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(72) Inventor: HEISEY, Andrew, Carl; 188 Lancaster Road, Walnut Creek, California 94595 (US).

(74) Agent: IRIZARRY, Stacey et al.; GTC Law Group PC & Affiliates, c/o CPA Global 900 Second Avenue South Suite 600, Minneapolis, Minnesota 55402 (US).

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(71) Applicant: OSTERHOUT GROUP, INC. [US/US]; Suite 570, 153 Townsend Street, San Francisco, California 94107 (US).

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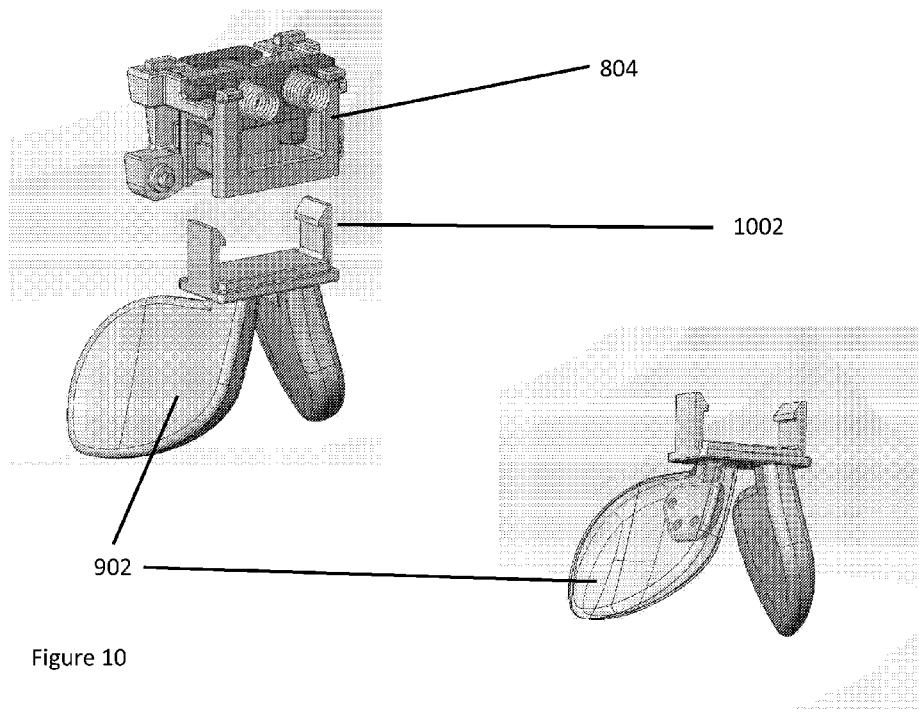


Figure 10

(57) Abstract: Aspects of the present disclosure relate to a head-worn computer, comprising a removable and replaceable adjustable nose bridge assembly, wherein the adjustable nose bridge assembly has at least three user adjustable features to adapt the adjustable nose bridge assembly to the user's nose, wherein a first adjustment of the at least three user adjustable features is adapted to move the adjustable nose bridge up and down relative a lens of the head-worn computer, wherein a second adjustment of the at least three user adjustable features is adapted to rotate a nose pad of the adjustable nose bridge about an axis substantially perpendicular to a top frame of the head-worn computer, and wherein a third adjustment of the at least three user adjustable features is adapted to flare the nose pad to the side of the axis.



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## ADJUSTABLE NOSE BRIDGE ASSEMBLY FOR HEADWORN COMPUTER

### Claim to Priority

[0001] This application claims the benefit of the following U.S. patent application, which is incorporated by reference herein in its entirety: United States Patent Application No. 15/249,637, filed August 29, 2016.

### Background

#### Field of the Invention

[0002] This disclosure relates to head worn computing. More particularly, this disclosure relates to 3-way adjustable nose bridge assemblies for head-worn computers.

#### Description of Related Art

[0003] Wearable computing systems have been developed and are beginning to be commercialized. Many problems persist in the wearable computing field that need to be resolved to make them meet the demands of the market.

### Summary

[0004] Aspects of the present disclosure relate to 3-way adjustable nose bridge assemblies for head worn computers.

[0005] These and other systems, methods, objects, features, and advantages of the present disclosure will be apparent to those skilled in the art from the following detailed description of the preferred embodiment and the drawings. All documents mentioned herein are hereby incorporated in their entirety by reference.

### Brief Description of the Drawings

[0006] Embodiments are described with reference to the following Figures. The same numbers may be used throughout to reference like features and components that are shown in the Figures:

[0007] Figure 1 illustrates a head worn computing system in accordance with the principles of the present disclosure.

[0008] Figure 2 illustrates a head worn computing system with optical system in accordance with the principles of the present disclosure.

[0009] Figure 3 illustrates three views of a head worn computer in accordance with the principles of the present disclosure.

[00010] Figure 4 illustrates a temple and ear horn in accordance with the principles of the present disclosure.

[00011] Figure 5 illustrates a temple and ear horn assembly in various states in accordance with the principles of the present disclosure.

[00012] Figure 6 illustrates an adjustable nose bridge assembly in accordance with the principles of the present disclosure.

[00013] Figure 7 illustrates an adjustable nose bridge assembly in accordance with the principles of the present disclosure.

[00014] Figure 8 illustrates adjustable nose bridge assemblies in accordance with the principles of the present disclosure.

[00015] Figure 9 illustrates adjustable nose bridge assemblies in accordance with the principles of the present disclosure.

[00016] Figure 10 illustrates adjustable nose bridge assemblies in accordance with the principles of the present disclosure.

[00017] Figure 11 illustrates a multiple adjustable nose pad assembly in accordance with the principles of the present disclosure.

[00018] Figure 12 illustrates a malleable platform use in connection with an adjustable nose bridge assembly in accordance with the principles of the present disclosure.

[00019] While the disclosure has been described in connection with certain preferred embodiments, other embodiments would be understood by one of ordinary skill in the art and are encompassed herein.

### **Detailed Description of the Preferred Embodiment(s)**

[00020] Aspects of the present disclosure relate to head-worn computing (“HWC”) systems. HWC involves, in some instances, a system that mimics the appearance of head-worn glasses or sunglasses. The glasses may be a fully developed computing platform, such as including computer displays presented in each of the lenses of the glasses to the eyes of the user. In embodiments, the lenses and displays

may be configured to allow a person wearing the glasses to see the environment through the lenses while also seeing, simultaneously, digital imagery, which forms an overlaid image that is perceived by the person as a digitally augmented image of the environment, or augmented reality ("AR").

[00021] HWC involves more than just placing a computing system on a person's head. The system may need to be designed as a lightweight, compact and fully functional computer display, such as wherein the computer display includes a high resolution digital display that provides a high level of emersion comprised of the displayed digital content and the see-through view of the environmental surroundings. User interfaces and control systems suited to the HWC device may be required that are unlike those used for a more conventional computer such as a laptop. For the HWC and associated systems to be most effective, the glasses may be equipped with sensors to determine environmental conditions, geographic location, relative positioning to other points of interest, objects identified by imaging and movement by the user or other users in a connected group, and the like. The HWC may then change the mode of operation to match the conditions, location, positioning, movements, and the like, in a method generally referred to as a contextually aware HWC. The glasses also may need to be connected, wirelessly or otherwise, to other systems either locally or through a network. Controlling the glasses may be achieved through the use of an external device, automatically through contextually gathered information, through user gestures captured by the glasses sensors, and the like. Each technique may be further refined depending on the software application being used in the glasses. The glasses may further be used to control or coordinate with external devices that are associated with the glasses.

[00022] Referring to Fig. 1, an overview of the HWC system 100 is presented. As shown, the HWC system 100 comprises a HWC 102, which in this instance is configured as glasses to be worn on the head with sensors such that the HWC 102 is aware of the objects and conditions in the environment 114. In this instance, the HWC 102 also receives and interprets control inputs such as gestures and movements 116. The HWC 102 may communicate with external user interfaces 104. The external user interfaces 104 may provide a physical user interface to take control instructions from a user of the HWC 102 and the external user interfaces 104 and the HWC 102 may communicate bi-directionally to affect the user's command and provide feedback to the

external device 108. The HWC 102 may also communicate bi-directionally with externally controlled or coordinated local devices 108. For example, an external user interface 104 may be used in connection with the HWC 102 to control an externally controlled or coordinated local device 108. The externally controlled or coordinated local device 108 may provide feedback to the HWC 102 and a customized GUI may be presented in the HWC 102 based on the type of device or specifically identified device 108. The HWC 102 may also interact with remote devices and information sources 112 through a network connection 110. Again, the external user interface 104 may be used in connection with the HWC 102 to control or otherwise interact with any of the remote devices 108 and information sources 112 in a similar way as when the external user interfaces 104 are used to control or otherwise interact with the externally controlled or coordinated local devices 108. Similarly, HWC 102 may interpret gestures 116 (e.g. captured from forward, downward, upward, rearward facing sensors such as camera(s), range finders, IR sensors, etc.) or environmental conditions sensed in the environment 114 to control either local or remote devices 108 or 112.

