

- Data (**Empiricism** , “Big Data”)
 - Use **large** corpora of text instead of human knowledge
 - Use **machine-learning** to identify important structure and relationships
 - **Quantify** the problem
 - Rely on **quantities which can be measured** from these large corpora, rather than human opinion
- For example:
 - For each word w define a number $U(w)$ which indicates how **useful** w is for Information Retrieval
 - Invent **algorithms** to find the **most useful** words
 - Invent **measures** of the **similarity** between queries and texts

Knowledge vs Data

- Need sophisticated computationally useful models of language and semantics to infer meaning
- Rational approaches accommodate complex structure but may be fragile and hard to generalise
 - “She ran, waving her hand in the air, across the bridge”
- Machine Learning (ML) is conceptually simpler, models are potentially huge, trained automatically
- NLP currently outperformed in most applications by ML – “Deep Learning”, “Deep Neural Networks” (e.g: Amazon Echo/Alexa, etc)
- **Bundles of Words** approach to language processing

‘Bundles of Words’

There was no possibility of taking a walk that day. We had been wandering, indeed, in the leafless shrubbery an hour in the morning; but since dinner (Mrs. Reed, when there was no company, dined early) the cold winter wind had brought with it clouds so sombre, and a rain so penetrating, that further out-door exercise was now out of the question

the 4
was 3
a 2
had 2
in 2
no 2
of 2
so 2
that 2
there 2
an 1
and 1
been 1
brought 1
but 1
clouds 1
cold 1
company 1
day 1
dined 1
dinner 1

early 1
exercise 1
further 1
hour 1
indeed 1
it 1
leafless 1
morning 1
mrs 1
now 1
out 1
out-door 1
penetrating 1
possibility 1
question 1
rain 1
reed 1
shrubbery 1
since 1
sombre 1
taking 1

walk 1
wandering 1
we 1
when 1
wind 1
winter 1
with 1

What is a word?

- Tokens \equiv things separated by white space
- Hyphenation
 - Database \equiv Data-base?
- Case
 - “the bath shop” vs “the Bath shop”
 - “the brown house” vs “the Brown house”
- Morphology
 - retrieval, retrieve, retrieved, retrieving,...
- Punctuation
 - The ‘honest’ politician vs the honest politician

Some arbitrary choices...

- Tokens \equiv things separated by white space
- Ignore case:
 - London \equiv london
 - BBC \equiv bbc
- Ignore non-alphanumerics at start and end of token:
 - 'honest' \equiv honest. \equiv honest! \equiv "honest \equiv honest

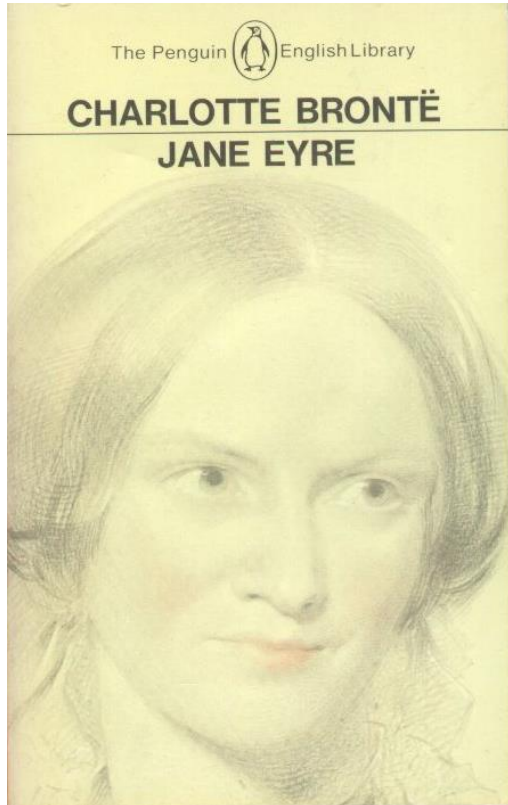
Analysis of Word Frequency

- `zipf.c`
 - ANSI C program for simple analysis of texts
 - Finds the set of different tokens in the text
 - Counts how many times each word occurs
 - Orders words according to the number of times they occur in the text (their **rank**)
 - Prints out the result, and
 - Stores results in a file `results`

Compilation of “Data Mining” C code

- Simple ANSI C
- OS independent – should work on any platform with any ANSI-compliant C compiler
- Download from course website
- Compile using MS Visual Studio .NET **command line**
- `cl zipf.c`

