

# Assignment 4,5 + Smoothing

(SNLP tutorial 4)

Vilém Zouhar, Awantee Deshpande, Julius Steuer

TODOth, TODOth May 2021

# Overview

- Task, Metrics
- Differential Privacy
- Homework

# OOV words

## Corpus

- Train set:



- Test set:



# OOV words

## Corpus

- Train set:



- Test set:



## Accumulate counts

• 	6		5		3		2		
• 	4		2		2		2		1
									1

# OOV words

## Corpus

- Train set:





- Test set:



## Accumulate counts

•  6	 5	 3	 2		
•  4	 2	 2	 2	 1	 1

## OOV words

- What about  and ?
- OOV rate:  $2 + 1/4 + 2 + 2 + 1 + 1 + 1 = 27\%$

- Solutions? character-level, subword units







# Additive smoothing (add- $\alpha$ -smoothing)

## Unigrams






- Add zero counts to frequency table

 6     5     3     2     0     0

- Increase all counts by  $\alpha = 1$







 6+1     5+1     3+1     2+1     0+1     0+1

- Divide by  $N = 22$

 0.32     0.27     0.18     0.13     0.05     0.05

## Perplexity

- Relative frequencies on test corpus:

 0.33     0.17     0.17     0.17     0.08     0.08







# Additive smoothing (add- $\alpha$ -smoothing)

## Unigrams






- Add zero counts to frequency table

 6     5     3     2     0     0

- Increase all counts by  $\alpha = 1$







 6+1     5+1     3+1     2+1     0+1     0+1

- Divide by  $N = 22$

 0.32     0.27     0.18     0.13     0.05     0.05

## Perplexity

- Relative frequencies on test corpus:

 0.33     0.17     0.17     0.17     0.08     0.08

- $PP = 2^{(0.33 \cdot 0.32 + 0.27 \cdot 0.17 + 0.18 \cdot 0.17 + 0.13 \cdot 0.17 + 2 \cdot (0.05 \cdot 0.08))} = 1.4$

## Additive smoothing: Bigrams

Recall the additive smoothing formula for unigrams:

$$p_{smoothed}(w_i) = \frac{C(w_i) + \alpha}{N + \alpha|V|} \quad (1)$$



## Additive smoothing: Bigrams

Recall the additive smoothing formula for unigrams:

$$p_{smoothed}(w_i) = \frac{C(w_i) + \alpha}{N + \alpha|V|} \quad (1)$$

- What is  $N$ ? What is  $V$ ?

Remember from Assignment 2 that:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i)}{C(w_{i-1})} \quad (2)$$

## Additive smoothing: Bigrams

Recall the additive smoothing formula for unigrams:

$$p_{smoothed}(w_i) = \frac{C(w_i) + \alpha}{N + \alpha|V|} \quad (1)$$

- What is  $N$ ? What is  $V$ ?

Remember from Assignment 2 that:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i)}{C(w_{i-1})} \quad (2)$$

- Smoothe the bigram count:  $C(w_{i-1}, w_i) \rightarrow C(w_{i-1}, w_i) + \alpha$
- Normalization:  $p_{smoothed}(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{?}$

# Additive smoothing: Bigrams

## Corpus



Bigrams:  ,  ,  ,  , ...,  ,  ← circular bigram!

Bigrams: AA, AA, AE, EA, ..., AE, EA

## Additive smoothing: Bigrams: bigram counts

- Collect bigram counts & conditional probabilities for history  $A$

Bigram	$C(w_i, w_{i-1})$	$C(w_{i-1})$	$\frac{C(w_{i-1}, w_i)}{C(w_{i-1})}$
AE	3	6	1/2
AA	2	6	1/3
AB	1	6	1/6

## Additive smoothing: Bigrams: add alpha

- We encounter an unknown bigram  $AF$

Bigram	$C_{\alpha}(w_{i-1}, w_i)$	$C_{\alpha}(w_{i-1})$	$\frac{C_{\alpha}(w_{i-1}, w_i)}{C_{\alpha}(w_{i-1})}$
AE	3+1	6+1	4/7
AA	2+1	6+1	3/7
AB	1+1	6+1	2/7
→ AF	0+1	6+1	1/7

## Additive smoothing: Bigrams: add alpha

- We encounter an unknown bigram  $AF$

Bigram	$C_\alpha(w_{i-1}, w_i)$	$C_\alpha(w_{i-1})$	$\frac{C_\alpha(w_{i-1}, w_i)}{C_\alpha(w_{i-1})}$
AE	3+1	6+1	4/7
AA	2+1	6+1	3/7
AB	1+1	6+1	2/7
→ AF	0+1	6+1	1/7

- Not a probability distribution!

## Additive smoothing: Bigrams: add alpha

- We encounter an unknown bigram  $AF$

Bigram	$C_{\alpha}(w_{i-1}, w_i)$	$C_{\alpha}(w_{i-1})$	$\frac{C_{\alpha}(w_{i-1}, w_i)}{C_{\alpha}(w_{i-1})}$
AE	3+1	6+1	4/7
AA	2+1	6+1	3/7
AB	1+1	6+1	2/7
→ AF	0+1	6+1	1/7

- Not a probability distribution!
- Solution: We need to adjust the divisor a tiny bit. But how tiny?

