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(54) Benævnelse: **FREMGANGSMÅDE TIL BESTEMMELSE AF AFSTANDEN MELLEM ØRERNE PÅ EN BÆRER AF ET LYDSGENERENDE OBJEKT OG ET ØREBÅRET, LYDGENERERENDE OBJEKT**

(56) Fremdragne publikationer:
WO-A1-2016/089133
US-A1- 2011 299 707
US-A1- 2013 177 166
US-A1- 2016 269 849
US-A1- 2017 013 389

DESCRIPTION

TECHNICAL FIELD

[0001] The disclosure primarily relates to a method for determining distance between ears of a wearer of a sound generating object.

BACKGROUND

[0002] In the art of virtual sound presentation by means of devices such as headsets, hearing aids or hearables, it is desirable that a listener has access to externalized sound, i.e. sound containing spatial cues. These spatial cues are typically generated by the software on the basis of the information available in electrical audio signals. The illusion of a virtual sound source, external with respect to the listener's head, is hereby created.

[0003] In order to obtain satisfactory user experience in this regard, it is necessary to accurately establish physical, i.e. Euclidean, distance between the two ears of the listener. This is e.g. the case if generic Head-Related-Transfer-Function (HRTF) needs to be adjusted to match the geometry of the user's head. A related example involves bilateral beamformers where the head size, represented by the ear-to-ear distance, is an important input parameter for more advanced beamforming applications.

[0004] Obviously, manual measurement of the ear-to-ear distance is available, but is cumbersome and prone to delivering inaccurate result.

[0005] EP 2 890 161 presents a method of determining acoustic head size of a user wearing a pair of hearing aids. Minimum requirement in terms of equipment to arrive at the solution is to employ two hearing instruments and an intermediate signal provider, typically a mobile telephone. These devices communicate with each other using audio signals in order to determine acoustic time delay between the two ears so as to estimate the acoustic head size. Here, acoustic head size may be defined as an acoustic distance between a pair of customarily arranged hearing aids. This acoustic distance is derived from the value of the time delay associated with the acoustic signals captured by the microphones of the respective hearing aid.

[0006] US 2013/0177166 relates to head-related transfer function (hrtf) selection or adaptation based on head size and includes determining a user's head size and forwarding information associated with the user's head size to a processing device.

[0007] Further relevant prior art is found in US 2016/269849 A1, US 2017/013389 A1, WO 2016/089133 A1 and US 2011 /299707 A1.

SUMMARY

[0008] One objective of the invention at hand is therefore to at least alleviate drawbacks associated with the current art.

[0009] The above stated objective is achieved by means of the method for determining distance between ears of a wearer of a sound generating object and an ear-worn, sound generating object according to the independent claims, and by the embodiments according to the dependent claims.

[0010] More specifically, a first aspect of the present disclosure provides a method for determining a distance (D) between ears of a wearer of a sound generating object, the method comprising: selecting a model for representing shape of the head of the wearer of the sound generating object so as to obtain a center axis of the wearer's head, wherein the center axis is an axis substantially perpendicular to a horizontal, ground plane and intersecting a head pivot point of the wearer's head; associating the first sound generating object with an ear of the wearer, wherein the first sound generating object comprises a first accelerometer and a second accelerometer, the respective accelerometers, i.e. the first accelerometer and the second accelerometer, being arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle a center axis of the wearer's head, wherein the first and second accelerometers are so arranged that a straight line that intersects the center axis of the wearer's head at a substantially right angle crosses the first and second accelerometers such that the acceleration components (a1, a2) have the same direction, the first and second accelerometers being spaced by a known distance (Δr); when the head of the wearer is in motion, determining, by means of the first accelerometer, a value of the first acceleration component (a1) and, by means of the second accelerometer, a value of the second acceleration component (a2), determining the distance (D) between the ears of the wearer on the basis of the obtained values of the acceleration components (a1, a2). In one or more exemplary methods, determining the distance (D) between the ears of the wearer is based on the model. In one or more exemplary methods, determining the distance (D) between the ears of the wearer is based on the known distance between the first accelerometer and the second accelerometer.

