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

Definition of $\text{consistent}(A,(s,t),(s',t'))$:
(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 $f_s ... f_t$. $(s',t')$ represents the sequence of English words $e_{s'} ... e_{t'}$.)

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 $\text{consistent}(A,(s,t),(s',t'))$ is true if and only if the following conditions are met:

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

Figure 1: The definition of the $\text{consistent}$ function.

**Question 1a:** Assume we have a training set with a single foreign sentence $f = \text{adog aswims}$ paired with the English sentence $e = \text{the dog swims}$. 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 $\text{consistent}$ 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 $\text{adog aswims}$ into English using the set of phrase pairs from question 1a. Assume a distortion limit $d = 2$. One possible derivation for this sentence is

$$(1, 1, \text{the dog}) (2, 2, \text{swims})$$

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:

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

(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 \( p_k \).

- \( \eta \) is a “distortion parameter” of the model.

Now consider the following derivations

\[
y_1 = (1, 3, \text{ we must also}), (7, 7, \text{ take}), (4, 5, \text{ this criticism}), (6, 6, \text{ seriously})
\]

\[
y_2 = (1, 3, \text{ we must also}), (4, 5, \text{ this criticism}), (6, 6, \text{ seriously}), (7, 7, \text{ take})
\]

**Question:** What is the value for \( f(y_1) - f(y_2) \)? (Express this in terms of the \( q \), \( g \) and \( \eta \) parameters.)
**Question 3**  Consider translating the foreign string *acat abarks* with a phrase-based model with the following lexicon:

(achat, cat)
(achat, the cat)
(abarks, barks)
(achat abarks, cat barks)
(achat abarks, the cat barks)

**Question:** Assume as usual that the initial state is $q_0 = (\ast, \ast, 00, 0, 0)$. Recall that each state is of the form $(e_1, e_2, b, r, \alpha)$ 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 $\alpha$ 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 $i \in \{1 \ldots n\}$ 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 $\alpha$ 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)