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Confidence Measures

 In speech recognition, confidence measures (CM) are used to evaluate reliability of recognition results.

 Confidence measures can help ASR systems to migrate from laboratory to real world.

Overview

 The approaches for computing CM can be presented as three major categories:

- CM as a combination of predictor features
- CM as a posterior probability
- CM as utterance verification

Utterance Verification

 Utterance verification (UV) is a procedure used to verified how reliable are the results.

 Usually utterance verification is considered as a statistical hypothesis testing problem.

Utterance Verification

Posing the problem in this fashion:

– Does the input speech (X) contain the keyword corresponding to the most likely keyword (W) as determined by the speech recognizer?

Utterance Verification

- For a typical pattern classifier, given an observation X as input, we always get a pattern class W as output.
- X could come from several sources:
 - X actually comes from the class W
 - X comes from other classes instead of W
 - X is an outlier

Neyman-Pearson Lemma

- According to Neyman-Pearson lemma, an optimal test is to evaluate a likelihood ratio between two hypothesis H₀ and H₁.
 - H₀: X is correctly recognized (Null Hypothesis)
 - H₁: X is wrongly recognized (Alternative Hypothesis)

$$\mathsf{LRT} = \frac{p(X|H_0)}{p(X|H_1)} \, \mathop{\gtrless}_{H_1}^{H_0} \, \tau$$

Where τ is the decision threshold.

Difficulty

 Computing null hypothesis is straightforward but the alternative hypothesis is a composite one, so that it is always very difficult to model H₁.

First Approach

The likelihood ratio can be written as:

$$LRT = \frac{P(X \mid H_0)}{P(X \mid H_1)} = \frac{L(X \mid W)}{\frac{1}{N-1} \sum_{\substack{W' \\ W \neq W'}} L(X \mid W')}$$

– Where L(X/W) is the likelihood of the observation X given pattern class W.

First Approach

- The models that are used for computing alternative hypothesis are called competing models.
- Computing LRT as it is defined, is required the evaluation of the likelihood of speech segment X for each of the models in the model set.
- To reduce the computational complexity, we can consider smaller number of competing models.

Second Approach

 The competing set (or cohort set) for a given W is defined to be a fixed number (K) of pattern classes that are most confusable with W.

Pattern	Cohort Set				
Class		-2		2.9	04
ae	eh	ay	aw	ey	ih
aw	ae	ah	ao	ow	aa
ao	aa	ow	aw	W	ah
m	n	ng	1	W	uw
ch	jh	sh	t	s	k
s	Z	f	sh	th	h#
sh	S	ch	Z	jh	zh

Second Approach

The likelihood ratio can be written as:

$$LRT = \frac{P(X \mid H_0)}{P(X \mid H_1)} = \frac{L(X \mid W)}{\frac{1}{K} \sum_{W' \in CohortSet} L(X \mid W')}$$

- For a typical pattern classifier, given an observation X
 as input, we always get a pattern class W as output.
- X could come from several sources:
 - X actually comes from the class W
 - X comes from other classes instead of W
 - X is an outlier
- If an observation X is classified as W but it actually does not belong to the class W, we simply call it as a rival of the class W.

The set of all rivals of W:

$$S_r(W) = \{X \mid L(W \mid X) > L(W' \mid X), \forall W' \neq W, X \not\subset W, and L(W \mid X) > \xi\}$$

The set of observations from W:

$$S_c(W) = \{X \mid L(W \mid X) > L(W' \mid X), \forall W' \neq W, X \subset W\}$$

- The capability of utterance verification depends on how well we can distinguish $S_c(W)$ from $S_r(W)$.
- Statistical hypothesis testing can still adopted as a tool to separate $S_c(W)$ from $S_r(W)$ statistically.
- The simplest way to model S_c(W) and S_f(W) is that we estimate two different models Λ_c and Λ_f for S_c(W) and S_f(W), respectively, based on all possible training data from each of the sets.

Once \(\Lambda_c \) and \(\Lambda_r \) are given, utterance verification is operated as the following likelihood ratio:

$$LRT = \frac{P(X \mid H_0)}{P(X \mid H_1)} = \frac{\Pr(X \in S_c(W))}{\Pr(X \in S_r(W))} = \frac{p(X \mid \Lambda_c)}{p(X \mid \Lambda_r)}$$

• It is straightforward to define $S_c(W)$ and $S_r(W)$ for every isolated word W.

 But for continuous speech recognition, it is very hard to associate a definite part of data to the rival set, because numerous boundaries are possible.

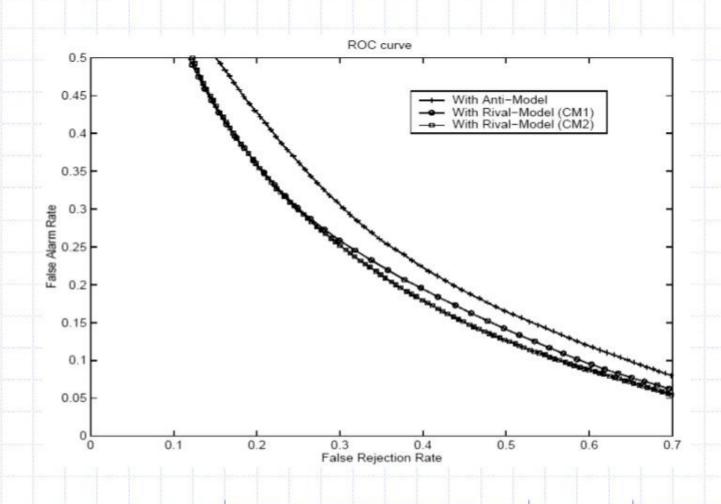
Using UV in Search Procedure

- It is possible to use utterance verification to correct some some possible recognition errors made by recognizer during search.
- At every time instant t, likelihood ratio testing is conducted for current path, if its score is below some threshold, this path will be rejectted.
- A wrong path with high likelihood but low verification score probability can be rejected during search.

Using UV in Search Procedure

- Another advantage of the above method is that likelihood ratio based confidence measure is calculated and attached with every phone in all possible paths.
- These phone scores can be easily put together to get the confidence measures for word, phrase, or the whole sentence.

Representing Results



Speech Recognition (Spring 2008)

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