

IMPROVED TOOL FOR VIRTUAL AUDITORY SPACE TESTING IMPLEMENTED IN MATLAB

S. Dyussekenova, F. Rund

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

Abstract

Virtual Auditory Space (VAS) can be used in a various fields, such as entertainment, medicine or assistive technologies. Virtual sound sources are usually positioned by filtering of the input signals with Head Related Transfer Function (HRTF). A new method for verification of created VAS was presented in our previous papers. The paper is devoted to the applied improvements of that method, which are functions for image edge detection and automatic graph plotting for a set of subjects.

1 Introduction

Virtual Auditory Space (VAS) can be used in a various fields, such as entertainment, medicine or assistive technologies. Virtual sound sources are usually positioned by filtering of the input signals with Head Related Transfer Function (HRTF) [5]. HRTF can be measured on each of the chosen subjects or synthesized [5, 6]. First way is more accurate, but the second one is faster and requires less effort.

When VAS is created, its usability and accuracy must be verified [1]. There are various methods to do that. The aim is to localize the virtual sound source correctly. Some methods are based on a selecting a speaker from the certain array. In that case the speakers only serve as visual cues for the selection. Other methods require the subject to indicate the sound source with some pointing device, for example a laser pointer. Sometimes a head-tracking device is used, the subjects just needs to turn in the direction of the sound.

A new VAS testing method is suggested in [1]. It is currently limited to the horizontal plane, but can be expanded to test both horizontal and vertical planes. The method's principle is apparent from the Fig. 1. The subject must compare the original sound signal from the loudspeaker with the filtered one from the earphones, and rotate until their positions would match. The web camera installed on the rotational chair saves the snapshot of a test image (Fig. 2), which is further used to evaluate the azimuth. The test image represents a line, whose thickness is directly proportional to the azimuth value.

The setup for the proposed test method [1] includes a custom made wide-band loudspeaker, a rotational chair equipped with a test image (Fig.2) and a web-camera, and stereophonic earphones. We used Trust SpotLight Webcam Pro camera for image detection due to its simple construction, LED lights and sufficient picture resolution.

The feedback for the test method was positive along [1]. One of the pros is the design, which allows the subject to listen to either the speaker or the earphones as many times as needed, or ask questions in case something isn't clear. However, while testing we faced some issues that had to be dealt with.

Firstly, Matlab script for image processing had to be changed. The original implementation along [1] used some functions from Image Acquisition Toolbox, which was not available in our case. The other one, suggested in [2], could not be used for the practical experiments due to unavoidable influence of the subject's shadow and light conditions of the testing area. To calculate the line thickness by counting the number of "black" pixels we converted the image to grayscale and altered its contrast. This resulted in a high error rate due to a light reflection we could not elude. Hence, for a qualitative measurement a new script based on a different principle was required. We've decided to apply the edge detection, so the line thickness can be calculated as the distance between the edges.

Secondly, since we had to compare the accuracy of two HRTF sets on a few subjects, we needed a script which would collect and organize measured data and provide us with some visual charts.

