A system for HRTF calibration through comparison of test sounds

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Title of the Invention

A system for HRTF calibration by comparing pairs of test sounds

Cross Reference to Related Applications

Not Applicable

Statement Regarding Federally Sponsored Research or Development

Not Applicable

Description of Attached Appendix

Not Applicable

Background of the Invention

This invention relates generally to the field of three-dimensional audio simulation, and more specifically to a system for HRTF (Head Related Transfer Function) calibration by allowing the listener to choose among test sounds.

Humans can perceive audio in three dimensions using just two inputs (i.e. two ears) by interpreting cues that depend on the direction from which audio arrives. The most significant cues derive from the way in which audio bounces off the ridges of pinnae and the way in which audio is shadowed by the head.

Since individuals have varying ear shapes and head sizes, audio originating from the same direction relative to the individual will generate different cues to different individuals. As a result, a given set of audio cues will not accurately

convey the same direction of origin to people with differently-shaped ears or different-sized heads.

Several prior technologies have attempted to accurately calibrate or customize a head related transfer function to the individual. The most accurate means is to set up a room with impulse-generators and have microphones planted deep into the ear canals of a listener or a model of a human head in order to produce recordings of impulse responses to audio originating from a wide range of directions relative to the listener's head.

A second means is to provide a listener with a set of prerecorded impulse responses that had been calibrated to previous listeners or models. The listener is to review the impulse responses and choose the set of impulse responses that is the most convincing to that individual.

A third means is to play sounds produced by a parametric HRTF and to ask the listener where the sound appears to be coming from, and to use the discrepancy between desired and perceived direction as an indication of how to calibrate the parametric HRTF to the individual.

The first means of calibrating an HRTF is very expensive. It requires impulse generators that must be placed at varying points in a room. The room must also be standardized so that the impulse responses are not heavily influenced by room variations. In addition, this method requires two microphones that can fit inside ear canals. Previous implementations of this means have required the services of personnel trained to set up and conduct the entire process.

The second means is less expensive in that it uses impulse responses from previously conducted recordings. However, it is much less reliable because the accuracy is only as good as the similarity between the ears and head of the listener and those of a previously recorded model or person.

The third means is less expensive, but the accuracy of the calibration depends on how well the user can depict the direction from which a sound appears to originate. It also requires a user interface that depicts an adjustable three-dimensional spatial direction. For an untrained listener, articulating the perceived direction and using the interface can be a nontrivial task; thus, the accuracy of the calibration will be compromised.

Brief Summary of the Invention

The primary object of the invention is to provide a cheaper system of calibrating head related transfer functions to individuals.

Another object of the invention is to provide a feedback system for head related transfer function calibration that is trivial to use by an untrained listener.

A further object of the invention is to provide a more accurate and controlled means of tuning the parameters of head related transfer functions to individuals.

Other objects and advantages of the present invention will become apparent from the following descriptions, taken in connection with the accompanying drawings, wherein, by way of illustration and example, an embodiment of the present invention is disclosed.

The invention is a system for calibrating a head related transfer function (HRTF) to an individual, comprising: a control device that contains a parametric head related transfer function, wherein said function comprises a set of parameters that represent physical dimensions of an average human, a set of parameters that represent a desired three-dimensional point of perceived origin in relation to said listener, two speakers that play stereo audio output from the control device, an input device capable of conveying information to said control device, wherein said control device applies said head related transfer function to a mono test sound such that the output is desired to appear to originate from a specified position related to the listener, and sends stereo audio output of said function to said pair of speakers, wherein said speakers emit an aural representation of said stereo audio, wherein said control device modifies said function to randomly vary parameters that represent said physical dimensions, and sends new stereo audio output of said modified function to said pair of speakers, wherein said speakers emit an aural representation of said new stereo audio, wherein said input device receives information from user that conveys which of said two stereo outputs appear to originate from a position closer to said desired position, wherein said control device is configured to save parameters of head related transfer function that created said stereo output preferred by said listener.