[00023] We will now describe each of the main elements depicted on Fig. 1 in more detail; however, these descriptions are intended to provide general guidance and should not be construed as limiting. Additional description of each element may also be further described herein.

[00024] The HWC 102 is a computing platform intended to be worn on a person's head. The HWC 102 may take many different forms to fit many different functional requirements. In some situations, the HWC 102 will be designed in the form of conventional glasses. The glasses may or may not have active computer graphics displays. In situations where the HWC 102 has integrated computer displays the displays may be configured as see-through displays such that the digital imagery can be overlaid with respect to the user's view of the environment 114. There are a number of see-through optical designs that may be used, including ones that have a reflective display (e.g. LCoS, DLP), emissive displays (e.g. OLED, LED), hologram, TIR waveguides, and the like. In embodiments, lighting systems used in connection with the display optics may be solid state lighting systems, such as LED, OLED, quantum dot, quantum dot LED, etc. In addition, the optical configuration may be monocular or binocular. It may also include vision corrective optical components. In embodiments, the optics may be packaged as contact lenses. In other embodiments, the HWC 102 may be in the form

of a helmet with a see-through shield, sunglasses, safety glasses, goggles, a mask, fire helmet with see-through shield, police helmet with see through shield, military helmet with see-through shield, utility form customized to a certain work task (e.g. inventory control, logistics, repair, maintenance, etc.), and the like.

[00025] The HWC 102 may also have a number of integrated computing facilities, such as an integrated processor, integrated power management, communication structures (e.g. cell net, WiFi, Bluetooth, local area connections, mesh connections, remote connections (e.g. client server, etc.)), and the like. The HWC 102 may also have a number of positional awareness sensors, such as GPS, electronic compass, altimeter, tilt sensor, IMU, and the like. It may also have other sensors such as a camera, rangefinder, hyper-spectral camera, Geiger counter, microphone, spectral illumination detector, temperature sensor, chemical sensor, biologic sensor, moisture sensor, ultrasonic sensor, and the like.

[00026] The HWC 102 may also have integrated control technologies. The integrated control technologies may be contextual based control, passive control, active control, user control, and the like. For example, the HWC 102 may have an integrated sensor (e.g. camera) that captures user hand or body gestures 116 such that the integrated processing system can interpret the gestures and generate control commands for the HWC 102. In another example, the HWC 102 may have sensors that detect movement (e.g. a nod, head shake, and the like) including accelerometers, gyros and other inertial measurements, where the integrated processor may interpret the movement and generate a control command in response. The HWC 102 may also automatically control itself based on measured or perceived environmental conditions. For example, if it is bright in the environment the HWC 102 may increase the brightness or contrast of the displayed image. In embodiments, the integrated control technologies may be mounted on the HWC 102 such that a user can interact with it directly. For example, the HWC 102 may have a button(s), touch capacitive interface, and the like.

[00027] As described herein, the HWC 102 may be in communication with external user interfaces 104. The external user interfaces may come in many different forms. For example, a cell phone screen may be adapted to take user input for control of an aspect of the HWC 102. The external user interface may be a dedicated UI, such as a keyboard, touch surface, button(s), joy stick, and the like. In embodiments, the external controller may be integrated into another device such as a ring, watch, bike, car, and the

like. In each case, the external user interface 104 may include sensors (e.g. IMU, accelerometers, compass, altimeter, and the like) to provide additional input for controlling the HWD 104.

[00028] As described herein, the HWC 102 may control or coordinate with other local devices 108. The external devices 108 may be an audio device, visual device, vehicle, cell phone, computer, and the like. For instance, the local external device 108 may be another HWC 102, where information may then be exchanged between the separate HWCS 108.

[00029] Similar to the way the HWC 102 may control or coordinate with local devices 106, the HWC 102 may control or coordinate with remote devices 112, such as the HWC 102 communicating with the remote devices 112 through a network 110. Again, the form of the remote device 112 may have many forms. Included in these forms is another HWC 102. For example, each HWC 102 may communicate its GPS position such that all the HWCS 102 know where all of HWC 102 are located.

[00030] Figure 2 illustrates a HWC 102 with an optical system that includes an upper optical module 202 and a lower optical module 204. While the upper and lower optical modules 202 and 204 will generally be described as separate modules, it should be understood that this is illustrative only and the present disclosure includes other physical configurations, such as that when the two modules are combined into a single module or where the elements making up the two modules are configured into more than two modules. In embodiments, the upper module 202 includes a computer controlled display (e.g. LCoS, DLP, OLED, etc.) and image light delivery optics. In embodiments, the lower module includes eye delivery optics that are configured to receive the upper module's image light and deliver the image light to the eye of a wearer of the HWC. In figure 2, it should be noted that while the upper and lower optical modules 202 and 204 are illustrated in one side of the HWC such that image light can be delivered to one eye of the wearer, that it is envisioned by the present disclosure that embodiments will contain two image light delivery systems, one for each eye. It should also be noted that while many embodiments refer to the optical modules as "upper" and "lower" it should be understood that this convention is being used to make it easier for the reader and that the modules are not necessarily located in an upper-lower relationship. For example, the image generation module may be located above the eye delivery optics, below the eye delivery optics, on a side of the eye delivery optics, or

otherwise positioned to satisfy the needs of the situation and/or the HWC 102 mechanical and optical requirements.

[00031] An aspect of the present disclosure relates to the mechanical and electrical construction of a side arm of a head worn computer. In general, when a head worn computer takes the form of glasses, sun-glasses, certain goggles, or other such forms, two side arms are included for mounting and securing the head worn computer on the ears of a person wearing the head worn computer. In embodiments, the side arms may also contain electronics, batteries, wires, antennas, computer processors, computer boards, etc. In embodiments, the side arm may include two or more sub-assemblies. For example, as will be discussed in more detail below, the side arm may include a temple section and an ear horn section. The two sections may, for example, be mechanically arranged to allow an ear horn section to move such that both side arms can fold into a closed position.

[00032] Figure 3 illustrates three separate views 102A, 102B and 102C of a head worn computer 102 according to the principles of the present disclosure. Turning to the head worn computer illustrated as 102A, one side arm of the HWC 102 is folded into its closed position. The ear horn section 308 of the side arm is rotated relative to its temple section 304 to create space relative to the other side arm 310 so when the other side arm is moved into its closed position it can fully close. In a situation where the ear horn did not rotate to create the space (not illustrated) the ear horn would physically interfere with the other side arm 310, when the side arm was in the closed position, and prevent the other side arm 310 from fully closing. The HWC 102B view illustrates the HWC 102B with both side arms folded into a fully closed position. Note that the ear horn 308 is in the rotated position with respect to its temple section 304 such that the other arm 310 closed without interfering with the ear horn 308. The HWC 102C view also illustrates both arms in closed positions with the ear horn 308 rotated to create the space for the other arm 310 to fully close. Figure 3 also illustrates a portion of the HWC 102 where electronics may be housed in a top mount 312. The top mount may contain electronics, sensors, optics, processors, memory, radios, antennas, etc.

[00033] Figure 4 illustrates a side arm configuration in accordance with the principles of the present disclosure. In this embodiment, the side arm includes two sub-assemblies: the temple section 304 and the ear horn 308. Figure 4 illustrates two views

of the side arm assembly, one from an outer perspective and one from a sectioned perspective. The ear horn includes a pin 402 that is designed to fit into a hole 404 and to be secured by connector 408. The connector 408 is rotatable and in one position locks the pin 402 in place and in another position unsecures the pin 402 such that the ear horn 308 can be removed and re-attached to the temple section 304. This allows the detachment and re-attachment of the ear horn 308 from the temple section 304. This also allows for the sale of different ear horns 308 for replacement, of which a variety of colors and patterns may be offered. In embodiments, the temple section 304 may include a battery compartment 410 and other electronics, wires, sensors, processors, etc.

[00034] Figure 5 illustrates several views of a HWC side arm with temple 304 and ear horn 308 sections. The views include outer perspectives and cross sections as well as various states of the security of the ear horn 308 with the temple section 304. Figure set 504 illustrates the ear horn 308 and the temple section 304 in a secure un-rotated position. The same pin 402 and connector 408 system described in connection with figure 4 is illustrated in the cross sections of figure 5. In the secured un-rotated position the pin is pulled internally within the temple section firmly such that it stays in place. Figure set 504 illustrates a state where the ear horn 308 is separated from the temple section 304. This state is achieved when pressure is used to pull on the ear horn 308. In embodiments, the pressure is exerted by a user pulling on the ear horn 308, which compresses a spring 510B that is mechanically associated with the pin 402 in the ear horn 308. The mechanism uses the spring to maintain pressure on the pin 402 to maintain connection with the connector 408 when the connector 408 is in a position to lock the pin 402 in position. Figure set 508 illustrates a state where, after the ear horn 308 has been pulled into the state described in connection with state 504, the ear horn 308 is rotated about the pin 402. This puts the ear horn 308 in a rotated position as described herein such that the first arm, with this rotated ear horn 308, does not interfere with the closure of the other arm 310 when the two arms are folded into the closed position.

