US 20200033560A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2020/0033560 A1**

Weber et al. (43) **Pub. Date: Jan. 30, 2020**

(54) **ELECTRONIC DEVICE SYSTEM WITH SUPPLEMENTAL LENSES**

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(21) Appl. No.: **16/276,286**

(22) Filed: **Feb. 14, 2019**

Related U.S. Application Data

(60) Provisional application No. 62/712,108, filed on Jul. 30, 2018.

Publication Classification

(51) **Int. Cl.**

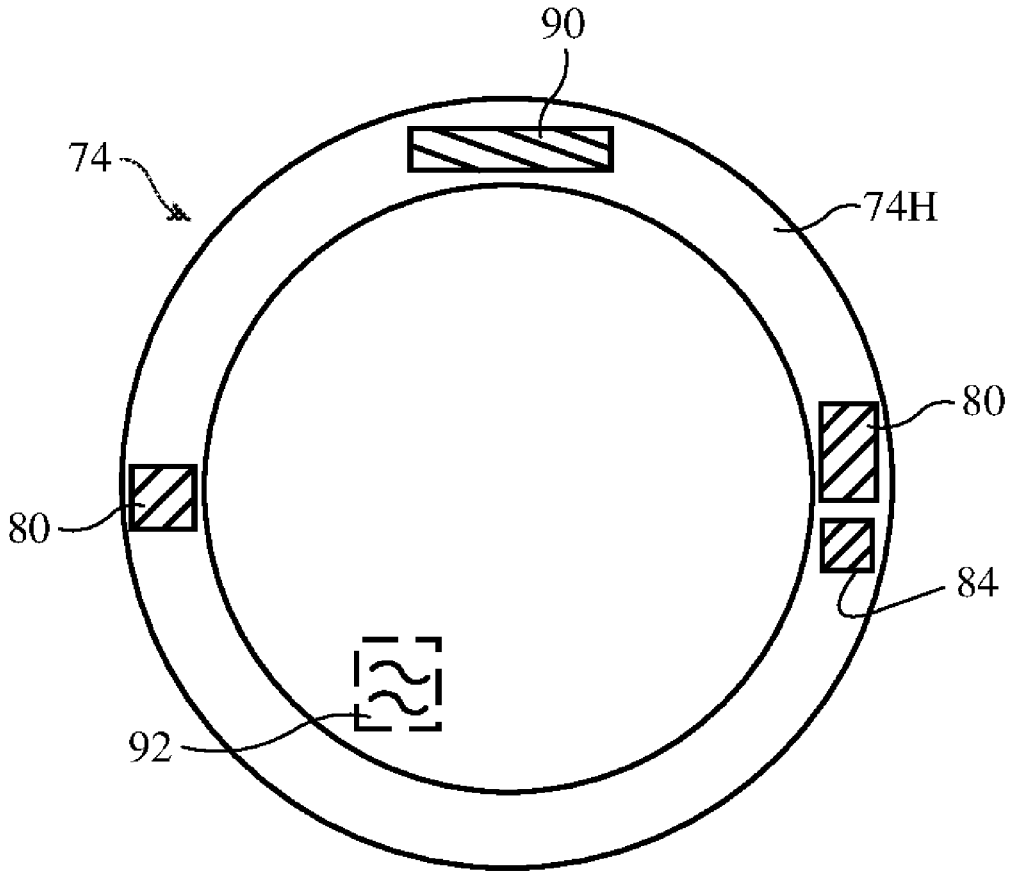
G02B 7/14	(2006.01)
G02B 27/00	(2006.01)
G02B 7/02	(2006.01)
G06F 1/16	(2006.01)
G06F 16/955	(2006.01)
G06K 19/06	(2006.01)
G06F 3/01	(2006.01)

(52) **U.S. Cl.**

CPC ***G02B 7/14*** (2013.01); ***G02B 27/0093*** (2013.01); ***G02B 7/023*** (2013.01); ***G06F 3/013*** (2013.01); ***G06F 16/9554*** (2019.01); ***G06K 19/06028*** (2013.01); ***G06K 19/0614*** (2013.01); ***G06F 1/163*** (2013.01)

(57) **ABSTRACT**

A head-mounted device may have a display that displays content for a user. Head-mounted support structures in the device support the device on the head of the user. A non-removable lens system may be supported by the head-mounted support structures. The head-mounted support structures may be configured to receive a removable supplemental lens system. The removable supplemental lens system may be used to customize the head-mounted display to accommodate the user's vision. Information such as information on the optical characteristics of the removable supplemental lens system and the user's eyeglass prescription may be stored in the removable supplemental lens system using bar codes, text, programmable memory, or other data storage. When the removable supplemental lens system is installed in the head-mounted device, control circuitry in the head-mounted device may retrieve the stored information. A gaze tracker system or other sensors may be used in retrieving the stored information.



