UNIVERSITÄT ZU KÖLN

Counting Words, Corpus Statistics, Encoding

Sprachverarbeitung (VL + Ü)

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INSTITUT FÜR DIGITAL HUMANITIES
UNIVERSITÄT ZU KÖLN

Recap

- Computational Linguistics as a discipline between computer science and linguistics
  - also known as »natural language processing«, (NLP)
- History of CL
  - Word embeddings
  - Transformer models
  - Chatbots
  - CL has exploded in the last 10 years
- Experiments are used to make progress in CL

Section 1

Corpora

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- (Large) collections of linguistic expressions
- Speech corpora: Spoken language
  - File formats: wav, mp3, ...
- Text corpora: Written language
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- Text corpora: Written language
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- Why do we look at corpora?
  - Making statements about language needs to take into account many language expressions
  - We under-estimate creativity, flexibility and productivity of language use

  → Empiricism

Meta data and annotations

Meta data: Data about the data

- Information about the corpus
- Language, date of creation, author(s), publication source, ...
- Machine-readable: XML, JSON, CSV, ...

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- Examples
  - Linguistic annotation: Parts of speech, named entities, syntactic relations, ...
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- Examples
  - Linguistic annotation: Parts of speech, named entities, syntactic relations, ...
  - Non-linguistic annotation: Sentiment expressions, rhetoric devices, arguments, ...
- Explicit location in the corpus: Document/word/character numbers in text, milliseconds in speech

Preparations (for text corpora)

- OCR: Optical Character Recognition (Manning/Schütze, 1999, 123)
  - Convert images (e.g., from a scan) into text
  - Huge improvements in last five years

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- OCR: Optical Character Recognition (Manning/Schütze, 1999, 123)
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  - Huge improvements in last five years
- Encoding: How to specify characters in a computer
  - Simple: ASCII (7 bit per character, $2^7 = 128$ different characters)
  - Outdated: Latin-1 / ISO-8859 (8 bit, $\Rightarrow 256$ diff. characters)
  - Modern: Unicode (e.g., UTF-8)
    - 1 B/char to 4 B/char
    - $1\,112\,064$ characters can be represented

Tools and Techniques

- Plain text editors
  - We often want to inspect the corpus as it is on disk (i.e., without an editor interfering too much)
  - Mac: Textmate/emacs/vi; Windows: Notepad++/emacs/vi

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- Regular expressions
  - The most important tool for corpus analysis
    - Cleanup (e.g., after scraping a corpus from the web)
    - Analysis (e.g., to find all variants of a word or deal with slang)
  - Usable in *all** programming languages and find tools

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- Command line
  - Large corpora often cannot be displayed with GUI tools
  - Command line tools faster and more memory efficient

Tokenization

- Segmenting a corpus into individual units
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- Tokens: Words, punctuation, numbers, symbols, ...
- Naive: Splitting at white space (space, newline, ...)
  - Why naive?
- Solved, but complex
  - E.g., syntactic points vs. morphological points
- Sometimes, shortcuts are ok – depends on the use case

Word Counts

Count	Word
585	die
584	und
407	er
404	der
348	zu
311	sich
259	nicht
250	sie
243	in
243	den
233	war
218	Gregor
189	mit
178	das
176	auf
171	es
162	dem
155	hatte
137	ein
136	aber
133	daß
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Als Gregor Samsa eines Morgens aus unruhigen Träumen erwachte, fand er sich in seinem Bett zu einem ungeheueren Ungeziefer verwandelt. ...

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- Number of words in a text
- Most frequent words (MFW) are function words
- ›Content words‹ that appear often indicate text content

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Stop Word Removal

- Common practice: Remove »stop words«
- But there are choices:
  - Should stop words be removed at all?
  - Which words do we consider stop words?

⚠ Removing words is not content-preserving

Zipf's Law

Manning/Schütze, 1999, 23 ff.