Drawings

Figure 1: Block diagram of a hypothetical parametric HRTF (Head Response Transfer Function)

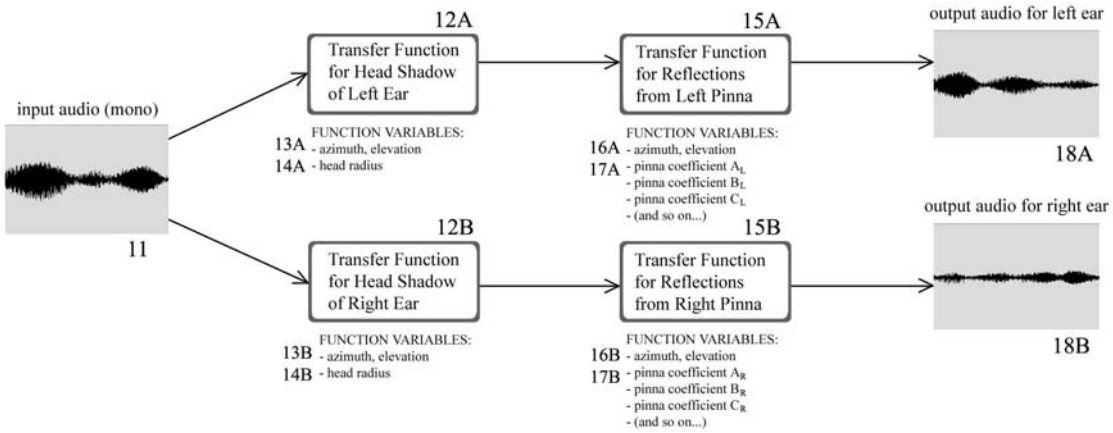


Figure 2: Examples of measurements that determine pinna coefficients in a hypothetical parametric HRTF

Each measurement is numbered and appears next to a line representing the distance between two ridges.

Figure 3: Block diagram of HRTF calibration process

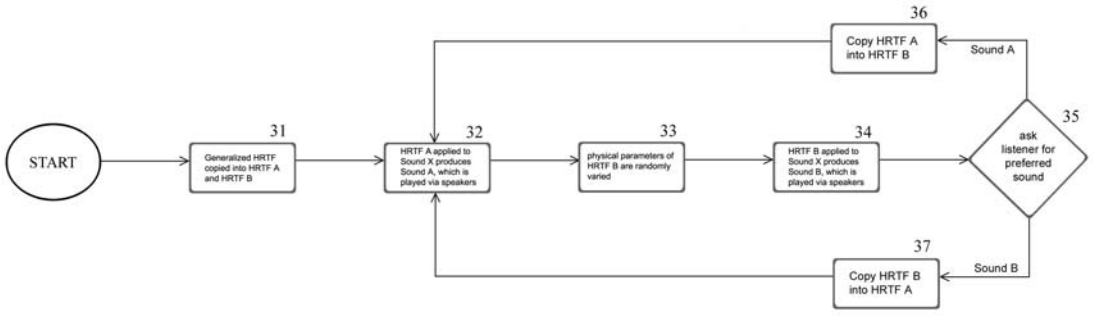
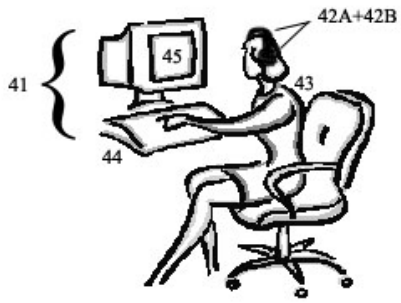


Figure 4: An embodiment of HRTF calibration system



Brief Description of the Drawings

The drawings constitute a part of this specification and include exemplary embodiments to the invention, which may be embodied in various forms. It is to be understood that in some instances various aspects of the invention may be shown exaggerated or enlarged to facilitate an understanding of the invention.

Figure 1 is a block diagram of a hypothetical parametric HRTF.

Figure 2 shows examples of measurement points between ridges in a pinna that represent coefficients in a hypothetical parametric HRTF.

Figure 3 is a flowchart diagram of the operations that comprise the calibration system.

