

MATLAB IMPLEMENTATION OF THE HRTF PERSONALIZATION METHOD USING STRUCTURAL COMPOSITION

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Abstract

Virtual Acoustic Space (VAS) is created with Head Related Impulse Response (HRIR) and its Fourier transform – Head Related Transfer Function (HRTF). Both these functions are very dependent on each person’s individual features. This article presents Matlab implementation in basic HRTF personalization, i.e. composing from HRTFs of the subjects with similar anthropometric parameters. The aim is to compose a HRTF that will resemble the measured one to a certain degree of accuracy. The result is the set of functions that compares people’s anthropometric features, creates a personalized HRTF and saves it in the database.

1 Introduction

Psychoacoustics, i.e. the study of sound perception, is applied in many various fields – entertainment, medicine, navigation etc. To position virtual sound sources in space we use Head Related Impulse Response (HRIR) and its Fourier transform – Head Related Transfer Function (HRTF) [5, 9]. Both these functions are very dependent on each person’s individual features, but measuring them requires a lot of time and effort. One of the solutions to this problem is HRTF personalization, i.e. composing from HRTFs of the subjects with similar anthropometric features [1, 8]. The aim is to compose a HRTF that will resemble the measured one to a certain degree of accuracy.

There are different ways to personalize a HRTF. The easiest way is to find subjects with partially similar anthropometric parameters and claim that their HRTF will work on frequencies that are associated with those parts. The other is to use just one measured HRTF and scale it in accordance with the differences in anthropometry [8].

The method we use was first introduced in [1] and combines both methods mentioned above. We use three HRTFs – one of a subject with similar head and torso parameters and two of subjects with similar pinna parameters (one for each ear). Since pinna affects HRTF the most on high frequencies (above 3 kHz) [11] this is where we then “scale” pinna HRTF on head HRTF.

Thus, the input to the Matlab function are subject’s anthropometric features, but it also considers structural composition of HRTF. It combines the information about the subject’s parameters with the information about HRTF’s characteristic spectral features (the so-called pinna notch and others) and their position to create a personalized HRTF. The main advantage of the function is that it uses all available anthropometric parameters from the database (5 for pinna, 17 for head and torso) while being computationally effective and maintaining its calculating speed [10].

2 HRTF personalisation

The first step is finding HRTFs we could use. The algorithm for choosing those matching HRTFs is described in [2]. It is based on an operator E_k .

$$E_k = \sum_{i=1}^N \frac{(p_i - p_i^k)^2}{\sigma_i^2} \quad (1)$$

where p_i is either d or x (pinna or head parameter), N is the number of used parameters, p_i is the value of the i th parameter for the subject, p_i^k is the value of the same parameter for the k -th subject

of the database, and σ_i is the variance of the i -th parameter across all subjects in the database. Subject k_0 is chosen to be the best match:

$$k_0 = \arg(\min_k E^k) \quad (2)$$

To combine those HRTFs we use 2 of the HRTF characteristic features. First is the minimum value between approximately 2.8 and 11 kHz in both HRTFs and the second is the local maximum closely behind the first point in pinna HRTF. These points are shown on Fig.1.

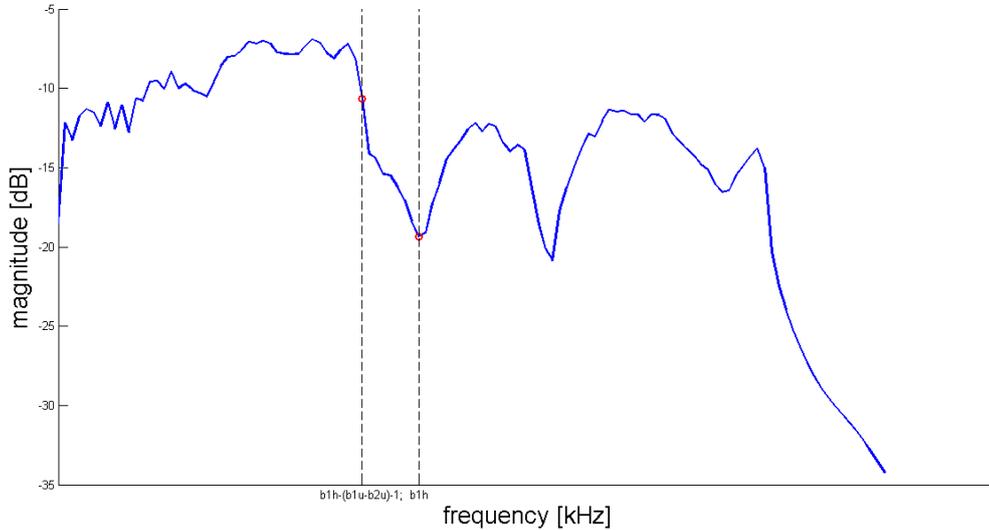


Figure 1: The personalized HRTF with highlighted characteristic points

3 Matlab implementation

Our task is to combine two HRTFs: one of a subject with similar head parameters, and the other of a subject with similar pinna parameters. The script structure was improved - instead of using a single file, we've prepared a set of functions. Now, when there's a mistake of some sort it is easier to isolate the cause of the problem and fix it. Furthermore, it makes the script much more flexible to changes. There are two separate functions to search "ideal" subject with a particular set of parameters (*searchdb*) and to scale pinna HRTF to head HRTF (*scaleHRTF*). They are called by the main function, whose purpose is to create personalized HRTF (*person*). All three functions are part of a bigger structure, along with the function to download subject's information from the database [4], functions for HRTF synthesis and others, that are still being worked on. In this paper we will discuss functions *searchdb*, *scaleHRTF* and *person*.