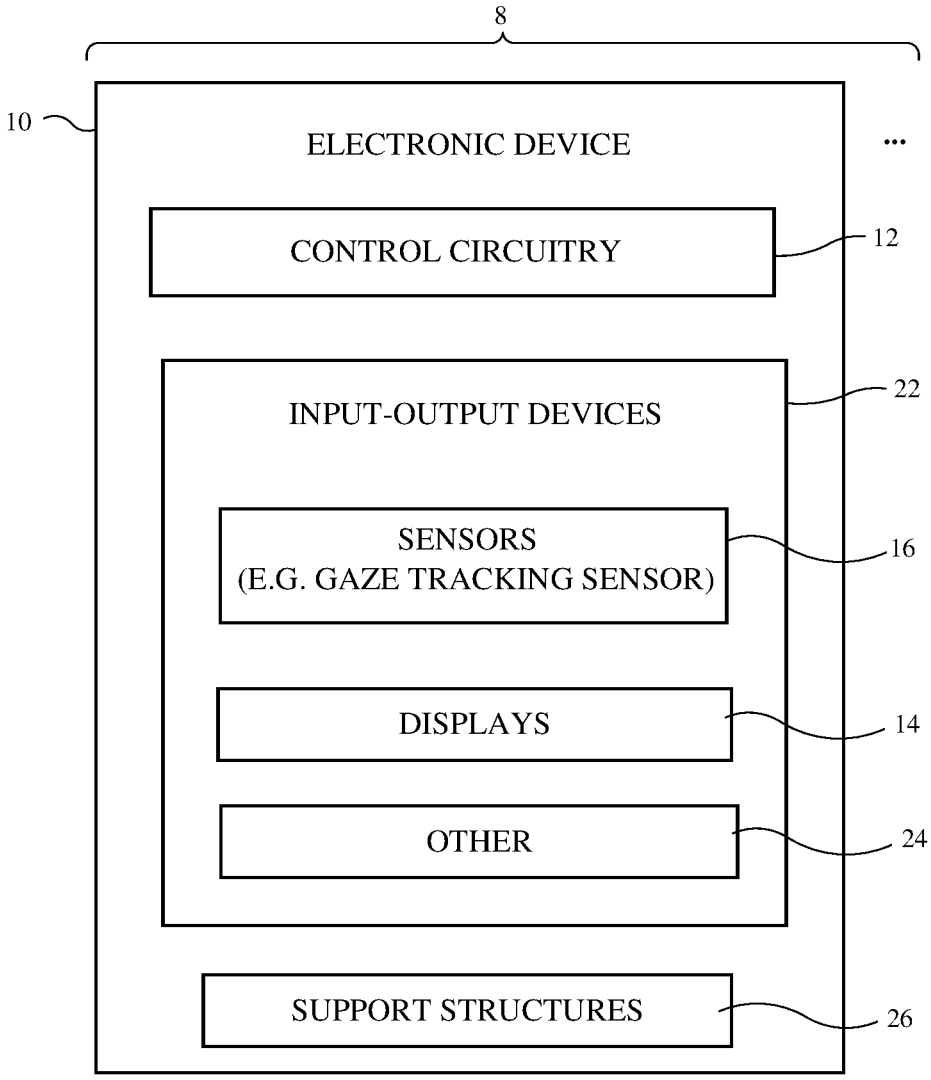

8
10
ELECTRONIC DEVICE
...
CONTROL CIRCUITRY
12
INPUT-OUTPUT DEVICES
22
SENSORS
(E.G. GAZE TRACKING SENSOR)
16
DISPLAYS
14
OTHER
24
SUPPORT STRUCTURES
26