[00035] An aspect of the present disclosure relates to an adjustable nose bridge. An adjustable nose bridge may be important with head worn computers, especially those with computer displays, to ensure comfort and alignment of the displays and/or other portions of the head worn computer. Figure 6 illustrates a HWC

102 with an adjustable nose bridge 602. The nose bridge is adjustable through a mechanism in the HWC 102. In embodiments, the mechanism includes a fixed notched attachment 604, a movable pin 608 adapted to fit into the notches of the notched attachment 604, and a selection device 610 that is attached to the movable pin 608. The movable pin 608 and nose bridge 602 are connected such that the as the movable pin 608 shifts in position the nose bridge 602 moves in position as well. The selection device 610 causes the movable pin 608 to engage and disengage with the fixed notched attachment 604 when presses and allowed to retract. As illustrated in figure 6, the selection device 610 is not in a pressed position so the movable pin 608 is engaged with the notched attachment 604 such that the nose bridge is securely attached in a stable position. Figure 7 illustrates a scenario where the selection device is pressed, or activated, such that the moveable pin 608 is no longer engaged with the fixed notched attachment 604. This allows the nose bridge 602 to move up and down with respect to the rest of the HWC 102. Once the movable pin 608 aligns with a notch of the notched attachment 604, the two parts may engage to re-secure the nose bridge in the HWC 102.

[00036] In embodiments, a side arm of the HWC 102 may include an audio jack (not shown) and the audio jack may be magnetically attachable to the side arm. For example, the temple section 304 or ear horn section 308 may have a magnetically attachable audio jack with audio signal wires associated with an audio system in the HWC 102. The magnetic attachment may include one or more magnets on one end (e.g. on the head phone end or the side arm end) and magnetically conductive material on the other end. In other embodiments, both ends of the attachment may have magnets, of opposite polarization, to create a stronger magnetic bond for the headphone). In embodiments, the audio signal wires or magnetic connection may include a sensor circuit to detect when the headphone is detached from the HWC 102. This may be useful in situations where the wearer is wearing the headphones during a period when there is not constant audio processing (e.g. listening for people to talk with periods of silence). In embodiments, the other side's headphone may play a tone, sound, signal, etc. in the event a headphone is detached. In embodiments, an indication of the detachment may be displayed in the computer display.

[00037] In embodiments, the HWC 102 may have a vibration system that vibrates to alert the wearer of certain sensed conditions. In embodiments, the vibration system (e.g. an actuator that moves quickly to cause vibration in the HWC 102) may be

mounted in a side arm (e.g. the temple portion 304, or ear horn 308), in the top mount 312, etc. In embodiments, the vibration system may be capable of causing different vibration modes that may be indicative of different conditions. For example, the vibration system may include a multi-mode vibration system, piezo-electric vibration system, variable motor, etc, that can be regulated through computer input and a processor in the HWC 102 may send control signals to the vibration system to generate an appropriate vibration mode. In embodiments, the HWC 102 may be associated with other devices (e.g. through Bluetooth, WiFi, etc.) and the vibratory control signals may be associated with sensors associated with the other device. For example, the HWC 102 may be connected to a car through Bluetooth such that sensor(s) in the car can cause activation of a vibration mode for the vibration system. The car, for example, may determine that a risk of accident is present (e.g. risk of the driver falling asleep, car going out of its lane, a car in front of the wearer is stopped or slowing, radar in the car indicates a risk, etc.) and the car's system may then send a command, via the Bluetooth connection, to the HWC 102 to cause a vibratory tone to be initiated in the HWC 102.

[00038] In embodiments, the connection between the speaker system and the HWC 102 may be positioned other than under the temple section. It may be positioned on a side, top, bottom, end of a section of the side arm, for example. It may be positioned on the front bridge, for example. In embodiments, the speaker system may be connected to a top or side portion and the speaker may be further positioned to face forward, away from the user's ear. This may be a useful configuration for providing sound to others. For example, such a configuration may be used when the user wants to provide translations to a person nearby. The user may speak in a language, have the language translated, and then spoken through the forward facing speakers.

[00039] The removable nature of the speaker systems may be desirable for breakaway situations so a snag does not tear the glasses from the user or pull hard on the user's ear. The removable nature may also be useful for modularity configurations where the user wants to interchange speaker types or attach other accessories. For example, the user may want ear buds at one point and an open ear speaker configuration at another point and the user may be able to make the swap with ease given this configuration. The port on the HWC 102 may also be adapted for other accessories that include lights or sensors for example. The accessory may have an ambient light sensor to assist with the control of the lighting and contrast systems used

in the HWC 102 displays, for example. In embodiments, the speaker port may be used as a charging port for the HWC 102 or data port for the HWC 102.

[00040] Another aspect of the present disclosure relates to an adjustable nose bridge assembly of a head-worn computer. Positioning of a head-worn computer can be complicated by the nature of the computer displays that are intended to be positioned in front of the user's eyes along with the fact that people have different shaped heads, noses, eye positions, etc. The inventors have appreciated the difficulties in such positioning and have developed an intuitive mechanism for a multi-axis adjustment system for the head-worn computer. In embodiments, the multi-axis adjustment system provides for vertical adjustment of the nose bridge, persistent rotational settings for the nose pads, and persistent outward/inward flex of the nose pads. Such a system is designed to be used on a wide variety of nose shapes and head sizes.

[00041] Figure 8 illustrates a portion of a head-worn computer 102 with a mounting area 802 for an adjustable nose bridge assembly 804.

[00042] Figure 9 illustrates an adjustable nose bridge assembly 804 in three different vertical positions 904, 908, and 910. In embodiments, the adjustable nose bridge 804 has a selection device 610 and nose pads 902. In embodiments, the selection device is a button, or other suitable user interface, and is mechanically arranged such that pushing the button releases the nose bridge such that it can be moved up and down. In this embodiment, the button engages with a tooth or other such feature to hold the nose bridge in place. In embodiments, the adjustment may be continuous or discrete and may be mechanically, electrically, or otherwise controlled.

[00043] Figure 10 illustrates an engagement mechanism for removing and replacing the nose pads from and to the vertical adjustment portion of the adjustable nose bridge assembly. As can be seen in figure 10, the nose pads are attached to a clip style mechanism that is adapted to mate with the vertical nose bridge adjustment system. Figure 10 also shows a clear version of one nose pad to illustrate how it is over-molded to a stiff (e.g. metal) member. The inventors appreciate that there are a number of ways to attach the nose pads to the vertical adjustment system and this example is provided as a non-limiting example.

[00044] Figure 11 illustrates a system providing two additional movable features for the nose pads. Together with the vertical adjustment portion, this

configuration provides for a three-way adjustment system. Adjustment 1002 illustrates how the nose pads may be rotated or otherwise manipulated from a rear facing view. Adjustment 1004 illustrates how the nose pads may be rotated or otherwise manipulated from a top view. Once assembled on the head-worn computer, the vertical adjustment and two nose pad rotational adjustments provide for a system that accommodates many nose, face, and head shapes.

[00045] Figure 12 illustrates a nose pad mount 1102. As previously described, the nose pads may be over-molded on to the ends of a mount. In this embodiment, the nose pads are over-molded on the ends of the nose pad mount 1102. The nose pad mount 1102 is designed to be malleable around the 2mm dimension shown. This permits the user to twist, turn, bend, flare, or otherwise manipulate the nose pad mount 1102 to change the positions of the nose pads, which then can accommodate the user's facial structure. While the embodiment shown in figure 12 illustrates a single piece, the inventors have appreciated that this mount may be assembled in multiple pieces.

[00046] Although embodiments of HWC have been described in language specific to features, systems, computer processes and/or methods, the appended claims are not necessarily limited to the specific features, systems, computer processes and/or methods described. Rather, the specific features, systems, computer processes and/or methods are disclosed as non-limited example implementations of HWC. All documents referenced herein are hereby incorporated by reference.

## Claims

We claim:

1. A head-worn computer, comprising

a removable and replaceable adjustable nose bridge assembly, wherein the adjustable nose bridge assembly has at least three user adjustable features to mechanically position the adjustable nose bridge assembly to the user's nose,

wherein a first adjustment of the at least three user adjustable features is adapted to move the adjustable nose bridge up and down relative a lens of the head-worn computer,

wherein a second adjustment of the at least three user adjustable features is adapted to rotate a nose pad of the adjustable nose bridge about an axis substantially perpendicular to a top frame of the head-worn computer, and

wherein a third adjustment of the at least three user adjustable features is adapted to flare the nose pad to the side of the axis.