- George Kingsley Zipf (1902-1950): American Linguist
- Basic property of human language
  - Frequency distribution of words (in a corpus) is stable
  - Word frequency is inversely proportional to its position in the ranking

$$f \propto \frac{1}{r}$$

(there is a constant k, such that $f \times r = k$)

Zipf's Law

Manning/Schütze, 1999, 23 ff.

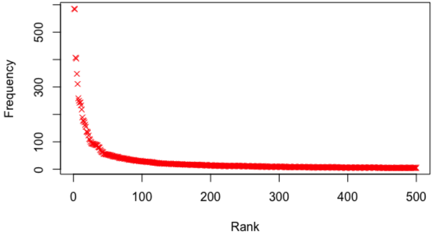

Figure: Words sorted after their frequency (red). Text: Kafka's »Die Verwandlung«.

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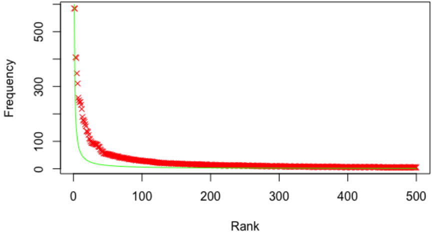

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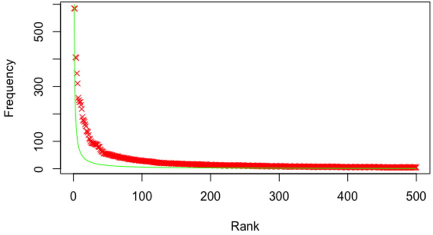

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Consequences

- Very few words appear with very high frequency
- The vast majority of words appear only once
  - It's difficult to learn something about these words!

Counting Words

- Absolute numbers are not that interesting
- Insights are only generated through comparison

Abs. number	Word form
20	women
67	woman
31	men
79	family
82	sister
83	friend
99	bath
117	father
133	man
144	sir

Table: Jane Austens's *Persuasion* (nouns)

Abs. number	Word form
0	friend
2	bath
11	women
23	men
30	father
68	woman
83	family
113	sir
121	man
282	sister

Table: Jane Austens's *Sense and Sensibility* (nouns)

Absolute Numbers

Word	Persuasion	Sense
woman	67	68
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...does it make sense to compare absolute numbers? No.

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- Scaling using their length: Division by the total number of words

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sister	82	0.000 97 %	282	0.002 33 %

...does it make sense to compare absolute numbers? No.

- The texts/corpora do not have the same size
- Scaling using their length: Division by the total number of words
- Visible changes: Proportion of »sister«: $3.4 \rightarrow 2.4$

Scaling

- Number of words: Result of a measurement
- If measuring in different scenarios, it's important to scale the results
  - »In a text that is much shorter, there are much less chances for a certain word to be used.«

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- It's not always obvious how to scaled
- When reading research: Was it scaled, and how?

Types and Tokens

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Example

the cat chases the mouse

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Example

the cat chases the mouse

- Tokens: the, cat, chases, the, mouse
- Types: the, cat, chases, mouse

Type-Token-Ratio (TTR)

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- Construct a sentence with 5 tokens and 1 type!

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- Construct a sentence with 5 tokens and 4 types!
  - »the cat loves the mouse«
- Construct a sentence with 5 tokens and 1 type!
  - »dog dog dog dog dog« (not really a sentence …)
  - It's not possible to create a ›proper‹ sentence with 1 type

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- Measure for ›lexical variability‹

$$TTR = \frac{\text{number of types}}{\text{number of tokens}}$$

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- Max value: 1 (there cannot be more types than tokens)
- Min value: $\epsilon = \frac{1}{\text{very large number}}$
- Real (German) texts
  - $10\,000$ words (Wikipedia): $\frac{4021}{10\,000} = 0.4021$

