Foundations:
Language Models

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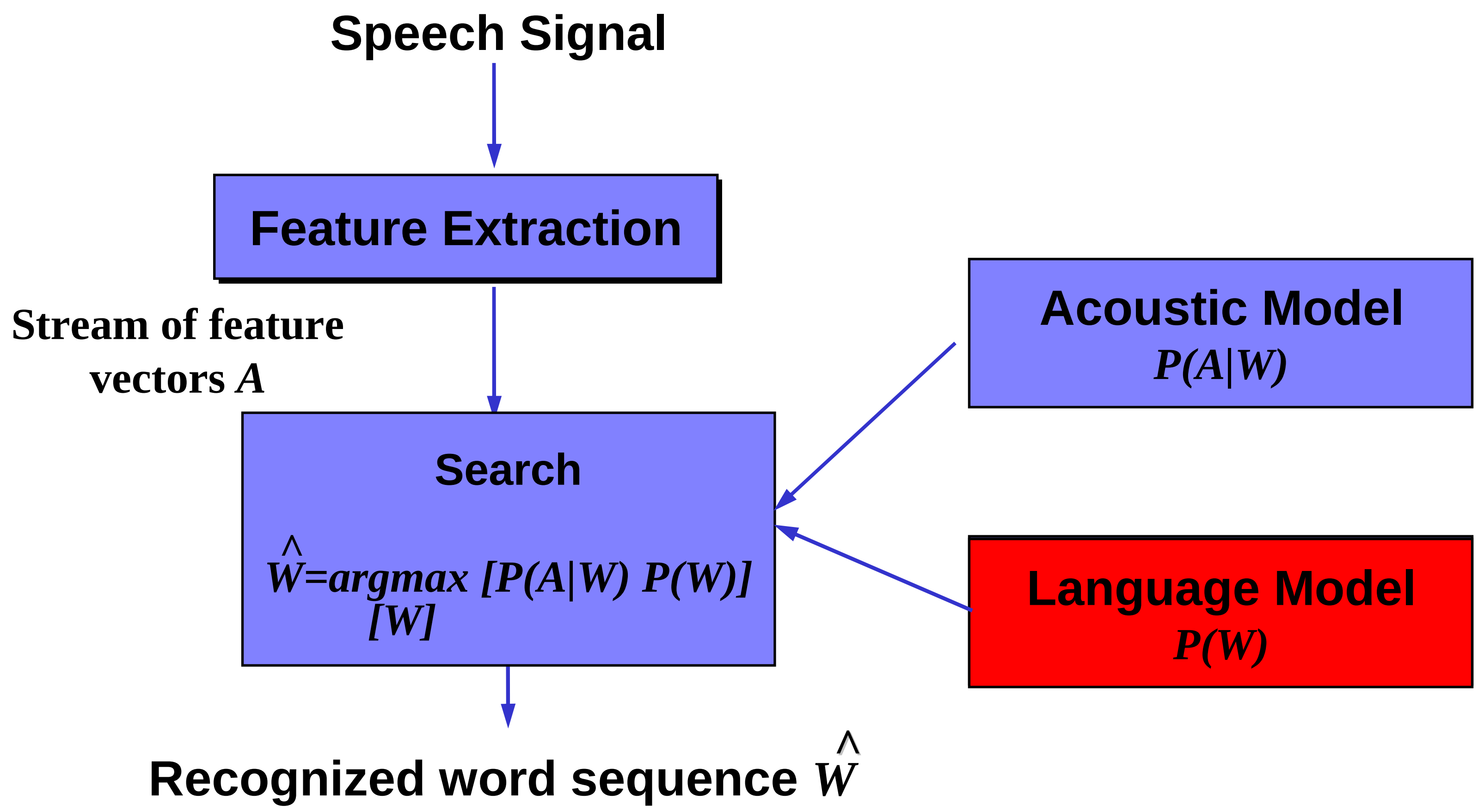
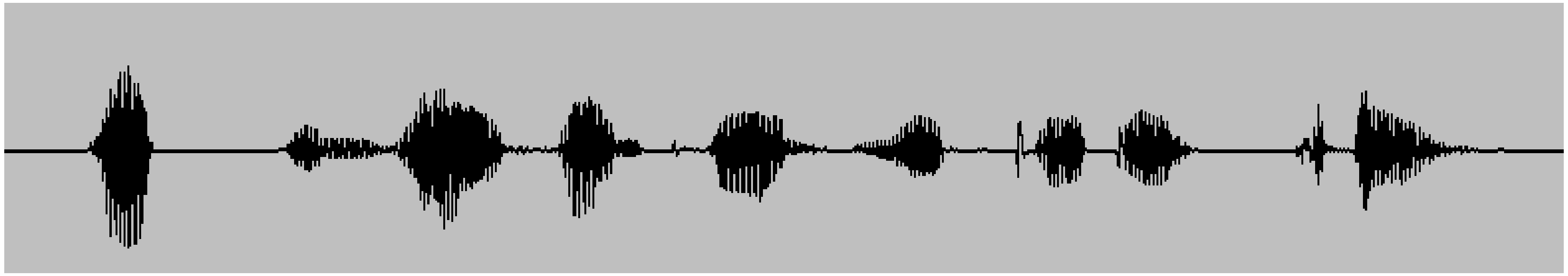
Using language Models