The first one uses algorithm, discussed above, to find person with the most similar parameters (either pinna parameters, or head) from the ARI database. The data are saved as SOFA files (Spatially Oriented Format for Acoustics), a format designed specifically for storing HRTFs with a focus on interchangeability and extendability [6]. So we had to use Matlab scripts provided by ARI [7] to extract the measured HRIR, which is the function's output.

```
function [ hrir ] = searchdb( dsub, xsub, dbase, xbase, idbase)
temp(j) = (xsub(j)-xbase(j,i))^2/v(j)^2;
...
E(i) = sum(temp);
...
kh = E == min(E); % idbase(k) - subject with ideal head
```

The *scaleHRTF* function's input are two HRIRs - one for the pinna and one for the head. As was stated above, we use two characteristic points shown on Fig. 1, the notch (b_{1h} and b_{1p} for head and pinna, respectively) and the local minimum (b_{2h} and b_{2p}) closely behind it. Using those points, pinna HRTF is "scaled" on head HRTF thus creating a new personalized one [1].

From the point b_{1h} to the end, the personalized HRTF is equal to pinna HRTF from the point b_{1p} . $N+1$ samples to the left (where N is the distance between points b_{1p} and b_{2p}) we place the connecting

point, where personalized HRTF is the mean value of the head HRTF and pinna HRTF values at this point. Prior to that point personalized HRTF is equal to head HRTF, after that it is equal to pinna HRTF. This algorithm is applied to left and right ears separately, since they are not similar to each other and have different parameters.

```
function [ pers ] = scaleHRTF( hrtf_p, hrtf_h)

pers = zeros(size(hrtf_p));
...
% HRTF [blh:end]
pers(blh_l:blh_l+temp,p) = hrtf_p(blp_l:blp_l+temp,p);
...
% HRTF [blh-(blu-b2u)-1:blh]
pers(blh_l-temp:blh_l,p) = hrtf_p(b2p_l:blp_l,p);
pers(blh_l-temp-1,p) = mean([hrtf_h(blh_l-temp-1,p), ...
    hrtf_p(b2p_l-1,p)]);
...
% HRTF [1:blh-(blu-b2u)-2]
pers(1:blh_l-temp-2,p) = hrtf_h(1:blh_l-temp-2,p);
```

These functions are called by a third one, *person*. The inputs to this function are anthropometric parameters of the subject, for whom we are creating a HRTF, and information about the subjects (pinna, head parameters and IDs) from the chosen database - in our case it's ARI [3]. The output is a personalized HRTF.

```
function [ pers ] = person( dsub, xsub, dbase, xbase, idbase)
```

In the end, we compared the personalized HRTF to the measured one on the positions, where the effects of the pinna become the most apparent [1]. The resulting graphs are shown on Fig.2.

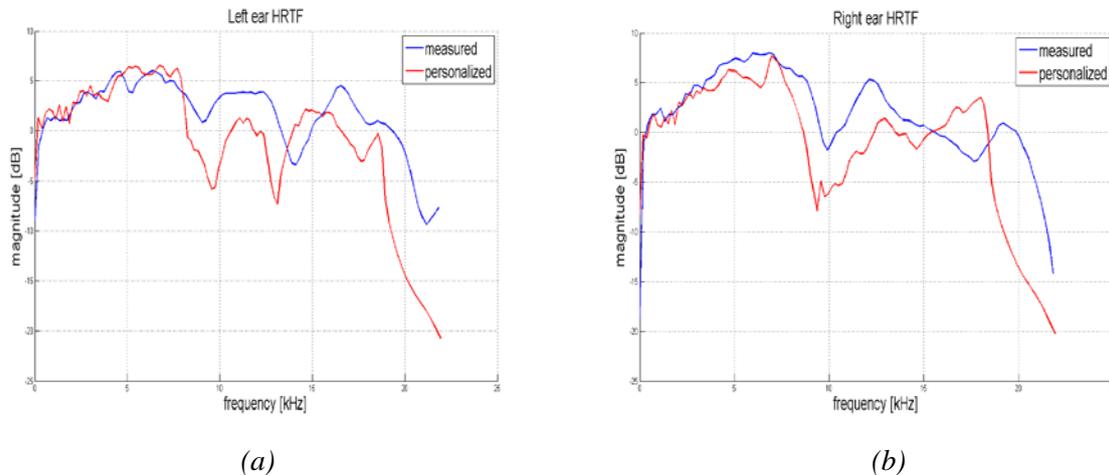


Figure 2: Comparison of personalized (red) and measured (blue) HRTF. (a) Left ear, (b) Right ear

Although our test of the personalized HRTF tells nothing about how the listener will react and which HRTF will be more preferable to him, we can see that while the shapes of compared HRTFs in general look alike, there are differences between some notches around 5 kHz and 15 kHz that are likely in correlation with the chosen scaling points. Also, at high frequencies the personalized HRTF is narrower than the measured one. Hence, further research and improvement of the scaling algorithm are needed.

The results will be used to expand the database maintained by Multimedia Technology group of Department of radioelectronics, CTU FEE in Prague [4].

4 Conclusion

In this paper we discussed an example of Matlab implementation in HRTF personalization. The original script was rewritten to gain computational effectiveness, and replaced with a structured set of functions that enable a better understanding of the script to someone who had no previous knowledge of it. It also helps to isolate and fix problems in the script, should they appear, and is generally easier to modify. Personalized HRTF was compared with a measured one, and although that does not determine which one will show better results on the subjective test, it helped to establish the direction of the future work on HRTF personalization. The study did not systematically examine the differences between measured and personalized HRTF for more subjects, the aim of the comparison was to indicate the personalization algorithm's problems. The extended comparison will be part of the future research.

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