TTR and Text Length

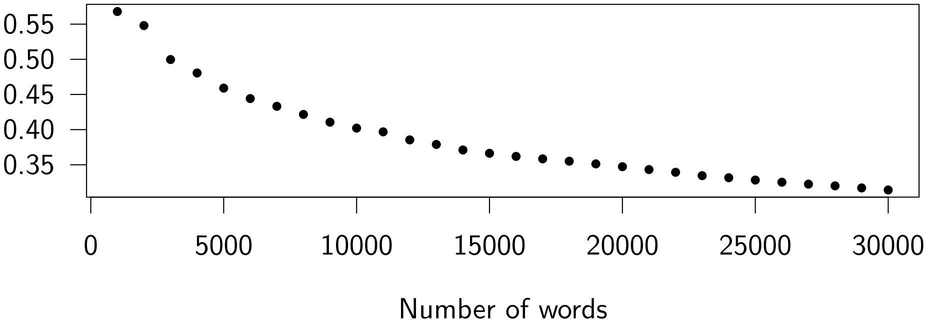

Figure: Type-Token-Ratio for increasing text lengths

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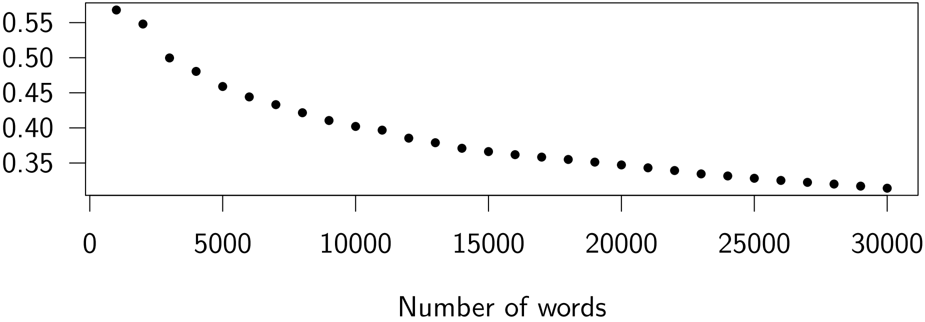

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- Increasing length → lower TTR!
- Why?

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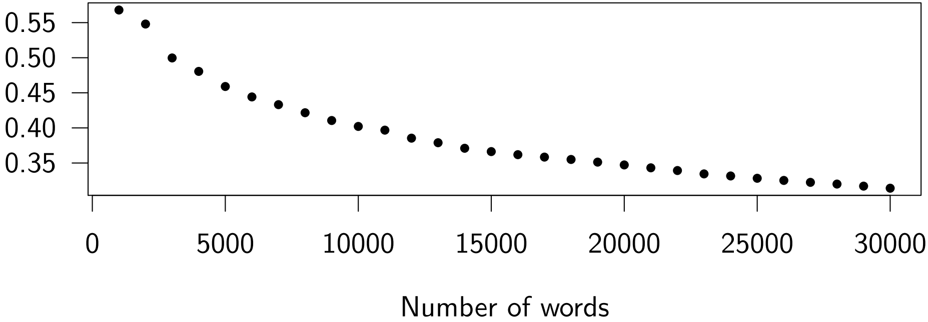

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- Calculate arithmetic mean over TTR values

$$
\begin{aligned}
TTR_n &= \frac{\text{number of types in } n\text{th window}}{\text{number of tokens in } n\text{th window}} \\
STTR &= \frac{1}{w}\sum_{i=0}^{w} TTR_i
\end{aligned}
$$

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Example

The dog barks.

- 1-grams: »the«, »dog«, »barks«, ».«
- 2-grams (bigrams): »the dog«, »dog barks«, »barks .«
- 3-grams (trigrams): »the dog barks«, »dog barks .«

Section 2

Encoding

Introduction

- How to represent text data in a computer
- Enumeration: Each character is assigned a number
- American Standard Code for Information Interchange (ASCII) Wikipedia: ASCII
  - $128 = 2^7$ characters, including control symbols for telegraphy
  - No German Umlauts etc.

