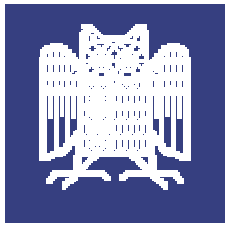


Statistics/Probability Theory for Computational Linguistics

Dietrich Klakow

Warning

- This course is for people who never had this topic or equivalent

The notion "probability of a sentence" is an entirely useless one…

Noam Chomsky, 1969

"Statistical natural-language processing is, in my estimation, one of the most fast-moving and exciting areas of computer science these days. "

-- Eugene Charniak, Department of Computer Science, Brown University, 1999

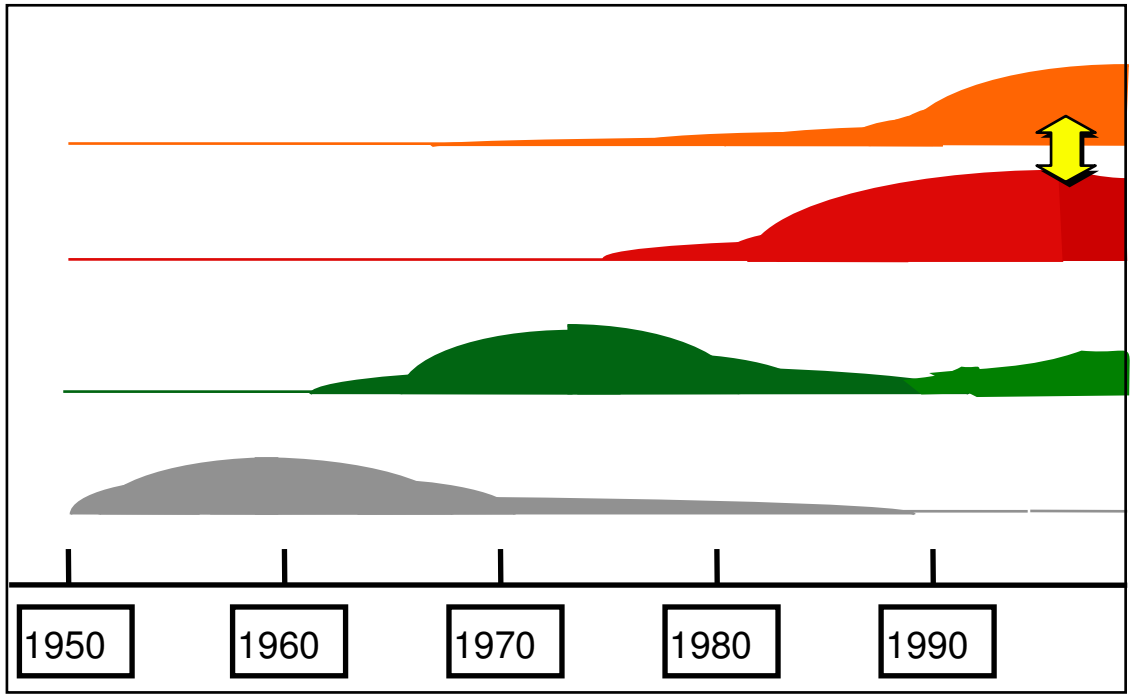
Basics Paradigms in Computational Linguistics

statistical methods

Declarative linguistic formalisms in CL

special methods

direct programming, no separation of description and processing



Based on a slide by Hans Uszkoreit

Literature

Foundations of Statistical Natural Language Processing

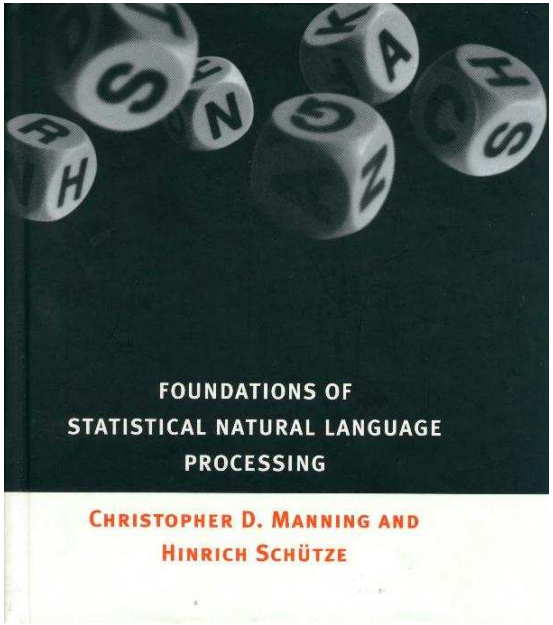
by Christopher D. Manning, Hinrich Schütze

Publisher: The MIT Press;

1st edition (June 18, 1999)