Statistical Analysis of Frequency



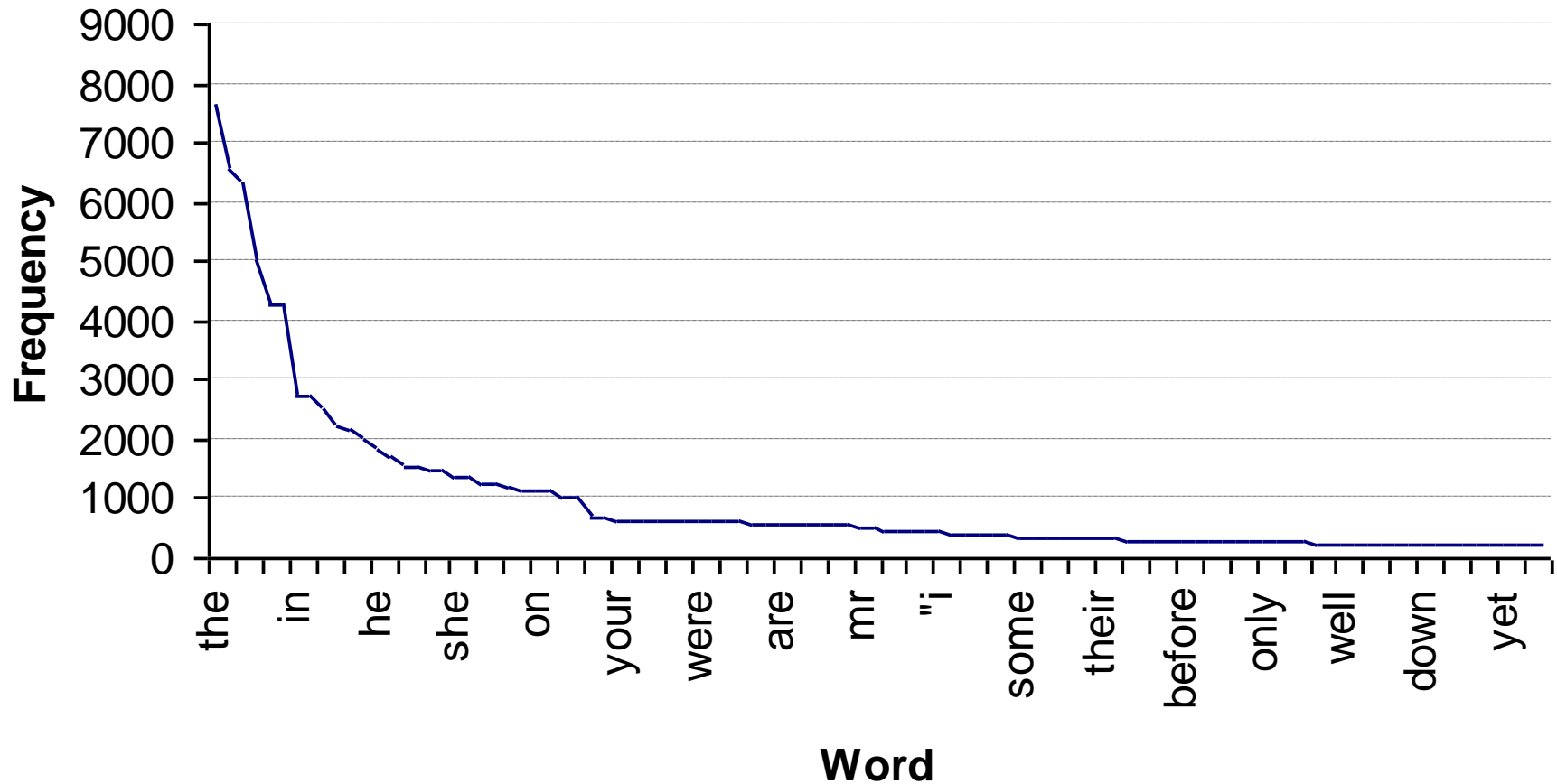
- Complete novels available online:
<http://www.literature.org>
- Start with “Jane Eyre”, Charlotte Brontë, 1847
- Penguin Edition - 489 pages
- 1,039 KBytes

Top 10 words in Jane Eyre

Top 10		101-110		7861-7870	
the	7638	can	218	abate	1
i	6536	about	217	abbot's	
and	6335	looked	216		1
to	5028	think	213	abigail	1
of	4299	seemed	209	abilities	1
a	4294	day	206	abode--whether	1
in	2717	any	204	abodes	1
you	2709	own	203	abominable	1
was	2495	much	200	abrid	1
it	2219	come	199	abruptness	1
				absences	1

