Difference Evaluation Method for Differential Diagnosis of Frequency Specific Hearing Loss

Hubert Dietl, Stephan Weiss

Communications Research Group

Dept. of Electronics and Computer Science,

University of Southampton, SO17 1BJ, UK.

http://www-mobile.ecs.soton.ac.uk

Outline

- Differentiating between patients with different hearing ability based on TEOAE;
- transformation methods used to parametrise the TEOAE data;
- assessment of the separability between the groups with different hearing ability — receiver operating characteristic;
- identifying a set of coefficients C_{opt} to optimise the differentiation of the three groups of different hearing ability;
- results and conclusion.

Objective Assessment of Hearing Loss

- Aim: test hearing without active participation of patient — important for e.g. infants;
- methods such as auditory evoked potentials are well established;
- transient evoked otoacoustic emissions (TEOAE) are quiet sounds produced in the inner ear, and can be used for diagnosis;
- this is generally to test on/off hearing, but frequency-specific information can be obtained;
- study on achievable distinction.

TEOAE Properties

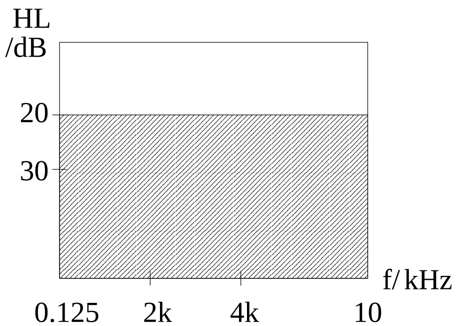
- Broadband click-stimulus contains frequencies between 0.5 and 5 kHz;
- these frequencies are reflected in the TEOAE and are generally believed to correspond to frequencies that are perceived by the ear;
- the TEOAE spectrum is latency-dependent: low frequency components possess a prolonged latency.

TEOAE Properties

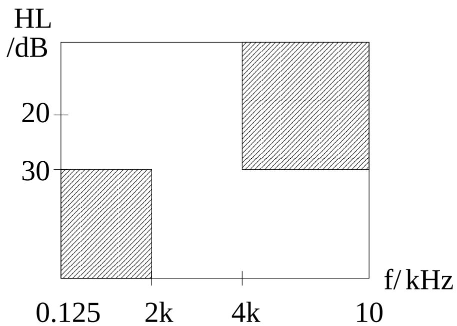
- TEOAE is generally very noisy and requires averaging.
- data per ear is available as partial averages, $\overline{\mathbf{x}}_{\mathrm{A}}$ and $\overline{\mathbf{x}}_{\mathrm{B}}$, (over 130 even and off indexed) stimulus-synchronous responses;
- detection: via correlation $\rho = \overline{\mathbf{x}}_{\mathrm{A}}^{T} \cdot \overline{\mathbf{x}}_{\mathrm{B}}$ or an SNR value, SNR $= \frac{\|\overline{\mathbf{x}}_{\mathrm{A}} + \overline{\mathbf{x}}_{\mathrm{B}}\|_2^2}{\|\overline{\mathbf{x}}_{\mathrm{A}} - \overline{\mathbf{x}}_{\mathrm{B}}\|_2^2}$.

Data

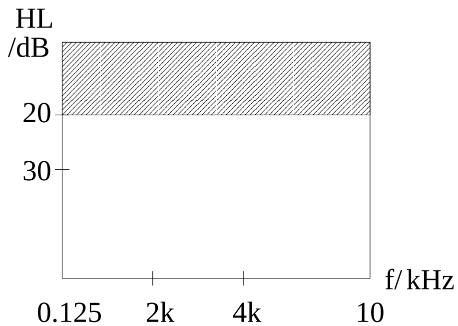
- Two studies with each approximately 200 ears from Universities of Homburg and Heidelberg;
- each study contains three classes of hearing ability:



normal hearing



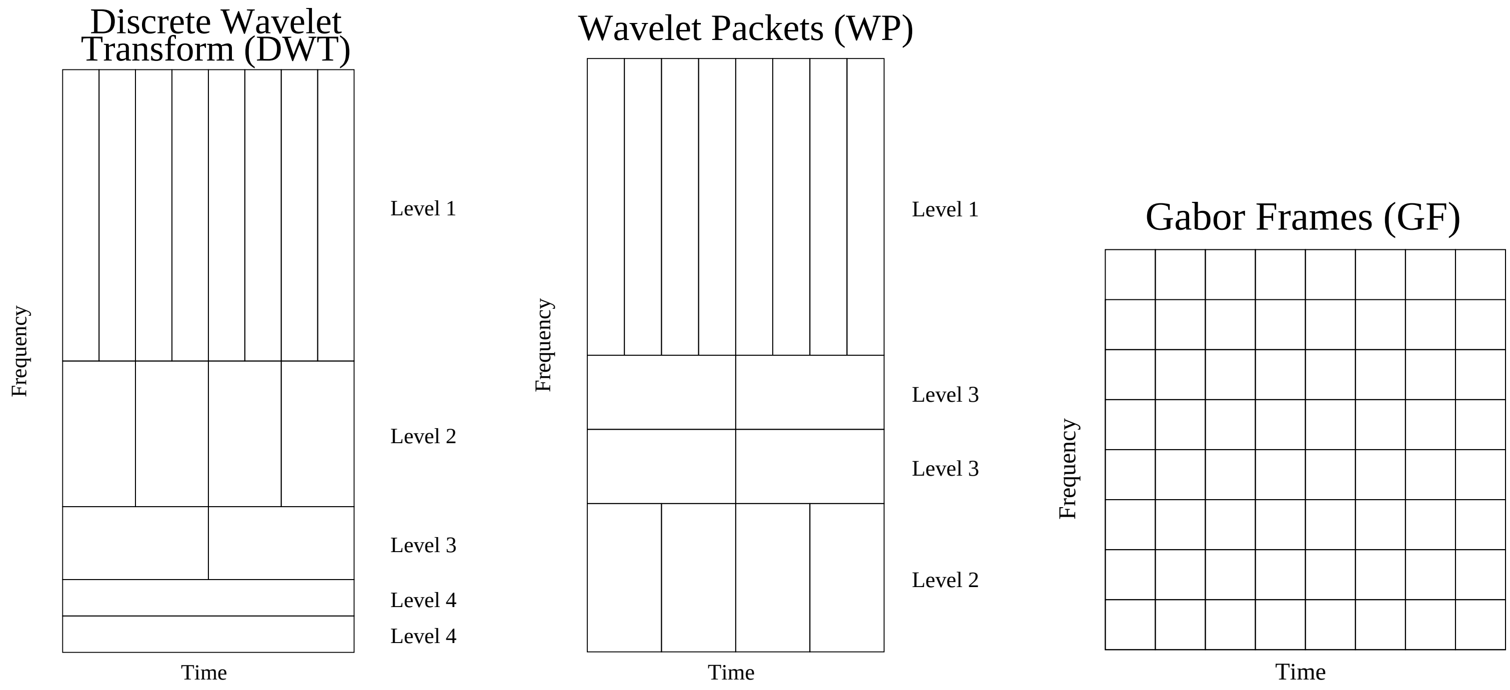
high-frequency hearing loss



pantonal hearing loss

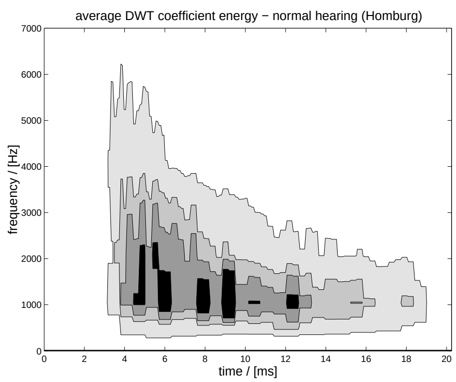
Transformation Methods

- TEOAE data parameterised by the following transforms, with an exemplary time-frequency tiling given:

