LAB REPORT 2

Simulated HRTFs Filter

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Digital Audio Systems, DESC9115, Semester 1 2012

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simulateHRTFs_filter.m

This filter Simulate a Structural model of the pinna-head-torso system.

Syntax

[ ] = simulateHRTFs_filter(theta, phi, input)
[ ] = simulateHRTFs_filter(theta, phi, input, Fs)
[ ] = simulateHRTFs_filter(theta, phi, input, Fs, r)
[ ] = simulateHRTFs_filter(theta, phi, input, Fs, r, c)

Description

[ ] = simulateHRTFs_filter(theta, phi, input), for a given mono signal 'input', with an assigned virtual incidence angle 'theta' and elevation angle 'phi', returns the virtual stereo signal in the file which will be suitable for headphone hearing. Output the stereo signal as a wave file named 'simulateHRTFs_filter_output.wav'. The digital signal process is a stimulation of the effect of Head Related Transfer Function on sound source localization.

[ ] = simulateHRTFs_filter(theta, phi, input, Fs), returns the results within assigned sample rate Fs.

[ ] = simulateHRTFs_filter(theta, phi, input, Fs, r), returns the results within assigned sample rate Fs and effective head radius r.

[ ] = simulateHRTFs_filter(theta, phi, input, Fs, r, c), returns the results within assigned sample rate Fs , effective head radius r and the speed of sound c.

Input signal should first be imported as data for processing, the function does not load *.WAV files. The user inputs the variables in the function call.

Input

Input = Signal to be processed (need to be a mono signal)

theta = the angle with the frontal plane

phi = the elevation angle

Fs =Sample rate in Hertz

r = the radius of the head

c = the speed of sound

Output

output = the virtual stereo signal with assigned inputs

'simulateHRTFs_filter_output.wav' = Written wave file of the output signal

Process

This function simulates a Structural model of the pinna-head-torso system. The model comes from C.P. Brown and R.O. Duda. 'A structural model for binaural sound synthesis.' IEEE Trans. Speech and Audio Processing, 6(5):476-488, Sept. 1998

Modified equations and part of the scripts also comes from Udo ZölzerWiley & SonsJohn. (2002). 'Digital Audio Effects.' Chapter 6.

There are 3 parts of this process.

1. Head Shadow and ITD
2. Shoulder Echo
3. Pinna Reflections

Among these 3 parts, the results of the first two processes will added together and used as the input for process 3. The Whole structure of the process is shown below in figure 1

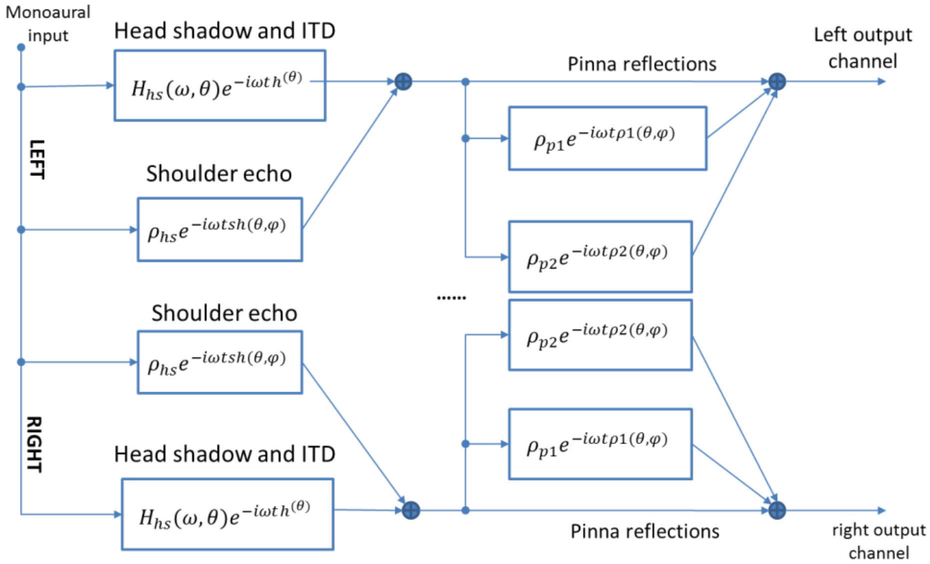

Figure 1 structural model of the pinna-head-torso system.

