**Last Class:**

1. Intro to part-of-speech tagging
2. TBL approach to p-o-s tagging

**Today:**

1. Hidden Markov Model Tagger



### HMM Tagger

Given $W = w_1, \ldots, w_n$, find $T = t_1, \ldots, t_n$ that maximizes

$$P(t_1, \ldots, t_n | w_1, \ldots, w_n)$$

Restate using Bayes' rule:

$$(P(t_1, \ldots, t_n) * P(w_1, \ldots, w_n | t_1, \ldots, t_n))/P(w_1, \ldots, w_n)$$

Ignore denominator...
Make independence assumptions...



### Independence Assumptions (factor 1)

$P(t_1, \ldots, t_n)$: approximate using **n-gram model**

**bigram** $\prod_{i=1,n} P(t_i \,|\, t_{i-1})$

**trigram** $\prod_{i=1,n} P(t_i \,|\, t_{i-2} t_{i-1})$



### Independence Assumptions (factor 2)

$P(w_1, \ldots, w_n \,|\, t_1, \ldots, t_n)$: approximate by assuming that a word appears in a category independent of its neighbors

$$\prod_{i=1,n} P(w_i \,|\, t_i)$$

Assuming bigram model:

$$P(t_1, \ldots, t_n) * P(w_1, \ldots, w_n | t_1, \ldots, t_n) \approx$$

$$\prod_{i=1,n} P(t_i | t_{i-1}) * P(w_i | t_i)$$

## Hidden Markov Models

Equation can be modeled by an HMM.

- **states**: represent a possible lexical category
- **transition probabilities**: bigram probabilities
- **observation probabilities**, **lexical generation probabilities**: indicate, for each word, how likely that word is to be selected if we randomly select the category associated with the node.



## Viterbi Algorithm

c: number of lexical categories

$P(w_t|t_i)$: lexical generation probabilities

$P(t_i|t_j)$: bigram probabilities

Find most likely sequence of lexical categories $T_1, \ldots, T_n$ for word sequence.

**Initialization**

For i = 1 to c do
  SCORE(i,1) = $P(t_i|\phi) * P(w_1|t_i)$
  BPTR(i,1) = 0



**Iteration**

For t = 2 to n
  For i = 1 to c
    SCORE(i,t) =
      $MAX_{j=1..c}(SCORE(j, t-1) * P(t_i|t_j)) * P(w_t|t_i)$
    BPTR(i,t) = index of j that gave max

**Identify Sequence**

T(n) = i that maximizes SCORE(i,n)
For i = n-1 to 1 do
  T(i) = BPTR( T(i+1), i+1 )



## Results

- Effective if probability estmates are computed from a large corpus
- Effective if corpus is of the same style as the input to be classified
- Consistently achieve accuracies of 96% or better using trigram model
- Cuts error rate in half vs. naive algorithm (90% accuracy rate)
- Can be smoothed using backoff or deleted interpolation...

## Extensions

- Can train HMM tagger on unlabeled data using the EM algorithm, starting with a dictionary that lists which tags can be assigned to which words.
- EM then learns the word likelihood function for each tag, and the tag transition probabilities.
- Merialdo (1994) showed, however, that a tagger trained on even a small amount hand-tagged data works better than one trained via EM.