How Speech Recognition works

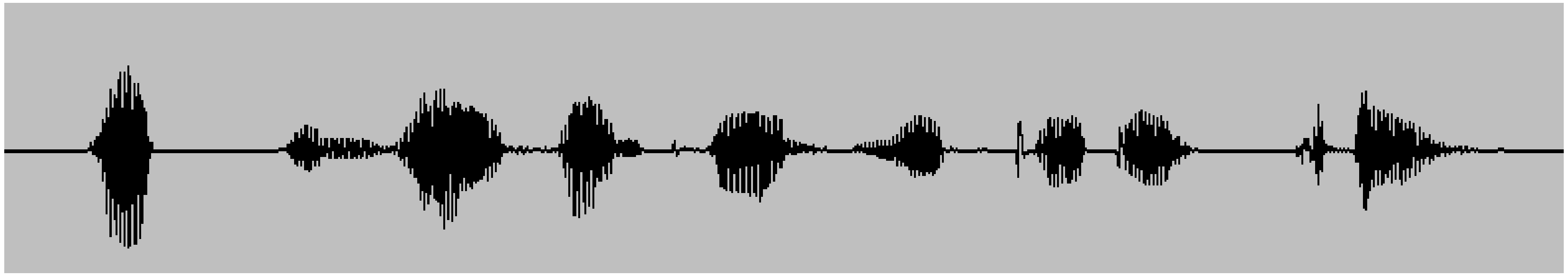


Guess the next word



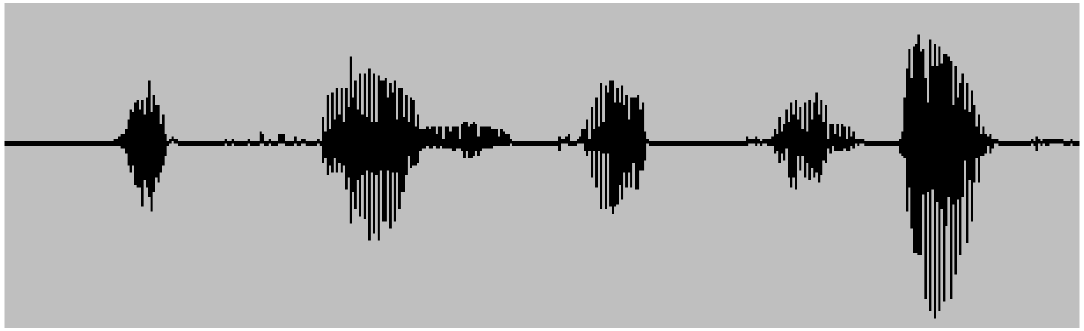
What‘s in your hometown newspaper ???