ISBN: 0262133601

List Price:$77.00



See http://cognet.mit.edu/library/books/mitpress/0262133601/cache/chap2.pdf

Motivation

Motivation 1

- Not everything that could happen will happen
- E.g. not all readings of a sentence are equally likely

Example for Ambiguous Readings

„Früher stellten die Frauen der Inseln am Wochenende Kopftücher mit Blumenmotiven her, die ihre Männer an den folgenden Montagen auf dem Markt im Zentrum der Hauptinsel verkauften.“

How many different readings are there? **258.048**

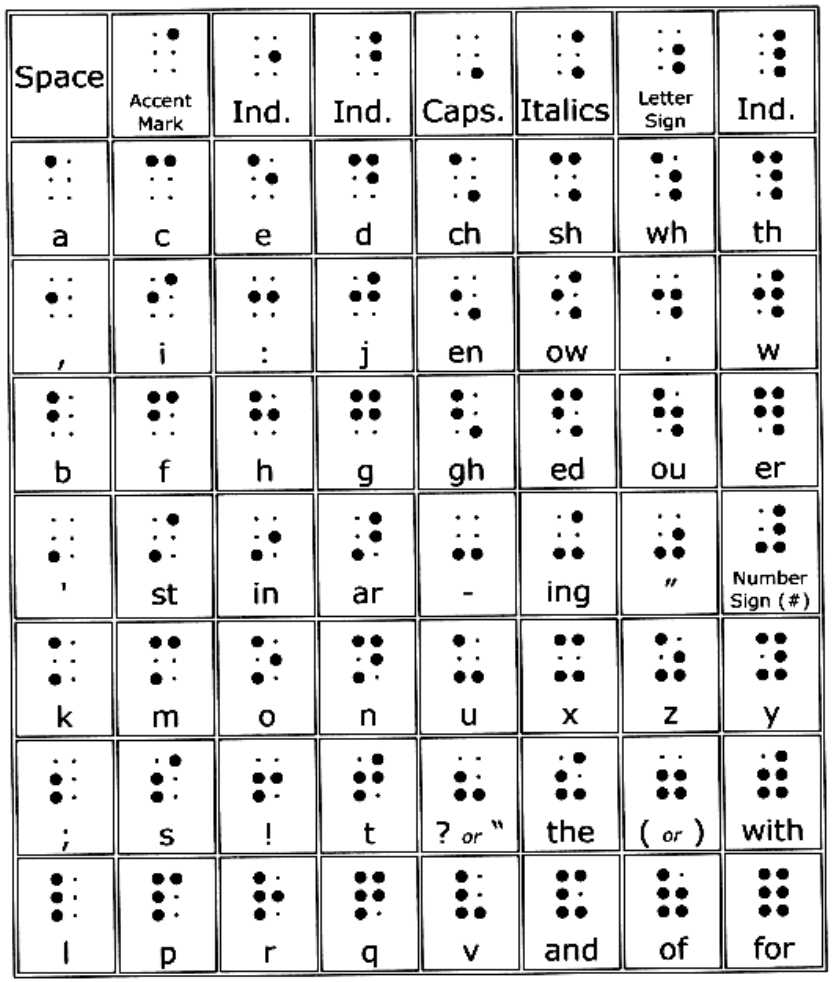
Most of those readings are unlikely for a probabilistic context free grammars

Adapted from HU

Motivation 2

- Using probability theory, quite powerful systems can be developed

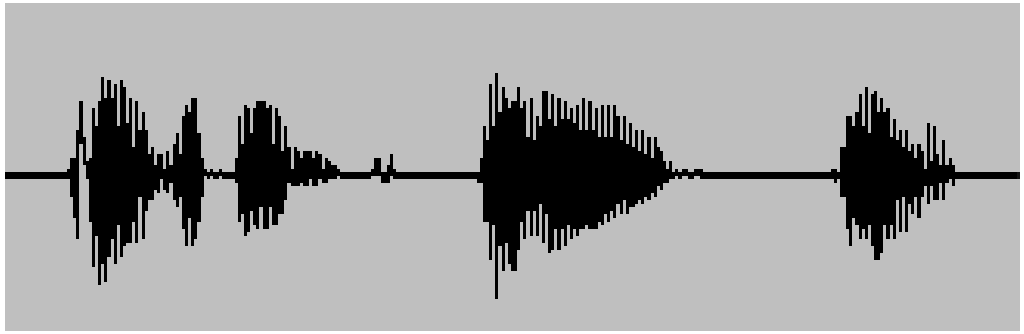
Language coding and compression



Space	Accent Mark	Ind.	Ind.	Caps.	Italics	Letter Sign	Ind.
a	c	e	d	ch	sh	wh	th
,	i	:	j	en	ow	.	w
b	f	h	g	gh	ed	ou	er
'	st	in	ar	-	ing	"	Number Sign (#)
k	m	o	n	u	x	z	y
;	s	!	t	? *or* "	the	(*or*)	with
l	p	r	q	v	and	of	for

