# Feature Transformation Applied to the Detection of Discontinuities in Concatenated Speech

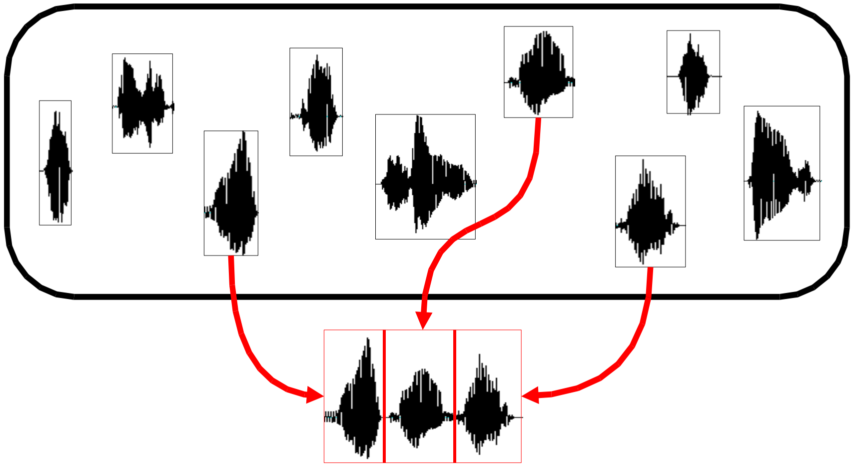
*Barry Kirkpatrick, Darragh O'Brien,* ***Ronán Scaife****,*
Faculty of Engineering and Computing
Dublin City University

# Overview

- Problem definition
- DCU database
- Approach
- Results: PCA
- Results: PCA+ANN
- Results: combining feature sets
- Summary and Conclusion

# Concatenative speech synthesis

- Database of recorded speech
- Chain segments of recorded speech units
- Natural sounding – State-of-the-art?
- Unit selection
- Inconsistent quality



# The problem

**Several levels:**

- how to emulate human judgments of “naturalness” for synthetic audio or video?
- how to optimally match human perception of discontinuity in synthetic speech?
- how to match human perception of spectral (rather than say $f_0$) discontinuity?…

# Why we need better models

- If we can accurately model human naturalness judgments, we can:
  – Produce better raw concatenations.
  – Develop spectral interpolation schemes to “repair” bad joins.
  – Optimise size and quality of unit selection database.

# Database (I)

- Based on simple perceptual experiment:
- 1 adult male recorded 300 mono-syllabic words from MRT list.
- 1800 CVC words created by PSOLA concatenating left- and right-hand parts with common vowel.
- Task was binary continuous/discontinuous judgment.

# Database (II)

- 12 listeners; 3 per subtest (6 words).
- Majority scoring of results.
- Initial use for database was to resolve widely differing reports of “optimal” join cost/distance measure.
- No attempt at spectral interpolation, although results may inform development of such algorithms.

# Database (III)

- 4 pitch-period linear fade.
- ***Not*** yet ready to embed into synthesizer.

# Present Study

- Many feature sets (MFCC, LSF, PSD, etc) have been proposed for unit selection join cost calculations.
- Many distance measures have been tried on above feature sets.
- Can more discriminating power be extracted from existing feature sets (*a la* ASR)?

# Approach (I)

- Explore Principal Component Analysis (PCA) and Artificial Neural Networks (ANN) to improve discrimination.
- Which ANN? General Regression Neural Network (GRNN).
- PCA front-end modestly improves discrimination, but mainly allows GRNN with manageable number of nodes.

# Approach (II)

- All units represented by time sequence of feature vectors x.
- For each candidate join, compute ***join vector*** as difference of adjacent frames:

$$x_{join} = x_{left} - x_{right}$$

(rather than scalar distance.)