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  - No German Umlauts etc.
- Unicode: A single standard to represent *all* characters from all languages unicode.org
  - $149\,186$ characters, including CJK ideographs Unicode 15.0 charts
  - Complex enumeration scheme

Unicode

- Code point: An integer in the Unicode standard
  - Written in hexadecimal and prefixed with `U+`
  - E.g.: `U+00E4` = »Latin Small Letter a with Diaeresis« = ä

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  - Written in hexadecimal and prefixed with `U+`
  - E.g.: `U+00E4` = »Latin Small Letter a with Diaeresis« = ä
- Mapping methods used to map each code point onto a code unit
  - Code unit: A sequence of bytes that represent some character
- Unicode transformation format (UTF): Most common mapping
  - UTF-8: uses one to four bytes for each code point, maximizes compatibility with ASCII
  - UTF-16, uses one or two 16-bit code units per code point
    - Strings in Java!
  - UTF-32, uses one 32-bit code unit per code point

UTF-8

- Code points `U+0000` to `U+007F` (128) represented in ASCII way, with a leading zero
  - E.g.: A_{ASCII} =`U+0041` $= 65_{10} = 41_{16} = 1000001_2 =$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

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- Code points `U+0080` to `U+07FF` (1920) are represented in two bytes
  - First byte starts with 110, second with 10
  - E.g.: ä $=$ `U+00E4` $= 228_{10} = 11100100_2 =$ | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |

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  - E.g.: ä = `U+00E4` $= 228_{10} = 11100100_2 =$ 1 1 0 0 0 0 1 1   1 0 1 0 0 1 0 0
- `U+0800` to `U+FFFF`: 1 1 1 0 _ _ _ _   1 0 _ _ _ _ _ _   1 0 _ _ _ _ _ _ (three bytes)
- `U+10000` to `U+10FFFF`: 4 Bytes, first one starting with 11110, others with 10

Parsing UTF-8

- If a byte starts with a 0: The character is one byte long
- If a byte starts with a 1:
  - The number of 1s before the first 0 determine how many bytes belong to this character
  - Check that they start with 10
  - Take them together as a single character

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Determining Encoding

- It is difficult to (automatically) determine the encoding of a text
- »11000011 10100100« is »ä« in UTF-8, but »Ã¤« in ISO Latin 1 – how to know what's correct?

Combined Characters

- For flexibility, there is a mechanism for combining characters
- `U+0300` to `U+036F` defines combining diacritical marks
- To be combined with the preceding character
- `U+0041 U+0308` represent »Ä« in decomposed form

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Normalization

- Normalization Form D (NFD):
  - »Canonical Decomposition«
  - All combined characters are represented in their decomposed form
- Normalization Form C (NFC):
  - »Canonical Decomposition, followed by Canonical Composition«

Combined Characters

Figure: Having fun with Unicode Source

More (Interesting) Oddities

- Ω
  - Represented as `U+2126` and `U+03A9`

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  - `U+03A9`: The Greek letter
  - `U+2126`: The physical unit for electrical resistance

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  - Represented as `U+2126` and `U+03A9`
  - `U+03A9`: The Greek letter
  - `U+2126`: The physical unit for electrical resistance
- »a« also represented twice
  - `U+0061`: Latin small letter a
  - `U+0430`: Cyrillic small letter a
  - ⚠ This is/was also a security risk, because `https://mybank.com` and `https://mybank.com` look similar

More (Interesting) Oddities: Emojis

- Country Flags
  - Emoji support came 2010, including country flags
  - No individual code point for each flag
  - Instead: Regional indicator symbols that represent ISO 3166-1 codes for countries
  - Implementations should render `U+1F1E9 U+1F1EA` as 🇩🇪
    - If that's not possible, use Roman letters (`U+1F1E9 U+1F1EA` = DE)

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- Emoji skin color variation: Similar to character combination
  - `U+1F44C U+1F3FB` = 👌🏻 `U+1F44C U+1F3FF` = 👌🏿

Not a solved prob

Section 3

Summary

Summary

- Types and tokens
- Zipf distribution
- Type-Token-Ratio
- Encoding
- Unicode

References I

Manning, Christopher D./Hinrich Schütze (1999). *Foundations of Statistical Natural Language Processing*. Cambridge, Massachusetts and London, England: MIT Press.