DTU Informatics
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OPTIMIZATION OF HEARING-AIDS

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Problem Statement

The primary purpose of a hearing aid is to provide amplification to make soft sounds audible to the hearing impaired user. A range of 'helping systems' assist the user in difficult listening conditions. The most effective of these helping systems is the directional microphone, which suppresses sounds that come from the side and to the rear of the user, and thereby makes it easier to hear the target sound.

The directional microphone is realized by a combination of two omni-directional microphones and a set of digital filters called the 'dir-processing'. Today, the 'dir-processing' is designed once for each hearing-aid model.

The problem is that the individual hearing-aid user does not achieve the optimal listening conditions when the dir-processing is only optimized once for each hearing aid model.

Current Method

Standard head model

Acoustical measurements performed on head model in order to optimize 'dir-processing'

Average 'dir-processing'

The 'dir-processing' can be optimized, for the individual user, by a number of acoustical measurements taken from a large number of loudspeakers positioned on a sphere around the hearing-aid user. Such measurements are, however, completely intractable in clinical practice.

Proposed Method

Input to the Proposed Method

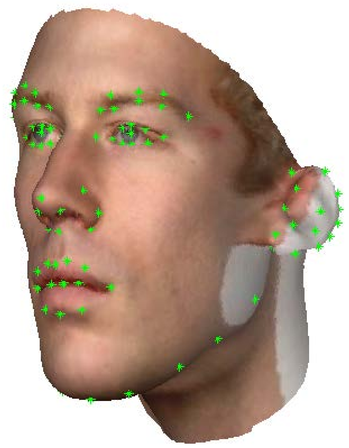
2D image of the individual with landmarks

Mean face based on the Basel Face Model

Fitting model parameters

Fitting 3D Model to 2D Images

Basel Face Model with fitted shape and applied 2D image texture



Acoustical Simulations

Individual Acoustical Simulations

Personalized 'dir-processing'

Overview

The listening conditions can be optimized by optimizing the 'dir-processing' for each individual hearing-aid user! A straight forward approach is to make acoustical measurements.

Since it is intractable to make acoustical measurements for each individual hearing-aid user, we will use an approach where the elaborate acoustical measurements [3,4] are replaced with numerical simulations, e.g. based on the Finite Element Method (FEM) [4]. This approach requires an accurate 3D geometrical representation of the individual hearing-aid user's head, which can be obtained by fitting a 3D Morphable Model (3DMM) to 2D images of the hearing-aid user's head and ear.

The long-term vision is that the hearing-aid dispenser uses his/her mobile phone or digital camera to acquire images of the customer's head and ears. The images will be sent together with the order forms to the hearing-aid manufacturer, where a 3D model of the customer head and ears will be estimated. Based on this model, the individual optimization of the 'dir-processing' will be computed by Finite Element Method (FEM) sound-field simulations and stored in the hearing aid.

3D Morphable Model

The 3D Morphable Model (3DMM) provides the foundation for building a 3D model of a face based on one or multiple images. The 3DMM is a vector representation of the shape and texture components of the face. The vector space representation is in [1] given as:

$$S = \sum_{i=1}^{m} a_i S_i \qquad T = \sum_{i=1}^{m} b_i T_i$$

Where $S_i = (x_1, y_1, z_1, \dots, x_k, y_k, z_k)$ and $T_i = (R_1, G_1, B_1, \dots, R_k, G_k, B_k)$

After performing PCA on the shape and texture vectors , they can be given as:

$$S = \bar{s} + \sum_{i=1}^{m-1} \alpha_i \cdot s_i \qquad T = \bar{t} + \sum_{i=1}^{m-1} \beta_i \cdot t_i$$

We want to build a 3DMM for the entire head including both the ears and facial region.

Cost function

The 3DMM is used in order to generate a 3D model of e.g. a human face or head. The 3DMM is fitted to one or multiple 2D images by optimizing the shape and texture coefficients, α and β.

The optimal fit is found by minimizing the sum of squares difference between the three color channels [1]:

$$E = \sum_{x,y} \left\| I_{input}(x,y) - I_{model}(x,y) \right\|^2$$

The final 3D model of the subject is very dependent on the 3DMM. The Basel Face Model [1] is a publicly available 3DMM for faces, it is however based on only 100 female and 100 male face scans, which limits the performance of the model.

A 3DMM build on a large database of face scans would be an advantage, in order to obtain a more flexible model. Furthermore, a 3DMM containing head scans including the ears is needed.

Personalized 'dir-processing'

The 'dir-processing' will be optimized for the individual hearing-aid user by making numerical simulations, based on the FEM [4].

[1] Blanz V and Vetter T, *Face Recognition Based on Fitting a 3D Morphable Model,* IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 25, no. 9, 2003
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[3] Laugesen S, Rasmussen KB, Christiansen T, *Design of a microphone array for headsets*, Proceedings of the IEEE Workshop on Applications of Signal Processing to Audio and Acoustics, 2003
[4] Rasmussen KB, Microphone System with Directional Response, US Patent 7,212,642, 2007