

GRAPHICAL USER INTERFACE FOR MEASURING THE JUST NOTICEABLE DIFFERENCE IN LOCALIZATION OF VIRTUAL ACOUSTIC SOURCES

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Abstract

This paper presents a Graphical User Interface (GUI) created in MATLAB, which allows measuring of the localization Just Noticeable Difference (JND) in different conditions. JND is one of the most predicative indexes in psychoacoustics, which can quantitatively assess the attributes of human hearing. The program interface allows the user to switch between various measuring methods, positioning algorithms and various tested stimuli in order to compare the efficiency of selected combinations or to simulate the conditions of other experiments. All the methods are based on the responses of the measured subject, whether the space position of two presented stimuli is different or not.

1 Introduction

Virtual positioning of variable sound sources is crucial for many modern applications e.g. assistive technology for visually impaired, entertainment industry issues, etc. The main goal of the virtual positioning is to modify the physical parameters of selected sound in such way the listener's brain evaluates the sound source position in desired location [2], [8]. This method unconditionally requires a binaural reproduction (listening through the headphones) because of an undesirable channel crosstalk.

One of the most important aspects of the localization cues is Just Noticeable Difference (JND), which indicates the smallest audible change of the sound source position [1], [3]. For designing the virtual acoustic space, the knowledge of the principles of the sound source localization is essential. The most important factors of evaluating the source position are different sound pressure levels in each ear channel, different time of incident sound waves and differences in spectral content. For the localization purposes, these principles are called Interaural Level Difference (ILD) and Interaural Time Difference. These main features are illustrated on Fig. 1.

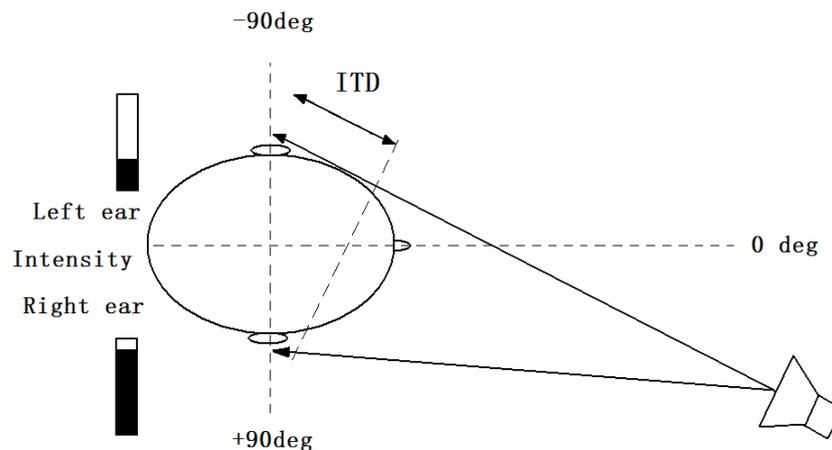


Figure 1: A scheme of basic sound-in-space listening features

The incident sound wave reaches the farther ear later and with lower intensity. ITD and ILD rises when the source is moving towards the extreme positions $\pm 90^\circ$. ILD (and partly ITD) is

frequency-dependent, so the accurate modeling is often simplified. ITD is often simply modeled for a head approximated by sphere [9], as shown in Eq. (1).

$$ITD = \frac{a}{c}(\phi + \sin \phi) \quad (1)$$

More comprehensive approach to the changes of the sound parameters offers the Head Related Impulse Response (HRIR) resp. Head Related Transfer Function (HRTF), which is a Fourier transform of HRIR [5], [7], [9]. HRTF is a complex function, which describes the physical changes of the sound, which occurs when the sound is emitted from a source to the listener's ear. HRTF can be measured or modeled. Different HRIR is assigned to each ear for a chosen position of the sound source. Convolution of an appropriate HRIR with a monaural source and subsequent assignment of both sources to a stereo file is a key for creating virtually positioned sound, as shown in Eq. (2).

$$\begin{aligned} y_L(t) &= HRIR_L(t) * x(t) \\ y_R(t) &= HRIR_R(t) * x(t) \end{aligned} \quad (2)$$

2 Graphical User Interface

The program communicates with the user resp. the examiner of the test through a simple GUI, where the options of the test can be set. The tested subject should not be aware of the program settings, because it might affect his choices resp. answers. Therefore, he communicates with the program only through a numeric pad on the keyboard and the examiner does all the program setting. The GUI consists of components such as Pop-up menus, Sliders, Edit texts, Text fields, Radio buttons and Push buttons. The whole interface is shown in Fig. 2.