Frequent letter combinations get their own symbol

Speech Recognition



Model probability of word sequence given speech signal

⇨ find most likely word sequence

Example for ambiguous translations (from Leos dictionary)

band das Band

band die Band - *Musikgruppe*

band [tech.] das Band

band die Bandbreite

band [chem.] die Bande - *im Spektrum* **band** das Beffchen **band** der Bereich **band** der Bund **band** der Frequenzbereich **band** die Gruppe **band** der Gurt **band** die Kapelle **band** die Leiste **band** die Musikkapelle **band** das Orchester **band** die Schar **band** die Schnur **band** [mus.] der Spielmannszug **band** der Streifen **band** die Truppe narrowband *also:* narrow-**band** *adj.* engbandig narrowband *also:* narrow-**band** *adj.* schmalbandig sideband *also:* side **band** [elec.] [telecom.] das Seitenband **Verben und Verbzusammensetzungen** to **band** together sich verbinden to **band** together sich vereinigen to **band** together sich zusammenrotten to **band** together sich zusammentun to **band** together zu einer Gruppe vereinigen to beat the **band** nie da gewesen sein to cross-**band** [tech.] absperren *[Holzverarbeitung]* **Zusammengesetzte Einträge** abrasive **band** - *cloth* [tech.] das Bandschleifleinen abrasive **band** - *paper* [tech.] das Bandschleifpapier adhesive **band** [tech.] das Klischeeklebeband attenuating **band** [aviat.] der Dämpfungsbereich audio **band** [phys.] der Hörbereich **band** aerial die Bandantenne **band**-aid das Heftpflaster **band**-aid [Amer.] [med.] das Pflaster **band**-aid [Amer.] [med.] das Wundpflaster **band** box die Hutschachtel **band** ceramics die Bandkeramik **band** collar der Stehkragen **band**-conveyor das Fließband **band** conveyor [tech.] der Gurtförderer **band**-conveyor das Transportband **band** edge die Bandkante **band** emission [autom.] die Bandemission **band** emission [autom.] die Bandenemission **band** gap [phys.] die Bandlücke **band** gate [tech.] der Bandausschnitt - *Spritzgusswerkzeug [Kunststoffe]* **band** grinder [tech.] die Bandschleifmaschine **band** matrix [math.] die Bandmatrix **band** of barrel das Fassband **band** of barrel der Fassreifen **band** of radiation [phys.] der Strahlungsbereich **band** of robbers die Räuberbande **band** overlap [tech.] die Bandüberlappung **band** printer [print.] der Banddrucker **band** radiation [autom.] die Bandenstrahlung **band** resaw [tech.] die Trennbandsäge **band** saw [tech.] die Bandsäge **band**-saw die Bandsäge **band** spectrum [tech.] das Bandenspektrum **band**-spread die Bandspreizung **band**-stand der Musikpavillon **band** structure [phys.] die Bandstruktur **band**-switch der Bereichsschalter **band**-switch der Bereichsumschalter **band** width die Bandbreite base **band** [tech.] das Basisband brake **band** [tech.] das Bremsband brass **band** [mus.] die Blaskapelle brass **band** [mus.] die Blechmusik brass **band** [mus.] der Spielmannszug broad **band** [tech.] das Breitband carrier **band** [tech.] das Trägerfrequenzband clay **band** [geol.] das Salband clincher **band** [autom.] das Wulstband *[Reifen]* conveyer **band** das Förderband cover **band** [tech.] das Deckband currency **band** [bank.] die Währungsbandbreite dance **band** die Tanzkapelle dead **band** [metr.] die Totzone edge **band** [tech.] der Umleimer *[Tischlerei]* elastic **band** [tech.] das Gummiband elastic **band** der Gummistrumpf error **band** der Zufallsstreubereich filter **band** [tech.] das Siebband flexible **band** die Randzeit - *Arbeitszeit* glassy **band** [tech.] glasiger Streifen guard **band** [elec.] der Rasen - *Abstand zwischen den Schrägspuren, den Videospuren, der benutzt wird, um eine gegenseitige Beeinflussung der Spuren zu vermeiden* guard **band** [elec.] der Schutzabstand - *Abstand zwischen den Schrägspuren, den Videospuren, der benutzt wird, um eine gegenseitige Beeinflussung der Spuren zu vermeiden* guard **band** [elec.] [telecom.] der Schutzbereich - *zwischen zwei Kanälen zur Vermeidung von Interferenzen* guard **band** [telecom.] der

⇨ Word Sense Disambiguation

Part-Of-Speech Tagging

Xinhua News Agency , Guangzhou , March 16 (Reporter Chen Ji) The latest statistics show that from January through February this year , the export of high-tech products in Guangdong Province reached 3.76 billion US dollars , up 34.8% over the same period last year and accounted for 25.5% of the total export in the province .

