STATISTICAL SHAPE MODELING OF THE HUMAN EAR CANAL FOR DESIGNING HEARING PROTECTION DEVICES AND AUDITORY WEARABLES

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Abstract

Current in-ear device designs rely mostly on a limited number of sizes or a 'one-size-fits-all' approach, based on basic shapes such as cones, circles, and/or ellipses. Moreover, the choice of size is often based on the linear scaling of an average design, leading to issues including insufficient or excessive contact pressure, improper device fit, and inferior acoustic performance. An understanding of ear shape is crucial for the acoustic performance of the in-ear device and for all-day wearability. To address this challenge, we present a method for generating statistical ear shapes for designing devices that are reflective of ear canal morphology. First, we collected ear impressions from 86 subjects, which were digitized using a 3D scanner. A novel landmarking algorithm was developed to reliably and automatically identify key features of the canal (i.e., entry plane and first/second bend). 3D parametric shapes of the canal were then created from these landmarks. Principal shape modes were identified using principal component analysis. k-means algorithm was utilized to identify clusters within the dataset based on relevant data features. The clustering process was conducted on the centroid axis, selected 2D cross-sections, and the 3D shape of the ear canal. Despite considerable variation within the dataset, the landmarking algorithm proved to be robust by performing well across all subjects. Using our parametric shapes, we calculated the average shape of the ear canal across the population. The first and second shape modes corresponded to overall size changes, and variations at the entry plane, respectively. After analyzing the data, we generated 4-5 clusters for centroid axis, cross-sections, and 3D shapes. The shapes derived from our analysis capture all ear canal morphologies, and offer a blueprint for innovative design of sound bores, flanges, and ear plugs tailored to fit the canal, thus, opening up new avenues in auditory equipment design.