1 IBM Model 1 (Part 1)

1.1 Question (time: 5:32, slide: 6)

Say we have the sentence pair, $e =$ the dog saw the cat and $f =$ adog asaw acat.

How many possible alignments are there between the sentences?

(a) 5^3

(b) 4^5

(c) 6^3

(d) 3^6

2 IBM Model 1 (Part 2)

2.1 Question (time: 1:42, slide: 10)

Consider the following sentence pair

- $e =$ the dog barks
- $f =$ abarks adog athe

and say we have the alignment $a_1 = 3, a_2 = 2, a_3 = 1$.

What is the value of $p(a|e, m)$ for this example under IBM Model 1?

2.2 Question (time: 4:20, slide: 11)

Consider the following sentence pair

- $e =$ the dog barks
- $f =$ abarks adog athe

Say we are given the alignment $a_1 = 3, a_2 = 2, a_3 = 1$ and the parameters

$$\begin{array}{rrr} t(\text{athe}|\text{the}) = 0.5 & t(\text{abarks}|\text{the}) = 0.5 & t(\text{adog}|\text{the}) = 0.0 \\ t(\text{athe}|\text{dog}) = 0.8 & t(\text{abarks}|\text{dog}) = 0.0 & t(\text{adog}|\text{dog}) = 0.2 \\ t(\text{athe}|\text{barks}) = 0.0 & t(\text{abarks}|\text{barks}) = 0.1 & t(\text{adog}|\text{barks}) = 0.9 \end{array}$$

What is the value of $p(f|a, e, m)$ for this example under IBM Model 1?

3 IBM Model 2

3.1 Question (time: 4:50, slide: 17)

Consider the sentence pair

- $e =$ the dog barks
- $f =$ abarks adog athe

Say we have the alignment $a_1 = 3, a_2 = 2, a_3 = 1$ and the parameters

$q(0\|1,3,3) = 0.0$	$q(1\|1,3,3) = 0.0$	$q(2\|1,3,3) = 0.4$	$q(3\|1,3,3) = 0.6$
$q(0\|2,3,3) = 0.0$	$q(1\|2,3,3) = 0.1$	$q(2\|2,3,3) = 0.9$	$q(3\|2,3,3) = 0.0$
$q(0\|3,3,3) = 0.0$	$q(1\|3,3,3) = 0.2$	$q(2\|3,3,3) = 0.4$	$q(3\|3,3,3) = 0.4$

What is the value of $p(a|e,m)$ for this example under IBM Model 2?

3.2 Question (time: 11:27, slide: 20)

Consider the sentence pair

- $e =$ the dog barks
- $f =$ abarks adog athe

and say we have the parameters

$t(\text{abarks}\|\text{the}) = 0.2$	$t(\text{abarks}\|\text{dog}) = 0.5$	$t(\text{abarks}\|\text{barks}) = 0.2$	$t(\text{abarks}\|\text{NULL}) = 0.1$
$q(3\|1,3,3) = 0.3$	$q(2\|1,3,3) = 0.2$	$q(1\|1,3,3) = 0.4$	$q(0\|1,3,3) = 0.1$

Define $a_1^* = \arg\max_{a \in \{0 \ldots l\}} q(a|1,3,3) \times t(f_1|e_a)$. What is the value of a_1^* for this example?

4 The EM Algorithm for IBM Model 2 (Part 1)

4.1 Question (time: 5:09, slide: 23)

Consider the sentence pair from the last slide

- $e =$ And the program has been implemented
- $f =$ Le programme a ete mis en application

and say we are given the alignment $a = \langle 2, 3, 1, 0, 6, 6, 6 \rangle$.

List the maximum-likelihood estimates (to three decimal places, separated by a space) for the parameters $t_{\text{ML}}(\text{Le}|\text{the})$, $t_{\text{ML}}(\text{Le}|\text{And})$, $t_{\text{ML}}(\text{mis}|\text{implemented})$, $t_{\text{ML}}(\text{en}|\text{implemented})$, $t_{\text{ML}}(\text{application}|\text{implemented})$, and $t_{\text{ML}}(\text{application}|\text{NULL})$.

5 The EM Algorithm for IBM Model 2 (Part 3)

5.1 Question (time: 8:02, slide: 28)

Consider the sentence pair

- $e^{(1)} = \text{the dog barks}$
- $f^{(1)} = \text{abarks adog athe}$

and say we have the following parameters

$t(\text{abarks}\|\text{the}) = 0.1$	$t(\text{abarks}\|\text{dog}) = 0.4$	$t(\text{abarks}\|\text{barks}) = 0.3$	$t(\text{abarks}\|\text{NULL}) = 0.2$
$q(3\|1,3,3) = 0.1$	$q(2\|1,3,3) = 0.4$	$q(1\|1,3,3) = 0.4$	$q(0\|1,3,3) = 0.1$

What is the value of $\delta(1,1,3)$?

A Answers

- (c)

  There are $l = 5$ English words plus the NULL word and $m = 3$ French words. The total number of alignments is $(l+1)^m = 6^3$.

- 0.01563

  Under IBM Model 1, all alignments are equally likely. The alignment probability is $p(a|e,m) = 1/(l+1)^m = 1/64$.

- 0.01

  The answer is 0.01. The probability calculation is $p(f|a,e,m) = \prod_{j=1}^{m} t(f_j|e_{a_j}) = t(\text{abarks}|\text{barks}) \times t(\text{adog}|\text{dog}) \times t(\text{athe}|\text{the}) = 0.01$.

- 0.108

  The answer is 0.108. The probability calculation is $p(a|e,m) = \prod_{j=1}^{m} q(a_j|j,l,m) = q(3|1,3,3) \times t(2|2,3,3) \times t(1|3,3,3) = 0.108$.

- 2

  There are four possibilities in the maximization,

  - $t(\text{abarks}|\text{NULL}) \times q(0|1,3,3) = 0.01$
  - $t(\text{abarks}|\text{the}) \times q(1|1,3,3) = 0.08$
  - $t(\text{abarks}|\text{dog}) \times q(2|1,3,3) = 0.10$
  - $t(\text{abarks}|\text{barks}) \times q(3|1,3,3) = 0.06$

  The best choice is $a_1 = 2$.

- 1 0 0.333 0.333 0.333 0

  The maximum-likelihood estimation is $t_{\text{ML}}(f|e) = \text{Count}(e,f)/\text{Count}(e)$ where $\text{Count}(e,f)$ is based on the word alignment pairs.

- 0.12

  The formula for calculating δ values is $\delta(k,i,j) = \frac{q(j|i,l_k,m_k) \times t(f_i^{(k)}|e_j^{(k)})}{\sum_{j=0}^{l_k} q(j|i,l_k,m_k) \times t(f_i^{(k)}|e_j^{(k)})}$. The numerator is $q(3|1,3,3) \times t(\text{abarks}|\text{barks}) = 0.03$ and the denominator is $\sum_{j=0}^{l_k} q(j|1,3,3) \times t(\text{abarks}|e_j^{(k)}) = 0.02 + 0.04 + 0.16 + 0.03 = 0.25$. The final value is 0.12.