Part-Of-Speech Tagging

Xinhua/NNP News/NNP Agency/NNP ,/, Guangzhou/NNP ,/, March/NNP 16/CD (/(Reporter/NNP Chen/NNP Ji/NNP)/SYM The/DT latest/JJS statistics/NNS show/VBP that/IN from/IN January/NNP through/IN February/NNP this/DT year/NN ,/, the/DT export/NN of/IN high-tech/JJ products/NNS in/IN Guangdong/NNP Province/NNP reached/VBD 3.76/CD billion/CD US/PRP dollars/NNS ,/, up/IN 34.8%/CD over/IN the/DT same/JJ period/NN last/JJ year/NN and/CC accounted/VBD for/IN 25.5%/CD of/IN the/DT total/JJ export/NN in/IN the/DT province/NN ./.

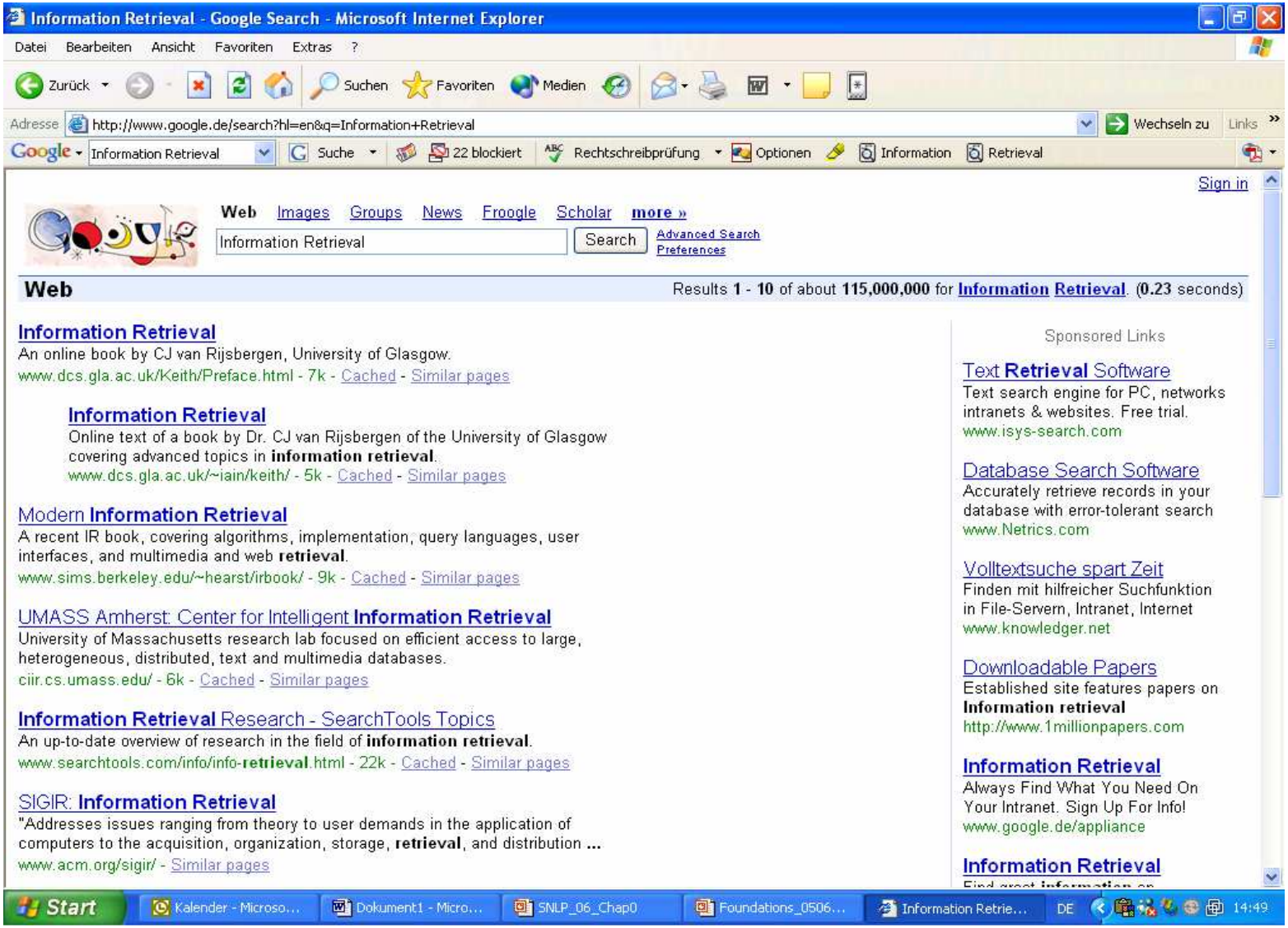
Named Entity Tagging

Task:

Identify names of people, organizations, locations, … in text

President <ENAMEX id="9" type="PERSON">Richard Nixon</ENAMEX> in <ENAMEX id="10" type="LOCATION">Moscow.</ENAMEX>

Information Retrieval



Text Classification
e.g. Spam Mail Classification

V/agra $3,3l
Amb/en
Mer/dia
C/alis $3,75
Val/um $l,21
X&nax
Som&

http://www.Chanatanxte.scriptmania.com/

Statistical Machine Translation

মানব পরিবারের সকল সদস্যের সমান ও অবিচ্ছেদ্য অধিকারসমূহ এবং সহজাত মর্যাদার স্বীকৃতিই হচ্ছে বিশ্বে শান্তি, স্বাধীনতা এবং ন্যায়বিচারের ভিত্তি

Whereas recognition of the inherent dignity and of the equal and inalienable rights of all members of the human family is the foundation of freedom, justice and peace in the world

History of Probability Theory

History of Probability Theory

- Antiquity
  - Search for ideal dice
    - Gambling, oracles
  - Insurances
    - Babylon, China
  - Pensions
    - Rom
- No formal approaches known

History of Probability Theory

- Medieval times
  - Research mostly done in cloisters
  - No significant progress in probability theory

History of Probability Theory

- Blaise Pascal (1623-1662)
  - Dice problems like this:
    - What is the chance that there is at least on six if you throw four dice at the same time
  - First approaches to combinatorics

History of Probability Theory

- Jakob Bernoulli (1655-1705)
  - Binomial distribution
    - Draw balls from an urn with returning them
  - Bernoulli chains
  - Law of large numbers:
    - The relative frequency of a random event will approach its theoretically expected fraction the more often the random experiment is repeated.

Law of large numbers

Number of rolls	Number of Heads		Ratio		Absolute difference	Relative difference
	Theo-ratical	Obser-ved	Theo-retical	Obser-ved		
100	50	48	0.500	0.480	2	0.020
1000	500	491	0.500	0.491	9	0.009
10000	5000	4970	0.500	0.497	30	0.003

History of Probability Theory

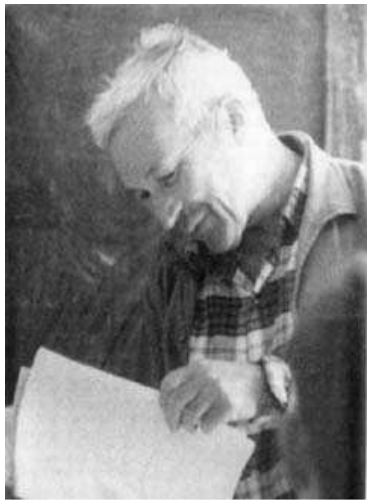
- Abraham de Moivre (1667-1754)
  - Normal distribution
  - Central limit theorem
    - If the random variable X is the some of infinitely many identically distributed random variables than X is normally distributed
    - Simulation from http://www.statistics4u.com/fundstat_germ/cc_central_limit.html

History of Probability Theory

- Thomas Bayes (1702–1761)
  - Conditional probabilities
  - Bayes rule

History of Probability Theory

- Andrej Kolmogorov (1903-1987)
- Axiomatic approach:
  - Probabilities are values between 0 and 1
  - Probabilities are normalised
  - Probabilities for “different” events add up



Early applications of statistics to Computational Linguistics

- Part-Of-Speech Tagging
  - Introduction of Hidden Markov Models in the mid 80s
  - In general much better then other methods known at that time
- Speech recognition
  - ca. 1980: Hidden-Markov-Modelle