Detailed Description of the Preferred Embodiments

Detailed descriptions of the preferred embodiment are provided herein. It is to be understood, however, that the present invention may be embodied in various forms. Therefore, specific details disclosed herein are not to be interpreted as limiting, but rather as a basis for the claims and as a representative basis for teaching one skilled in the art to employ the present invention in virtually any appropriately detailed system, structure or manner.

Figures 1 and 2 represent information that is already known prior to this invention; they are presented here to aid in understanding parametric HRTFs and to illustrate the effect of this calibration system.

Referring now to Figure 1, a block diagram of a hypothetical parametric HRTF is shown in order to demonstrate what elements of a parametric HRTF will be modified in the calibration system presented. Audio signal 11 serves as the signal input to the function. Transfer functions 12A and 12B represent the effect of the head shadow for audio entering the left and right ear, respectively. Function variables 13A and 13B represent parameters specific to desired direction of origin for transfer functions 12A and 12B, respectively. For example, a value of pi/2 for the azimuth might represent a sound projected from the right side of the listener. Function variables 14A and 14B represent the radius of the head of the listener. Transfer functions 15A and 15B represent the effect of sound bouncing off the prominent features of the left and right pinnae, respectively. Function variables 16A and 16B represent parameters specific to desired direction of origin for transfer functions 15A and 15B, respectively.

Function variables beginning at 17A and 17B represent sets of coefficients that correspond to measurements specific to the left and right pinnae, respectively. The HRTF outputs audio signals 18A and 18B to the left and right channels, respectively.

Referring now to Figure 2, examples of distances between ridges in pinnae are shown. Lines 21 to 27 represent measurements of these distances and they determine the sets of coefficients beginning at 17A and 17B from Figure 1. The distances between such ridges vary from person to person, and this is why no single HRTF can accurately simulate three-dimensional sound for all persons.

Referring now to Figure 3, a block diagram of this HRTF calibration process is shown. The process begins at step 31, at which point the parameters of a generalized HRTF are loaded into a pair of variable parametric HRTFs, labeled as HRTF A and HRTF B. At this point HRTF A and HRTF B are identical. At step 32, the control device applies HRTF A to a predetermined mono signal (Sound X), and the listener hears the resulting stereo signal (Sound A). At step 33, the control device modifies HRTF B by randomly varying parameters that represent physical dimensions. Coefficients 15A, 15B, 17A and 17B are examples of such parameters. At step 34, the control device applies HRTF B to a predetermined mono signal (Sound X), and the listener hears the resulting stereo signal (Sound B). The listener must now choose which sound was more accurately projected from the intended point of origin.

In one embodiment, the listener has the option of hearing each sound again before making a choice. In another embodiment, the listener may state that the sounds were indistinguishable from each other, at which point the control device

returns to step 32. In yet another embodiment, the listener has more than two sounds to choose from.

If the listener chooses Sound A, the system enters step 36, at which point the parameters of HRTF are copied into HRTF B so that they are identical. The system then returns to step 32.

If the listener chooses Sound B, the system enters step 37, at which point the parameters of HRTF B are copied into HRTF A so that they are identical. The system then returns to step 32.

In one embodiment, the system continues until a predetermined number of iterations has commenced, at which point the system stops right before returning to step 32. At this point HRTF A and HRTF B are identical, and the function is saved as the individual's calibrated HRTF. In another embodiment, the listener has the option of ending the process and declaring the last chosen function as the individual's calibrated HRTF.

In a further embodiment, the range in random variation of step 33 becomes smaller after each successive iteration.

Referring now to Figure 4, one possible embodiment of this calibration system is shown to demonstrate the ease of use for the listener. Computer 41 serves as the control device. Headphone speakers 42A and 42B serve as the speakers for the stereo output. Listener 43 uses keyboard 44 as the input device. Instructions are displayed through monitor 45.