FIG. 1

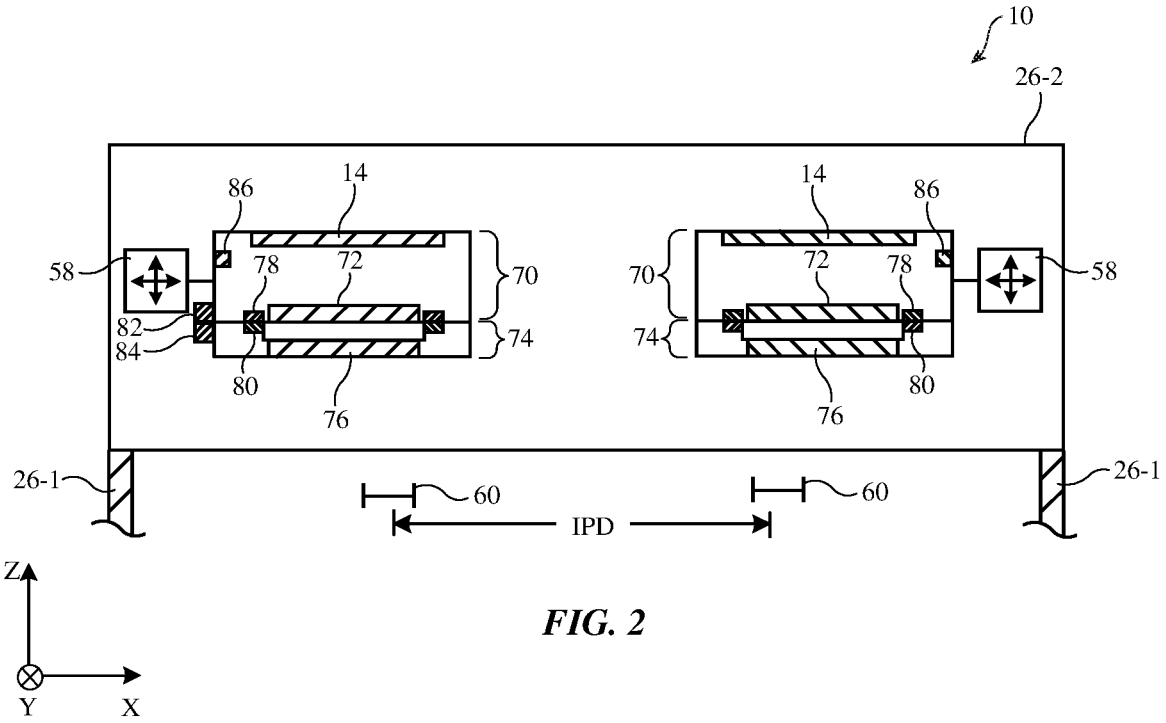


FIG. 2

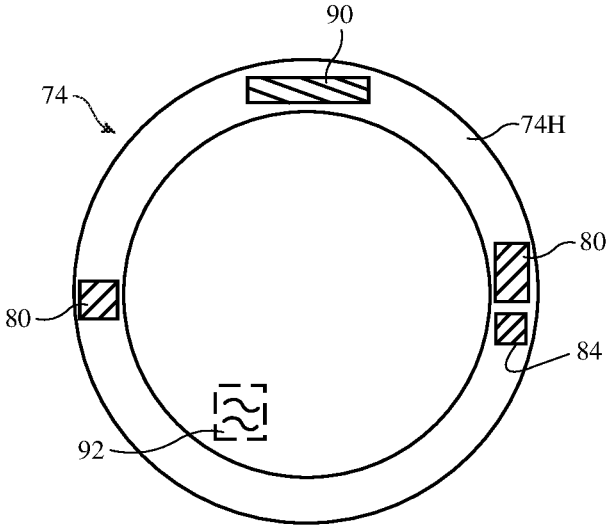


FIG. 3

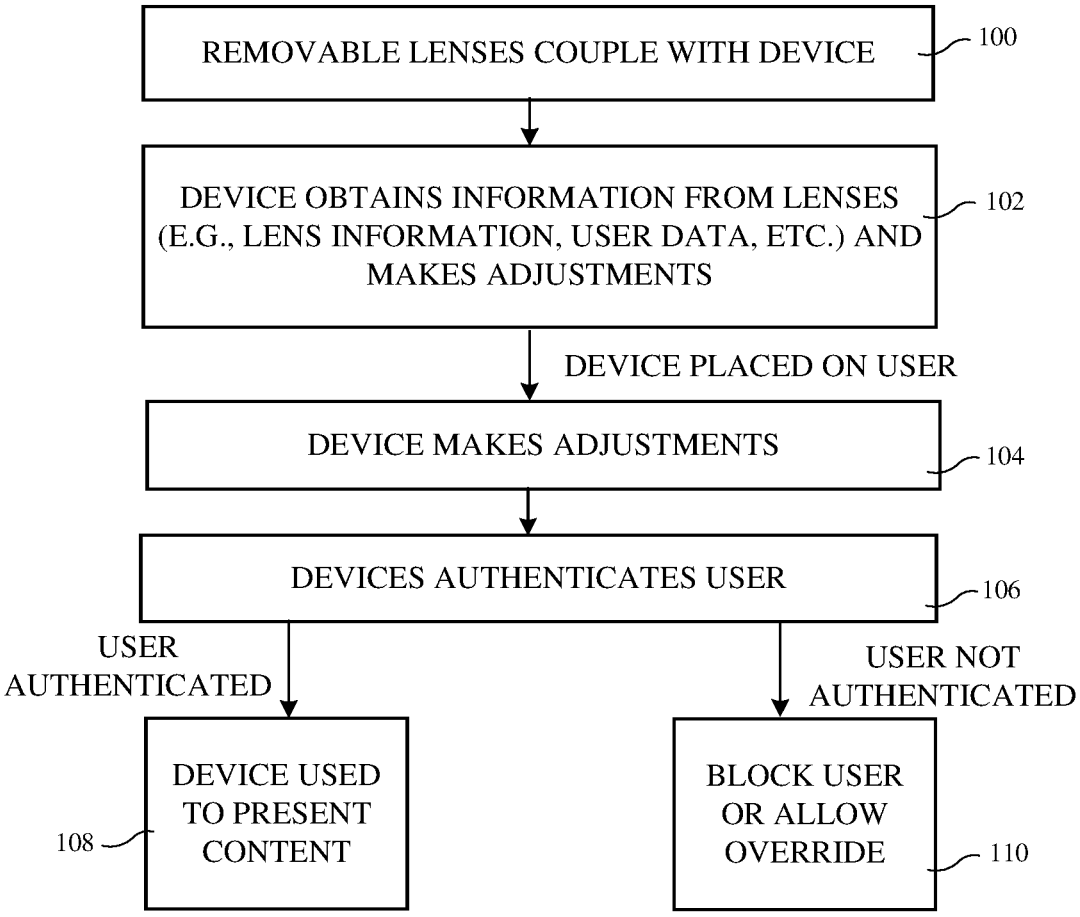

REMOVABLE LENSES COUPLE WITH DEVICE
100
DEVICE OBTAINS INFORMATION FROM LENSES (E.G., LENS INFORMATION, USER DATA, ETC.) AND MAKES ADJUSTMENTS
102
DEVICE PLACED ON USER
DEVICE MAKES ADJUSTMENTS
104
DEVICES AUTHENTICATES USER
106
USER AUTHENTICATED
USER NOT AUTHENTICATED
DEVICE USED TO PRESENT CONTENT
108
BLOCK USER OR ALLOW OVERRIDE
110

FIG. 4

ELECTRONIC DEVICE SYSTEM WITH SUPPLEMENTAL LENSES

[0001] This application claims the benefit of provisional patent application No. 62/712,108, filed Jul. 30, 2018, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

[0002] This relates generally to electronic devices and, more particularly, to wearable electronic device systems.

[0003] Electronic devices are sometimes configured to be worn by users. For example, head-mounted devices are provided with head-mounted structures that allow the devices to be worn on users' heads. The head-mounted devices may include optical systems with lenses. The lenses allow displays in the devices to present visual content to users.

[0004] Some users of head-mounted devices have visual defects such as myopia, hyperopia, astigmatism, or presbyopia. It can be challenging to ensure that an optical system in a head-mounted device operates satisfactorily for these users. If care is not taken, it may be difficult or impossible for a user with visual defects to focus properly on content that is being displayed.

SUMMARY

[0005] A head-mounted device may have a display that displays content for a user. Head-mounted support structures in the device may support the device on the head of the user. A non-removable lens system may be supported by the head-mounted support structures and may be used to present content on the display to eye boxes. The user may view the content when the user's eyes are located in the eye boxes.

[0006] The head-mounted support structures may be configured to receive a removable supplemental lens system in alignment with the non-removable lens system. Magnetic coupling structures or other engagement structures may be used to removably couple the supplemental lens system to the head-mounted device.

[0007] The removable supplemental lens system may be used to adjust the lens characteristics of the non-removable lens system and thereby customize the head-mounted display to accommodate the user's vision. For example, the removable supplemental lens system may include supplemental left and right lenses that align with and supplemental corresponding left and right lenses in the non-removable lens system and that include astigmatic lens characteristics and other characteristics that allow the head-mounted device to be used by a user with astigmatism or other visual defects.