Guess the next word



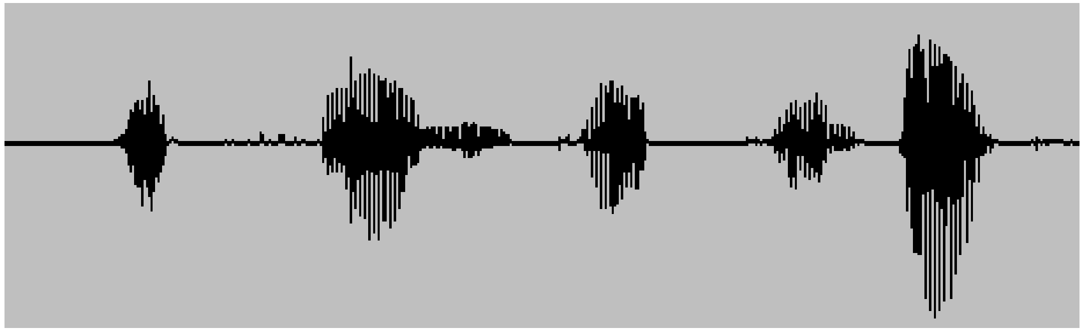
What‘s in your hometown newspaper today

Guess the next word



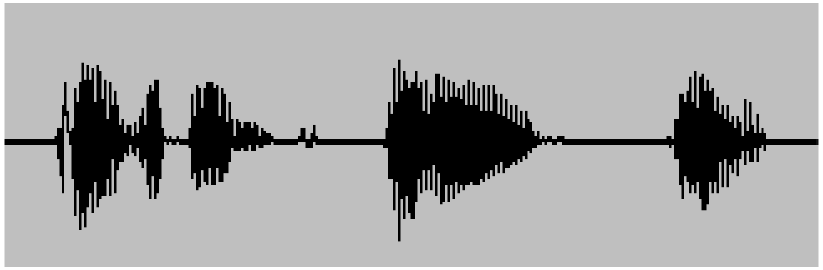
It‘s raining cats and ???

Guess the next word



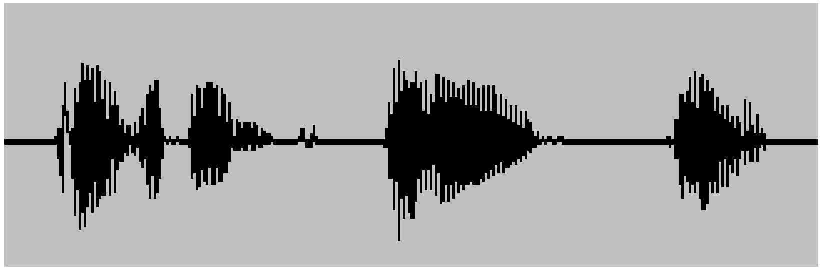
It‘s raining cats and dogs

Guess the next word



President Bill ???

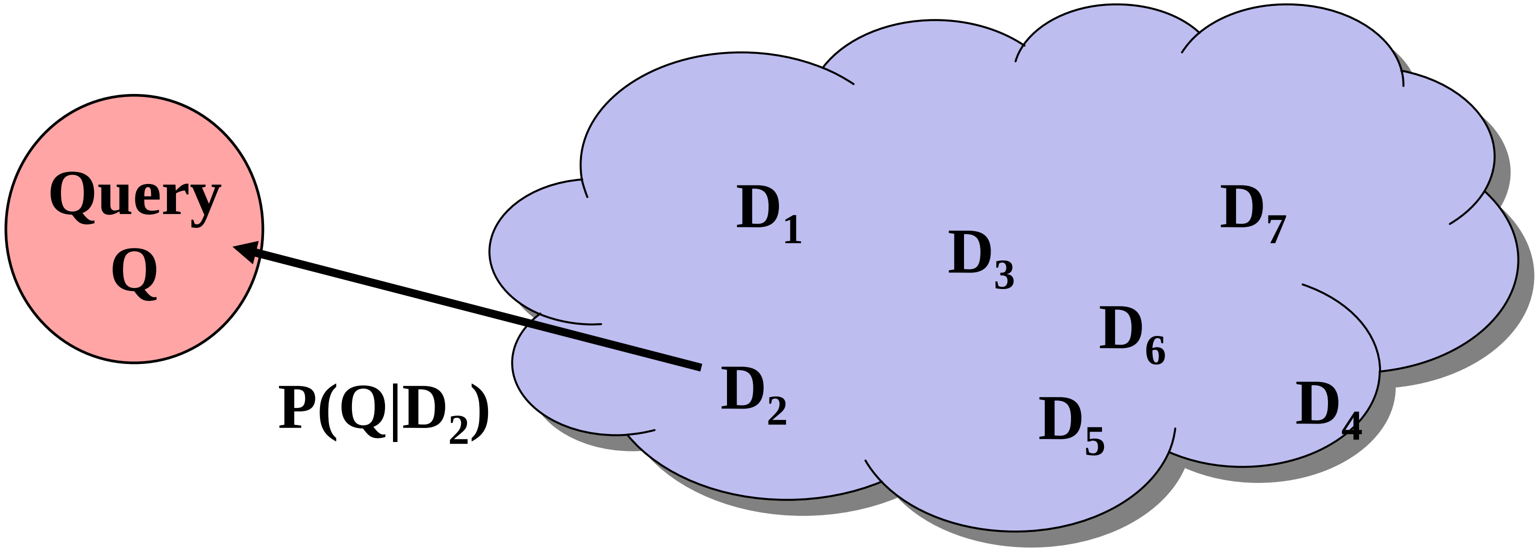
Guess the next word



President Bill Gates

Information Retrieval

- Language model introduced to information retrieval in 1998 by Ponte&Croft



Ranking according to $P(Q|D_i)$

Measuring the Quality of Language Models

Definition of Perplexity

$$PP = P(w_1 \ldots w_N)^{-1/N}$$

$$= \exp\left(-\frac{1}{N} \sum_{w,h} N(w,h) \log\left(P(w \mid h)\right) \right)$$