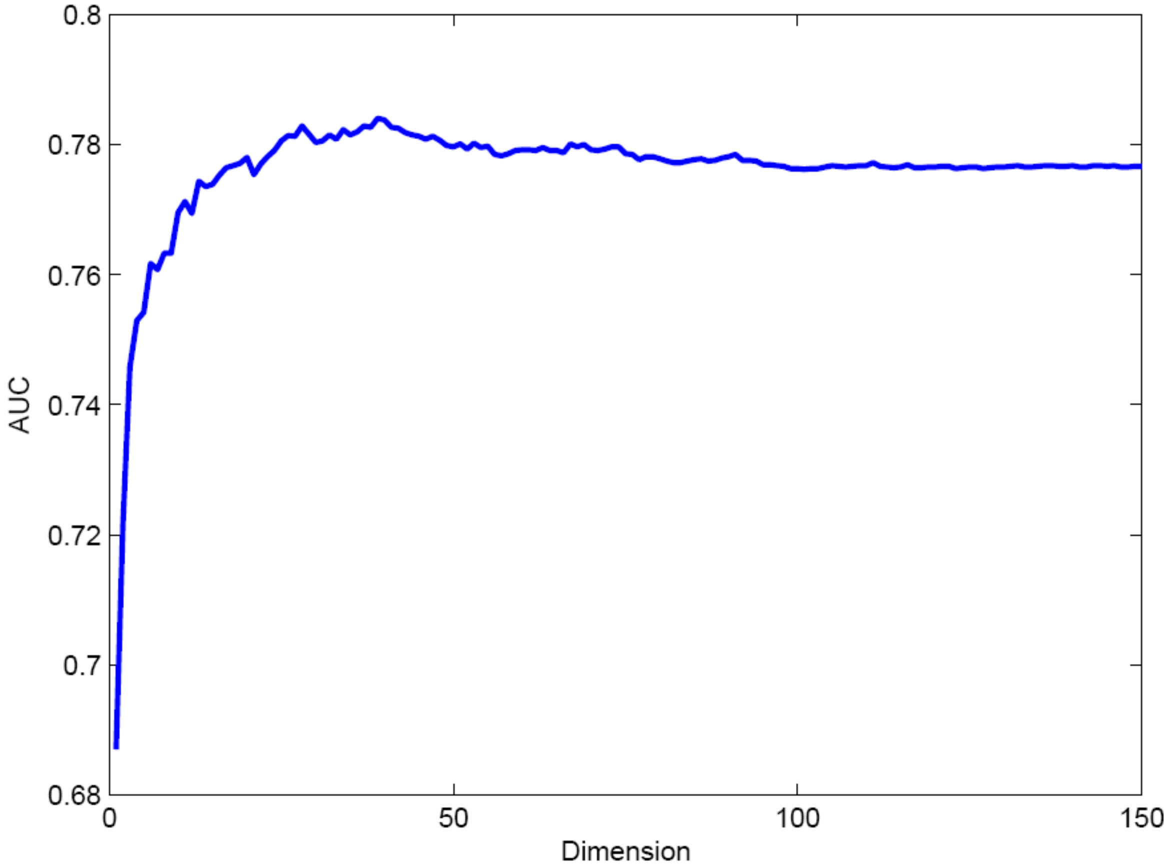
# Approach (III)

- PCA resolves raw join vectors into uncorrelated components, ordered as to variance.
- Number of PCA components per frame much less than original feature dimension (39 vs 256 for logPSD.)
- Study restricted to ***spectral*** discontinuity (not energy or fundamental frequency.)

# PCA performance vs dimension

AUC vs PCA output dimension;

(log PSD feature).



# PCA alone

- Computed across entire dataset.
- PCA tested with:
  - o MFCC
  - o LSF
  - o LogPSD (from DFT)
- Modest discrimination ***increase*** for MFCC and logPSD, larger ***decrease*** for LSF.
- Large reduction in dimensionality.

# PCA gains

| Feature | x | PCA(x) |
|---|---|---|
| MFCC | 0.75 | 0.7696 |
| LSF | 0.7381 | 0.6966 |
| PSD (log DFT) | 0.7615 | 0.7841 |

AUC results for each feature set: without and with PCA.

# Combining PCA and ANN

- Can (non-linear) processing improve on PCA-processed features?
- For each of MFCC, LSF and log PSD, computed discrimination when PCA followed by (GRNN) ANN.
- Results assessed by area (AUC) under Receiver Operating Characteristic (ROC).

# ANN Details (I)

- Database split equally into training and testing sets.
- Of 1800 concatenated words, 434 perceived discontinuities, equally split between training and testing set.

