

NLP - Fall 2016 - Midterm Exam

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(1) Probability Models and Smoothing:

- a. (4pts) You are given the following training data for the prepositional phrase (PP) attachment task.

v	n1	p	n2	Attachment
join	board	as	director	V
is	chairman	of	N.V.	N
using	crocicidolite	in	filters	V
⋮	⋮	⋮	⋮	⋮

In order to resolve PP attachment ambiguity we can train a probability model: $P(A = N \mid v, n1, p, n2)$ which predicts the attachment A as N if $P > 0.5$ and V otherwise. Since we are unlikely to see the same four words $v, n1, p, n2$ in novel unseen data, in order for this probability model to be useful we need to take care of zero counts.

Provide a Jelinek-Mercer *interpolation* smoothing model $\hat{P}(A = N \mid v, n1, p, n2)$ for this PP attachment probability model. Assume that our training data is large enough to contain all the prepositions we might observe in unseen data. You cannot assume that all the verbs and nouns in the unseen data were seen in training.

In the interpolation model if you use any new variables then provide the constraints that the variables must obey such that \hat{P} continues to be a valid probability.

- b. (2pts) You are given a text of words: w_1, \dots, w_N and you proceed to estimate bigram probabilities with the maximum likelihood estimate using the bigram frequencies $c(w_i, w_{i-1})$ and unigram frequencies $c(w_i)$:

$$\hat{P}(w_i \mid w_{i-1}) = \frac{c(w_i, w_{i-1})}{c(w_{i-1})}$$

The frequency for all individual words w_i are non-zero, i.e. $c(w_i) > 0$ for all w_i but many bigrams w_i, w_{i-1} have zero counts. To avoid zeroes in the numerator of the above equation, you decide to add a small factor δ to each count in the following manner:

$$\hat{P}(w_i \mid w_{i-1}) = \frac{\delta + c(w_i, w_{i-1})}{c(w_{i-1})}$$

Where $0 < \delta < 1$. Is this equation correct? If not, what is the basic condition on $P(w_i \mid w_{i-1})$ violated in this formula? If incorrect, provide a correction for this formula.

- c. (4pts) For bigram probabilities, Katz backoff smoothing is defined as follows:

$$P_{katz}(w_i \mid w_{i-1}) = \begin{cases} \frac{c^*(w_{i-1}, w_i)}{c(w_{i-1})} & \text{if } c(w_{i-1}, w_i) > 0 \\ \alpha(w_{i-1})P_{katz}(w_i) & \text{otherwise} \end{cases}$$

where $\alpha(w_{i-1})$ is chosen to make sure that $P_{katz}(w_i \mid w_{i-1})$ is a proper probability

$$\alpha(w_{i-1}) = 1 - \sum_{w_i} \frac{c^*(w_{i-1}, w_i)}{c(w_{i-1})}$$

Provide two definitions for the new count $c^*(w_{i-1}, w_i)$, (1) using the Good-Turing method, and (2) the absolute discounting method. Assume that $1 = \sum_{w_i} P_{katz}(w_i)$.

(2) **Word Alignment and Machine Translation:**

IBM Model 1 provides the probability of an alignment **a** and source sentence **f** given a target sentence **e** using the parameters *t* follows:

$$\Pr(\mathbf{f}, \mathbf{a} \mid \mathbf{e}) = \prod_{i=1}^I t(f_i \mid e_{a_i})$$

- a. (5pts) In order to compute the most likely alignment **a** we need to compute $P(\mathbf{a} \mid \mathbf{f}, \mathbf{e})$. Derive the following formula and provide the value of *Z* using parameters *t*:

$$\log \Pr(\mathbf{a} \mid \mathbf{f}, \mathbf{e}) = \sum_{i=1}^I \log t(f_i \mid e_{a_i}) - \log Z$$

- b. (5pts) Consider the following sentence aligned and word aligned parallel corpus.

1	2	3	4
the	house	is	small
1	2	3	4
klein	ist	das	Haus

1	2	3	4
the	building	is	small
	/	/	/
1	2	3	4
das	Haus	ist	klein

1	2	3	4	5
the	home	is	very	small
			/	
1	2	3	4	
das	Haus	ist	klitzeklein	

1	2	3	4	
the	house	is	small	
			/	
1	2	3	4	5
das	Haus	ist	ja	klein

Provide the values of the following parameters:

- i $t(\text{klein} \mid \text{small})$
 - ii $t(\text{klitzeklein} \mid \text{small})$
 - iii $t(\text{ja} \mid \text{small})$
 - iv $t(\text{ja} \mid \text{very})$
- c. (5pts) Compute $\Pr(\mathbf{ja} \text{ klitzeklein} \mid \mathbf{small})$ using IBM Model 1 without NULLs. Show all the steps in the computation and write your answer as a fraction $\frac{x}{y}$.