Introduction to Probability Theory

Introduction to Probability Theory

-> White board

Simple Experiments

Simple statistical experiments

- Zipf distribution
- -> Perl script

Simple statistical experiments

- Distribution of the length of questions
- -> Perl script

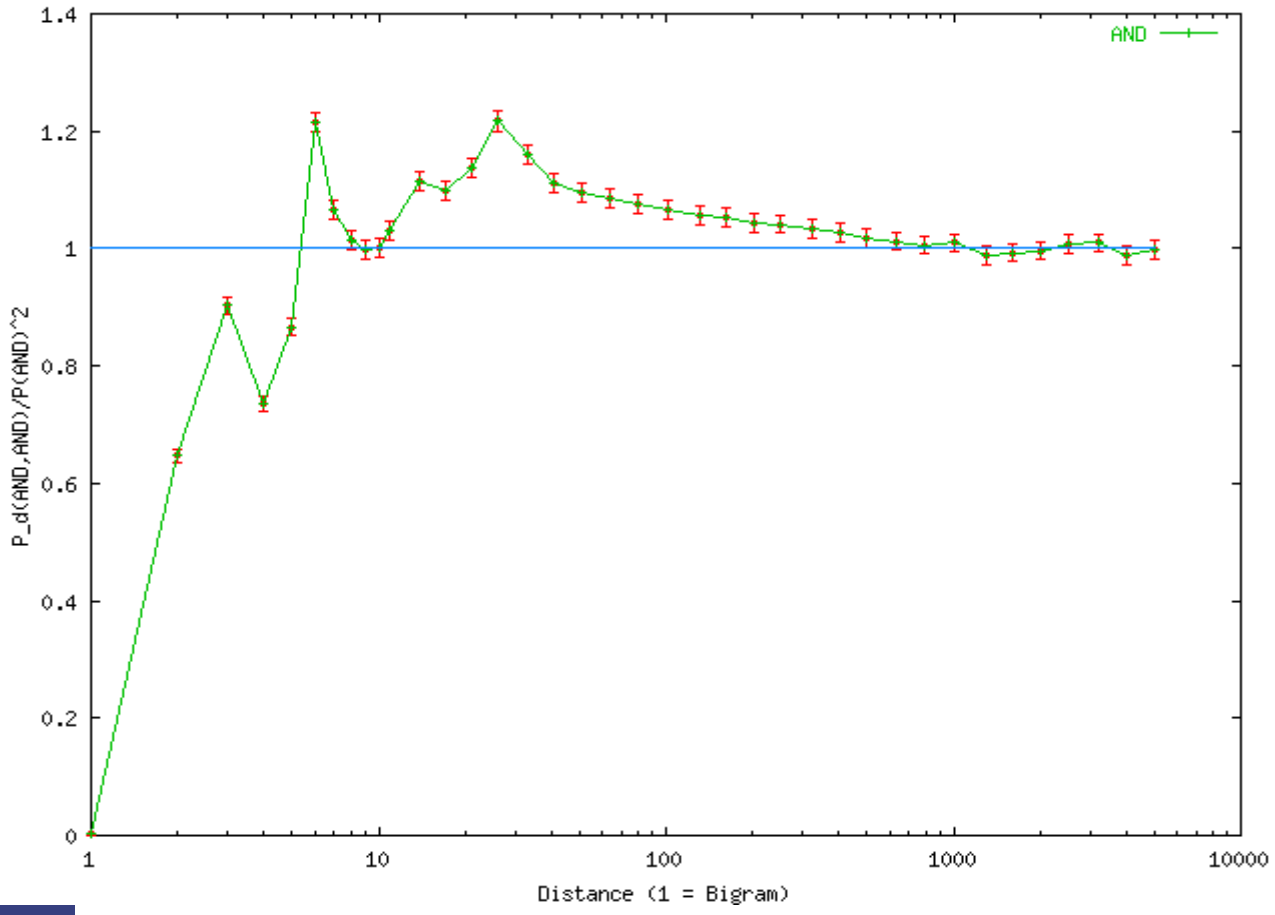
Correlation Function

- Definition:

$$c_d(w) = \frac{P_d(w\ w\ )}{P(w\ )^2}$$

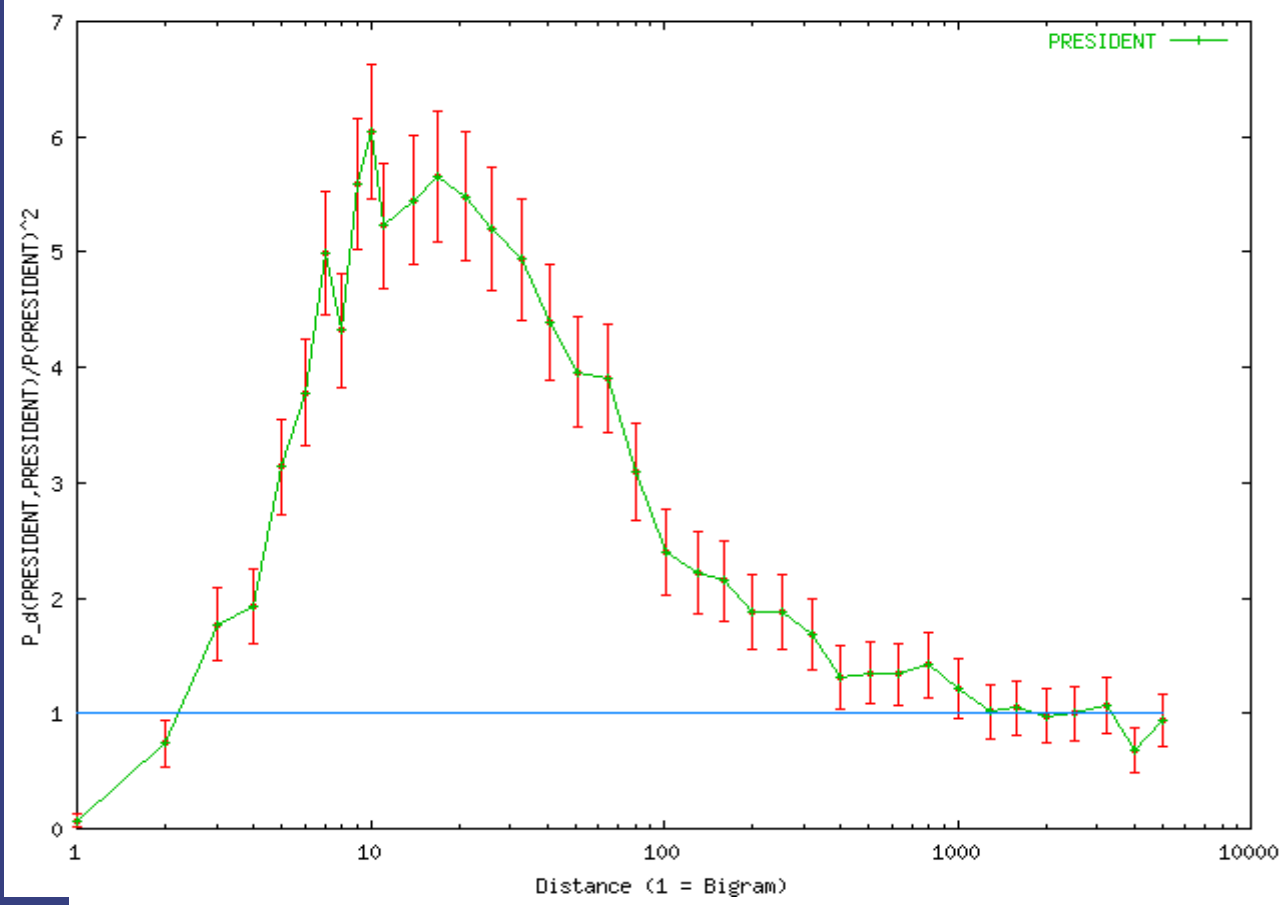
- d: distance of two observations of word w
- Statistical independence: c(w)=1

Correlation Function „and”



Only weak short range dependencies

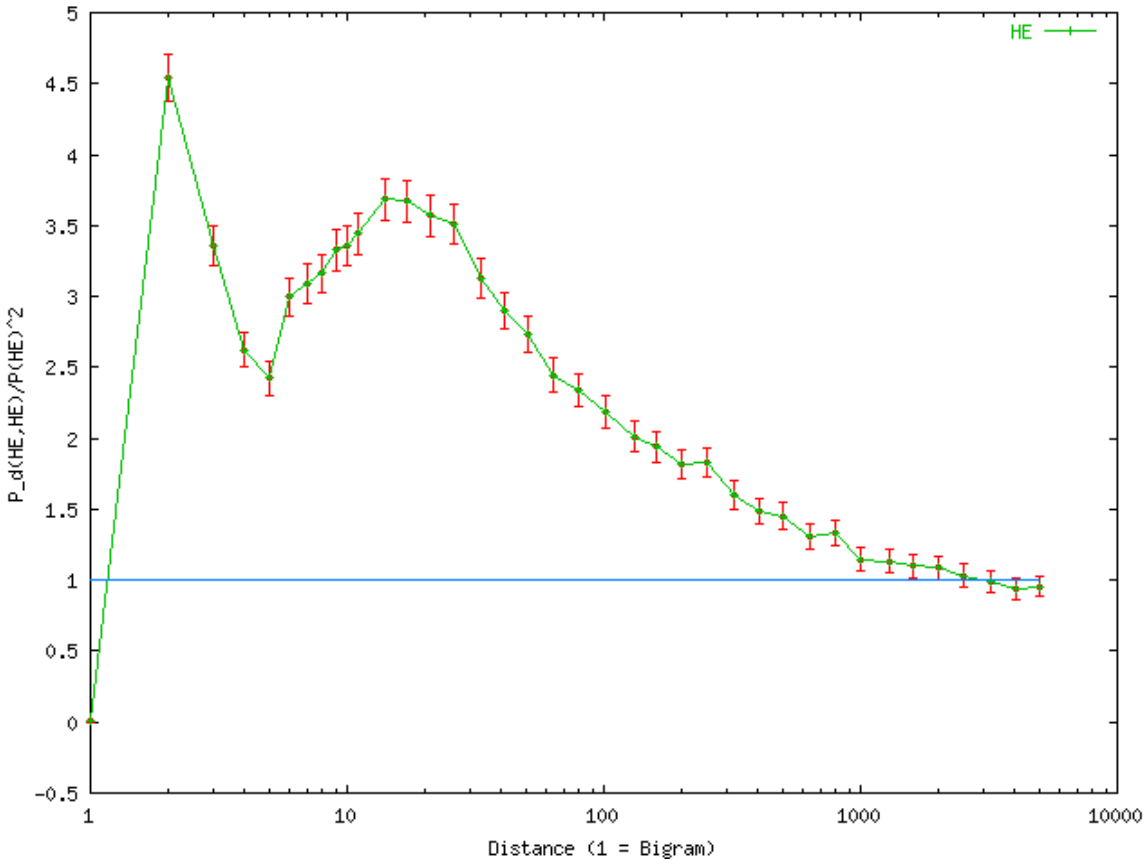
Correlation Function „President”