[0008] Removable supplemental lens systems associated with different users may be configured to operate with a shared head-mounted device. To ensure that the head-mounted device can customize its operation for each user, the removable supplemental lens system of each user may be provided with information that identifies the user associated with that removable supplemental lens system and other stored information. This information be stored in the removable supplemental lens system using bar codes or other optically readable patterns, programmable memory, or other data storage. A memory reader, gaze tracking system, or other sensor may be used in retrieving the stored information.

[0009] The information that is stored in the removable supplemental lens system may include information on the optical characteristics of the removable supplemental lens system, user information such as the user's eyeglass prescription, and/or other information. When the removable supplemental lens system is installed in the head-mounted device, control circuitry in the head-mounted device may retrieve the stored information and may take appropriate action. For example, the control circuitry may use lens positioners to adjust lens spacing and other operating parameters of the lens systems based on the user's interpupillary distance and other information on the user.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a schematic diagram of an illustrative electronic device such as a head-mounted display device in accordance with an embodiment.

[0011] FIG. **2** is a top view of an illustrative head-mounted device in accordance with an embodiment.

[0012] FIG. **3** is a diagram of an illustrative removable supplemental lens in accordance with an embodiment.

[0013] FIG. **4** is a flow chart of illustrative operations associated with using a head-mounted device in accordance with an embodiment.

DETAILED DESCRIPTION

[0014] Electronic devices may include displays and other components for presenting content to users. The electronic devices may be wearable electronic devices. A wearable electronic device such as a head-mounted device may have head-mounted support structures that allow the head-mounted device to be worn on a user's head.

[0015] A head-mounted device may contain a display formed from one or more display panels (displays) for displaying visual content to a user. A lens system may be used to allow the user to focus on the display and view the visual content. To ensure that a wide range of users are able to clearly focus on the display and view visual content, the head-mounted device may receive removable supplemental lenses. The supplemental lenses may address the visual defects of users that are not otherwise addressed by the lens system. For example, a user with astigmatism may have supplemental lenses that correct for astigmatism. When this user desires to view content with the head-mounted device, the supplemental lenses may be installed within the head-mounted device to help correct for the user's astigmatism. With one illustrative arrangement, the supplemental lenses may be coupled to the head-mounted support structures using magnets or other removable fasteners that attach the supplemental lenses to non-removable lenses in the device.

[0016] If desired, removable supplemental lenses may be provided with the ability to store information that is subsequently retrieved and used by the head-mounted device. This information, which may sometimes be referred to as supplemental lens information or stored information may include lens power information and other information that is specific to the supplemental lenses and/or user information for a user associated with the lenses (e.g., a username, eyeglasses prescription information, etc.). Storage circuitry such as programmable read-only memory may be used to store the supplemental lens information and/or the supplemental lens information may be stored in other ways (e.g., using bar codes, text on the supplemental lenses, other patterned optically readable information, etc.). During operation, after a user has installed the supplemental lenses in a head-

mounted device, the head-mounted device may retrieve and use the supplemental lens information. For example, information on the optical characteristics of the lens may be used by the head-mounted device to help correct for optical aberrations in the lenses (e.g., spherical aberration, chromatic aberration, pincushion distortion, barrel distortion, etc.), information on the user may be used to adjust the interpupillary distance of lenses or may be used to present the user with a login screen that has been prepopulated with the user's username, etc.

[0017] A schematic diagram of an illustrative system that may use supplemental head-mounted display lenses is shown in FIG. **1**. As shown in FIG. **1**, system **8** may include one or more electronic devices such as electronic device **10**. The electronic devices of system **8** may include computers, cellular telephones, head-mounted devices, wristwatch devices, and other electronic devices. Configurations in which electronic device **10** is a head-mounted device are sometimes described herein as an example.

[0018] As shown in FIG. **1**, electronic devices such as electronic device **10** may have control circuitry **12**. Control circuitry **12** may include storage and processing circuitry for controlling the operation of device **10**. Circuitry **12** may include storage such as hard disk drive storage, nonvolatile memory (e.g., electrically-programmable-read-only memory configured to form a solid-state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **12** may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processors, power management units, audio chips, graphics processing units, application specific integrated circuits, and other integrated circuits. Software code may be stored on storage in circuitry **12** and run on processing circuitry in circuitry **12** to implement control operations for device **10** (e.g., data gathering operations, operations involved in processing three-dimensional facial image data, operations involving the adjustment of components using control signals, etc.). Control circuitry **12** may include wired and wireless communications circuitry. For example, control circuitry **12** may include radio-frequency transceiver circuitry such as cellular telephone transceiver circuitry, wireless local area network (WiFi®) transceiver circuitry, millimeter wave transceiver circuitry, and/or other wireless communications circuitry.

