3D Audio
&
Personal Acoustics
Ear morphology: Did you know that …

… Natural evolution has designed the human ear to perceive sound direction?

… everybody has different ears?

HRTF (Head Related Transfer Function) are directional acoustic filters created by the reflection of sound waves on the ear. Our brain has “memorized” these directional filters and recognizes sound direction with “pattern matching”.

Like fingerprints, ears are a biometric sign!
### DIGITAL EAR Applications

The DIGITAL EAR, set of specific parameters related to the 3D shape of the ear of individuals can be leveraged in several use cases.

<table>
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<tr>
<th><strong>3D Audio</strong></th>
<th><strong>Custom Fit Ear Piece</strong></th>
<th><strong>“In The Ear” Microphone Directivity</strong></th>
<th><strong>Augmented Reality Audio</strong></th>
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</thead>
</table>
| Spatial Audio perception depends on the shape of the ear (HRTF). All 3D Audio engine are based on the concept of HRTF. Personalized HRTF are used to provide improved spatial audio experience to the end user. | Custom made ear piece for better performance, comfort and insulation in several applications:  
- Earphones  
- Hearing aids  
- Hearables (sensors)  
- Hearing Protections  
- Water protections | Leverage the shape of the ear to improve directivity of microphones located in the hearing instrument.  
- “In The Ear” (ITE) Hearing Aids  
- Hearables | Improve the frequency response of the ”Near the Ear” drivers with near field HRTF in one single direction.  
Main application is in Augmented Reality (AR) headsets or glasses which use an “open ear” solution to superimpose existing and simulated 3D audio. |
PROBLEM: Capturing a DIGITAL EAR is complicated

Until now, it has been complex and expensive!

3D scanning (Not Applicable!)

High Resolution Ear Scanner for audiologists (>10k€)

Acoustic HRTF capture in anechoic room (> 100k€)

Traditional Silicon Ear Impression (<100€)
3D Audio & Personal Acoustics Solutions
SOLUTION: 3D Sound Labs DIGITAL EAR

2D Picture provides personal 3D Ear Model and HRTF (Head Related Transfer Function)

Core Tech. #1
Machine Learning based acquisition from 2D pictures

3D Ear Database

Core Tech. #2
Low Cost Cloud Based Advanced Numerical Simulation

Personal 3D Ear Model

Personal 3D Audio Parameters (HRTF)
DIGITAL EAR for 3D Audio HRTF

2D Picture provides personalized HRTF for VR/AR, Video Games and 3D Audio Music

**Personalized HRTF Files**

- **Extension .sofa**
  AES69-2015 - AES standard for file exchange - Spatial acoustic data file format used for object based HRTF for far field description.

- **Extension .hrtf**
  3D Sound Labs file format for its VR Audio SDK including object based HRTF for far field and near field as well as HRTF designed for High Order Ambisonics (HOA) to Binaural rendering.
DIGITAL EAR for 3D Audio HRTF

3D Sound Labs HRTF Individualization solution based on 2D pictures provides performances similar to HiRes Scanning and to Acoustic Capture.
Solution: VR Audio SDK

High Order Ambisonics

VR Audio Engine core processing made in High Order Ambisonics domain yields key benefits:

**Low CPU Usage** for:
- Low Latency Head Tracking
- High number of sources
- Ambisonics: B-Format (FOA) & HOA

**Scalability:**
- CPU Load management
- One content for both High End (PC based) and Low End (Mobile)

Realism & Immersion

3D Sound Labs has introduced two features that dramatically improve the spatial audio rendering.

**HRTF Individualization**
Head related transfer function personalization provide a dramatic improvement to spatial sound perception.

**Low Sound Coloration in HOA Domain**
Specific and proprietary processing in HOA domain brings a more realistic and natural sound quality.
VR Audio SDK Performance

3D Sound Labs HOA to Binaural rendering method provides **less sound coloration** than virtual speaker methods and object base, **with lower CPU %**

* SDK Versions: 3D Sound Labs (v 0.3.0) HOA 1st to 4th order, Google (1.0.1) LQ & HQ modes, Oculus (1.1.0)

** Average ISSD (Inter Subject Spectral Difference) in Bark applied between the frequency response and the HRTF of the 84 subjects of the ARI database. The ISSD is a metric that is based on the variance in the difference between frequency spectrum that illustrates well the difference of coloration between two HRTF.