[0011] Here, the term distance is in the context of the present application to be construed as Euclidean distance, i.e. a straight-line distance between two points in space. In this context, this Euclidian distance cannot be correlated with the above-discussed acoustic distance. Further, center axis of the wearer's head is an axis substantially perpendicular to a horizontal, ground plane, said axis further intersecting a head pivot point, i.e. a point around which the head rotates side to side. Moreover, associating the first sound generating object with an ear of the wearer entails arranging said object at or in proximity of the ear.

[0012] In the following, positive effects and advantages of the invention at hand are presented with reference to the first aspect of the invention.

[0013] By executing the method in accordance with the above, an automatic adjustment of the distance between the ears of the wearer may be achieved. In other words, no involvement of the user is required in order to handily and accurately determine the ear-to-ear distance. Moreover, said method is due to its inherent simplicity easily integrated in the existing software. Ultimately, the effect conferred by the inventive method is the improved fidelity with respect to presentation of the virtual (3D) audio signals generated by the sound generating object.

[0014] In addition, by accurately and automatically determining the head size, more advanced beamforming models may be employed in the sound generating object, in particular in the hearing aid. In a related context, estimation of the direction of arrival (DOA) of the speech signal could be significantly improved when the head size is accurately determined.

[0015] In another aspect of the present disclosure, a first sound generating object configured to be worn at an ear of a wearer is provided, wherein the first sound generating object comprises means for allowing the wearer of the sound generating object to select a model for representing shape of the head so as to obtain a center axis of the wearer's head, wherein the center axis is an axis substantially perpendicular to a horizontal, ground plane and intersecting a head pivot point of the wearer's head, a first accelerometer and a second accelerometer, the respective accelerometers, i.e. the first accelerometer and the second accelerometer, being arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle the center axis of the wearer's head, wherein the first and second accelerometers are so arranged that a straight line that intersects the center axis of the wearer's head at a substantially right angle crosses the first and second accelerometers such that the acceleration components (a1, a2) have the same direction, the first and second accelerometers being spaced by a known distance (Δr), wherein the first accelerometer is provided with means for determining a value of a first acceleration component (a1) and the second accelerometer is provided with means for determining a value of a second acceleration component (a2), and wherein the first, ear-worn, sound generating object (4) is provided with means for determining, on the basis of the obtained values of the acceleration components (a1, a2), a distance (D) between the ears of the wearer.

[0016] In one or more exemplary first, ear-worn, sound generating objects, the means for determining the distance (D) between the ears of the wearer comprises means for determining the distance (D) between the ears of the wearer based on the model. In one or more exemplary first, ear-worn, sound generating objects, the means for determining the distance (D) between the ears of the wearer comprises means for determining the distance (D) between the ears of the wearer based on the known distance between the first accelerometer and the second accelerometer.

[0017] Further advantages and features of embodiments will become apparent when reading the following detailed description in conjunction with the drawings

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a perspective view of a head of a user schematically showing an ear-worn, sound generating object.

Fig. 2 is a close-up of an accelerometer configuration according to one embodiment of the present invention.

Fig. 3 is a flow chart illustrating method steps according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like reference signs refer to like elements.

[0020] A method for determining a distance (D) between ears of a wearer of a sound generating object is disclosed. The method comprises selecting a model for representing shape of the head of the wearer of the sound generating object so as to obtain a center axis of the wearer's head.

[0021] The method comprises associating, such as arranging or positioning, the first sound generating object with an ear of the wearer, wherein the first sound generating object comprises a first accelerometer and a second accelerometer, the respective accelerometers being arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle the center axis of the wearer's head, wherein the first and second accelerometers are so arranged that a straight line that intersects the center axis of the wearer's head at a substantially right angle crosses the first and second accelerometers such that the acceleration components (a1, a2) have the same direction, the first and second accelerometers being spaced by a known distance. Thus, it is clear that the first sound generating object is positioned or arranged at or near the wearer's ear, such as behind-the-ear, in-the-ear or partly within the ear.

