An Audible Handheld Ultra-Sonic-Sonar (AHRUS) to Support Human Echo Location

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Abstract—A portable device to support human echolocation is presented in the form of a handheld audible ultrasonic sonar called AHRUS. The device generates a bundled ultrasonic beam with which the environment can be scanned. A special modulation process uses the non-linear properties of the air as a transmission medium. After reflection at an obstacle, the beam changes to audible sound, which can be perceived with normal human hearing. In this way, blind people can perceive illuminated objects as if they were emitting noise themselves. This gives the impression of a kind of simple bat hearing supporting orientation in unfamiliar surroundings.

Keywords—Human Echo Localization; Audible Ultrasound Sonar; Blind People; Spatial Hearing; Obstacle Detection

I. INTRODUCTION

The human echolocation is used by people who are visual impaired or blind to help build a mental spatial map of their environment. Echolocation is often enabled by creating a clicking sound with their tongue. Objects in the environment reflect discernible sounds to the human ear. The human brain can construct a structured image of the environment to build a mental spatial map. With this method, also known as flash sonar, trained users reach enormous perception performances. The position, size, or density of objects could be determined. [1]

Unlike bats, which perceive structures in submillimeter range by ultrasonic echolocation, the human perception is restricted by the large wavelength of acoustic waves. This article shows how these disadvantages can be overcome by using parametric ultrasound to get a little closer to bat hearing.

II. BENEFITS OF ULTRASOUND

Fig: 1 shows the difference between the sound propagation of a sharp tongue click and the featured Audible-High-Resolution-Ultrasonic-Sonar (AHRUS), which works as a kind of acoustic scanning beam.

Ultrasonic waves are reflected back by little, finely structured or soft objects where acoustic waves pass through objects like fences, bushes or thin piles without any considerable reflection.

Another problem is smooth surfaces whose normal does not point in the direction of the user. As light will be spread back at finely structured surfaces, even roughly structured surfaces act like a mirror for acoustic waves. As a result, transversal sound waves from the user to the objects are reflected away from the user (stealth effect). This way, it is not possible for the user to detect such objects. Ultrasonic waves with high frequencies or short wavelengths, conversely, are reflected to the sound source at smaller structures as soon as the wavelength reaches the order of magnitude of the structure size.

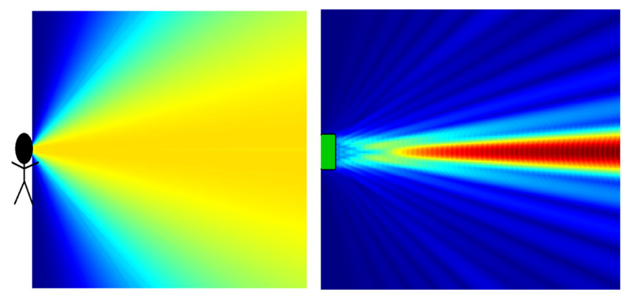

Figure 1. Comparison of sound intensity and directivity of a tongue click (left) and the AHRUS system (right). [3]

III. HOW IT WORKS

Nevertheless, a way to use ultrasonic waves in combination with the human ear is enabled by nonlinear acoustics. This principle is also called a parametric ultrasonic loudspeaker. They are usually used for highly directed audio spotlights, e.g. for a playback of sharply demarcated audio information in a museum. [2]

In the presence of high sound pressure levels, the air behaves in a nonlinear manner. This enables the transformation of ultrasonic to acoustic waves in the air itself by amplitude modulation of the ultrasonic signal.

During the process of transformation, the physical features of the ultrasonic signal retain in the acoustic signal. This auto conversion from ultrasonic to acoustic waves, enables the user at perceive ultrasonic signals with their own ears.

IV. REALIZATION OF A HANDHELD DEVICE

AHRUS is a new tool that brings human echolocation a step closer to bat hearing and makes it easier for inexperienced people to get started. The small device emits

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a sharply bundled ultrasound beam, which gradually turns into audible sound using the concept of parametric ultrasound.It can be compared to a kind of acoustic flashlight, with the sound cone of which the environment is scanned. In the imagination of the experienced user, an acoustic image is created that is far more finely structured than with classic echolocation with tongue clicks. [3]

Fig: 2 shows the prototype of the AHRUS system. It is operated via a menu with voice output to adjust system-parameters.

Figure 2. 3D-Printed AHRUS-Prototype.

The transducer is composed of 19 piezo ultrasound emitters, producing an ultrasound pressure level up to 135 dB at a frequency of 40 kHz. The beam is very focused with an aperture angle of about 5 degrees.

The short wavelength of the ultrasonic waves of 8mm (0.3 in) results in well audible echoes, also from rarely structured or small obstacles like wire fences or twigs.

A configurable synthesizer for signal generation has been implemented on an ARM Cortex-M4 signal processor. It allows the generation of click, noise or sound signals, as a continuous signal or pulses with selectable pulse frequency and width. A frequency modulation for generation of signals in which the frequency increases or decreases, so called chirp-signals, is also included. Chirps are also used by bats or dolphins for echo localization.

V. CONCLUSION

AHRUS was developed at the Institute for Technology & Computer Science in Gießen with the support of people that are blind themselves. It is intended to demonstrate the possibilities of spatial auditory perception and form a basis for future research activities.

AHRUS tries to eliminate the significant disadvantages of classic active echolocation techniques. By using self-demodulating ultrasonic waves, it enables the perception of much smaller object structures.

In contrast to electronic aids that use headphones as audio interface to the user, AHRUS uses the individual and efficient ears of the user himself. With the great advantage, the ears stay free to hear the normal information from the environment. By using soft but striking signals, e.g., noisy clicks, the signals are easy to hear but not disturbing during travel. Because of the advantages of ultrasonic waves and configurable signals, AHRUS is an excellent extension to classical flash sonar.

Nonetheless, the full potential of AHRUS will be discovered after more people who are blind use this technology to discover its pros and cons. We hope to find a strong partner for the production of the device soon to be able to offer the technology to a large group of blind users.

REFERENCES

[1] Kish, D. (2009). Human echolocation: How to “see” like a bat. New Scientist, 202(2703), 31-33.

[2] Weinzierl, S. (Ed.). (2008). Handbuch der Audiotechnik. Springer Science & Business Media.

[3] von Zabiensky, F., Kreutzer, M., & Bienhaus, D. (2018). Ultrasonic waves to support human echolocation. In Universal Access in Human-Computer Interaction. Methods, Technologies, and Users: 12th International Conference, UAHCI 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part I 12 (pp. 433-449). Springer International Publishing.