

# Assignment 4,5 + Smoothing 1

## (SNLP Tutorial 5)

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# Assignment 4

- Exercise 1: Huffman encoding
- Exercise 2: Conditional entropy of DNA
- Bonus: Huffman encoding adaptations

# OOV words

## Corpus

- Train set:



- Test set:



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## Accumulate counts

• 	6		5		3		2		
• 	4		2		2		2		1
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### Corpus








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- OOV rate?

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- $3/12 = 25\%$

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- What about  and .
- OOV rate?
- $3/12 = 25\%$
- Solutions?



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## OOV words

- What about  and .
- OOV rate?
- $3/12 = 25\%$
- Solutions?

## OOV words

- How do we even know this will be an issue?

# Subword Units

Solution to OOV words: go lower

- Characters:  $V = \{a, b, c, \dots, \_ \}$

## Questions

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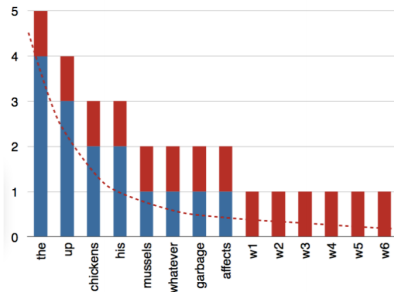
## Questions

- Can we still get an unknown “word”?
- How do we define perplexity for subword language models?

# Smoothing

- Words present in vocabulary, but have  $\sim 0$  probabilities
- Words present in vocabulary, but have unseen context

Solution: Assign probability mass from frequent events to infrequent events  
(Smoothing/Discounting)



- Will cover different smoothing methods over the next few tutorials








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

## Distribution






- 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

- Recall perplexity formula:

$$PP = \sum_{w,h} f(w, h) \cdot \log_2 p(w|h) \quad (1)$$







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## Perplexity

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- PP:  $2^{-(0.33 \cdot (-1.64) + 0.17 \cdot (-1.89) + 0.17 \cdot (-4.32) + 0.17 \cdot (-2.47) + 0.08 \cdot (-2.94) + 0.08 \cdot (-4.32))} = 2^{(-2.6)} \approx 6$
- What would be PP with unsmoothed model?

## Additive smoothing: Bigrams

Recall the additive smoothing formula for unigrams:

$$C^*(w_i) = C(w_i) + \alpha \quad (2)$$

$$N^* = \sum_{w_i \in V} C^*(w_i) = N + \alpha|V| \quad (3)$$

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Smoothen the bigram count:  $C(w_{i-1}, w_i) \rightarrow C(w_{i-1}, w_i) + \alpha$

# 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	$C(A, w_i)$	$C(A)$	$\frac{C(A, w_i)}{C(A)}$
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	$C(A, w_i)$	$C(A)$	$\frac{C_\alpha(A, w_i)}{C(A)}$
AE	3+1	6	4/6
AA	2+1	6	3/6
AB	1+1	6	2/6
→ AF	0+1	6	1/6

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

## Additive smoothing: Bigrams: normalization

- Add  $\alpha \cdot 4$  to history count
- Pretend that we have seen the history  $|V| = 4$  times more.

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Bigram	$C(A) + \alpha V $	$\frac{C_\alpha(A, w_i)}{C(A) + \alpha V }$
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- Now the probabilities sum up to 1:  $4/10 + 3/10 + 2/10 + 1/10 = 1$

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$\rightarrow AF$	$6 + 5$	$1/11$
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$\rightarrow AF$	$6 + 5$	$1/11$
$\rightarrow AD$	$6 + 5$	$1/11$

- $C(A)$  is constant, unsmoothed count
- 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:

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V|} \quad (6)$$

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- For n-grams of length  $n$ :

$$p(w_i|w_{i-1} : w_{i-n+1}) = \frac{C(w_{i-n+1} : w_i) + \alpha}{C(w_{i-n+1} : w_{i-1}) + \alpha|V_{(w_{i-n+1}:w_{i-1}, \bullet)}|} \quad (8)$$

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- We already know the shared (train + test) vocabulary  $V$

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- We find that the formula we found is identical to the one on the lecture slides!

$$p(w_i | w_{i-1} : w_{i-n+1}) = \frac{C(w_{i-n+1} : w_i) + \alpha}{C(w_{i-n+1} : w_{i-1}) + \alpha |V|} \quad (10)$$

## MARY HAD A LITTLE LAMB

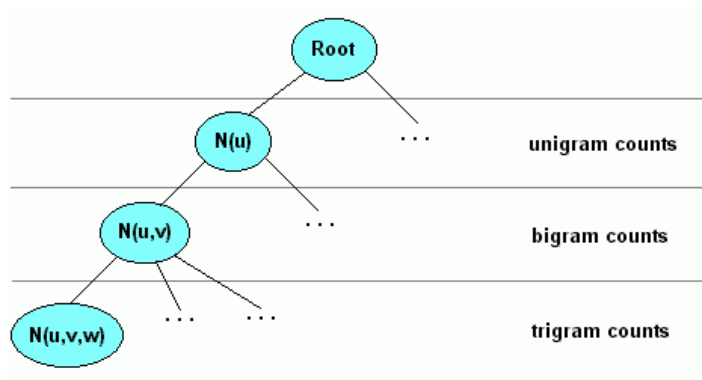
- Consider the bigram (LITTLE MARY)
- Consider the trigram (HAD A LAMB)

For a trigram  $p(w_3|w_2, w_1)$ , use probability of bigram  $P(w_3|w_2)$ , else back-off to unigram probability  $P(w_3)$ .

$$0.5 \cdot p(w_3|w_2, w_1) + 0.25 \cdot p(w_3|w_2) + 0.25 \cdot p(w_3)$$
$$0.5 \cdot p(\text{lamb}|\text{a, had}) + 0.25 \cdot p(\text{lamb}|\text{a}) + 0.25 \cdot p(\text{lamb})$$

Will be covered in more detail in further tutorials.

# Count Trees



# Assignment 5

- Exercise 1: OOV Words
- Exercise 2: Additive smoothing
- Exercise 3: Perplexity, infinite smoothing, interpolation
- Bonus: Other language models

# Resources

- ① UdS SNLP Class: <https://teaching.lsv.uni-saarland.de/snlp/>
- ② Additive smoothing: [https://en.wikipedia.org/wiki/Additive\\_smoothing](https://en.wikipedia.org/wiki/Additive_smoothing)
- ③ n-gram count trees: <http://ssli.ee.washington.edu/WS07/notes/ngrams.pdf>
- ④ n-gram models: <https://web.stanford.edu/~jurafsky/slp3/3.pdf>
- ⑤ Count-trees figure: <https://www.w3.org/TR/ngram-spec/>