Different words 15,827, Total words 184,640

Word frequency plot for Jane Eyre



Zipf's Law

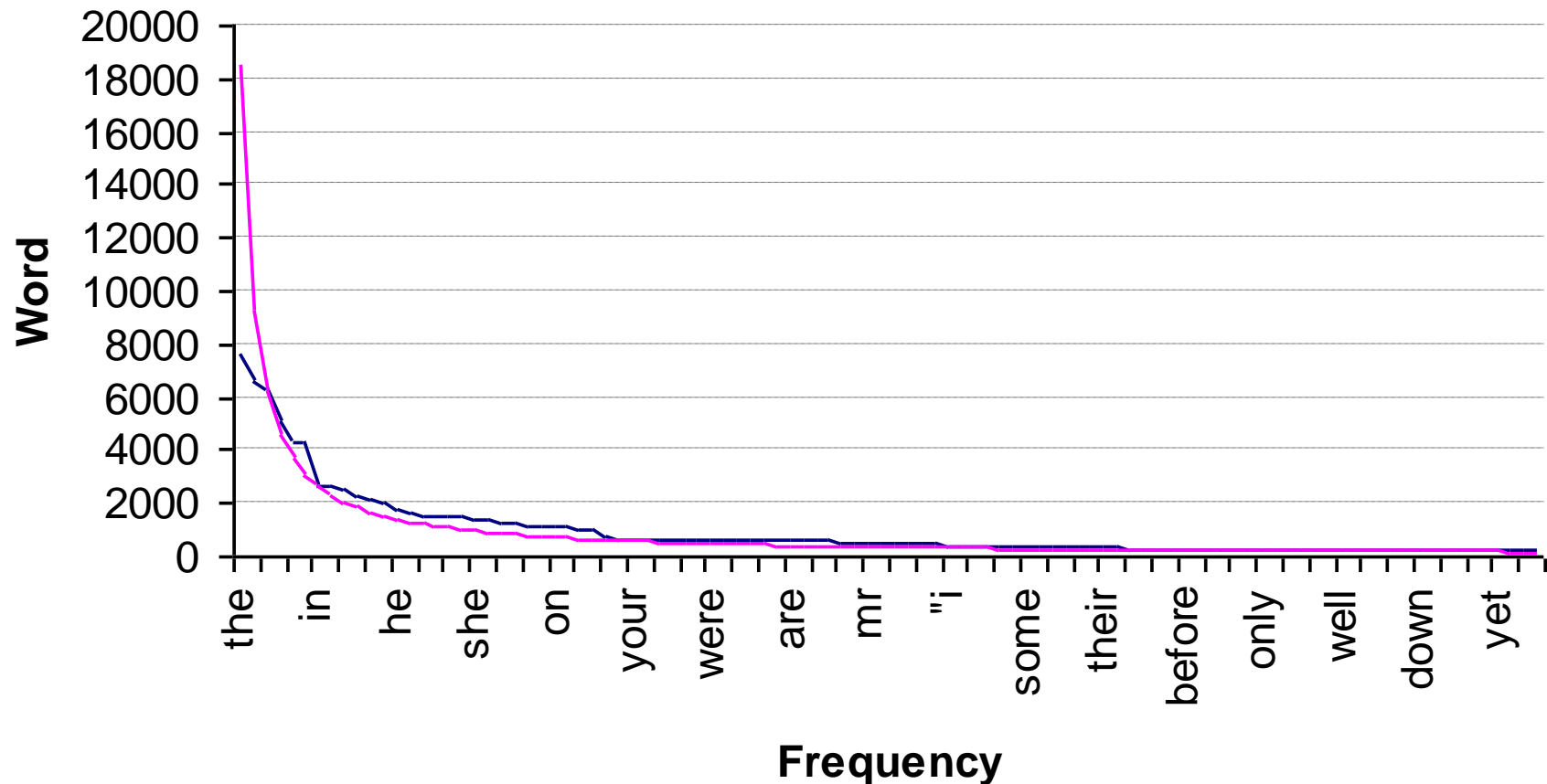
- George Kingsley Zipf (1902-1950)
 - For each word w , let $F(w)$ be the number of times w occurs in the corpus
 - Sort the words according to frequency
 - The word's rank-frequency distribution will be fitted closely by the function:

$$F(r) = \frac{C}{r^\alpha}, \text{ where } \alpha \approx 1, C \approx 0.1$$

Zipf's Law

$$\begin{aligned} \text{total} &= 184,640 & \% < 10 \text{ occurs?} \\ \text{vocab} &= 15,824 \\ f(r) &= \frac{0.1}{r} & f(10) &= \frac{0.1}{10} = \frac{0.1}{10} \\ r &= 1846.4 \end{aligned}$$

Zipf's law ——— Actual statistics from "Jane Eyre" $\frac{13990}{15824} \approx 88\%$



Zipf's Law (logarithm form)