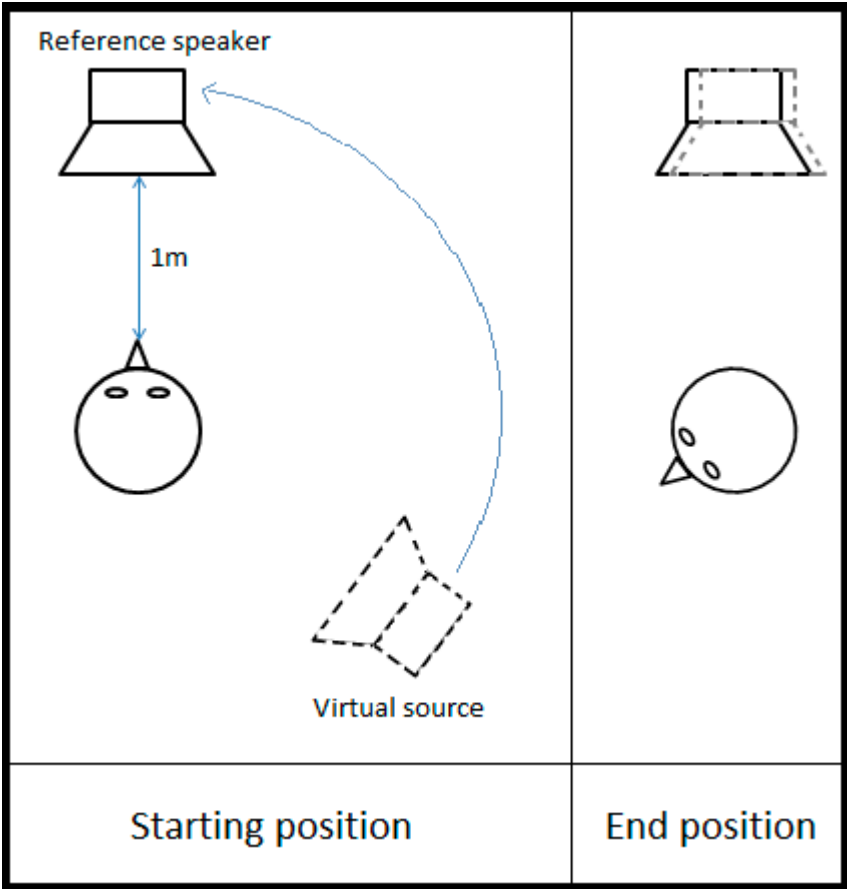


Figure 1: The principle of the VAS testing method proposed in [1]

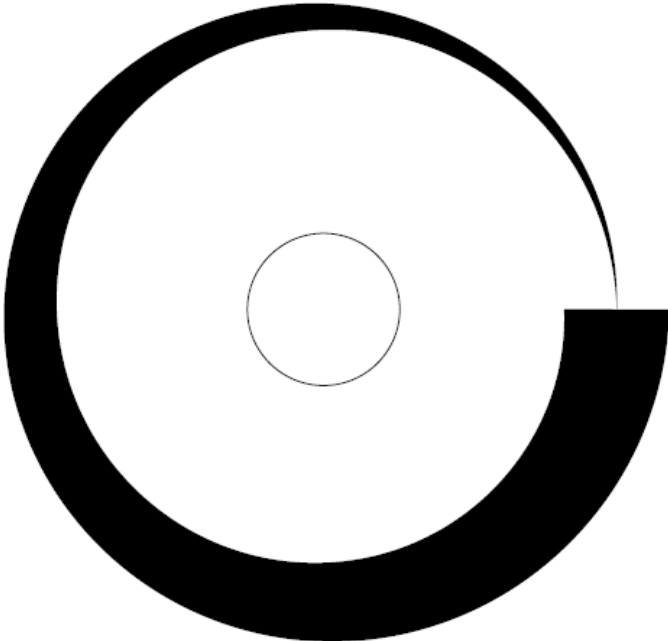


Figure 2: The test image for an azimuth detection

2 Azimuth measurement

As mentioned above, azimuth is evaluated through the test image processing. Picture, taken by a web-camera, is converted to a grayscale image.

In [1] it is the grayscale image then binarized with the Bernsen algorithm [3]. But this algorithm works properly only when the contrast is large enough, and as was mentioned above this caused errors on either the small or the large angles. We've tried other binarization algorithms (Otsu, Niblack, Sauvola) [3], but all of them were usable only on a limited part of the image. Inspired by [4], we wrote a new function for image edge detection.

Our first step is to extract the *edges* with the function of the same name from the Image Processing Toolbox. The line, however, is dotted. To connect the dots we dilate the line with linear structuring elements and then fill the holes inside the line (functions *strel*, *imdilate* and *imfill*, respectively, are used). That caused a small increase of an edge thickness and thus, the test line. To reduce the error that comes with it, we thin the final line a little with *imerode* function.

Then we process the result image with *edges* and *imdilate* functions again. The rest part of the script interpolates the edges in case there are some gaps. All steps are seen on Fig. 3.

Finally, the image thickness is calculated and the azimuth angle is evaluated. The function's average accuracy is about 1.99° . Fig. 4 shows incorrectly processed image in comparison to the one processed with the edge detection function.

