Individualized directional microphone optimization in hearing aids based on reconstructing the 3D geometry of the head and ear from 2D images

The goal of this thesis is to improve intelligibility for hearing-aid users by individualizing the directional microphone in a hearing aid. The general idea is a three step pipeline for easy acquisition of individually optimized directional filters. The first step is to estimate an individual 3D head model based on 2D images, the second step is to simulate individual head related transfer functions (HRTFs) based on the estimated 3D head model and the final step is to calculate optimal directional filters based on the simulated HRTFs. The pipeline is employed on a Behind-The-Ear (BTE) hearing aid.

We verify the directional filters optimized from simulated HRTFs based on a listener-specific head model against two set of optimal filters. The first set of optimal filters is calculated from HRTFs measured on a 3D printed version of the head model. The second set of optimal filters is calculated from HRTFs measured on the actual human subject.

A verification of the 'simulated' directional filters against the optimal filters for the human subject revealed a 0.5 dB reduction in articulation-index weighted directivity index, which corresponds to 5% less speech intelligibility. A comparison against non-individual directional filters revealed equally high Articulation-Index weighted Directivity Index (AI-DI) values for our specific test subject. However, measurements on other individuals indicate that the performance of the non-individual filters vary among subjects, and in particular individuals who deviate from an average of the population could benefit from having individualized filters.

We developed a pipeline for 3D printing of full size human heads. The 3D printed head facilitated the second verification step, which revealed a 0.3 dB reduction from optimal to simulated directional filters. This indicates that the simulation are more similar to measurements on the 3D printed head than measurements on the human subject. We suggest that the larger difference between simulation and human measurements could arise due to small geometrical errors in the head model or due to differences in acoustical properties between human skin and virtual material properties in the simulation.

The BTE hearing aid showed very little room for improvement using individualized directional filters, however the directional filters in an In-The-Ear (ITE) hearing aid revealed an improvement in AI-DI values of up to 3.6 dB between an average filter and an optimal filter. This suggests that hearing-aid users with ITE hearing aids could benefit more from having individualized directional filters than what was shown for a BTE hearing aid.

This thesis is a step towards individualizing the directional microphone in hearing aids, which could contribute with improved sound for a group of hearing-aid users. In particular, we believe that ITE hearing-aid users could have a large benefit from an individualized directional microphone.