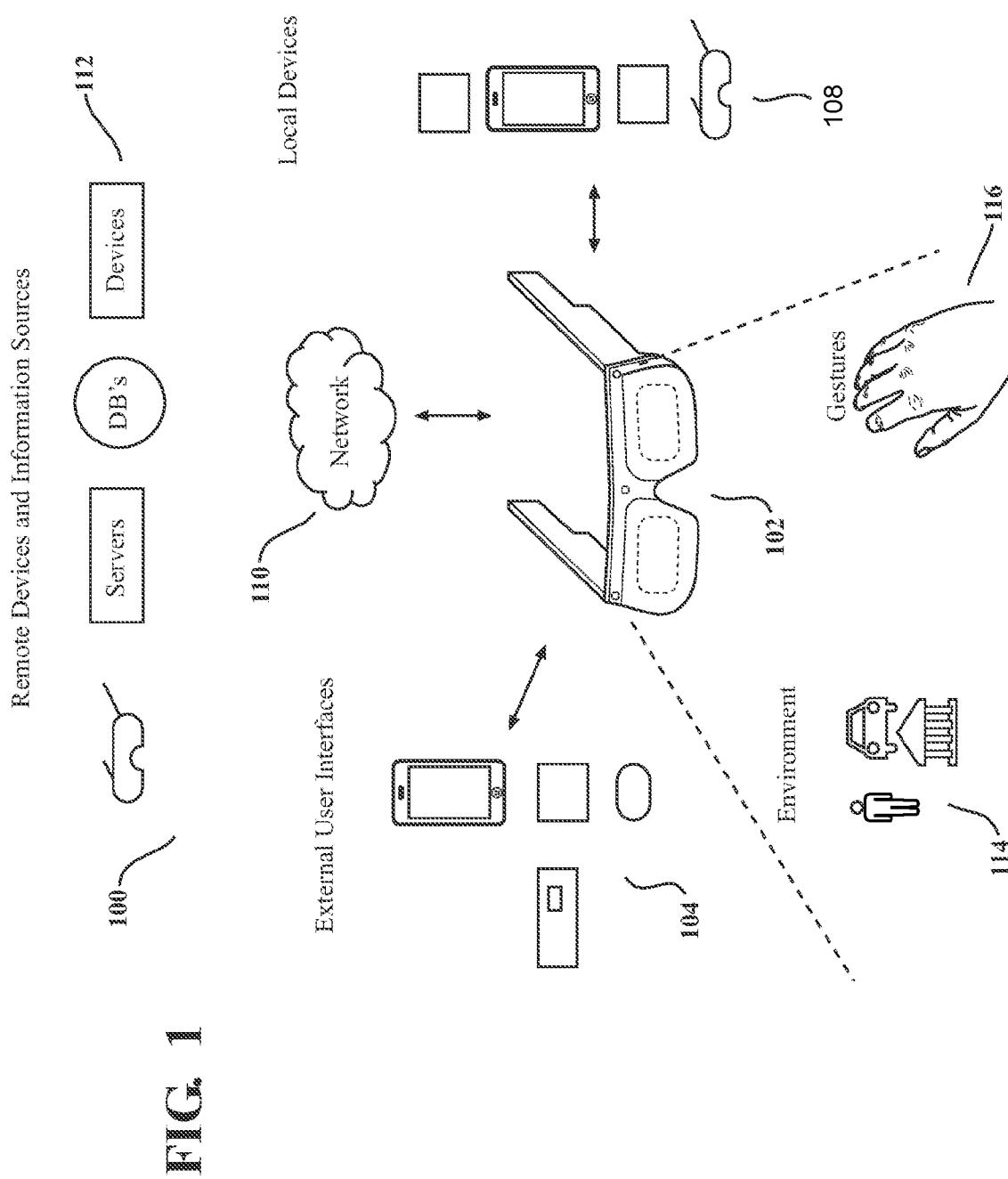
2. The head-worn computer of claim 1, wherein the first adjustment includes a user activated feature to release the nose bridge assembly from the head-worn computer so that the user moves the nose bridge assembly and wherein the user activated feature further locks the nose bridge in place once the user has completed the move.

3. The head-worn computer of claim 1, wherein the second adjustment includes a malleable member that maintains a persistent position after a user adjustment.

4. The head-worn computer of claim 1, wherein the third adjustment includes a malleable member that maintains a persistent position after a user adjustment.

5. The head-worn computer of claim 1, wherein the second and third adjustments include a malleable member that maintains a persistent position after a user adjustment, wherein the malleable member performs both the second and third adjustments.

6. The head-worn computer of claim 1, wherein the nose pad is mounted on a malleable metal mount, wherein the malleable metal mount maintains a position of the nose bridge but is user adjustable.



