

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:



Accumulate counts

•  6	 5	 3	 2		
•  4	 2	 2	 2	 1	 1

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: $V = \{a, b, c, \dots, _ \}$
- Syllables: $V = \{bo, ve, r, how, \dots, _ \}$
- Data-driven units (subwords): $V = \{smi, les, es, clo, \dots, _ \}$
- ▶ Byte Pair Encoding, Word Piece, Sentence Piece
- ▶ Start with the alphabet, merge and add frequent character-level n-grams
- ▶ E.g. bedclothes became white \rightarrow bed @cloth @es be @came @white
- ▶ Used heavily in any modern NLP (MT, LM, QA, ...)

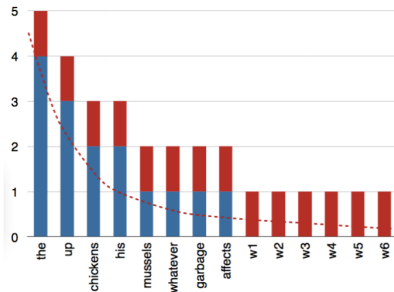
Questions

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

Smoothing

- Words present in vocabulary, but have ~ 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- α -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:

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







Additive smoothing (add- α -smoothing)

Distribution






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Perplexity

- Relative frequencies on test corpus:

 0.33  0.17  0.17  0.17  0.08  0.08

- 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:

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

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

$$p^*(w_i) = \frac{C(w_i) + \alpha}{N^*} = \frac{C(w_i) + \alpha}{N + \alpha|V|} \quad (4)$$

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i)}{C(w_{i-1})} \quad (5)$$

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

- 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.

Bigram	$C(A) + \alpha V $	$\frac{C_\alpha(A, w_i)}{C(A) + \alpha V }$
AE	$6 + 4$	$4/10$
AA	$6 + 4$	$3/10$
AB	$6 + 4$	$2/10$
\rightarrow AF	$6 + 4$	$1/10$

- 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?

Bigram	$C(A) + \alpha V $	$\frac{C_\alpha(A, w_i)}{C(A) + \alpha V }$
AE	$6 + 5$	$4/11$
AA	$6 + 5$	$3/11$
AB	$6 + 5$	$2/11$
$\rightarrow AF$	$6 + 5$	$1/11$
$\rightarrow AD$	$6 + 5$	$1/11$

- $C(A)$ 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:

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

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

$$p(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + \alpha}{C(w_{i-1}) + \alpha|V_{(w_{i-1}, \bullet)}|} \quad (7)$$

- For n-grams of length n :

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

Additive smoothing: Bigrams: general case

- For n-grams of length n :

$$p(w_i | w_{i-1} : w_{i-n+1}) = \frac{C(w_{i-n+1} : w_i) + \alpha}{C(w_{i-n+1} : w_{i-1}) + \alpha |V_{(w_{i-n+1}:w_{i-1}, \bullet)}|} \quad (9)$$

- We already know the shared (train + test) vocabulary V
- $V_{(A, \bullet)}$ is then $AA, AB, AC, AD, AE, AF \Rightarrow |V_{(A, \bullet)}| = 6 = |V|$
- 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

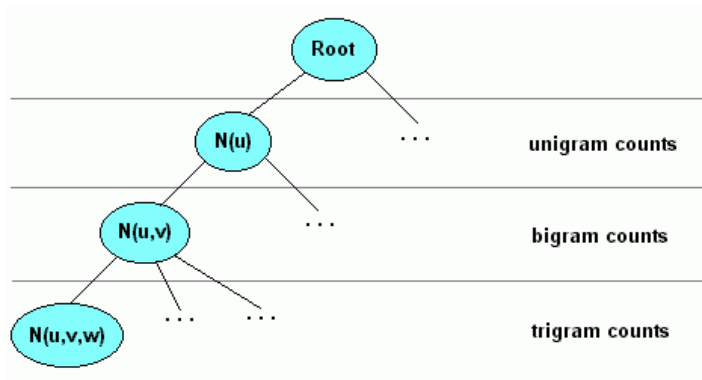
- Consider the bigram (LITTLE MARY)
- Consider the trigram (HAD A LAMB)

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
- 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/>