**Motivation**

**Individualized Head Related Transfer Function (HRTF)**

*“One's unique audio imprint”*

- **With generic HRTF**
  - Reproduce wrong or mismatched audio cues where brain could not relate to the real situation, resulting in the sound to be perceived inside the head or front-back confusions.

- **With HRTF**
  - Reproduce the exact audio cues that trick a person's brain into a "being there" auditory illusion with accurate directional perception and externalized sound.

*“Existing HRTF individualization techniques such as *equivalent* measurements in anechoic chamber, *anthropometric* measurements, or *listening* and evaluation either require tedious measurement, training or result in degraded performance”*

This motivates us to develop a technique that:

- Allow unconstrained continuous head movements with direction recorded.
- Measure HRTFs with low variance in conventional headband.
- High-resolution accurate measurement.
- Natural sound playback.
- Obtain HRTF at true resolution up to 1 degree, providing better spatial perception for dynamic sound rendering.
- Using the patented iHRTF method, 3D audio headsets can enhance the sensation of “being there”.

**Reference and Acknowledgment**

- *Nguyen Duy Hai, Santi Peksi, Rishabh Ranjan, Jianjun He, Boon Slang Tan, Rishabh Gupta, Woon-Seng Gan;*
- *School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore; Aaxim Integrated, San Jose, United States; Immerzen Labs Pte. Ltd., Singapore; Sivantos Pte. Ltd, Singapore*

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**Integration of Acquisition and Rendering**

**Real-Time Rendering (tracking of human head)**

**Miniature electret condenser microphone for hearing instruments**

**US PATENT 9,357,282**

**Multi Emitter Structure**

**Compact MEMs microphone design**

**In-Situ Fast HRTF Acquisition**

**Spatial Audio Reproduction Over Patented Headphone**

**Real-Time Adaptive HRTF Estimation**

**Enhanced Interpolation and Distance Rendering**

**Results**

**Comparison between standalone Head Tracker and VR Headgear**

- **HRIR/HRTF for HATO aligned, az=0-60, el=0**
  - With and Without VR

- **Overall Mean SD, ILD, ITD at 120cm, variable az and el**
  - With and Without VR

- **Subjective Performance**
  - ABX test further confirmed our objective results. 95% identification accuracy for Generic vs Individualized; and 50-70% identification accuracy for Static vs Dynamic, which indicates that our measured HRTF is almost indistinguishable from conventional static methods.

**Subjective Evaluation ABX**

1. Easily differentiate 0.5 - Guessing level

**Specification**

**ACQUISITION**

- **Hardware**
  - Microphone: Miniature electret condenser microphone for hearing instruments
    - Deviation between left and right = 1dB
    - Sensitivity @1kHz: 32(+/-3) dB, re: 1V per Pascal
  - Size: 3.55 x 3.55 x 1.27mm

- **Software**
  - No of Grid in Frontal Directions: Azimuth [-60:5:60] Elevation [-30:10:30]
  - Distance 1 m
  - Excitation Signal: White Noise
  - Length of acquired impulse response: 600 samples @ 48 kHz
  - Recording Duration: 90-180 secs

**Rendering**

- **Hardware**
  - **Headphone**: “Listening device and accompanying signal processing method”
  - **Patented**: US PATENT 9,357,282

- **Software**
  - **Rendering Update**: 50 Hz
  - **Rate**: Head Tracking Speed 90 Hz

- **Playback Scenes**
  - Single Static Sound Source
  - Multiple Static Sound Sources
  - Moving Sound Sources

**DATA ANALYTICS**

- **HRTIR Accuracy**: MSE of ipsilateral and contralateral ear at each azimuth and elevation
- **Head movement pattern**
  - 6 Degree of Freedom (DoF)
  - 3 Axis Pitch 3 Axis Left/Right
  - 3 Axis Yaw 3 Axis Up/Down
  - 3 Axis Roll 3 Axis Front/Back
- **Degree of transition**
  - Head and Torsos Aligned (roll variation between head and torso = 2 degrees)
  - Head and Torsos Not Aligned (roll variation between head and torso = 6 degrees)

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