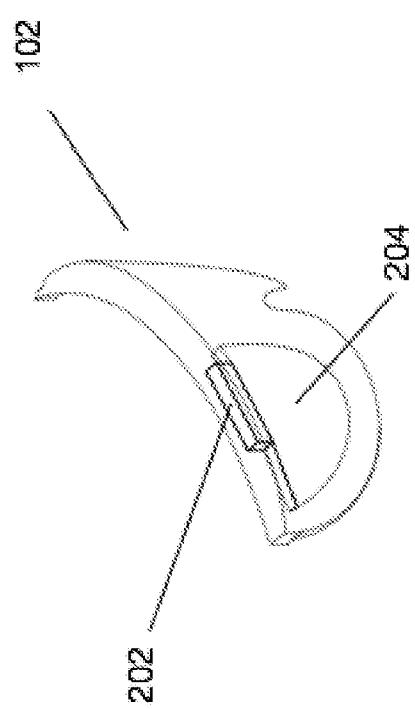


Figure 2

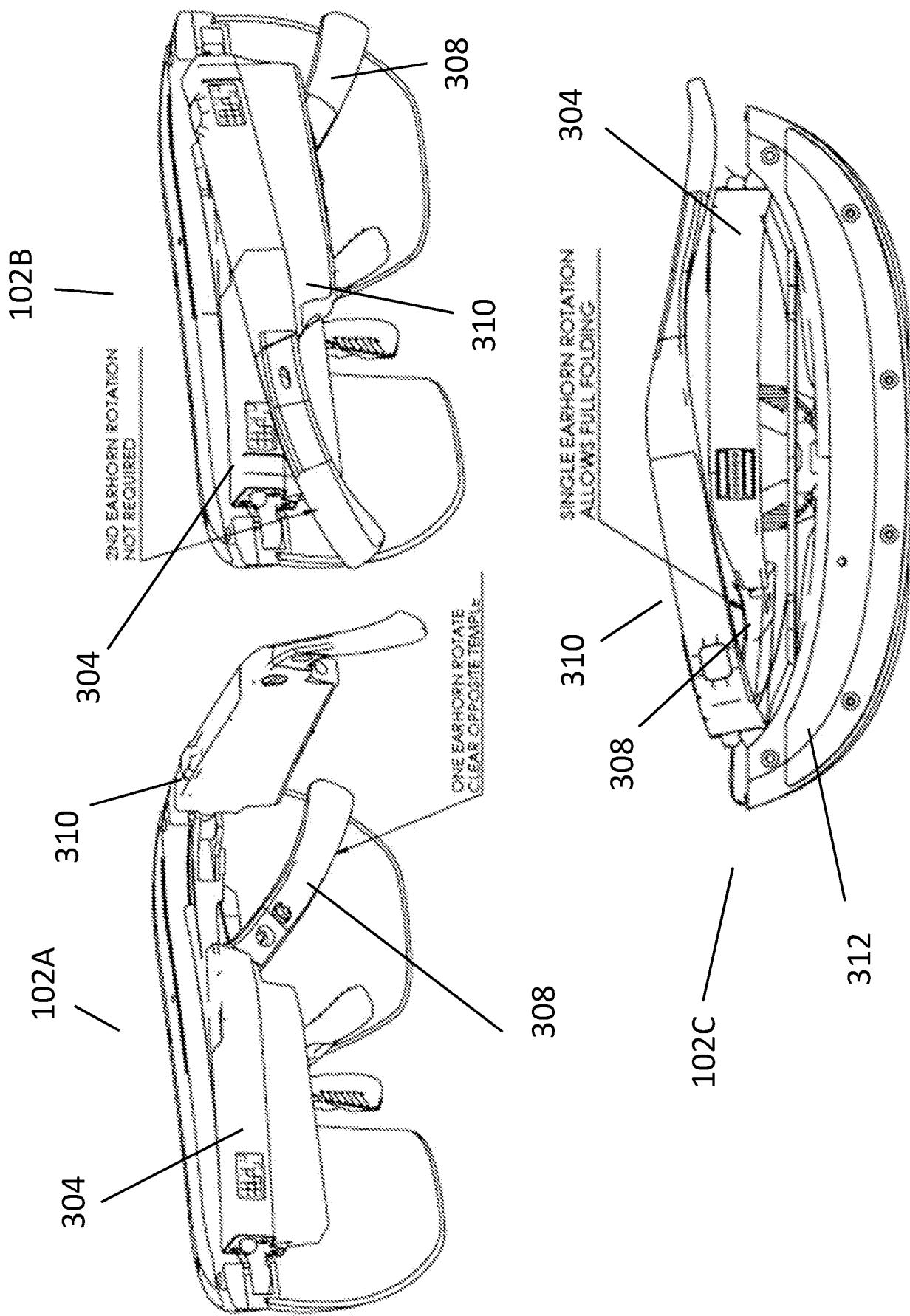


Figure 3

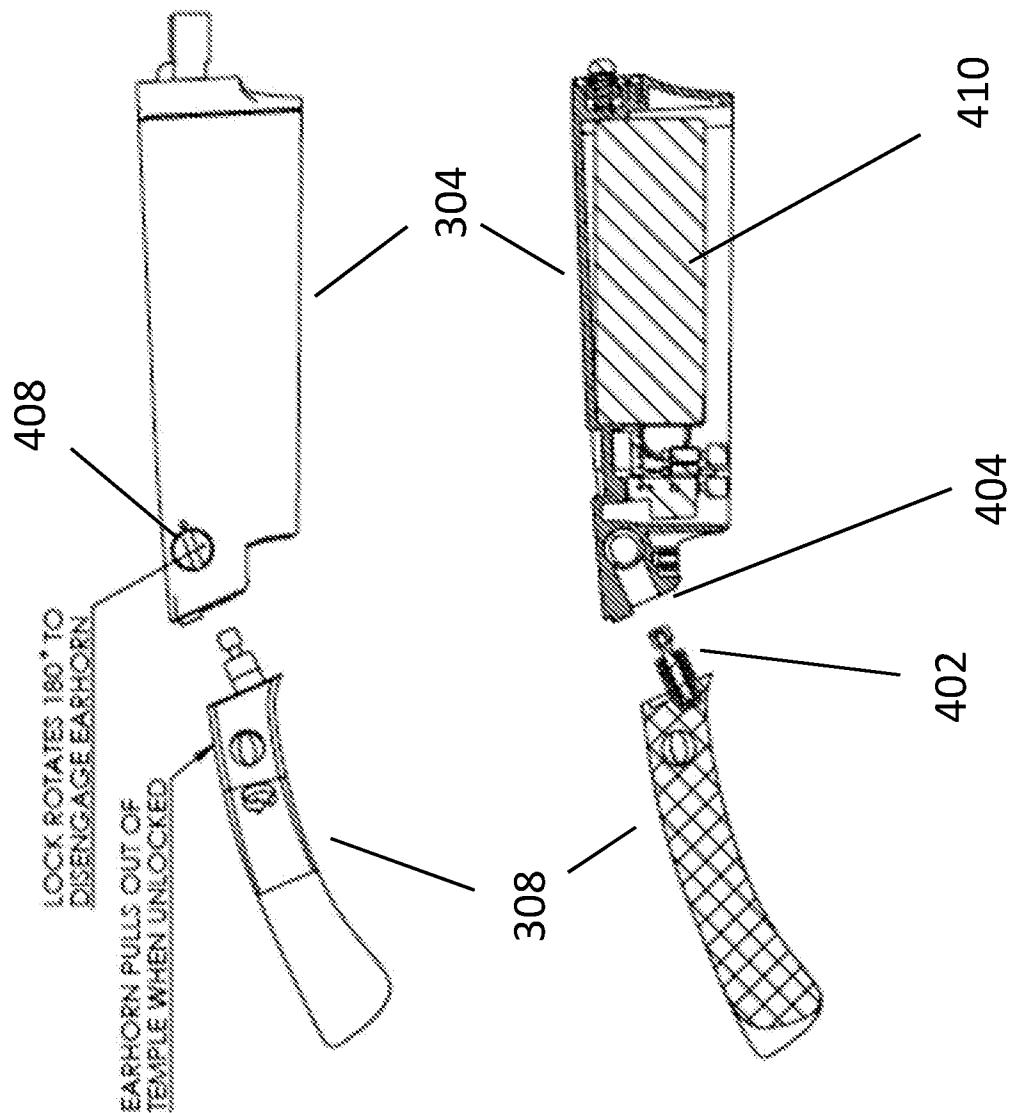


Figure 4

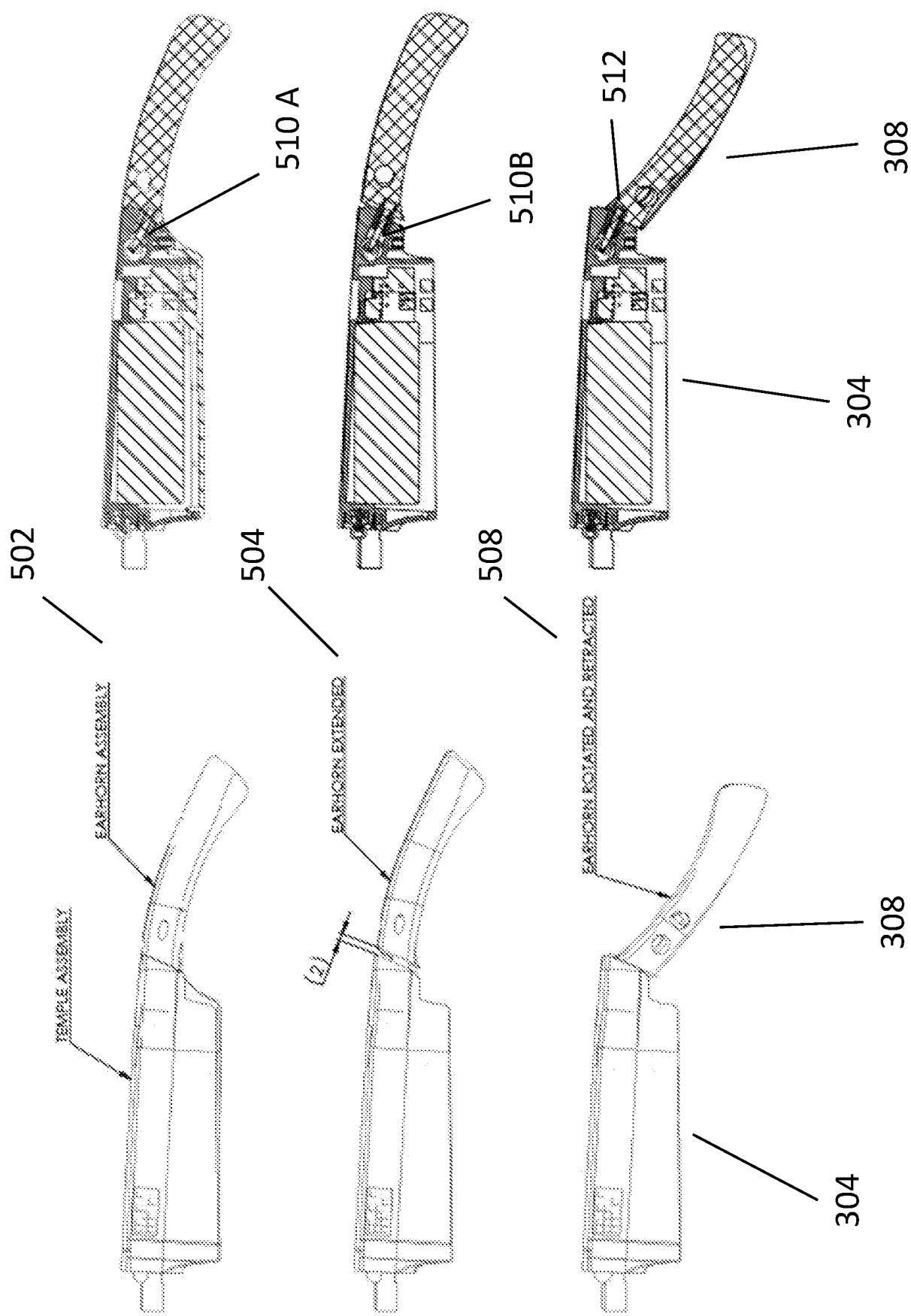


Figure 5

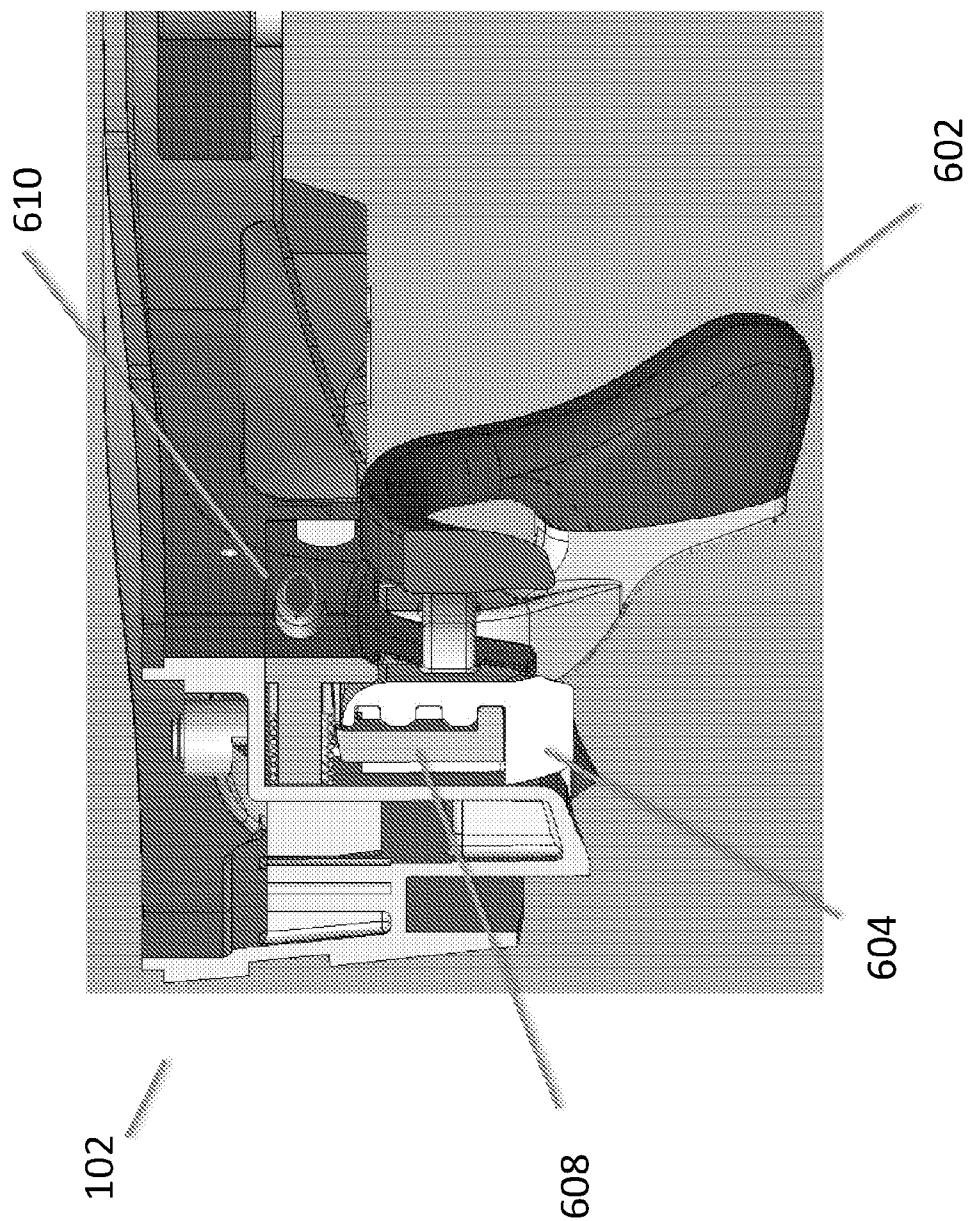


Figure 6

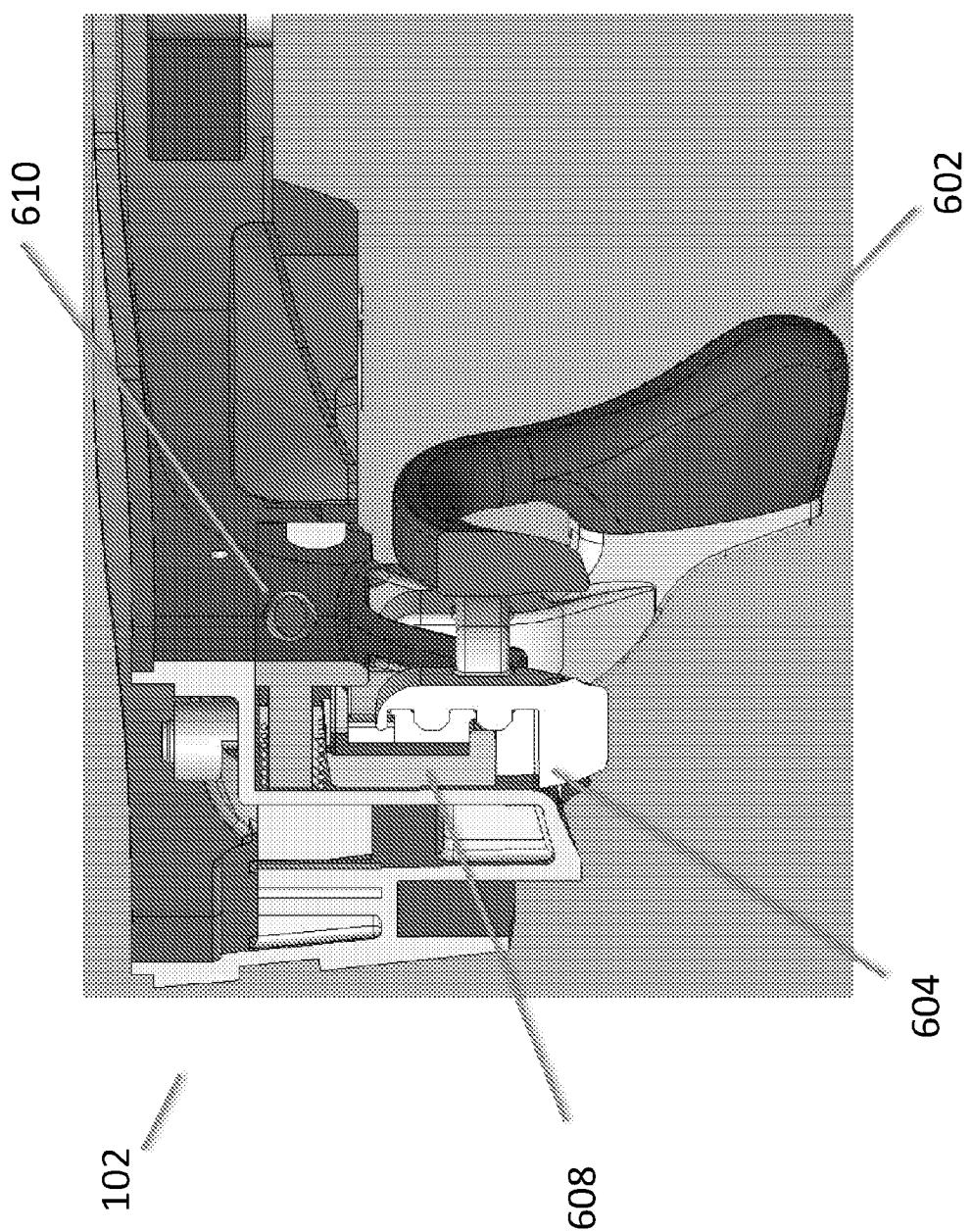


Figure 7

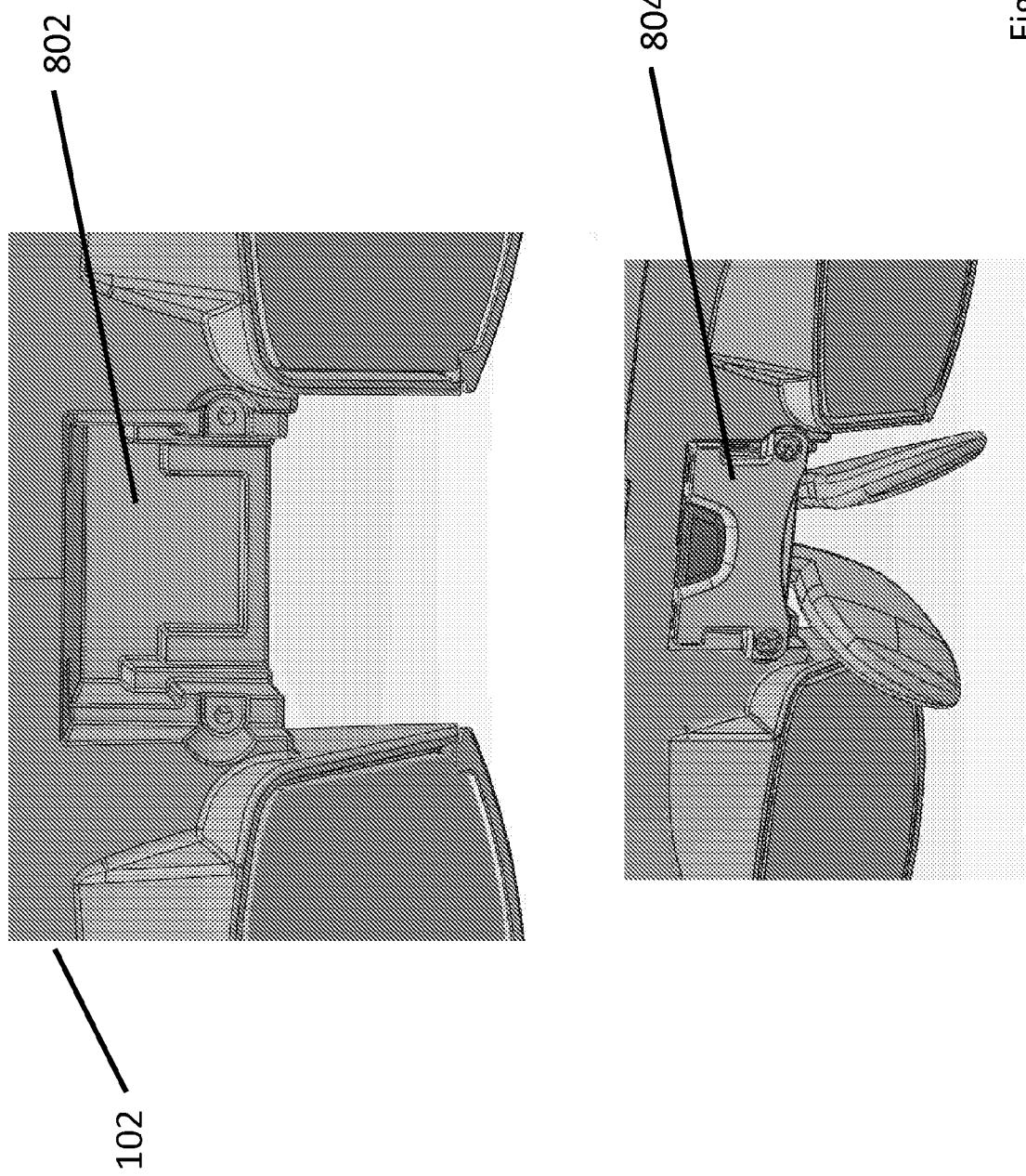


Figure 8

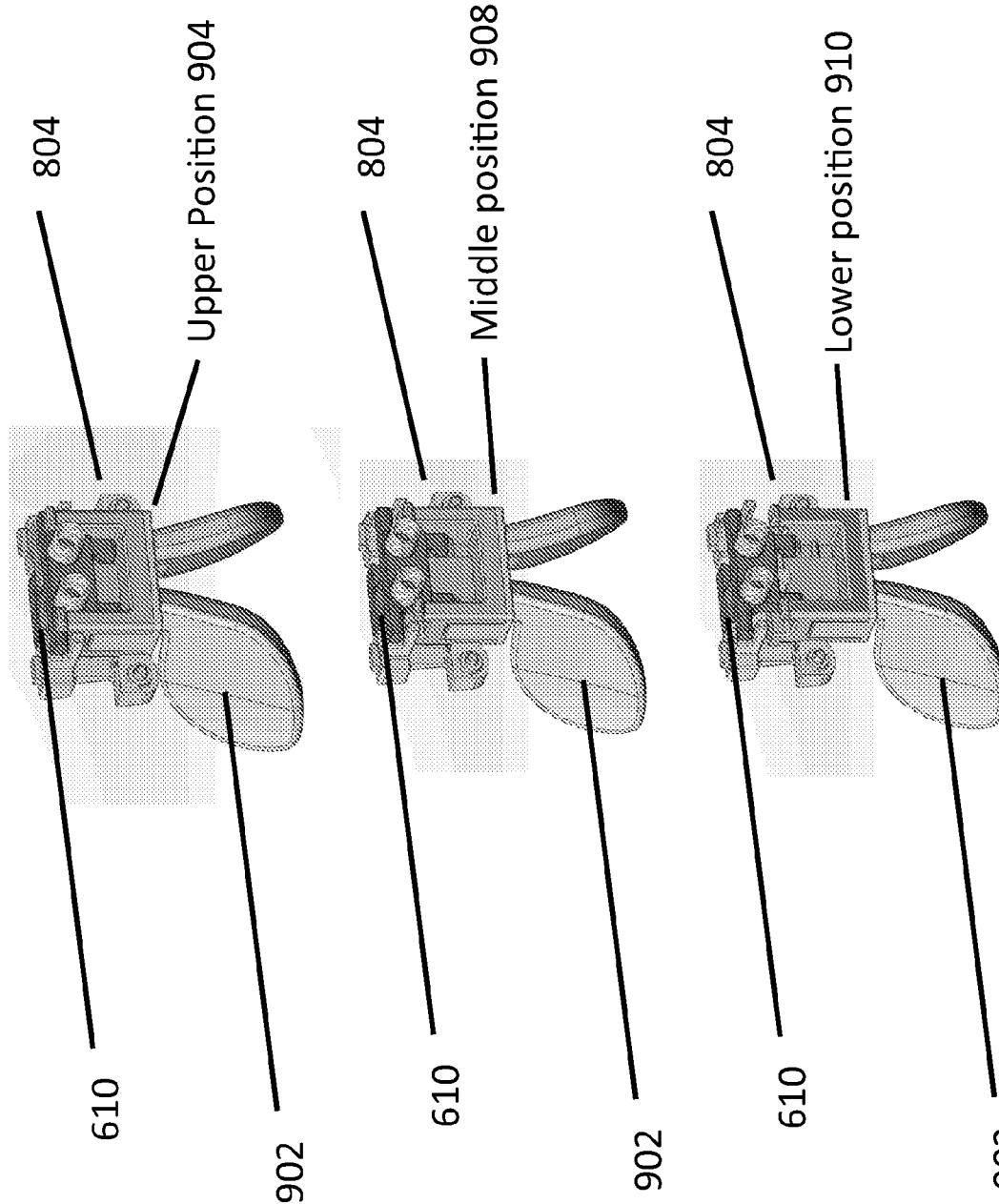


Figure 9

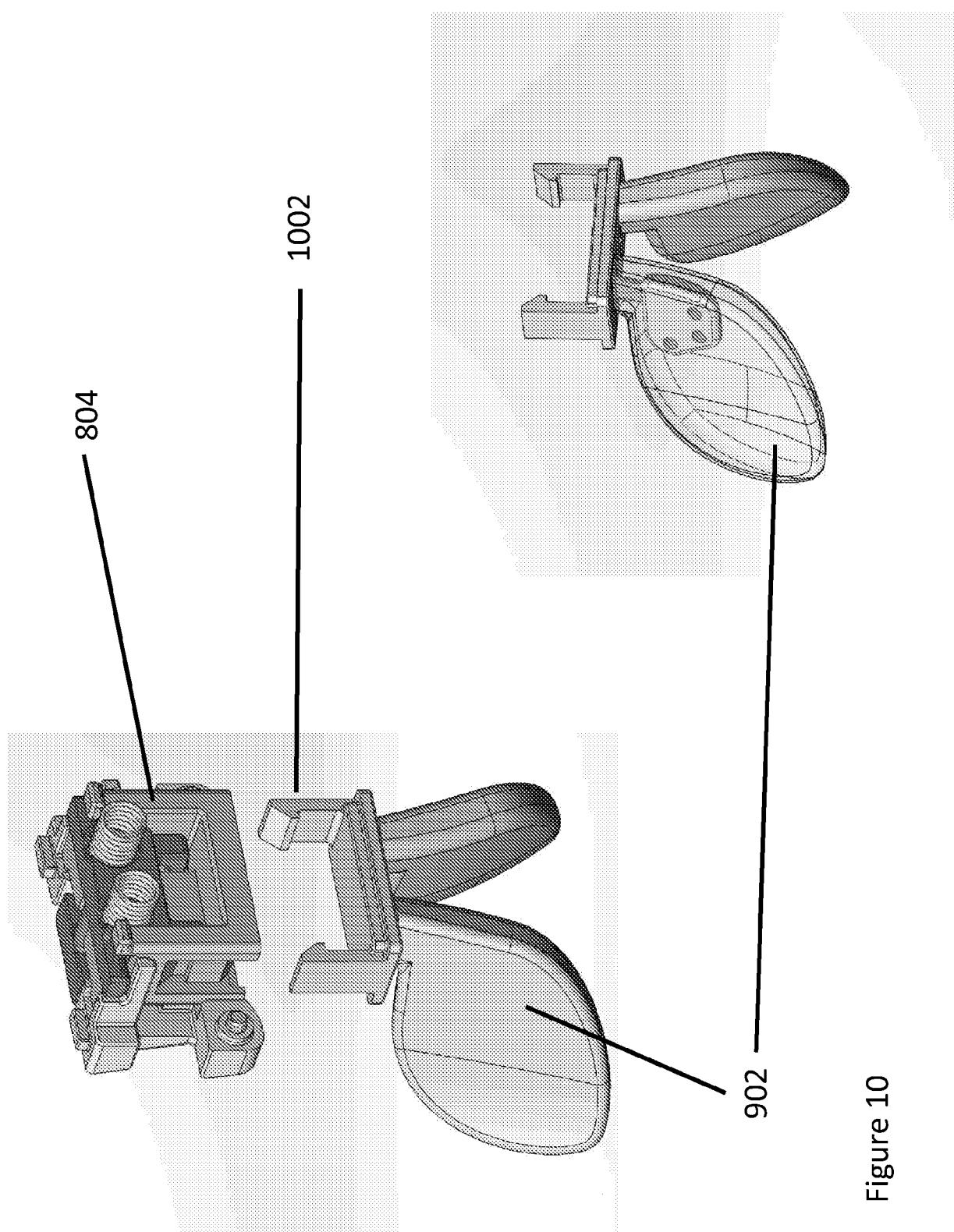


Figure 10

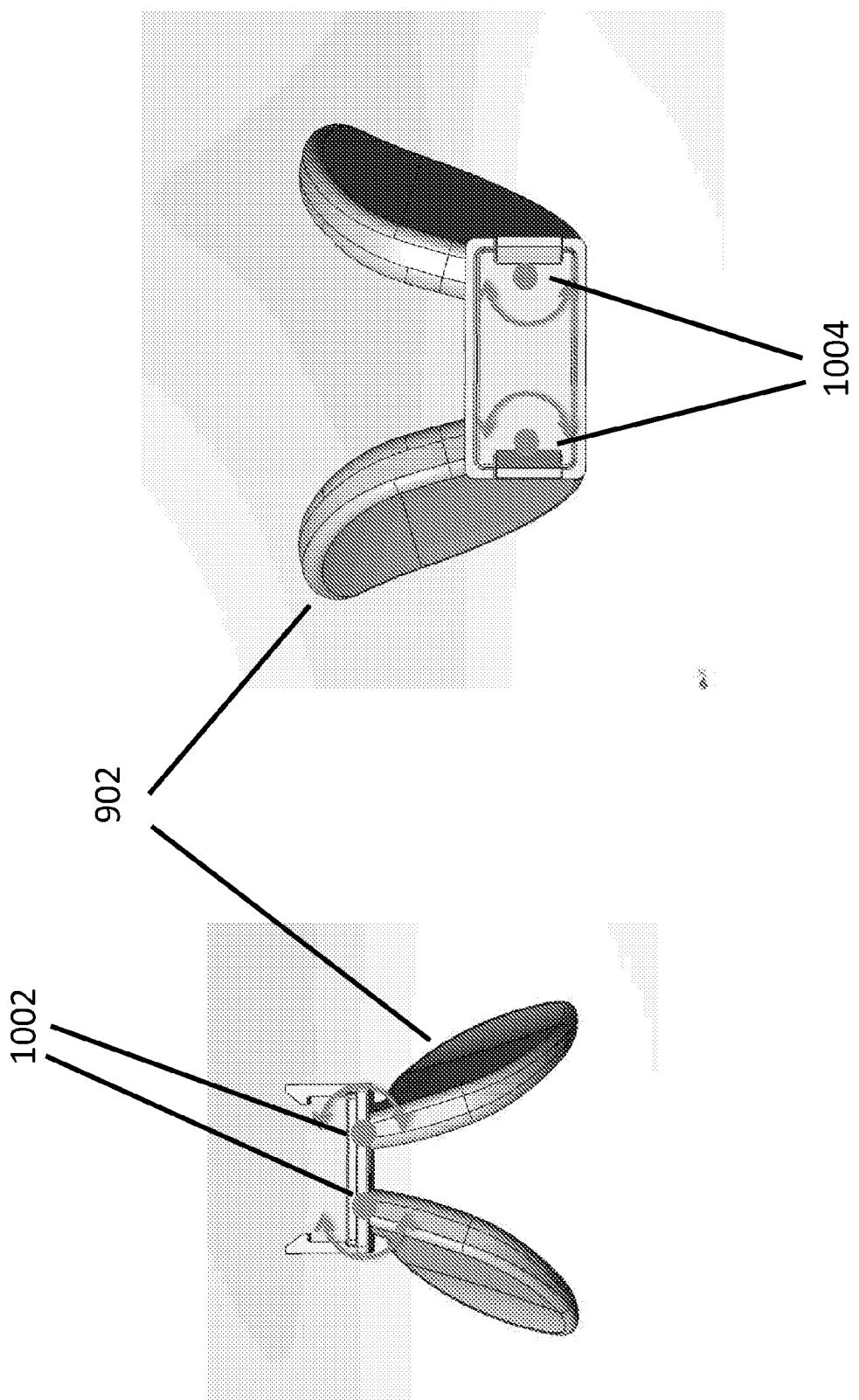


Figure 11