[0022] The method comprises determining, by means of the first accelerometer when the head of the wearer is in motion, a value of a first acceleration component (a1) and, by means of the second accelerometer, a value of a second acceleration component (a2), and determining the distance (D) between the ears of the wearer on the basis of the model, the obtained values of the first and second acceleration components (a1, a2), and the known distance between the first accelerometer and the second accelerometer.

[0023] The first acceleration component may intersect at a substantially right angle the center axis of the wearer's head and/or the straight line crossing the first accelerometer and the second accelerometer. In other words, the first acceleration component may form a substantially right angle with the center axis of the wearer's head and/or the straight line crossing the first accelerometer and the second accelerometer.

[0024] The second acceleration component may intersect at a substantially right angle the center axis of the wearer's head and/or the straight line crossing the first accelerometer and the second accelerometer. In other words, the second acceleration component may form a substantially right angle with the center axis of the wearer's head and/or the straight line crossing the first accelerometer and the second accelerometer.

[0025] In the method, the distance (D) may be determined as a function of time and averaged over a time interval. The length of the time interval may be at least 60 seconds.

[0026] Also disclosed is a (first) ear-worn, sound generating object comprising means for allowing the wearer of the sound generating object to select a model for representing shape of the head so as to obtain a center axis of the wearer's head; a first accelerometer and a second accelerometer, the respective accelerometers being arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle the center axis of the wearer's head, wherein the first and second accelerometers are so arranged that a straight line that intersects the center axis of the wearer's head at a substantially right angle crosses the first and second accelerometers such that the acceleration components (a1, a2) have the same direction, the first and second accelerometers being spaced by a known distance; wherein the first accelerometer is provided with means for determining a value of a first acceleration component (a1) and the second accelerometer (12) is provided with means for determining a value of a second acceleration component (a2); and wherein the ear-worn, sound generating object is provided with means for determining, on the basis of the obtained values of the first and second acceleration components (a1, a2), a distance (D) between the ears of the wearer. The distance (D) between the ears of the wearer may be based on the model. The distance (D) between the ears of the wearer may be based on the known distance between the first accelerometer and the second accelerometer.

[0027] In other words, the sound generating object is configured to, when worn at the ear of the user, determine the distance (D) between the ears of the wearer based on first acceleration component and the second acceleration component. The acceleration components are determined in a plane substantially perpendicular to the center axis.

[0028] The first, ear-worn, sound generating object may be a hearing instrument.

[0029] The sound generating object may be enclosed by an earpad belonging to a headphone. Thus, a headphone comprising an earpad is disclosed, the earpad enclosing the sound generating object.

[0030] The sound generating object may be an ear piece being part of a headset. Thus, a headset comprising an ear piece is disclosed, the earpiece comprising a sound generating object as disclosed herein.

[0031] The sound generating object may be a hearable.

[0032] Also disclosed is use of a first accelerometer and a second accelerometer in an ear-worn, sound generating object as disclosed herein in order to determine a distance (D) between the ears of the wearer, wherein the respective accelerometers are arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle a center axis of the wearer's head, wherein the first accelerometer is spaced from the second accelerometer by a known distance, and wherein the first accelerometer is provided with means for determining a value of a first acceleration component (a1) and the second accelerometer is provided with means for determining a value of a second acceleration component (a2), when the head (2) of the wearer is in motion.

[0033] Fig. 1 is a perspective view of a head 2 of a user schematically showing an ear-worn, sound generating object 4. More specifically, a skull and a portion of a spine 9 including cervical vertebrae is illustrated. Further, a center axis 6 of the wearer's head and a corresponding head pivot point 5 are shown. As defined above, the center axis 6 is an axis substantially perpendicular to a horizontal, ground plane, and it intersects the head pivot point 5, i.e. a point around which the head rotates side to side. As it may be seen, the head pivot point 5 is positioned at an interface of the skull and the topmost vertebrae 7, also called atlas. The ear-worn, sound generating object 4 is also shown. Here, said object may be chosen from the group comprising hearing instruments, earpads belonging to a headphone, ear pieces being part of a headset or hearables. Relevant structural features of the sound generating object will be more thoroughly described in conjunction with Fig. 2.