$$F(r) = \frac{C}{r^\alpha}, \text{ where } \alpha \approx 1, C \approx 0.1$$

Therefore,

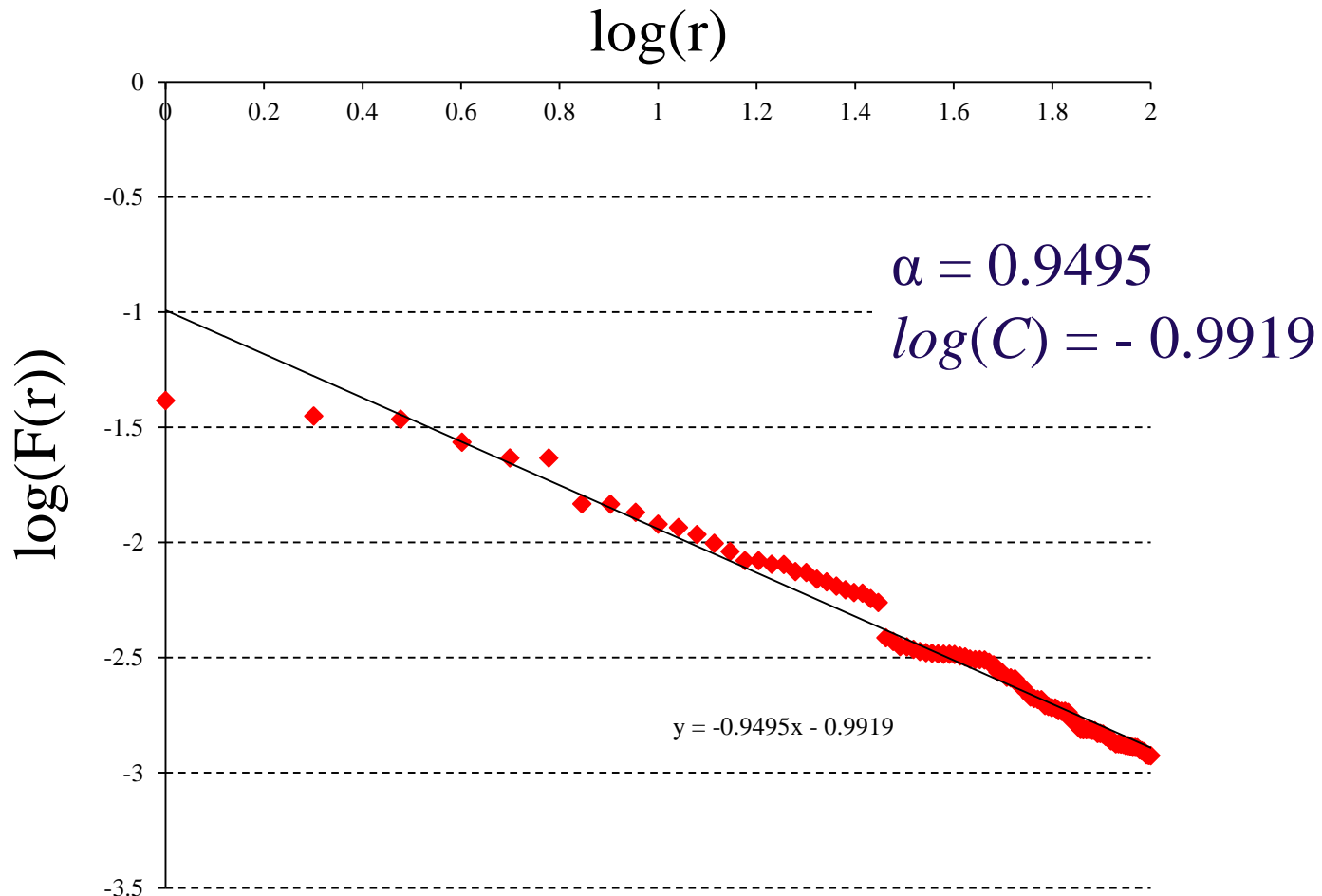
$$\log(F(r)) = \log(C) - \alpha \log(r)$$

Handwritten red annotations:
A red triangle under $\log(F(r))$.
A red triangle under $\log(C)$.
A red triangle under α .

- On a log-log scale, Zipf's Law predicts a straight-line relationship between log-rank and log-frequency, where α is the slope of the line and C is the intersection with the vertical axis
- This provides a way to estimate C and α