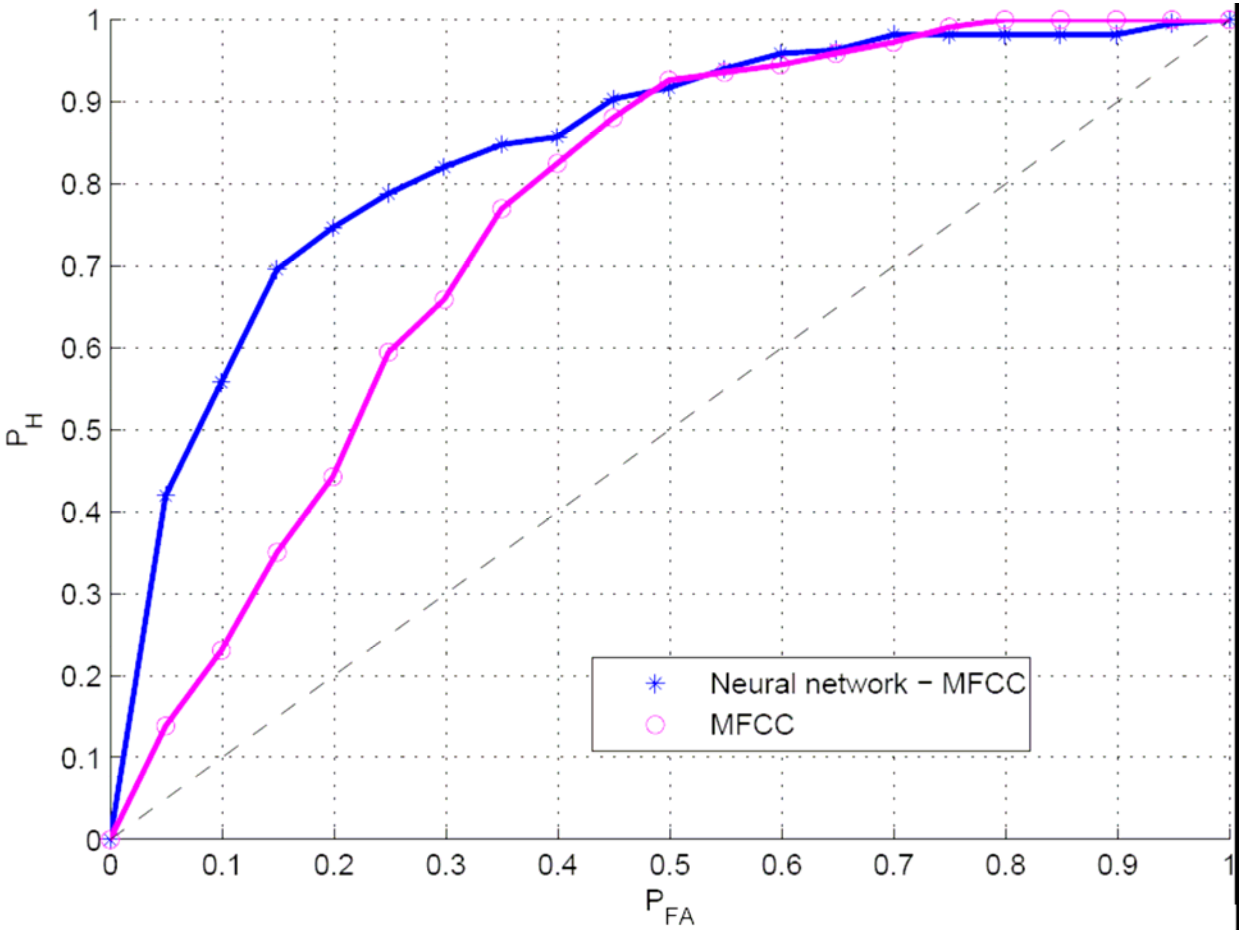
# ANN Details (II)

- GRNN trained with target output (from perceptual test) of 1 for discontinuity, 0 for continuous.
- Results assessed with AUC as for PCA-only case.

