

# HEAD-TRACKING FOR VIRTUALLY AUDITORY SPACE IMPLEMENTED IN MATLAB

*F. Rund, D. Štorek*

Department of Radioelectronics, Faculty of Electrical Engineering  
Czech Technical University in Prague, Prague, Czech Republic

## Abstract

Common problem in virtual auditory space (VAS) is so-called front-back confusion. As there is no binaural difference between signals coming from the position ahead of and behind of the listener, the listener slightly moves (turns) his head in order to determine the azimuth of the real sound source. However, in case of artificially created (virtual) sound source, presented via headphones, head rotation gives no effect. A head-tracking device can be used for enhancing orientation in the VAS. The paper is devoted to simple implementation of the above mentioned system in Matlab. The implementation details and the results of the experiment are presented in the paper. Due to experimental results the impact of head-tracking on virtual sound source localization was proved.

## 1 Introduction

Virtual Auditory Space (VAS) can be used for many purposes, e.g. for navigation of visually impaired, as described in [1]. Common problem in virtually auditory space (VAS) created e.g. by using of HRTF (Head Related Transfer Function) is so-called front-back confusion. There is no binaural difference between signals coming from the position ahead of and behind of the listener. Only spectral difference is present. In real environment the listener slightly moves (turns) his head in order to determine the azimuth of the real sound source. However, in case of artificially created (virtual) sound source, presented via headphones, head rotation gives no effect (see Fig. 1, left). A head-tracking device can be used for enhancing orientation in the VAS.

The head-tracking system allows to correct a choice of appropriate pair of HRTF for the following positioning processing, as indicated by Eq. 1. Coefficients  $\delta$  and  $\varepsilon$  stands for the correction for azimuth and median plane. Index *HT* refers to Head-Tracking, index *SS* refers to Sound Source.

$$HRTF_{HT}(\phi, \xi) = HRTF_{SS}(\phi - \delta, \xi - \varepsilon) \quad (1)$$

The paper is devoted to simple implementation of the above mentioned system in Matlab. This simple implementation is intended for test purposes to assess the impact of head movement on accuracy of determination the direction in VAS.

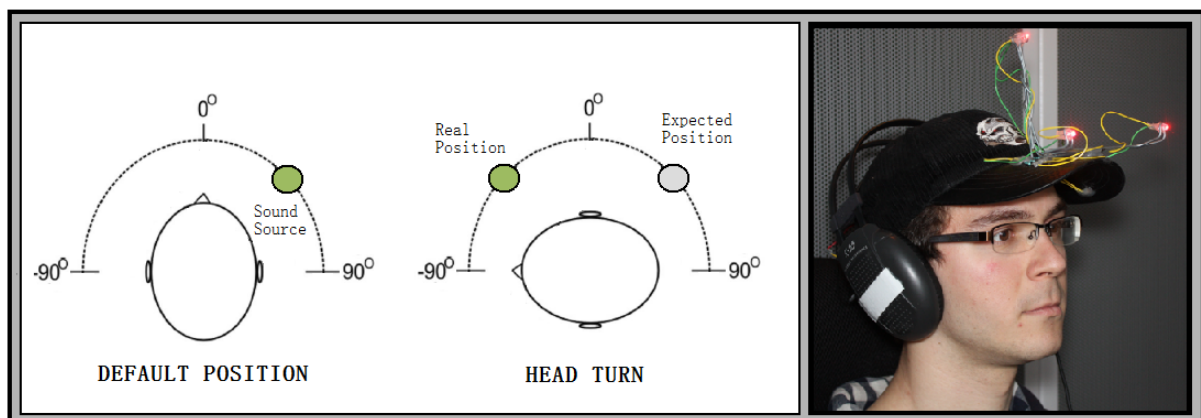


Figure 1: Problem of determining the position of the virtual sound source after head movement (left). Experimental setup for head-tracking (right).

## 2 Head tracking system

There are more principles how to detect head motion, e.g. a hardware device with accelerometers and gyroscopes can be used. But for simple assessing the role of the head-tracking for improving the VAS resolution can be used less complex solution. For the first experiment we exploited FreeTrack solution [2], originally used in computer games. The solution uses web-camera for tracking the position of LEDs placed on the user's cap (Fig. 1, right) and is able to e.g. emulate a joystick for controlling a game. In our experiment we read the coordinates from the FreeTrack emulating joystick for the Matlab and used it for correction of position of a virtually positioned sound.

The experimental head-tracking system consists of the following parts (see Fig. 1):

- A cap with LEDs (Fig. 1, right)
- A web-camera for scanning position of the LEDs
- FreeTrack software [2] for transfer the camera image to coordinates and emulation of a joystick
- Jst.dll software [3] for read the joystick coordinates to Matlab
- Matlab script, described below, for creating a virtual sound from desired position and correcting the position of the sound along head movements.
- Earphones for presenting the sound.