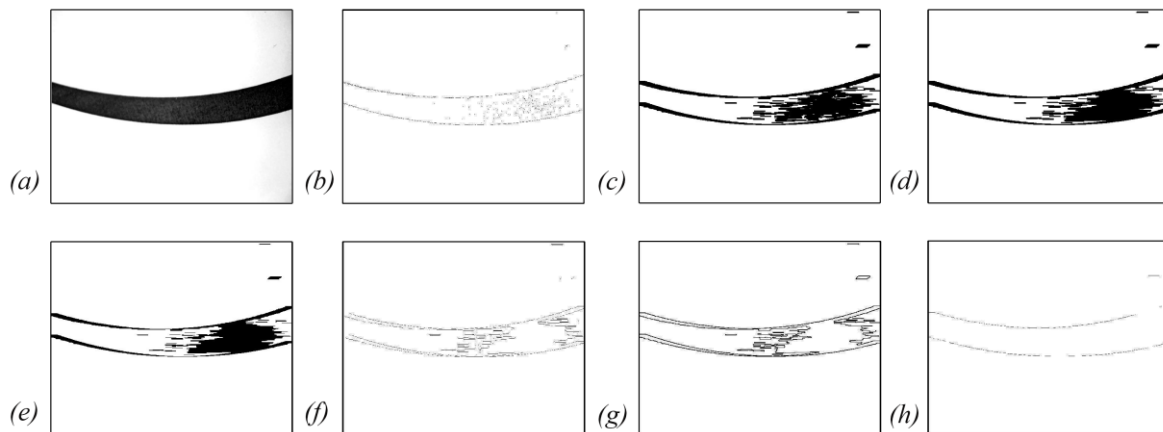


Figure 3: Steps of the camera picture analysis. (a) Original image; image processing with (b) edge (c) imdilate (d) imfill (e) imerode (f) edge (g) imdilate functions; (h) edges interpolation

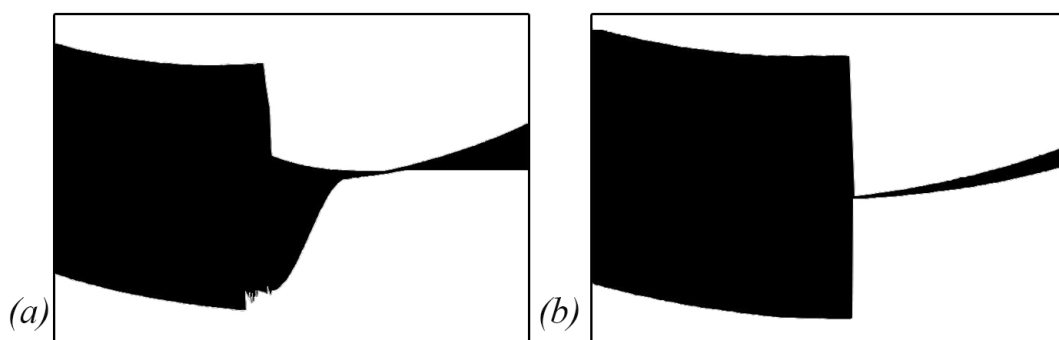


Figure 4: Processed image before(a) and after(b) applying edge detection function

3 Graph plotting

For a better comparison we require some visual charts. Plus, collected data have to be properly organized.

During the testing, each subject's data are saved in a separate folder as a *.mat file. The *mkdir*, *save*, and *movefile* functions are used. When the test phase is over and the necessary calculations are made, we plot graphs for all subjects, one by one. All the plots for all subjects are saved on one picture for a better comparison. There are two pictures that represent two differently synthesized HRTF sets. Thus we can compare them too.

In the end we've got all the data, measured and calculated during the test, and all the plots collected in two separate folders. Example of the plots for one of the HRTF sets is on the Fig.5.

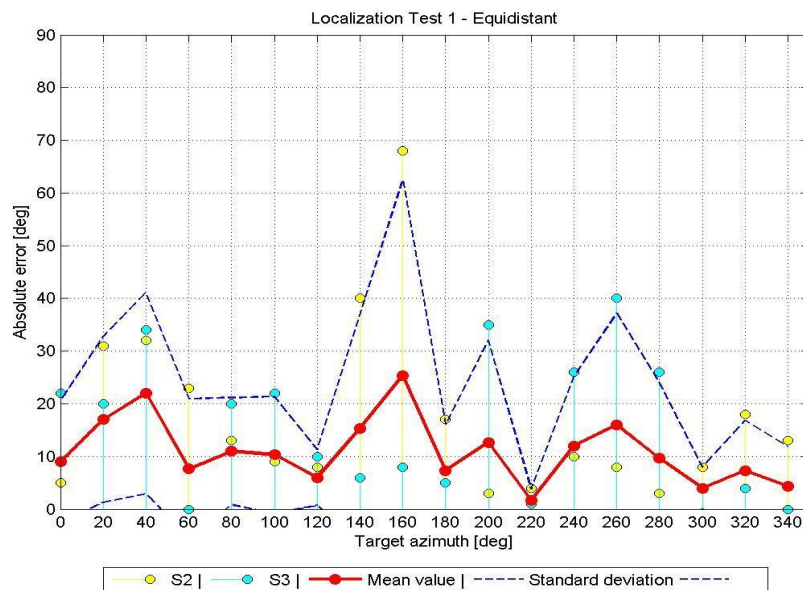


Figure 5: Example of a test output

4 Conclusion

The Matlab functions for image processing with edge detection and automatic graph plotting for a number of subjects were presented. Those functions were suggested as an improvement for a VAS testing method, described in [1]. Both functions were tested and proved to be efficient.

Acknowledgements

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

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