# PCA+ANN results

| Feature | x | PCA+ANN (x) |
|---|---|---|
| MFCC | 0.7565 | 0.8413 |
| LSF | 0.7468 | 0.7955 |
| PSD (log DFT) | 0.7673 | 0.8744 |

# MFCC+PCA+ANN

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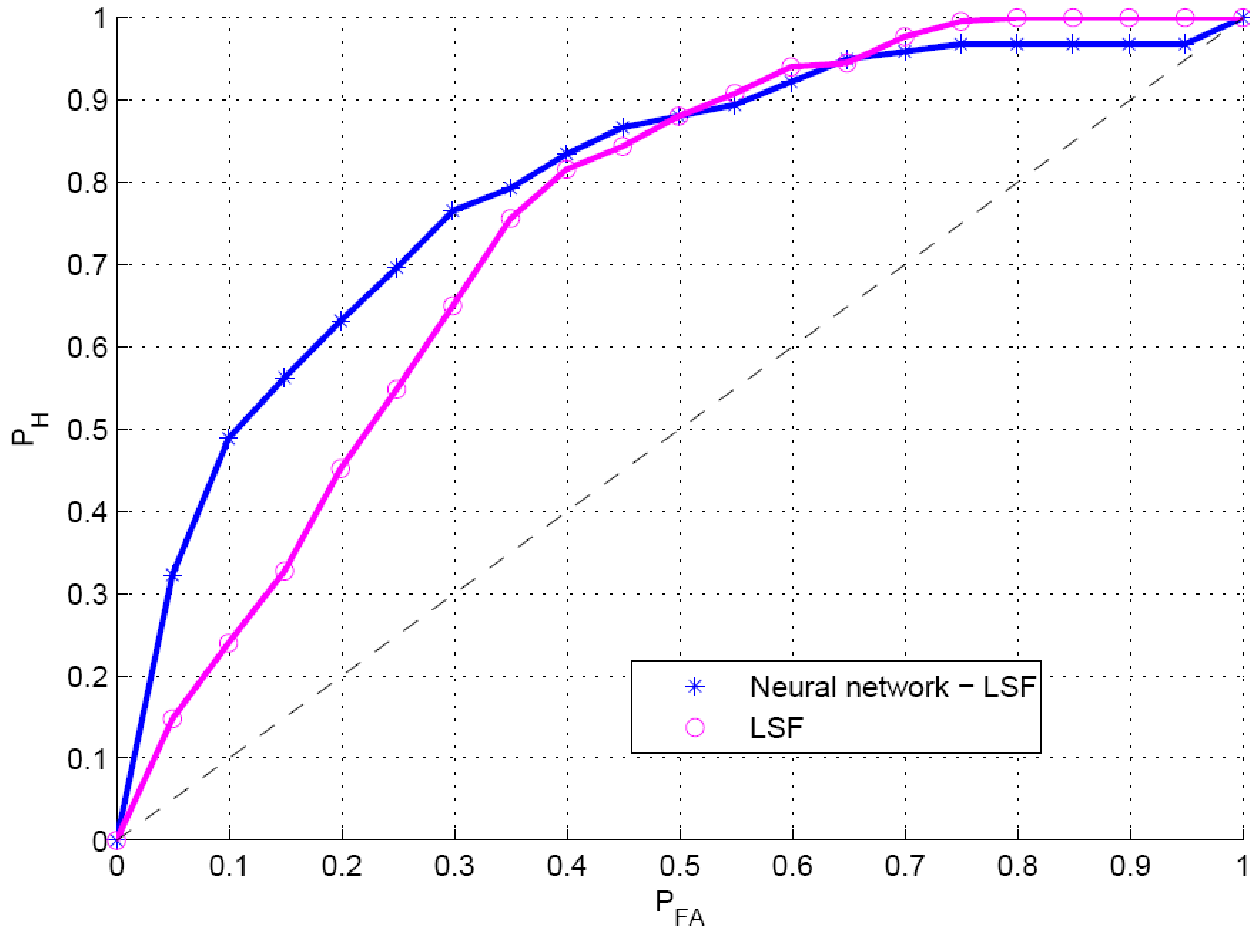
# LSF+PCA+ANN