-Long range (semantic) dependency

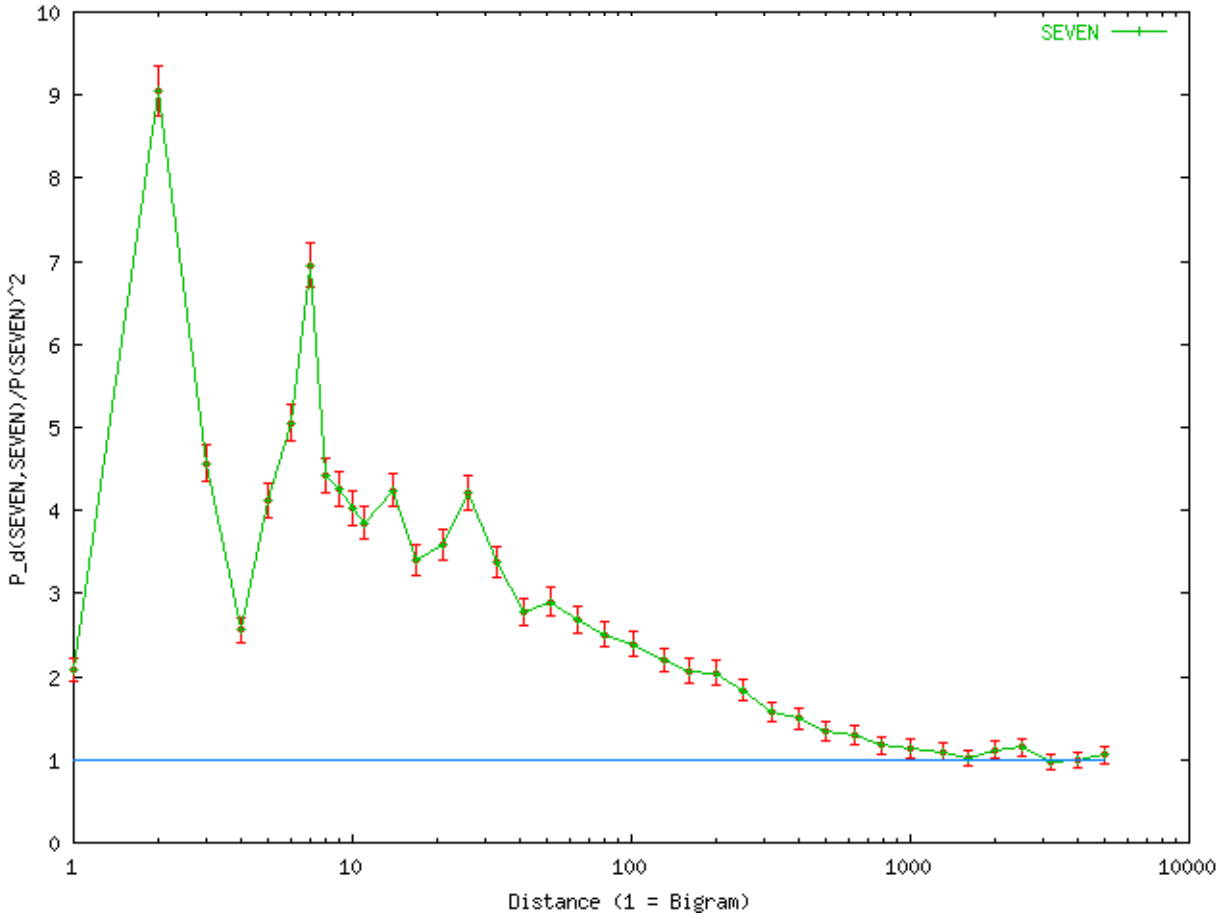
-Decay of correlations after about 1000 words

Correlation Function „he“



Short- and Long Range Dependencies

Correlation Function „seven”



Summary

- Examples for applications
- History of probability theory
- Introduction to basic notions
- Simple experiments