Questions for Flipped Classroom Session of COMS 4705 Week 9, Fall 2014. (Michael Collins)

Definition of $\texttt{consistent}(A, (s, t), (s', t'))$:
(Recall that A is an alignment matrix with $A_{i,j} = 1$ if French word i is aligned to English word j. (s, t) represents the sequence of French words $f_s \ldots f_t$. (s', t') represents the sequence of English words $e_{s'} \ldots f_{s'}$.)
For a given matrix A, define

$$A(i) = \{j : A_{i,j} = 1\}$$

Similarly, define

$$A'(j) = \{i : A_{i,j} = 1\}$$

Thus $A(i)$ is the set of English words that French word i is aligned to; $A'(j)$ is the set of French words that English word j is aligned to.
Then $\texttt{consistent}(A, (s, t), (s', t'))$ is true if and only if the following conditions are met:

1. For each $i \in \{s \ldots t\}$, $A(i) \subseteq \{s' \ldots t'\}$
2. For each $j \in \{s' \ldots t'\}$, $A'(j) \subseteq \{s \ldots t\}$
3. There is at least one (i, j) pair such that $i \in \{s \ldots t\}$, $j \in \{s' \ldots t'\}$, and $A_{i,j} = 1$

Figure 1: The definition of the `consistent` function.

Question 1a: Assume we have a training set with a single foreign sentence $f =$ *adog aswims* paired with the English sentence $e =$ *the dog swims*. Assume we have alignments $A_{1,2} = A_{2,3} = 1$, with all other $A_{i,j}$ values equal to 0. List the full set of phrase pairs extracted from this example. (Recall that all phrase pairs are extracted which satisfy the `consistent` definition in Figure 1.)

Question 1b: Assume we have a training set consisting of a single pair of sentences f and e, together with an alignment matrix A. What values do f, e and A take to give the following phrase pairs as the full set of phrase pairs extracted?:

(adog, the dog)
(adog, dog)
(adog, dog swims)
(adog, the dog swims)

Question 1c: Now assume that we translate the sentence *adog aswims* into English using the set of phrase pairs from question 1a. Assume a distortion limit $d = 2$. One possible derivation for this sentence is

(1, 1, the dog) (2, 2, swims)

Write down the full set of derivations for this foreign sentence.

Question 2 Recall that in phrase-based systems, a derivation y is a sequence of phrases $p_1 \ldots p_L$ where each p_i is a triple (s, t, e) and s is the start point of the phrase, t is the end point of the phrase, and e is a sequence of English words. A phrase represents the fact that words $w_s \ldots w_t$ inclusive in the target language can be translated as the English sequence of words e. The score for any derivation is calculated as follows:

$$f(y) = h(e(y)) + \sum_{k=1}^{L} g(p_k) + \sum_{k=1}^{L-1} \eta \times |t(p_k) + 1 - s(p_{k+1})| \tag{1}$$

The components of this score are as follows:

- $e(y)$ is the target-language string for derivation y. $h(e(y))$ is the log-probability for the string $e(y)$ under a trigram language model. Hence if $e(y) = e_1 e_2 \ldots e_m$, then

$$h(e(y)) = \log \prod_{i=1}^{m} q(e_i | e_{i-2}, e_{i-1}) = \sum_{i=1}^{m} \log q(e_i | e_{i-2}, e_{i-1})$$

- $g(p_k)$ is the score for the phrase p_k.
- η is a "distortion parameter" of the model.

Now consider the following derivations

$y_1 =$ (1, 3, we must also), (7, 7, take), (4, 5, this criticism), (6, 6, seriously)

$y_2 =$ (1, 3, we must also), (4, 5, this criticism), (6, 6, seriously), (7, 7, take)

Question: What is the value for $f(y_1) - f(y_2)$? (Express this in terms of the q, g and η parameters.)

Question 3 Consider translating the foreign string *acat abarks* with a phrase-based model with the following lexicon:

(acat, cat)
(acat, the cat)
(abarks, barks)
(acat abarks, cat barks)
(acat abarks, the cat barks)

Question: Assume as usual that the initial state is $q_0 =$ (*, *, 00, 0, 0). Recall that each state is of the form (e_1, e_2, b, r, α) where e_1 and e_2 are the last two words of the partial translation, b is a bit string recording which words have been translated, r is the end point of the most recent phrase, and α is the score of the partial translation. Assume that we use beam search to find the highest scoring derivation, with the distortion limit $d = \infty$, and a beam size that is also infinite. What is the full set of states in Q_1 and Q_2 when the algorithm terminates? (Recall that Q_i for $i \in \{1 \dots n\}$ where n is the length of the source sentence contains the full set of states with exactly i words in the source language translated.) You do not need to specify the values for the score α for each state.

Hint: the full set of phrases for the input sentence *acat abarks* is

(1, 1, cat)
(1, 1, the cat)
(2, 2, barks)
(1, 2, cat barks)
(1, 2, the cat barks)