While the invention has been described in connection with a preferred embodiment, it is not intended to limit the scope of the invention to the particular form set forth, but on the contrary, it is intended to cover such alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

Claims

What is claimed is:

1. A system for calibrating a head related transfer function (HRTF) to an individual, comprising:

a control device that contains a parametric head related transfer function, wherein said function comprises (a) a set of parameters that represent physical dimensions of an average human, (b) a set of parameters that represent a desired three-dimensional point of perceived origin in relation to said listener;

two speakers that play stereo audio output from the control device;

an input device capable of conveying information to said control device;

wherein said control device (c) applies said head related transfer function to a mono test sound such that the output is desired to appear to originate from a specified position related to the listener, and (d) sends stereo audio output of said function to said pair of speakers;

wherein said speakers emit an aural representation of said stereo audio;

wherein said control device (e) modifies said function to randomly vary parameters that represent said physical dimensions, and (f) sends new stereo audio output of said modified function to said pair of speakers;

wherein said speakers emit an aural representation of said new stereo audio;

wherein said input device receives information from user that conveys which of said two stereo outputs appear to originate from a position closer to said desired position;

wherein said control device is configured to save parameters of head related transfer function that created said stereo output preferred by said listener;

2. The system of claim 1 wherein said control device uses (a) saved parameters of said function in (c) applying to said mono test sound, (d) sends resulting stereo audio output of said new function to said pair of speakers, (e) modifies said function to randomly vary parameters that represent said physical dimensions, (f) sends new stereo audio output of said modified function to said pair of speakers, wherein said input device receives information from user that conveys which of said two new stereo outputs appear to originate from a position closer to said desired position, and said control device is configured to save parameters of head related transfer function that created said new stereo output preferred by said listener.

3. The system of claim 2 further comprising repeating (b) said sending audio output, (e) said modifying said function, (f) said sending second audio output, (g) said receiving said listener's preference among said pair of stereo outputs, and (h) said saving parameters of said preferred function until a specified number of iterations have commenced.

4. The system of claim 2 further comprising repeating (b) said sending audio output, (e) said modifying said function, (f) said sending second audio output, (g) said receiving said listener's preference among said pair of stereo outputs, and (h) said saving parameters of said preferred function until said listener accepts either function as final calibrated function.

5. The system of claim 1 wherein (b) said parameters change to represent a new desired perceived origin.

6. The system of claim 1 wherein the listener has the option of expressing that the stereo outputs appear to originate from the same position, upon which the control device (d) replays first stereo output and (e) modifies said first function to new random variation of (a) said parameters;

7. The system of claim 1 wherein the listener has the option of expressing that the stereo outputs appear to originate from the same position, upon which the control device (d) replays first stereo output and (e) modifies said second function to new random variation of (a) said parameters;

8. The system of claim 1 wherein the listener has the option of expressing that the stereo outputs appear to originate from the same position, upon which

the control device (d) replays second stereo output and (e) modifies said first function to new random variation of (a) said parameters;

9. The system of claim 1 wherein the listener has the option of expressing that the stereo outputs appear to originate from the same position, upon which the control device (d) replays second stereo output and (e) modifies said first function to new random variation of (a) said parameters;

10. The system of claim 1 wherein the listener has the option of repeating presentation of said pair of audio outputs;

11. The system of claim 1 further comprising repeating (e) said modifying said function and (f) said sending stereo output such that said listener chooses from more than two output sounds.

12. The system of claim 1 wherein a monitor displays instructions to said listener for use of said system.

13. The system of claim 2 wherein a different mono test sound is used for each presentation to said listener.

Abstract of the Disclosure

. A head related transfer function (HRTF) can simulate a three-dimensional sound image to the person to whom the function is calibrated. A system for HRTF calibration can be achieved by presenting pairs of test sounds that were created by the same parametric HRTF but with different values for the parameters that represent physical properties of a human being. A control device outputs stereo audio such that the output is desired to appear to originate from a specified position. Upon hearing the pair of output sounds, the user chooses the sound that best depicts the desired point of origin and inputs this choice to the control device. The HRTF that produced the chosen sound serves as the new default HRTF for the individual, and the above process is repeated until a predetermined number of iterations as commenced or the listener chooses a sound as that of a final calibrated HRTF.