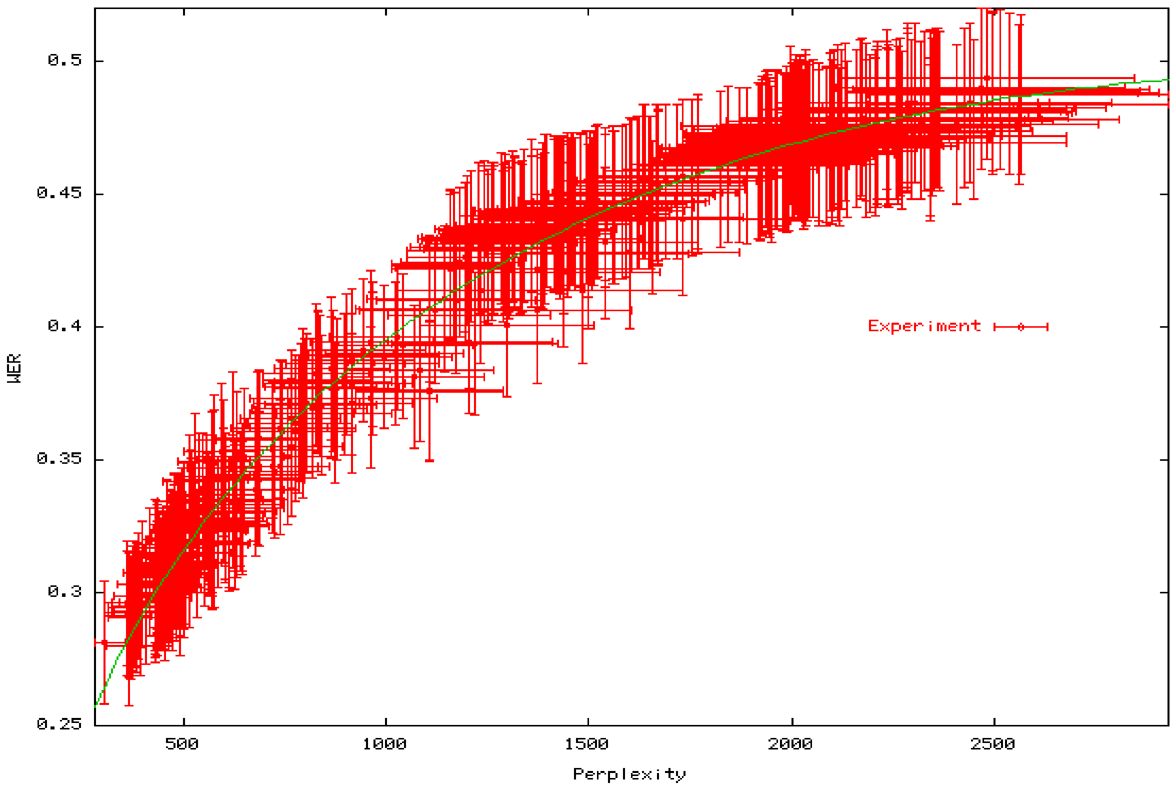
P(w|h):	language model
N(w,h):	frequency of sequence w,h in some test corpus
N:	size of test corpus

Interpretation

Calculate perplexity of uniform distribution

(white board)

Perplexity and Word Error Rate



Perplexity and error rate are correlate within error bars

Estimating the Parameters of a Language Model

Goal

- Minimize perplexity on training data

$$PP = \exp\left(-\frac{1}{N_{Train}} \sum_{w,h} N_{Train}(w,h) \log\left(P(w \mid h)\right) \right)$$

Define likelihood

L=-log (PP)

$$L = \frac{1}{N_{Train}} \sum_{w,h} N_{Train}(w,h) \log\left(P(w \mid h)\right)$$

Minimizing perplexity
$\mapsto$
maximizing likelihood

How to take normalization constraint into account?