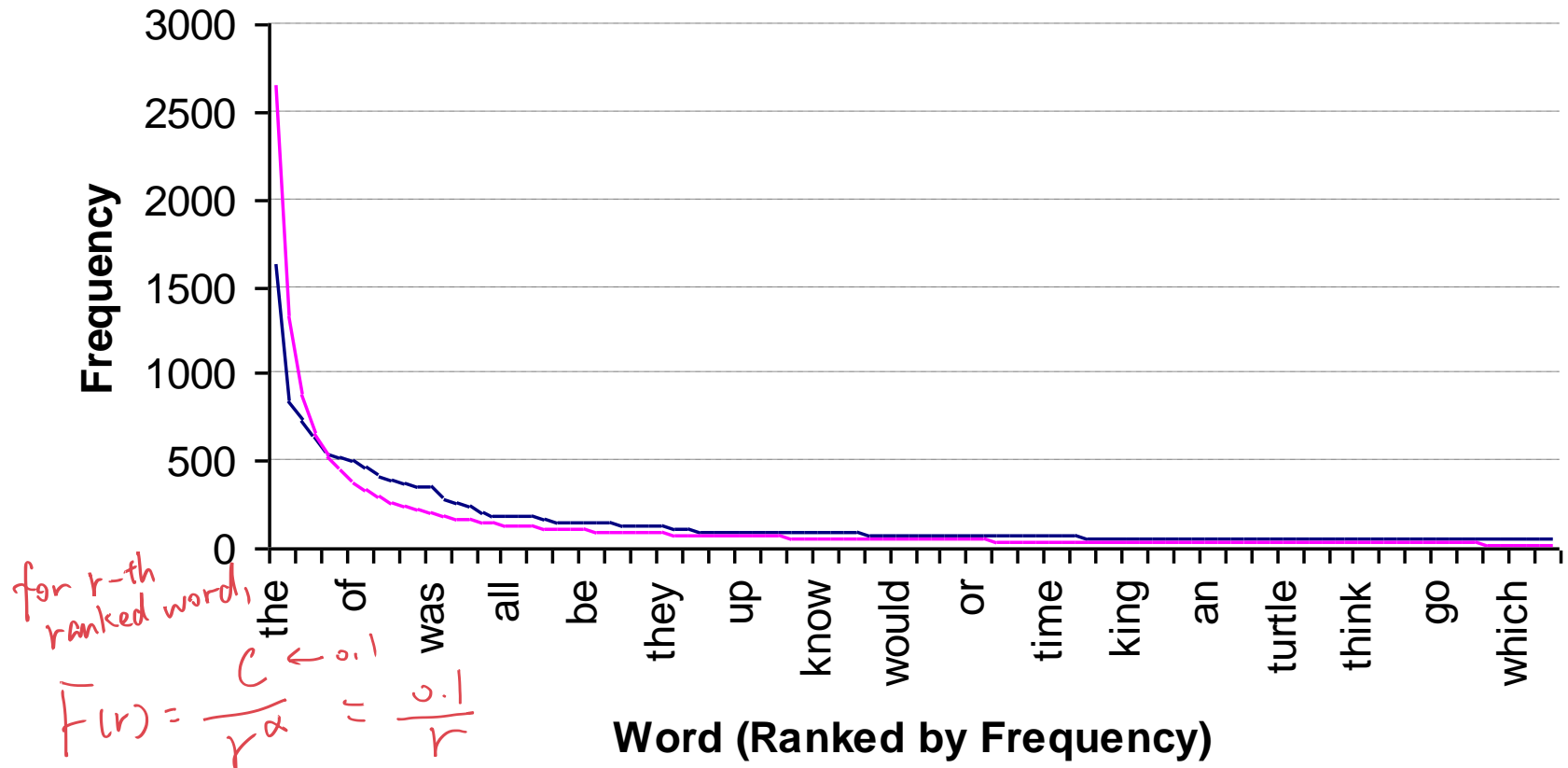
Zipf's Law (logarithm form)