[0034] For certain applications it is possible, albeit tedious, to precisely determine the head pivot point in real life. The position of the center axis is subsequently determined on the basis of this information. However, a more convenient approach is to approximate the shape of the head with that of a well-known geometric body, e.g. a cylinder, an ellipsoid or a sphere, having a known pivot point/position of the center axis. These approximations and their implications on the parameters such as head pivot point are well known to the artisan. For the purposes of this invention, an approximate model in accordance with the above delivers sufficient precision and is easily integrated into the surrounding software infrastructure.

[0035] Fig. 2 is a close-up of an accelerometer configuration according to an embodiment of the present invention. The configuration is shown in top view and the center axis extends perpendicularly to the plane of the paper. A sound generating object, here a hearing aid, is schematically shown. The hearing aid comprises a first and a second accelerometers, the respective accelerometer being arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle a center axis of the wearer's head. Further, the two accelerometers are so arranged that a straight line that intersects the center axis of the wearer's head at a substantially right angle crosses the two accelerometers. The accelerometers are spaced by a known distance (Δr). In hearing aids, this distance is, due to spatial constraints, typically below 10 mm, preferably between 5 and 8 mm.

[0036] Using the above set-up and in order to determine the distance (D) between the ears of the wearer, the accelerations measured with the two accelerometers are $a_{meas1}(t)$ and $a_{meas2}(t)$ and the distance (Δr) is a known distance. Now, the distances to be calculated are, firstly, a distance R_1 from the center axis of the head to a first accelerometer and the corresponding distance R_2 to a second accelerometer, where $R_2>R_1$, i.e. R_1 is positioned closer to the center axis than R_2. As discussed in connection with Fig. 1, position of the center axis of the wearer's head is obtained when the wearer of the sound generating object selects a model for representing shape of the head. R_2 and R_1 are calculated in the following manner once the user starts to rotate his head:
The magnitude of the angular acceleration originating from the head rotation is a_0 at a given time t_0.

[0037] Since α_0 is constant for the entire head (at time t_0) we have:

$$\alpha_0 = \frac{a_{meas2}}{R_2} = \frac{a_{meas1}}{R_1} \quad (1)$$

[0038] Combined with $\Delta r = R_2 - R_1$ we have two equations with two unknowns that we can solve for R_1:

$$R_1 = \frac{\Delta r}{\frac{a_{meas2}}{a_{meas1}} - 1} \quad (2)$$

[0039] The distance D will now be:

$$D = 2\,R_1 = \frac{2\,\Delta r}{\frac{a_{meas2}}{a_{meas1}} - 1} \quad (3)$$

[0040] By executing the method in accordance with the above, an automatic adjustment of the distance (D) between the ears of the wearer may be achieved. In other words, no involvement of the user is required in order to handily and accurately determine the ear-to-ear distance. Moreover, said method is due to its inherent simplicity easily integrated in the existing software.

Ultimately, the effect conferred by the inventive method is the improved fidelity with respect to presentation of the virtual (3D) audio signals generated by the sound generating object. In addition, by accurately and automatically determining the head size, more advanced beamformers may be employed. In a related context, estimation of the direction of arrival (DOA) of the speech signal could be significantly improved when the head size is accurately determined.

[0041] Even better, less noisy results may be obtained when the distance (D) is determined as a function of time and averaged over a time interval. Typically, the length of the time interval is at least 60 seconds. In certain applications, even longer time intervals may be used.

[0042] In the above context, hearing aids carrying two accelerometers are known in the art. In particular, such a set-up is disclosed in WO9914985 attempting to reduce vibrations in the miniature hearing aids. To this purpose, two accelerometers are arranged in a hearing aid of the completely-in-the-canal-type (CIC). The accelerometers are so positioned within the hearing aid so that they are physically secured to its housing since they measure vibrations that arise due to feedback loop in the hearing aid. Otherwise, their position in the hearing aid is completely arbitrary.