The subject of the test is wearing the LEDs cap and the earphones (Fig. 1 right), and is sitting in front of a computer equipped by standard web camera and soundcard. FreeTrack software (after calibration process) sends the head-tracking information to the Matlab script, which generates the virtual source in correct position. If the subject moves his head, the position of the virtual source is corrected by the Matlab script.

## 3 Matlab implementation

As stated above, the core of the system is the Matlab script. The script reads information from the head-tracking device and corrects the azimuth and elevation of a virtual sound source, along eq. (1). Then creates the virtual source at corrected position – i.e. sends the audio data to the left and right channel of the earphones.

The code of the script was based on the code we described in [4]. It was the script, which positioned the virtual sound source according to a joystick position. Therefore, in case of head-tracking, the information from the joystick is not the information of the virtual sound position, but is added to the virtual sound position value to correct it.

The script uses the virtually positioned data set (sound matrix) generated as is described in [4]. So, at first is the matrix of virtually positioned sounds loaded from the appropriate *.mat* file. For the purpose of the test, positions (azimuths and elevations) of generated virtually positioned samples are determined by the code. The main part of the code is the *while* cycle in the test case terminated only if the elevation is bigger than some threshold – it means, the subject elevate his head to show that wants to continue to next test sample. Inside the cycle loop, the tracking information is read. FreeTrack can emulate a joystick, thus the solution from [3] is used for reading the information to Matlab (same as in case of [4]). The coordinates from (emulated) joystick are converted to angle and elevation (in degrees) and the input position of the to-be-virtually-created sound is corrected. Then the sound from the corrected position is send to the user earphones and the cycle continues with its next turn.

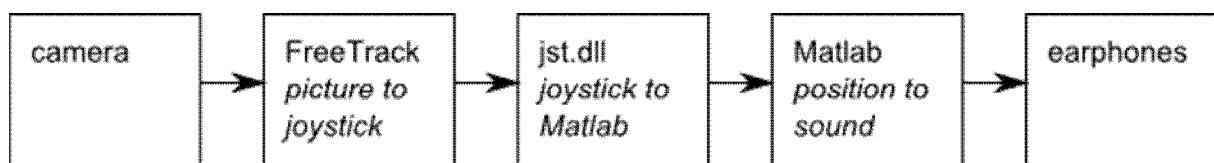


Figure 2: Experimental head-tracking system

## 4 Results

For the assessment of the role of head-tracking for VAS, a simple experiment was carried out. The subject was presented by 24 stimuli situated in various virtual positions as in front of the subject, as behind the subject. The results of both localization tests (static – without head-tracking and dynamic – with head-tracking) are summarized in Tab. 1.

The efficiency of both methods is assessed by two coefficients. ALE (Average Localization Error) is defined by (2), FBC (Front-Back Confusion) is a mean value of mismatching the front-back position.

$$ALE_{HT|NHT} = \frac{1}{N} \sum_{k=1}^N |\xi_C - \xi_P| \quad (2)$$

where  $\xi_C$  stands for correct position,  $\xi_P$  for perceived position,  $N$  is number of presented stimuli. Indexes *HT* (Head Tracking) and *NHT* (Non-Head Tracking) define whether the head motions are compensated. So, the smaller the coefficient, the better localization.

Static and dynamic localization test was performed to four subjects. Indexes ALE and FBC confirm that head motion compensation based on head tracking substantially improves evaluation of virtual sound source position and reduces front-back confusion. Notice the results of Subject 2 who was able to make only one mistake during the test after short practicing. A disadvantage of proposed system was only 26 degrees possible head move to each side, which could affect the localization precision.

## 5 Conclusion

A simple system for assessing the role of head-tracking to localization in Virtual Auditory Space implemented with help of Matlab was described. The system was served only for the first insight in the problem of head-tracking. However, as shows the results, even with a simple head-tracking system, the results are significantly better than without it, especially the front-back confusion was decreased.

Next step in our research is implementation of head-tracking device and real-time implementation of the system. The head-tracking will be provided by combination of accelerometer and gyroscope, and transmitted to the computer wirelessly (e.g. via Bluetooth communication).

Table 1: STATIC AND DYNAMIC LOCALIZATION TEST RESULTS

Subject	ALE <sub>NHT</sub>	ALE <sub>HT</sub>	FBC <sub>NHT</sub>	FBC <sub>HT</sub>
1.	39.4	20.7	0.17	0.08
2.	45.0	1.9	0.39	0.00
3.	39.4	28.1	0.21	0.13
4.	42.3	18.2	0.24	0.11
<b>average</b>	<b>41.6</b>	<b>17.2</b>	<b>0.25</b>	<b>0.08</b>

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Ing. František Rund, Ph.D.

Department of Radioelectronics, FEE, CTU in Prague, Technická 2, 166 27 Praha 6, Czech Republic  
email: xrund@fel.cvut.cz

Ing. Dominik Štorek

Department of Radioelectronics, FEE, CTU in Prague, Technická 2, 166 27 Praha 6, Czech Republic,  
email: storedom@fel.cvut.cz