Zipf's Law ——— Actual statistics from “Jane Eyre” ♦



Word Frequency Plot: Alice in Wonderland

Zipf's law ———— Actual statistics from "Alice in Wonderland" ————



Different words 2,787, Total words 26,395

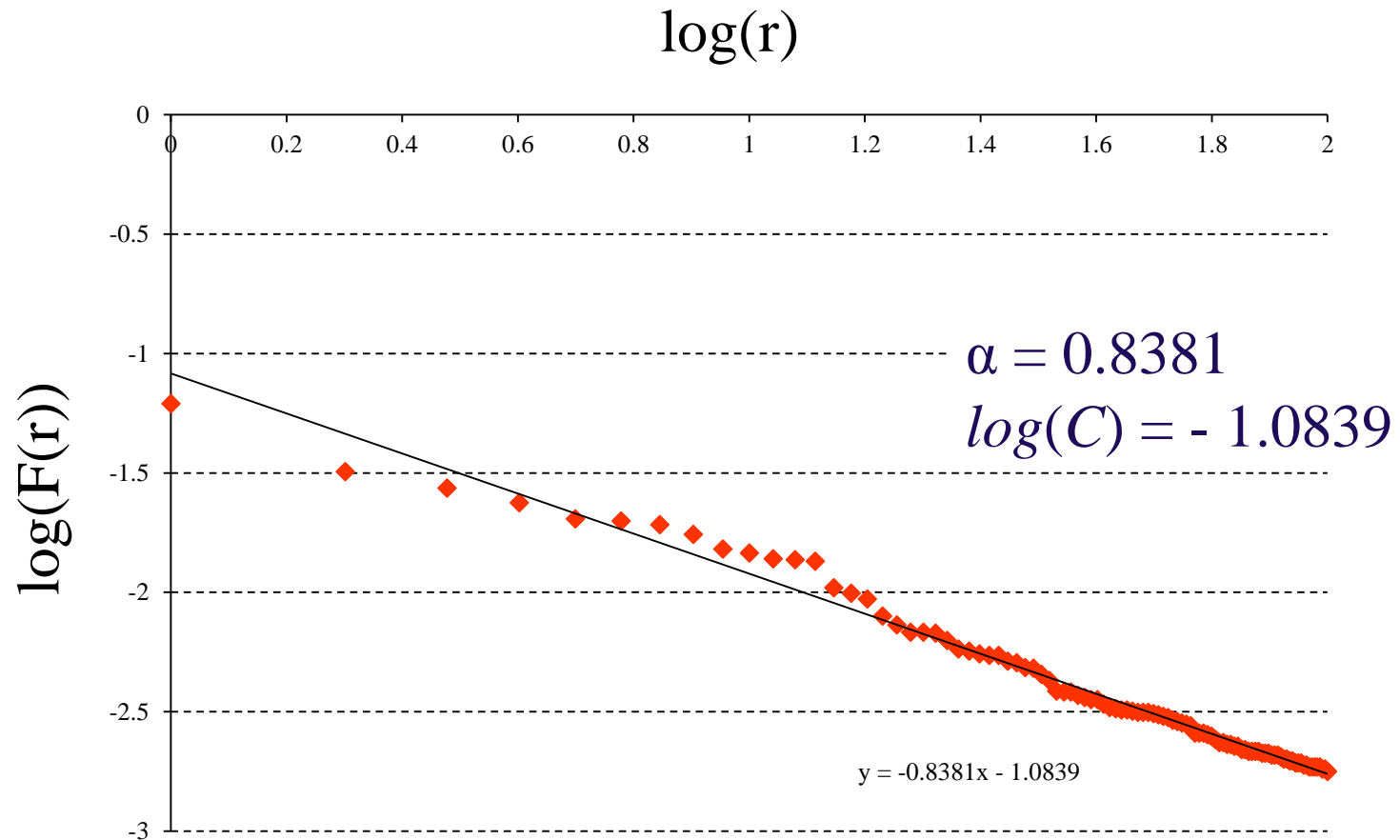
$$f(r) = \frac{1}{\text{total}}$$