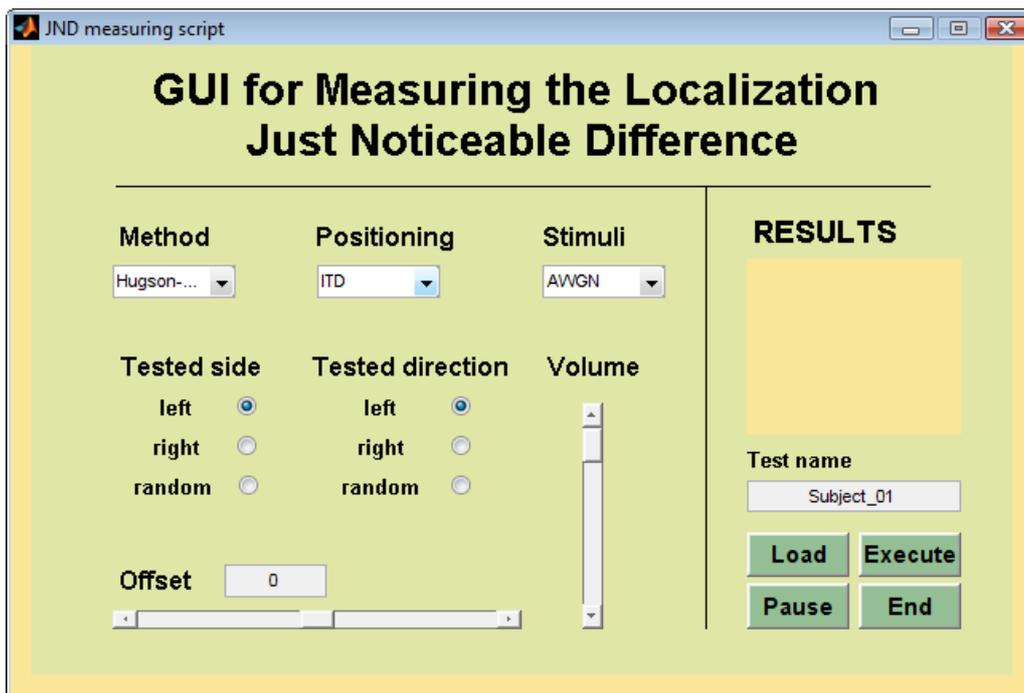


Figure 2: The main screen of the interface illustrating the variability of selected parameters, such as selected stimuli, positioning algorithms and positioned stimuli.

On the top of the GUI, there are three Pop-Up menus, which allow setting one of the standard measuring methods [4], type of positioning algorithm (ITD, ILD, HRTF) and a sound (stimuli), which will be virtually positioned. The Slider 'Offset' determines the position of virtually positioned sound, where the JND will be measured. The program also allows a simple adjustment of volume of presented stimuli. The two groups of Radio buttons 'Tested side' and 'Tested direction' refer to the movement of the source according to selected method of JND measuring. The meaning of these two parameters is briefly explained in Fig. 3 on the following page.

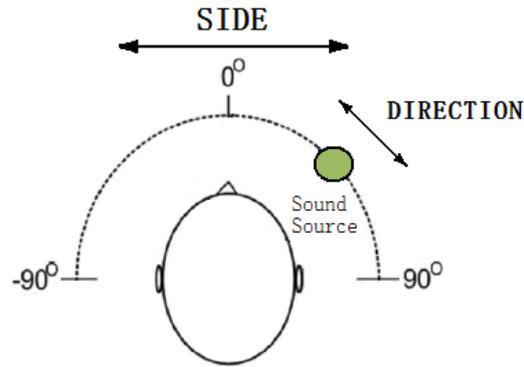


Figure 3: A brief scheme illustrating the meaning of optional parameters ‘side’ and ‘direction’

According to the selected measuring method, the chosen answers (perceptible / imperceptible difference in source positions) can directly affect the whole length of the test. When appropriate method is selected, the test sequence can be also loaded from .txt file in order to keep the same test settings. On the right side of the interface, the program shows the results continuously during the test for brief orientation in subject’s answers. The test sequence can be paused whenever during the test by the button ‘Pause’. For better orientation in results of multiple tests, the examiner enters the name of the tested subject or the name of the test to the Edit text field ‘Test name’. All the subject’s answers can be subsequently saved when the test performance is completed.