[0043] Fig. 3 is a flow chart illustrating a method for determining a distance (D) between ears of a wearer of a sound generating object, according to one embodiment of the present invention. The method may be performed in a device such a hearing aid, hearable or a headphone. In particular, the applications where accelerometers are integrated in hearing aids are experiencing increased interest from the industry. The method comprises to select 20 a model for representing shape of the head of the wearer of the sound generating object means for allowing the wearer of the sound generating object to select a model for representing shape of the head so as to obtain a center axis of the wearer's head. According to the preferred models, the shape of the head is approximated by a well-known geometric body, e.g. a cylinder, an ellipsoid or a sphere. An approximate model in accordance with the above provides sufficient precision and is easily integrated into the surrounding software infrastructure. Subsequently, the method comprises to associate 30 the first sound generating object with an ear of the wearer, wherein the first sound generating object comprises a first accelerometer and a second accelerometer, the respective accelerometers being arranged to measure at least an acceleration component (a1, a2) intersecting at a substantially right angle a center axis of the wearer's head, said two accelerometers being spaced by a known distance (Δr). The method further comprises to, when the head of the wearer is in motion, determine 40, by means of the first accelerometer, a value of the first acceleration component (a1) intersecting at a substantially right angle a center axis of the wearer's head and, by means of the second accelerometer, a value of the second acceleration component (a2) intersecting at a substantially right angle a center axis of the wearer's head. The method also comprises to, on the basis of the obtained values of the acceleration components (a1, a2), determine 50 the distance (D) between the ears of the wearer.

[0044] In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

Patent documents cited in the description

- EP2890161A [0005]
- US20130177166A [0006]
- US2016269849A1 [0007]
- US2017013389A1 [0007]
- WO2016089133A1 [0007]
- US2011299707A1 [0007]
- WO9914985A [0042]

Patentkrav

1 . Fremgangsmåde til at bestemme en afstand (D) mellem ører på en bærer af et lydgenererende objekt (4), hvilken fremgangsmåde omfatter:

udvælgelse (20) af en model til at repræsentere formen af hovedet (2) af bæreren af det lydgenererende objekt (4) for at opnå en midterakse (6) af bærerens hoved, hvori midteraksen er en akse i det væsentlige vinkelret til et vandret jordplan og skærende et hoveddrejepunkt for bærerens hoved,

associering (30) af det første lydgenererende objekt (4) med bærerens øre, hvor det første lydgenererende objekt (4) omfatter et første accelerometer (10) og et andet accelerometer (12), de respektive accelerometre (10, 12)) er indrettet til at måle i det mindste en accelerationskomponent (a1, a2), der i en i det væsentlige ret vinkel skærer midteraksen (6) af bærerens hoved, hvor det første og andet accelerometer (10, 12) er arrangeret således, at en ret linje (14), der skærer midteraksen (6) af bærerens hoved i en i det væsentlige ret vinkel, krydser det første og andet accelerometer (10, 12), således at accelerationskomponenterne (a1, a2) har samme retning, det første og det andet accelerometre (10, 12) med en kendt afstand (Δr),

når bærerens hoved (2) er i bevægelse, bestemme (40) ved hjælp af det første accelerometer (10) en værdi af en første accelerationskomponent (a1) og ved hjælp af det andet accelerometer (12), en værdi af en anden accelerationskomponent (a2),

bestemmelse (50) af afstanden (D) mellem bærerens ører på basis af modellen, de opnåede værdier af den første og anden accelerationskomponent (a1, a2) og den kendte afstand mellem det første accelerometer og det andet accelerometer .

2. Fremgangsmåde ifølge krav 1, hvor afstanden (D) bestemmes som en funktion af tiden og gennemsnittet over et tidsinterval.

