

# Assignment 6 + Smoothing 3

## (SNLP Tutorial 7)

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8th, 10th June 2021

[github.com/zouharvi/uds-snlp-tutorial](https://github.com/zouharvi/uds-snlp-tutorial)

- Contributions welcome
- “Cheating” allowed

# Assignment 6

- Exercise 1: MAP and MLE
- Exercise 2: Good Turing Smoothing
- Exercise 3: Cross-Validation

# Kneser-Ney Smoothing

Idea: Can we use the lower order distributions in a better way?

I WENT TO THE GROCERY \_\_\_\_\_ .

Options:

$W_1$ : STORE

$W_2$ : YORK

# Kneser-Ney Smoothing

Idea: Can we use the lower order distributions in a better way?

I WENT TO THE GROCERY \_\_\_\_\_ .

Options:

$W_1$ : STORE

$W_2$ : YORK

Use the fact that YORK generally appears as context or *continuation* of the word NEW.

# Kneser-Ney Smoothing

Data: 🍌 🍏 🍆 🍌 🍒 🍇 🌿 🍒 🍇 🍌 🍒 🍇 🍏

# Kneser-Ney Smoothing

Data: 🍌 🍏 🍆 🍌 🍒 🍇 🌿 🍒 🍇 🍌 🍒 🍇 🍏

$$N(\text{🍏}) = 2 \implies P(\text{🍏}) = 2/13$$

$$N(\text{🍇}) = 3 \implies P(\text{🍇}) = 3/13$$

# Kneser-Ney Smoothing

Data: 🍌 🍏 🍆 🍌 🍒 🍇 🌿 🍒 🍇 🍌 🍒 🍇 🍏

$$N(\text{🍏}) = 2 \implies P(\text{🍏}) = 2/13$$

$$N(\text{🍇}) = 3 \implies P(\text{🍇}) = 3/13$$

But,

$$N(\bullet \text{ 🍏}) = 2 (\text{🍌 🍏}, \text{🍇 🍏})$$

$$N(\bullet \text{ 🍇}) = 1 (\text{🍒 🍇})$$

$$\therefore P(\text{🍏}) = 2/12$$

$$P(\text{🍇}) = 1/12$$



# Kneser-Ney Smoothing

$$P_{CONTINUATION}(w) = \frac{|\{w' : C(w', w) > 0\}|}{|\{(w_i, w_j) : C(w_i, w_j) > 0\}|}$$

For bigrams,

$$P_{KN}(w_i | w_{i-1}) = \frac{\max\{C(w_{i-1}, w_i) - d, 0\}}{\sum_{w'} C(w_{i-1} w')} + \lambda(w_{i-1}) P_{CONTINUATION}(w_i)$$

$$\lambda(w_{i-1}) = \frac{d}{c(w_{i-1})} \cdot |\{w : C(w_{i-1}, w) > 0\}|$$

# Kneser-Ney Smoothing

## General Formula

$$P_{KN}(w_i | w_{i-n+1:i-1}) = \frac{\max\{C_{KN}(w_{i-n+1:i-1}, w_i) - d, 0\}}{\sum_{w'} C_{KN}(w_{i-n+1:i-1} w')} + \lambda(w_{i-n+1:i-1}) \cdot P_{KN}(w_i | w_{i-n+2:i-1})$$

$$\text{where } C_{KN}(\bullet) = \begin{cases} \text{count}(\bullet) & \text{for highest order} \\ \text{continuation\_count}(\bullet) & \text{for lower orders} \end{cases} \quad (1)$$

# Kneser-Ney Smoothing Questions

- How are unseen words handled by KN Smoothing?
- For a KN-Smoothed language model,

$$\text{Information content("Vader")} = 15$$

$$\text{Information content("Star")} = 10$$

Which unigram is assigned a higher probability by KN smoothing? Would the information content be the same for absolute discounting?

- Will the probabilities be affected for frequent higher order n-grams?
- Can Kneser-Ney smoothing be implemented for unigrams?

# Pruning

- Back-off models and interpolation save n-grams of all orders.

We are storing all  $V^n + V^{n-1} + \dots + V + 1$  distributions!

- Idea: Store the counts which exceed a threshold  $c(\bullet) \geq K$ . Also called a “cut-off”.

## Pruning: Comment on the implementation

```
assert tree.get("5634") == 1
```



## Pruning: How to build a count tree

```
tree.add("ABCE")
tree.add("ABCD")
tree.add("ABCD")
tree.add("QBCD")
tree.add("QQCD")
tree.add("BCDA")
tree.add("1234")
tree.add("1234")
tree.add("1234")
tree.add("1234")
tree.add("1234")
tree.add("5634")
```

# Assignment 7

- Exercise 1: Count Trees and Pruning
- Exercise 2: Kneser-Ney Smoothing
- Bonus: Comparison of smoothing techniques

# Resources

- ① UdS SNLP Class: <https://teaching.lsv.uni-saarland.de/snlp/>
- ② n-gram models: <https://web.stanford.edu/~jurafsky/slp3/3.pdf>
- ③ Kneser-Ney Smoothing: <https://medium.com/@dennyc/a-simple-numerical-example-for-kneser-ney-smoothing-nlp-4600addf38b8>
- ④ Comparison of Smoothing Techniques:  
[https://people.eecs.berkeley.edu/~klein/cs294-5/chen\\_goodman.pdf](https://people.eecs.berkeley.edu/~klein/cs294-5/chen_goodman.pdf)