6.864, Fall 2005: Problem Set 6

Total points: 140 regular points

Due date: 5pm, 8 December 2005

Late policy: 5 points off for every day late, 0 points if handed in after 5pm on 12 December 2005

Question 1 (25 points) Figure 1 shows the perceptron algorithm, as described in lecture 20. Now say we alter the parameter update step to be the following:

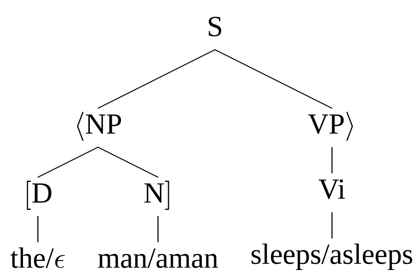
$$
\begin{array}{l}
\text{If } (z_i \neq y_i) \\
\quad \mathcal{A} = \{z : z \in \text{GEN}(x_i), z \neq y_i, \mathbf{W} \cdot \Phi(x_i, z) \geq \mathbf{W} \cdot \Phi(x_i, y_i)\} \\
\quad n = |\mathcal{A}| \\
\quad \mathbf{W} = \mathbf{W} + \Phi(x_i, y_i) - \frac{1}{n} \sum_{z \in \mathcal{A}} \Phi(x_i, z)
\end{array}
$$

Show that the modified algorithm makes at most $\frac{R^2}{\delta^2}$ updates before convergence, where R and δ are as defined in the lecture (i.e., show that the convergence theorem that we described in lecture also holds for this algorithm). Hint: the proof is quite similar to the proof of convergence given in lecture.

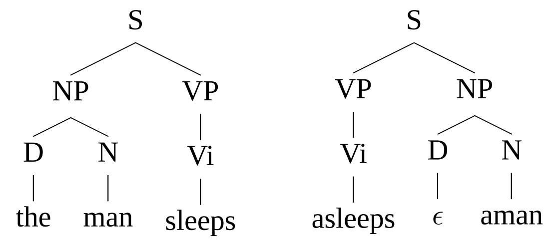
Inputs:	Training set (x_i, y_i) for $i = 1 \ldots n$
Initialization:	$\mathbf{W} = 0$
Define:	$F(x) = \text{argmax}_{y \in \text{GEN}(x)} \Phi(x, y) \cdot \mathbf{W}$
Algorithm:	For $t = 1 \ldots T$, $i = 1 \ldots n$ $z_i = F(x_i)$ If $(z_i \neq y_i)$ $\mathbf{W} = \mathbf{W} + \Phi(x_i, y_i) - \Phi(x_i, z_i)$
Output:	Parameters $\mathbf{W}$

Figure 1: The perceptron algorithm, as introduced in lecture 20.

Question 2 (25 points) In lecture 17 we defined transduction PCFGs. For example, a transduction PCFG would assign a probability to a structure such as the following (see the lecture notes for more details):



The above structure can be considered to represent an English string **e**, an English parse tree **E**, a French string **f**, and a French parse tree **F**, in this case:



Say $P(\mathbf{e}, \mathbf{E}, \mathbf{f}, \mathbf{F})$ is the probability assigned to an $\mathbf{e}, \mathbf{E}, \mathbf{f}, \mathbf{F}$ tuple by the transduction PCFG. Give pseudo-code for an algorithm that takes an $\mathbf{e}, \mathbf{E}$ pair as input, and returns

$$\arg\max_{\mathbf{f}, \mathbf{F}} P(\mathbf{e}, \mathbf{E}, \mathbf{f}, \mathbf{F})$$

Question 3 (90 points)

In this question you will implement code for IBM translation model 1. The files `corpus.en` and `corpus.de` have English and German sentences respectively, where the i'th sentence in the English file is a translation of the i'th sentence in the German file.

Implement a version of IBM model 1, which takes `corpus.en` and `corpus.de` as input. Your implementation should have the following features:

- The parameters of the model are $T(f|e)$, where f is a German word, and e is an English word or the special symbol NULL. You should only store parameters of the form $T(f|e)$ for (f, e) pairs which are seen somewhere in aligned sentences in the corpus.
- In the initializiation step, you should set $T(f|e) = \frac{1}{n(e)}$ where $n(e)$ is the number of different German words seen in German sentences aligned to English sentences that contain the word e.
- Your code should run 10 iterations of the EM algorithm to re-estimate the $T(f|e)$ parameters.

Note: your code should have the following functionality. It should be able to read in a file, line by line, where each line has an English word, for example

dog
eats
man
. . .

For each line it should return a list of German words, together with probabilities $T(f|e)$. The list of German words should contain all words for which $T(f|e) > 0$.