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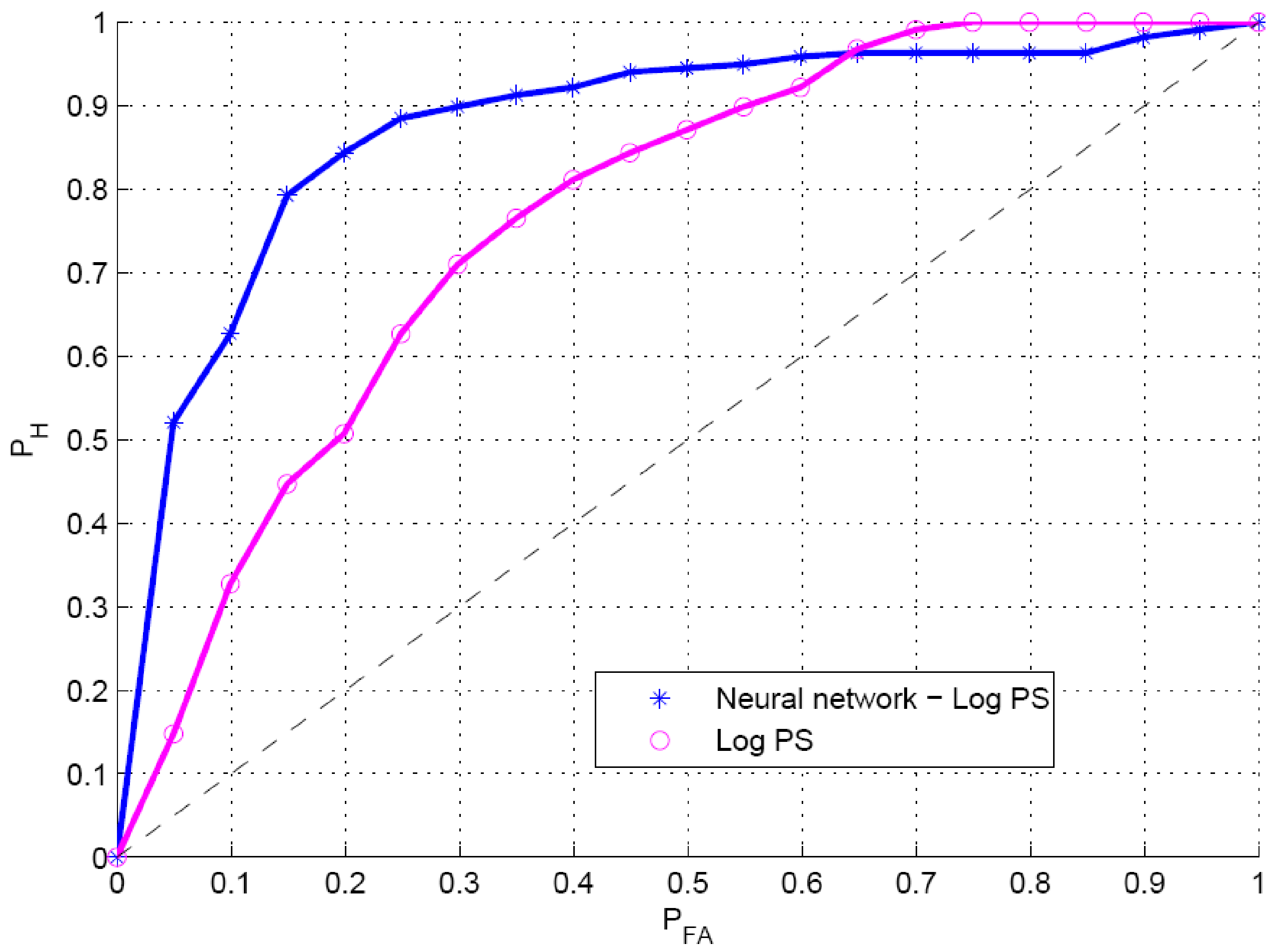
# logPSD +PCA+ANN