Calculating the maximum likelihood estimate (white board)

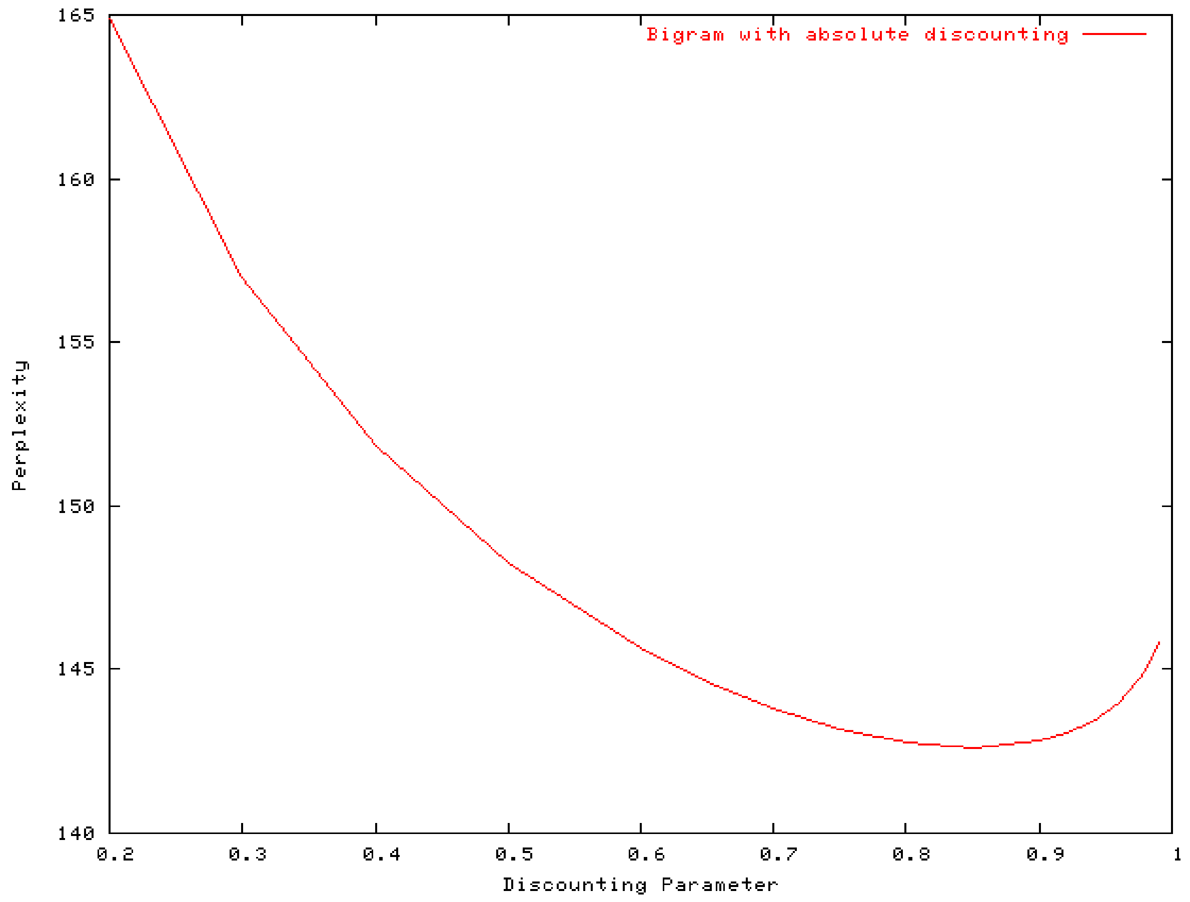
Maximum likelihood estimator

$$P(w|h) = \frac{N_{Train}(w,h)}{N_{Train}(h)}$$

What´s the problem?

Backing-off and Smoothing

Influence of Discounting Parameter



Possible further Improvements

Linear Smoothing

$$P(w_0 \mid w_{-1}) = \lambda_1 \frac{N_{Train}(w_{-1}w_0)}{N_{Train}(w_{-1})} + \lambda_2 \frac{N_{Train}(w_0)}{N_{Train}} + (1-\lambda_1-\lambda_2)\frac{1}{V}$$

V: size of vocabulary

Marginal Backing-Off (Kneser-Ney-Smoothing)

- Dedicated backing-off distributions
- Usually about 10% to 20% reduction in perplexity

Class Language Models

- Automatically group words into classes
- Map all words in the language model to classes
- Dramatic reduction in number of parameters to estimate
- Usually used in linear with word language model

Summary

- How to build a state-of-the art plain vanilla language model:
  - Trigram
  - Absolute discounting
  - Marginal backing-off (Kneser-Ney smoothing)
  - Linear interpolation with class model