$$\frac{0.1}{r} = \frac{10}{26395} \quad r = 263.95 \approx 264$$

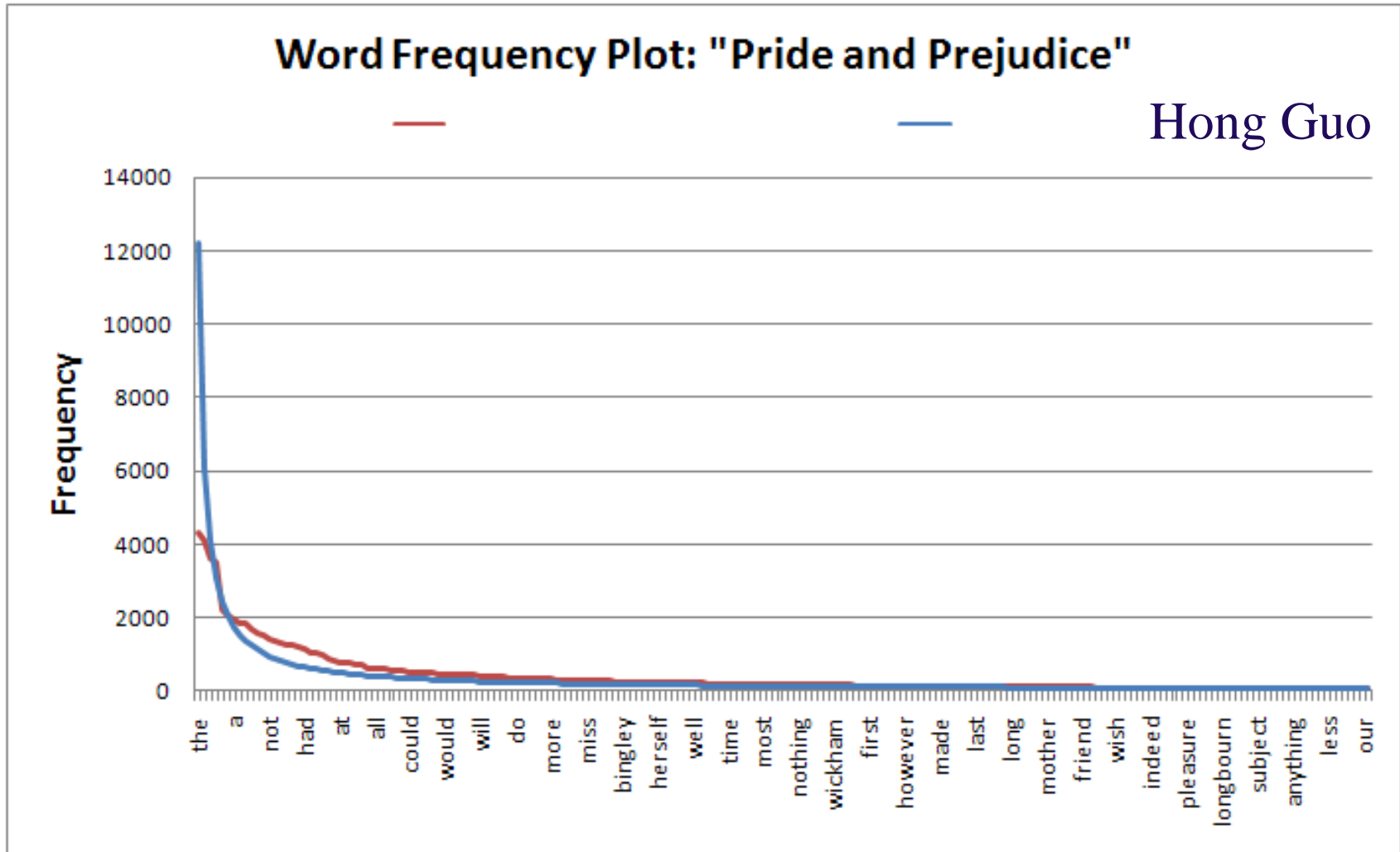
$$\frac{2787 - 264}{2787} = 90\%$$

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Log-log plot – Alice in Wonderland

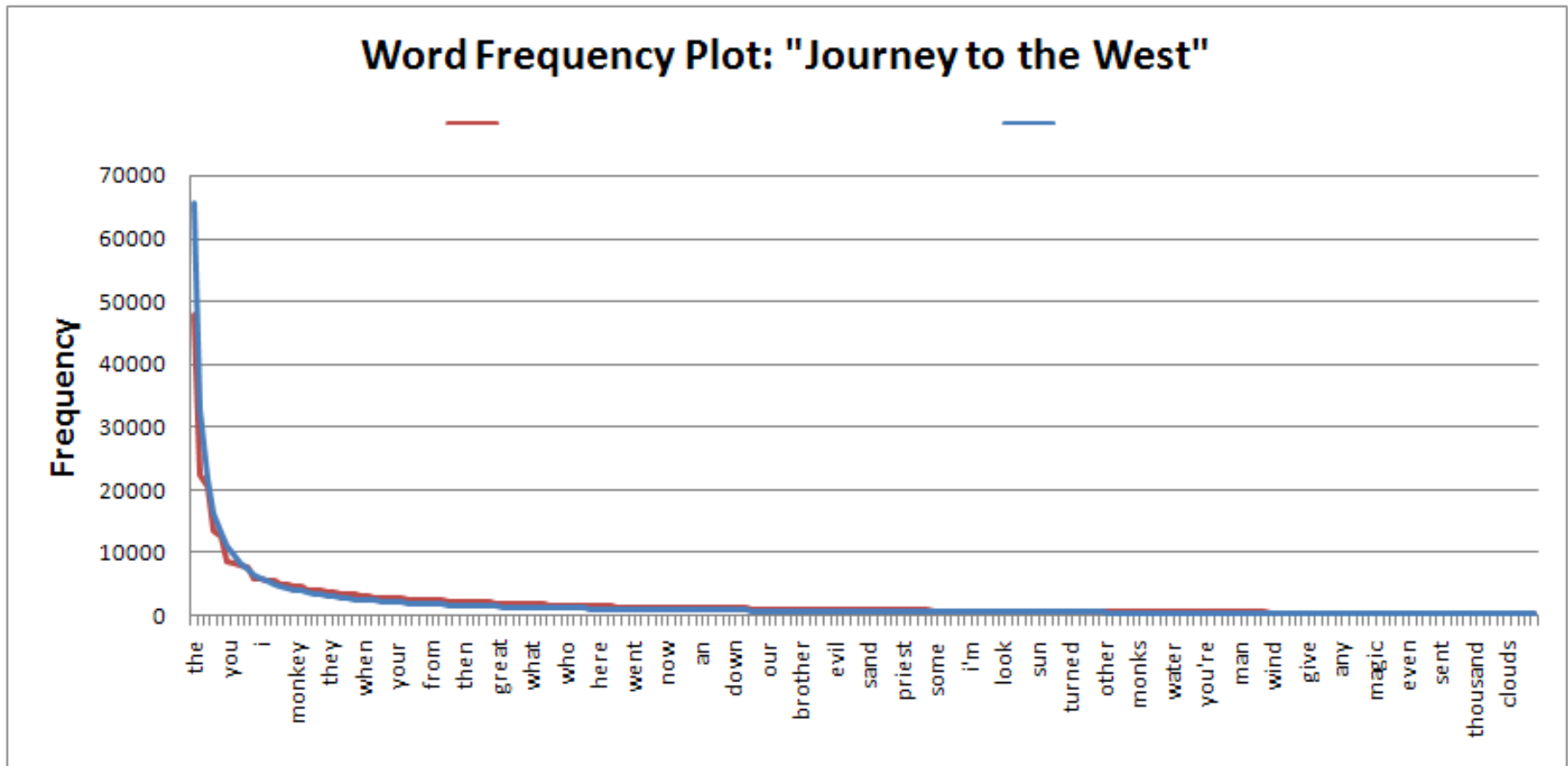


Zipf - Pride and Prejudice



Zipf vs “Journey to the West”