*** Laptop Lenovo ideapad - CPU Intel i5-4210U @2,40 GHz, Windows 8.1 64bits, Single-core mode
VR Audio SDK Quality

3DSL Solution provides **less coloration artifacts and better spatialization** than Virtual Speakers Method

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Binaural Direct result matches the original HRTF used (by definition). 3DSL HOA Filters give very comparable results, contrarily to Virtual Speaker method which introduces artifacts.
VR Audio SDK: Hybrid Mode (Objects + HOA)

Unique 3D Sound Labs Hybrid mode provides different level of spatial precision to:
- Optimize CPU usage
- Manage End user attention in VR Story telling

Precise Sounds:
- One enemy gun shot
- Two team mates' talking

Normal Sounds:
- Two explosions
- Two Friendly gunshots
- Drone engine

Ambiance Sounds:
- Street atmosphere

Precise and Normal sounds all rendered with 6 early reflections to provide realistic audio sound scene.

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<th>Object Based Rendering</th>
<th>Hybrid Based Rendering</th>
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<tbody>
<tr>
<td>• 8 sounds with each 6 early reflections: 56 objects</td>
<td>• 3 precise sounds with the first 2 early reflections object based and 4 next early reflection in HOA order 2</td>
</tr>
<tr>
<td>• 1 ambiance sound in stereo (poor realism)</td>
<td>• 5 normal sounds with early reflections in HOA order 2</td>
</tr>
<tr>
<td>• Difficult for the “player” to make a difference between important sound (enemy shot) and other sounds.</td>
<td>• 1 realistic ambiance sound in HOA order 2</td>
</tr>
</tbody>
</table>

CPU
25%  
CPU
10%
DIGITAL EAR for Custom Ear Piece

2D Picture provides personal 3D Ear Model for 3D Printing

Ear 3D Model

Ear Impression Extracted from 3D Ear model

3D Printed Ear Piece
DIGITAL EAR for Hearable Microphone Directivity

2D Picture provides personal 3D Ear Model enabling the biometric calibration microphone beamforming enabling improved frontal directivity for better speech intelligibility in noise.

Better Directivity

Implant is precisely calibrated for each ear

Ear 3D Model

3D Model with in Ear Device

Numerical Simulation
3D Sound Labs, a Technology Company

Founders

Xavier Bonjour (Chairman)
- Technicolor, LG and Philips
- Startup board member: Movea
- Heriot-Watt University, ESIEE, ESCP.

Dimitri Singer (CEO)
- General/growth management: Coolsand, Wipulse, TikiLabs
- Coach, mentor, advisor for multiple startups
- Telecom Paris, INSEAD

Renaud Séguier (Scientific Advisor)
- Professor at CentraleSupelec
- Co-founder of DYNAMYZ, successful start-up company.
- PhD in Signal Processing,

Team based in France

Software, Databases and Models

4 Filed Patents
3D Audio & Personal Acoustics
# HRTF Individualization – Benefits for 3D Audio

<table>
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<tr>
<th>Localization</th>
<th>Spatial Resolution (Image analogy)</th>
<th>Spectral “Coloration” (Image analogy)</th>
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<tr>
<td><strong>Standard HRTF</strong>&lt;br&gt;Localization errors</td>
<td><strong>Crisp and Clear perception of the soundscape</strong></td>
<td><strong>Unnatural Timbral Coloration</strong></td>
</tr>
<tr>
<td><strong>Personal HRTF</strong>&lt;br&gt;Good Localization</td>
<td></td>
<td><strong>Natural Timbral “Coloration”</strong></td>
</tr>
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</table>
3D Sound Labs – Binci Project

The BINC project “Binaural Tools for Creative Industries” has the objective to allow the creation of immersive binaural 3D music and other binaural contents for applications in the virtual reality, augmented reality or videogames sector.

3D Audio Content Creation Tools

Advanced 3D Audio content creation plug-in allowing for head-tracking and HRTF individualization, including 3D Sound Labs rendering for consistent experience between creation and play out.

3D Audio Multiple Speakers System

Rental or purchase of inflatable domes with integrated loudspeakers for innovative experiences based on 3D sound at music festivals, promotional events, ...

3D Audio Player on Mobile Platforms (VR/AR/Headphones with Headtracking)
Use Case: Recorded content Distribution Exemple

3D Sound Labs and Viaccess-Orca are first to present VR video with compressed 3rd Order Ambisonics 3D Audio on a mobile platform.

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**Mixing Console outputs to Ambisonics**
(16 Channels HOA 3rd Order)

**4K video from Multiple 360 VR cameras**

**Vorbis**
Open Source Multichannel Compression

**H264**
~20 Mbps

**VR Audio Player**
(HOA to Binaural)

**VR Video Player**

**Existing Mobile VR Platform with High End 3D Audio**

**VR Headset**

Player CPU usage <20%

Credits: Eric Münch

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**AEROSPOT VR**