All possibilities of the program settings through the Pop-up menus are graphically summarized in Figure 4.

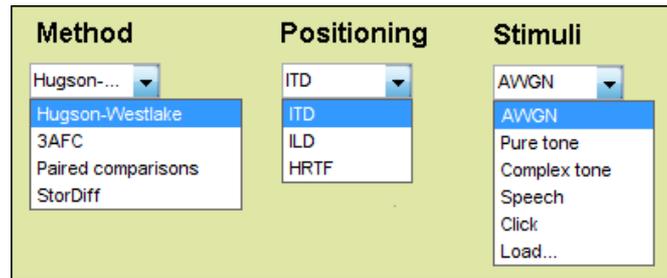


Figure 4: Graphical list of all expanded menus determining the parameters of testing process

3 Implementation

When the program is running, a function initializes the GUI components. The user can set all the settings of the test, and after pushing the ‘Execute’ Push button, the test is started. According to the selected positioning method (switch(.) function chosen), another function with multiple parameters collected from the desired setting is called. A complete database of virtually positioned stimuli (switch(.) function again) is created as a matrix of two-channel vectors. The chosen parameters ‘Method’, ‘Tested side’ and ‘Tested direction’ directly affect only the pointers, which subsequently select a sequence of stereo sounds according to the method settings.

The computational complexity depends on density of virtually positioned sounds. In case of the ‘HRTF’ positioning method is selected, the first initialization might be a bit time-consuming (also depends on the length of the vectors of HRIR and stimulus). Eq. 3 describes the processing of sound virtually positioned by HRTF method. A brief flow chart of the program is shown in Fig. 5.

$$\begin{aligned}
 signal_L &= conv(sum, HRIR_L); \\
 signal_R &= conv(sum, HRIR_R); \\
 signal &= [signal_R; signal_L]; \\
 wavwrite(signal, 44100, ['signal_binaural.wav']);
 \end{aligned}
 \tag{3}$$

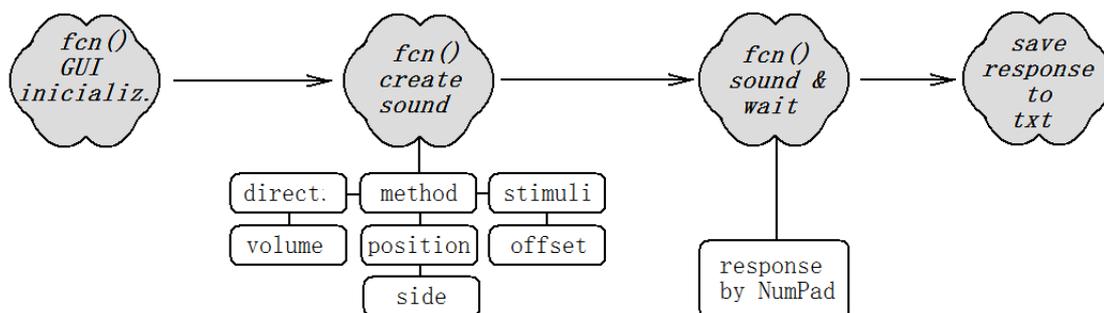


Figure 5: Simplified diagram of the implemented measuring process

4 Results

A program created in MATLAB with graphical user interface for psychoacoustic measurements of Just Noticeable Difference in the localization of the virtually positioned sounds was briefly presented in this article. The program allows the user (the examiner of the test) multiple choice in program settings e.g. measuring methods, positioning and type of stimuli. The tested subject enters his answers by numeric pad and does not set the program settings. Finally, a .txt file with subject's answers can be exported for further processing of the results. Not all methods have been implemented yet.

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