Hong Guo



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Some non-text examples

- Mathematics Today, vol. 47, no. 5, October 2011
- “Urban maths – Zipf’s Law”
 - Populations of the countries of the world
 - UK new car sales 2010
 - Counts of first digit from 1,836 equity prices quoted in The Times

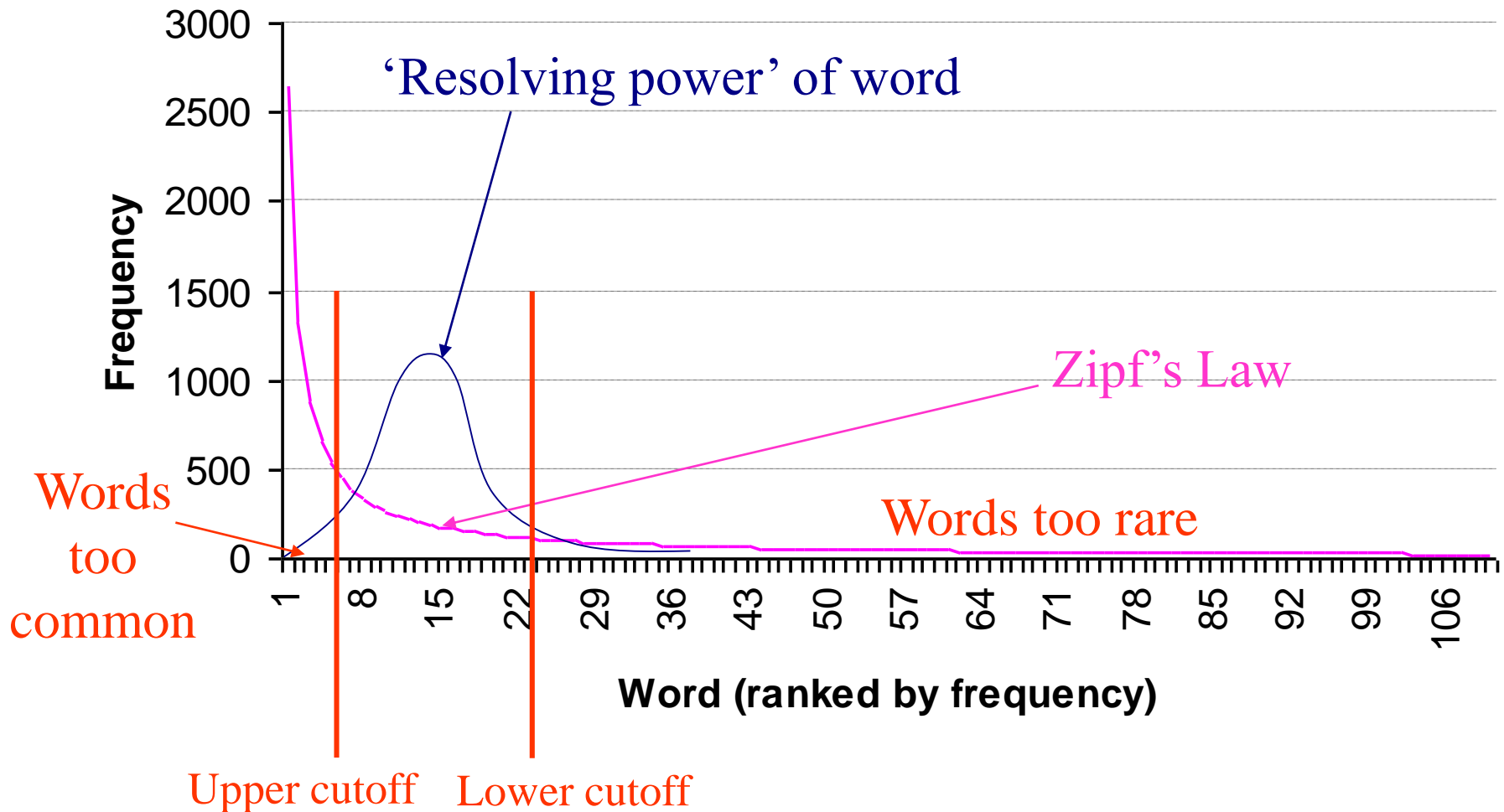
Zipf's Law

- Why does it hold?
- Is it relevant to Information Retrieval?

Why does Zipf's Law work?

- Zipf's law appears to reflect a number of factors:
 - The requirements of humans to communicate
 - Use as little effort as possible to successfully communicate a message
 - Basic combinatorics
 - The requirement of grammar for simple 'glue' words
 - Author and topic vocabularies

'Resolving Power' of words



Homework

- Calculate α and C for the PayPal UserAgreement
 - Download the PayPal user agreement
 - Download zipf.c from the course website
 - Compile it under your favourite OS (see hints in comments at top of source)
 - Plot the result on a log-log scale using Excel
 - Find the best straight-line fit