3. Fremgangsmåde ifølge krav 2, hvor længden af tidsintervallet er mindst 60 sekunder.

4. En første lydgenererende genstand (4) konfigureret til at blive båret ved øret på en bærer, den første lydgenererende genstand (4) omfatter:

organer til at tillade bæreren af den lydgenererende genstand at vælge en model til at repræsentere formen af hovedet (2) for at opnå en midterakse (6) af bærerens hoved, hvori midteraksen er en akse i det væsentlige vinkelret på en vandret , jordplan og skærende et hoveddrejepunkt for bærerens hoved,

et første accelerometer (10) og et andet accelerometer (12), hvor de respektive accelerometre er indrettet til at måle i det mindste en accelerationskomponent (a1, a2), der skærer i en i det væsentlige ret vinkel midteraksen af bærerens hoved (2), hvor første og andet accelerometer (10, 12) er arrangeret således, at en lige linje (14), der skærer midteraksen (6) af bærerens hoved i en i det væsentlige ret vinkel, krydser det første og andet accelerometer (10, 12), således at accelerationskomponenter (a1, a2) har samme retning, idet det første og det andet accelerometer (10, 12) er adskilt med en kendt afstand (Δr), hvor det første accelerometer (10) er forsynet med midler til at bestemme en værdi af en første accelerationskomponent (a1), og det andet accelerometer (12) er forsynet med midler til at bestemme en værdi af en anden accelerationskomponent (a2), og hvor det første lydgenererende objekt (4) er forsynet med midler til på basis af modellen at bestemme de opnåede værdier af den første og anden accelerationskomponent (a1, a2) og den kendte afstand mellem det første accelerometer og det andet accelerometer, en afstand (D) mellem bærerens ører.

5. Første lydgenererende objekt (4) ifølge krav 4, hvor det første lydgenererende objekt er et høreapparat.

6. Første lydgenererende objekt (4) ifølge krav 4, hvor det første lydgenererende objekt er omsluttet af en ørepude tilhørende en hovedtelefon.

7. Første lydgenererende objekt (4) ifølge krav 4, hvor det første lydgenererende objekt er et ørestykke, der er en del af et headset.