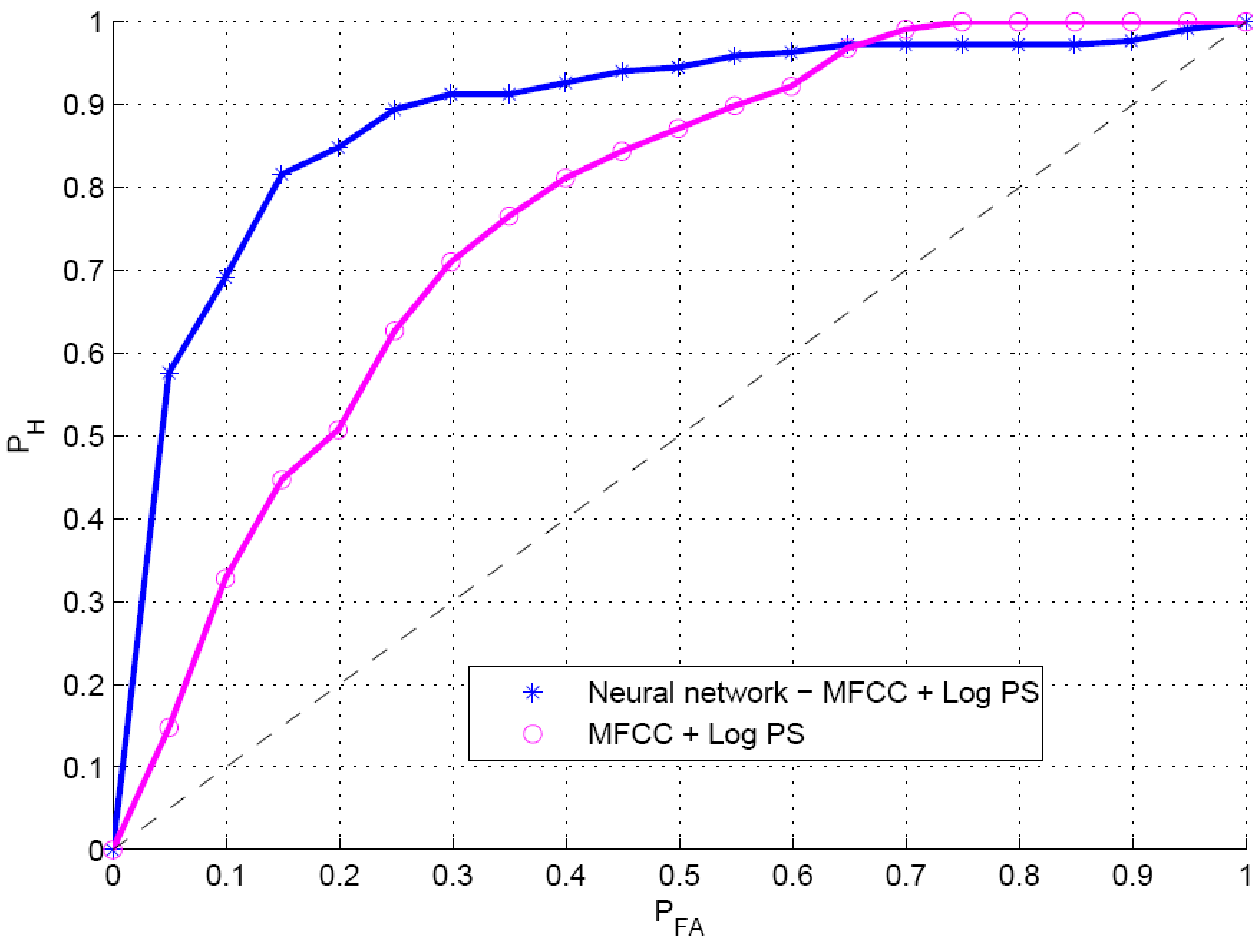


# Combining Feature Sets

- Further modest increases in AUC obtained by concatenating feature vectors:

| Features | x | PCA+ANN (x) |
|---|---|---|
| MFCC+LSF | 0.7468 | 0.8581 |
| MFCC+logPSD | 0.7673 | 0.8859 |
| LSF+logPSD | 0.7517 | 0.8753 |
| LSF+MFCC +logPSD | 0.7517 | 0.8829 |

# MFCC and logPSD combined

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# Summary & conclusion

- Application of feature transformation to join cost optimisation.
- PCA to reduce dimensionality.
- ANN learns continuous/discontinuous discrimination function.
- Approach extracts useful extra discrimination.
- Feature sets may be usefully combined.

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# Unit selection

- Select optimum sequence of units
- Cost criterion
- Target cost – well defined
- Join cost – ill-defined
- Perception of joins
- F0, energy and spectral measures
- Problem – spectral measure

# Related work

- Many previous studies addressing this problem:
  - Macon and Wouters (1998)
  - Klabbers and Veldhuis (1998, 2001, 2007)
  - Stylianou and Syrdal (2001)
  - Vepa and King (2004, 2006)
  - Bellegarda (2004, 2006)
- Focused on comparing different feature sets
- Results inconsistent and largely inconclusive
- Sources of inconsistency?

# Relating results

- Relating human results to subjective measures
- Receiver Operating Characteristic (ROC) curves
- Performance metric; area under the ROC curve (AUC)