## Additive smoothing: Bigrams: normalization

- add  $\alpha$  to history count!
- Pretend that we have seen the history  $|V| = 3$  times more.



## Additive smoothing: Bigrams: normalization

- add  $\alpha 3$  to history count!
- Pretend that we have seen the history  $|V| = 3$  times more.

Bigram	$C_{\alpha}(w_{i-1}) + \alpha V $	$\frac{C_{\alpha}(w_{i-1}, w_i)}{C_{\alpha}(w_{i-1}) + \alpha V }$
AE	$7 + 3$	$4/10$
AA	$7 + 3$	$3/10$
AB	$7 + 3$	$2/10$
$\rightarrow$ AF	$7 + 3$	$1/10$

## Additive smoothing: Bigrams: normalization

- add  $\alpha 3$  to history count!
- Pretend that we have seen the history  $|V| = 3$  times more.

Bigram	$C_{\alpha}(w_{i-1}) + \alpha V $	$\frac{C_{\alpha}(w_{i-1}, w_i)}{C_{\alpha}(w_{i-1}) + \alpha V }$
AE	$7 + 3$	$4/10$
AA	$7 + 3$	$3/10$
AB	$7 + 3$	$2/10$
$\rightarrow$ AF	$7 + 3$	$1/10$

- Now the probabilities sum up to 1:  $4/10 + 3/10 + 2/10 + 1/10 = 1$

## Additive smoothing: Bigrams: normalization

- We encounter another n-gram  $AD$
- What is  $|V|$  now?

## Additive smoothing: Bigrams: normalization

- We encounter another n-gram  $AD$
- What is  $|V|$  now?

Bigram	$C_{\alpha}(w_{i-1}) + \alpha V $	$\frac{C_{\alpha}(w_{i-1}, w_i)}{C_{\alpha}(w_{i-1}) + \alpha V }$
AE	$7 + 4$	$4/11$
AA	$7 + 4$	$3/11$
AB	$7 + 4$	$2/11$
$\rightarrow$ AF	$7 + 4$	$1/11$
$\rightarrow$ AD	$7 + 4$	$1/11$

## Additive smoothing: Bigrams: normalization

- We encounter another n-gram  $AD$
- What is  $|V|$  now?

Bigram	$C_{\alpha}(w_{i-1}) + \alpha V $	$\frac{C_{\alpha}(w_{i-1}, w_i)}{C_{\alpha}(w_{i-1}) + \alpha V }$
AE	$7 + 4$	$4/11$
AA	$7 + 4$	$3/11$
AB	$7 + 4$	$2/11$
$\rightarrow$ AF	$7 + 4$	$1/11$
$\rightarrow$ AD	$7 + 4$	$1/11$

- $C_{\alpha}(A)$  is constant
- Probabilities sum up to 1:  $4/11 + 3/11 + 2/11 + 1/11 + 1/11 = 1$

## Additive smoothing: Bigrams: general case

- General formula for smoothed bigram Probabilities:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V|} \quad (3)$$

## Additive smoothing: Bigrams: general case

- General formula for smoothed bigram Probabilities:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V|} \quad (3)$$

- What is  $V$ ?

## Additive smoothing: Bigrams: general case

- General formula for smoothed bigram Probabilities:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V|} \quad (3)$$

- What is  $V$ ?
- $|V|$  = Number of bigram **types** starting with  $w_{i-1}$



## Additive smoothing: Bigrams: general case

- General formula for smoothed bigram Probabilities:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V|} \quad (3)$$

- What is  $V$ ?
- $|V|$  = Number of bigram **types** starting with  $w_{i-1}$

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V_{(w_{i-1}, \bullet)}|} \quad (4)$$

## Additive smoothing: Bigrams: general case

- General formula for smoothed bigram Probabilities:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V|} \quad (3)$$

- What is  $V$ ?
- $|V|$  = Number of bigram **types** starting with  $w_{i-1}$

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V_{(w_{i-1}, \bullet)}|} \quad (4)$$

- For n-grams of length  $n$ :

$$p(w_i|w_{i-1} : w_{i-n+1}) = \frac{C(w_{i-n+1} : w_i) + \alpha}{C(w_{i-n+1} : w_{i-1}) + \alpha|V_{(w_{i-n+1}:w_{i-1}, \bullet)}|} \quad (5)$$

# Kneser-Ney Smoothing

TODO

- absolute discounting

# Cross-Validation

TODO

# Estimating LOO Parameters

TODO ??

# Laplace Smoothing

- add epsilon

TODO

# Linear Discounting

- linear interpolation

# Good-Turing Discounting

TODO



# Count Trees

- remove infrequent nodes

TODO

# Privacy

TODO differential privacy

# Resources

- ① UdS SNLP Class, WSD: <https://teaching.lsv.uni-saarland.de/snlp/>
- ② Classical Statistical WSD: <https://www.aclweb.org/anthology/P91-1034.pdf>
- ③ n-gram count trees: <http://ssli.ee.washington.edu/WS07/notes/ngrams.pdf>