Algorithms

All the algorithms used here come from do ZölzerWiley & SonsJohn. (2002). 'Digital Audio Effects.' Chapter 6. The original algorithms come from the model Brown and Duda published in 1998.

First, use a first-order continuous-time system, which is a pole-zero couple in the Laplace complex plane as an approximation of the head shadow effect.

$$s_z = \frac{\omega_0}{\alpha(\theta)} \quad (1)$$

$$s_p = -2\omega_0 \quad (2)$$

Where $\omega_0$is related to the effective radius a of the head and the speed of sound c by

$$\omega_0 = \frac{c}{a} \quad (3)$$

The position of the zero varies with the azimuth angle θ according to the function is

$$\alpha(\theta) = 1.05 + 0.95cos\left(\frac{\theta}{150°}180°\right) \quad (4)$$

Here, notice that the value 1.05, 0.95 and 150 are used to make approximation to the frequency response curves. The pole-zero couple can be directly translated into a stable IIR digital filter by bilinear transformation, and the resulting filter is

$$H_{hs} = \frac{(\omega_0+\alpha F_s)+(\omega_0+\alpha F_s)z^{-1}}{(\omega_0+F_s)+(\omega_0+F_s)z^{-1}} \quad (5)$$

The ITD can be obtained by means of a first-order allpass filter whose group delay in seconds in the following function of the azimuth angle θ

$$\tau_h(\theta)\begin{cases} -\frac{a}{c}cos\theta \quad if\ 0 \le |\theta| \le \frac{\pi}{2} \\ \frac{a}{c}\left(|\theta| - \frac{\pi}{2}\right) \quad if\ \frac{\pi}{2} \le |\theta| \le \pi \end{cases} \quad (6)$$

An approximate expression of the time delay of the effects of shoulder and torso can be deduced by the measurement reported in (C.P. & R.O., 1998)

$$\tau_{sh} = 1.2\frac{180°-\theta}{180°}\left(1 - 0.00004\left((\varphi - 80°)\frac{180°}{180°+\theta}\right)^2\right)\ in\ ms \quad (7)$$

Finally, the pinna provides multiple reflections can be obtained by means of a tapped delay line. A formula for the time delay of these echoes is shown below:

$$\tau_{P_n} = A_n cos(\theta/2)sin\big(D_n(90° - \varphi)\big) + B_n \quad (8)$$

The parameters are given in Table 1 together with the amplitude values ρ_{P_n}.

Table 1 parameters for calculating amplitude and time delay of the reflections produced by the pinna model

n	ρp_n	A_n[samples]	B_n[samples]	D_n
2	0.5	1	2	≅1
3	-1	5	4	≅0.5
4	0.5	5	7	≅0.5
5	-0.25	5	11	≅0.5
6	0.25	5	13	≅0.5

Examples

Using the given wave file 'speech.wav', create a virtual stereo version of it as if it comes from an incidence angle of 45 degree and elevation angle of 0 degree, output the result signal then listen to the original input and the processed one.

% Create WAV file in current folder, and use it as input signal.

```
[input,Fs]=wavread('speech');
```

% get the input signal and sample rate from the wave file

```
[output]=simulateHRTFs_filter(45,0,input);
```

% using the function simulateFRTFs_filter to get the virtual sound source from 45 degree incidence angle

```
sound(input, Fs);
sound(output,Fs);
```

% listen to the results and compare the original one with the new one.

REFERENCES

[1] Francis Rumsey (2001) *Spatial Audio*, chapter 3

[2] Udo Zölzer, John Wiley & Sons, (2002), *Digital Audio Effects*, chapter 6

[3] Durand R. Begault (2000) *3-d Sound for Virtual Reality and Multimedia*, chapter 2&4

[4] Wiley (2007) *spatial sudio processing*, chapter 7

[5] C. Phillip Brown and Richard O. Duda, *Fellow, IEEE* (1998)*A Structural Model for Binaural Sound Synthesis*