8. Første lydgenererende objekt (4) ifølge krav 4, hvor det første lydgenererende objekt er et hørbart.

DRAWINGS

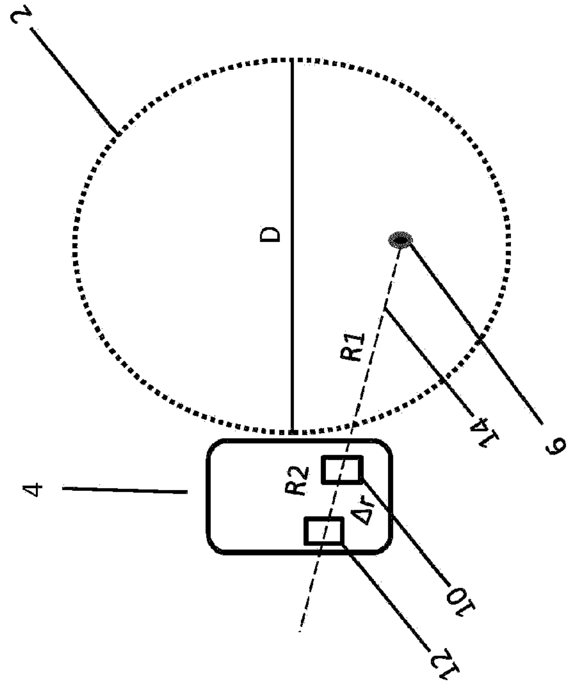

Fig. 2

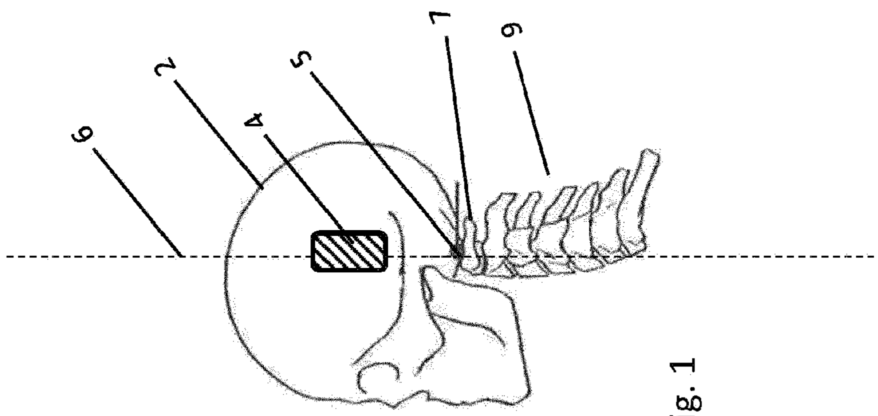

Fig. 1

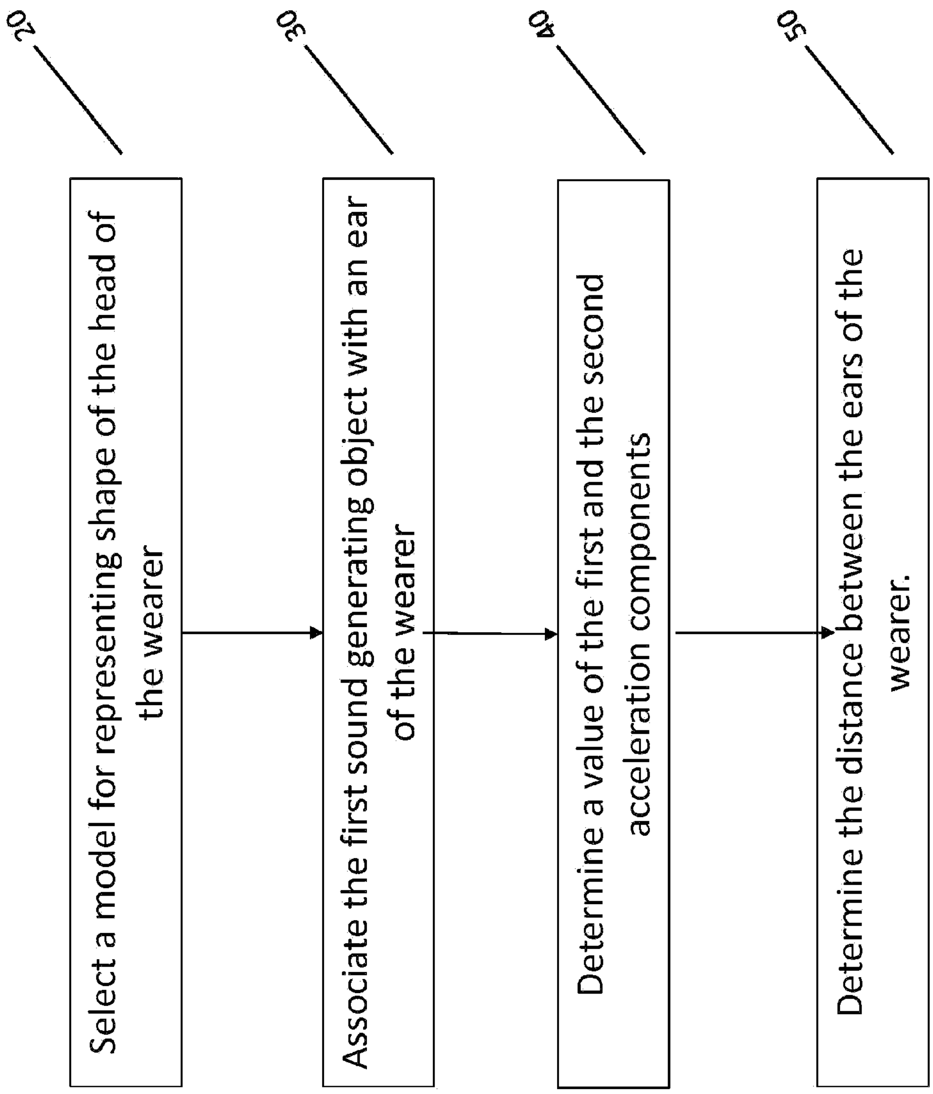
20
Select a model for representing shape of the head of the wearer
30
Associate the first sound generating object with an ear of the wearer
40
Determine a value of the first and the second acceleration components
50
Determine the distance between the ears of the wearer.

Fig. 3