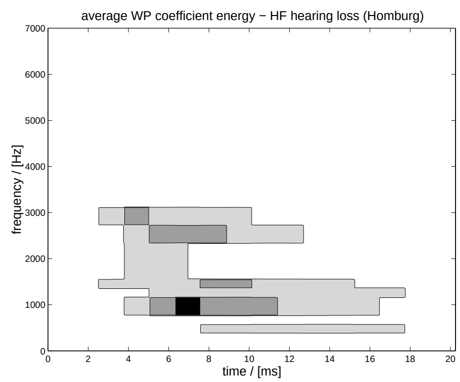


TF Analysis of TEOAE data

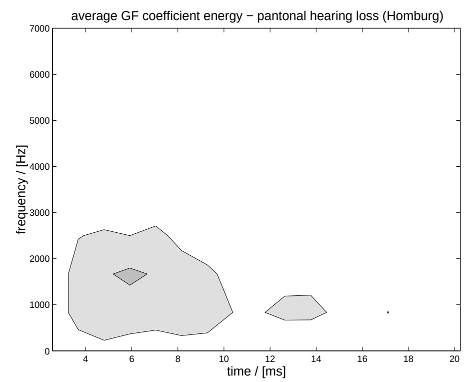
- Time-frequency (TF) analysis over the different hearing ability groups of the Homburg data yields:



normal hearing, DWT



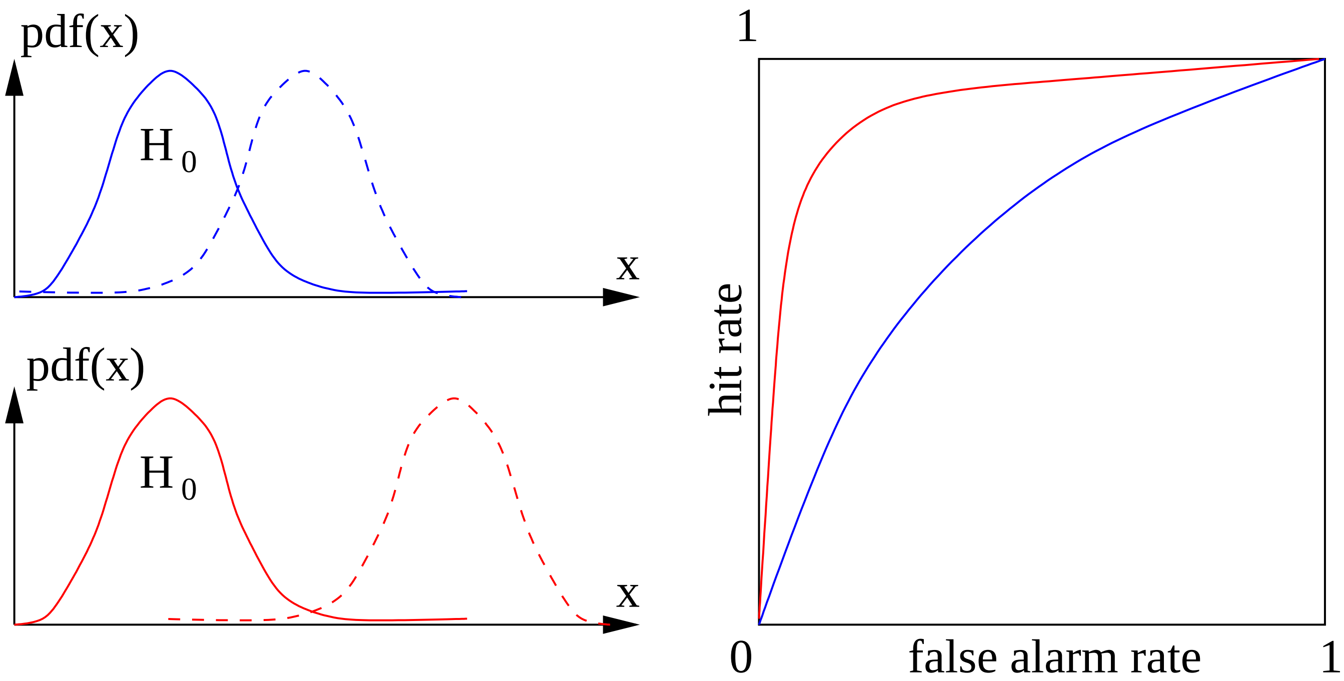
high-frequency hearing loss, WP



pantonal hearing loss, GF

Separability — Receiver Operating Characteristic

- An ROC measures the separability independent of a specific threshold:



- the measure for separability is the area under the ROC curve.

Set Initialisation

- Assume: Transform is given by

$$\mathbf{y}_i = \mathbf{T}_\mathrm{j} \cdot \overline{\mathbf{x}}_i = \left[y_i[0] \;\; y_i[1] \;\; \cdots \;\; y_i[511] \right]^\mathrm{T}$$

  with $j = \{\mathrm{DWT}, \mathrm{WP}, \mathrm{GF}\}$;

- we calculate an SNR estimate for all possible coefficients:

$$\text{SNR}^{(1)}[k] = \frac{(y_\mathrm{A}[k] + y_\mathrm{B}[k])^2}{(y_\mathrm{A}[k] - y_\mathrm{B}[k])^2 + \epsilon}$$

- we pick the coefficient for which the separability between two groups is maximum;

- this single coefficient does generally not offer sufficient separability.

Set Growth

- All adjacent coefficients in the TF plane to the one already selected are considered as candidates for the optimal set C_{opt}, and for each a new SNR is estimated:

$$\mathrm{SNR}^{(i)}[l] = \frac{(y_{\mathrm{A}}[l] + y_{\mathrm{B}}[l])^2 + \sum_{k \in C_{i-1}} (y_{\mathrm{A}}[k] + y_{\mathrm{B}}[k])^2}{(y_{\mathrm{A}}[l] - y_{\mathrm{B}}[l])^2 + \sum_{k \in C_{i-1}} (y_{\mathrm{A}}[k] - y_{\mathrm{B}}[k])^2 + \epsilon}$$

  and the separability between two groups is calculated;
- the set that maximises the separability is retained;
- this procedure is iterated, until the separability does not increase any more, resulting in the set C_{opt}.

Set Growth

- To broaden the search algorithm, the second largest coefficient is selected as starting the search procedure;
- neighbourhood search is broadened by including also the adjacent coefficients to the ones described previously;
- reason: by this generalisation an improvement of the separability results is expected;
- application of this difference evaluation method to other biomedical data.

Results

- The following values for separability were achieved for the data:

group distinction	transform	separability: Homburg	separability: Heidelberg	previous study: Hombg	previous study: Heidelbg
NH — HF	DWT	0.905	0.862	0.878	0.853
NH — PT	GF	0.949	0.957	0.918	0.963
HF — PT	WP	0.871	0.887	0.768	0.847

- the Heidelberg data was employed as a control group for testing with the adjusted coefficient set received by the Homburg data; it gave similar or even better results;
- comparison with a previous study.

Results

- Pantonal hearing loss and high-frequency hearing loss are most difficult to distinguish;
- normal hearing and pantonal hearing can be separated best;
- best results are achieved by different transforms;
- results indicate an improvement compared to a previous study where only the DWT and a narrow search algorithm was used.

Conclusions

- A time-frequency analysis of TEOAE was performed in order to evaluate the reliability for determining frequency-specific hearing loss using this difference evaluation method;
- different transforms were used for parameterisation;
- the spectrograms showed differences in the TF distributions of the three groups of different hearing ability;
- this difference was exploited by determining sets of distinctive coefficients based on the Homburg data.

Conclusions

- The validity of the result was checked by the Heidelberg data;
- the adjustment to the first data set does not impede generalisation;
- good separability was established; the determined distinctive coefficient sets made physiologically sense and improved previous results;
- application of this difference evaluation method to other biomedical data, e.g. EEG to be done in the future.