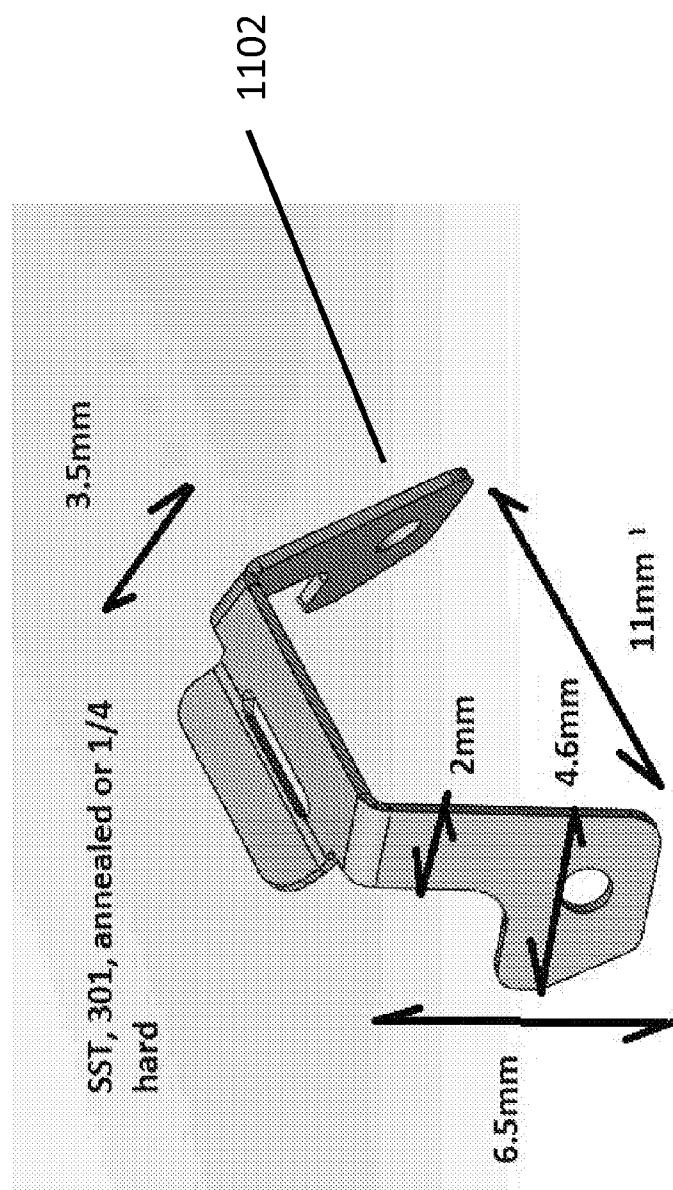


Figure 12

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/46701

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G02B 27/01, G02C 5/04, G02C 5/06, G02C 5/12 (2017.01)

CPC - G02B 2027/0178, G02B 27/017, G02C 5/122, G02C 5/04, G02C 5/124

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,480,174 B1 (KAUFMANN et al.) 12 November 2002 (12.11.2002) Entire document, especially col 3m ln 58-63, col 4, ln 23-35, col 6, ln 37-41, col 6, ln 50-54, col 7, ln 15-54 and figs. 1, 8-9, 12A and 14.	1-6
Y	US 2013/0235331 A1 (HEINRICH et al.) 12 September 2013 (12.09.2013) Entire document, especially para [0028]-[0029], [0052]-[0053], [0081] and figs. 1 and 10.	1-6
A	US 2015/0309317 A1 (OSTERHOUT GROUP, INC.) 29 October 2015 (29.10.2015) Entire document.	1-6
A	US 2011/0241975 A1 (MUKAWA et al.) 06 October 2011 (06.10.2011) Entire document.	1-6
A	US 2016/0103325 A1 (OPTINVENT) 14 April 2016 (14.04.2016) Entire document.	1-6
A	US 5,971,538 A (HEFFNER) 26 October 1999 (26.10.1999) Entire document.	1-6
A	US 6,157,291 A (KUENSTER e al.) 05 December 2000 (05.12.2000) Entire document.	1-6

Further documents are listed in the continuation of Box C.

See patent family annex.

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

22 September 2017

Date of mailing of the international search report

06 NOV 2017

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents  
P.O. Box 1450, Alexandria, Virginia 22313-1450  
Facsimile No. 571-273-8300

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300  
PCT OSP: 571-272-7774