[0019] During operation, the communications circuitry of the devices in system **8** (e.g., the communications circuitry of control circuitry **12** of device **10**), may be used to support communication between the electronic devices. For example, one electronic device may transmit video and/or audio data to another electronic device in system **8**. Electronic devices in system **8** may use wired and/or wireless communications circuitry to communicate through one or more communications networks (e.g., the internet, local area networks, etc.). The communications circuitry may be used to allow data to be received by device **10** from external equipment (e.g., a tethered computer, a portable device such as a handheld device or laptop computer, online computing equipment such as a remote server or other remote computing equipment, or other electrical equipment) and/or to provide data to external equipment.

[0020] Device **10** may include input-output devices **22**. Input-output devices **22** may be used to allow a user to provide device **10** with user input. Input-output devices **22** may also be used to gather information on the environment in which device **10** is operating. Output components in devices **22** may allow device **10** to provide a user with output and may be used to communicate with external electrical equipment.

[0021] As shown in FIG. **1**, input-output devices **22** may include one or more displays such as display(s) **14**. In some configurations, display **14** of device **10** includes left and right display panels in alignment with the user's left and right eyes, respectively. In other configurations, display **14** includes a single display panel that extends across both eyes.

[0022] Display **14** may be used to display images. The visual content that is displayed on display **14** may be viewed by a user of device **10**. Displays in device **10** such as display **14** may be organic light-emitting diode displays or other displays based on arrays of light-emitting diodes, liquid crystal displays, liquid-crystal-on-silicon displays, projectors or displays based on projecting light beams on a surface directly or indirectly through specialized optics (e.g., digital micromirror devices), electrophoretic displays, plasma displays, electrowetting displays, or any other suitable displays.

[0023] Display **14** may present computer-generated content such as virtual reality content and mixed reality content to a user. Virtual reality content may be displayed in the absence of real-world content. Mixed reality content, which may sometimes be referred to as augmented reality content, may include computer-generated images that are overlaid on real-world images. The real-world images may be captured by a camera (e.g., a forward-facing camera) and merged with overlaid computer-generated content or an optical coupling system may be used to allow computer-generated content to be overlaid on top of real-world images. As an example, a pair of mixed reality glasses or other augmented reality head-mounted display may include a display device that provides images to a user through a beam splitter, prism, holographic coupler, or other optical coupler. Configurations in which display **14** is used to display virtual reality content to a user through lenses are described herein as an example.

[0024] Input-output circuitry **22** may include sensors **16**. Sensors **16** may include, for example, three-dimensional sensors (e.g., three-dimensional image sensors such as structured light sensors that emit beams of light and that use two-dimensional digital image sensors to gather image data for three-dimensional images from light spots that are produced when a target is illuminated by the beams of light, binocular three-dimensional image sensors that gather three-dimensional images using two or more cameras in a binocular imaging arrangement, three-dimensional lidar (light detection and ranging) sensors, three-dimensional radio-frequency sensors, or other sensors that gather three-dimensional image data), cameras (e.g., infrared and/or visible digital image sensors), gaze tracking sensors (e.g., a gaze tracking system based on an image sensor and, if desired, a light source that emits one or more beams of light that are tracked using the image sensor after reflecting from a user's eyes), touch sensors, buttons, capacitive proximity sensors, light-based (optical) proximity sensors, other proximity sensors, force sensors, sensors such as contact sensors based on switches, gas sensors, pressure sensors, moisture sensors, magnetic sensors, audio sensors (microphones), ambient light sensors, microphones for gathering voice commands and other audio input, sensors that are configured to gather information on motion, position, and/or orientation (e.g., accelerometers, gyroscopes, compasses, and/or inertial mea-

surement units that include all of these sensors or a subset of one or two of these sensors), and/or other sensors.

[0025] User input and other information may be gathered using sensors and other input devices in input-output devices **22**. If desired, input-output devices **22** may include other devices **24** such as haptic output devices (e.g., vibrating components), light-emitting diodes and other light sources, speakers such as ear speakers for producing audio output, and other electrical components. Device **10** may include circuits for receiving wireless power, circuits for transmitting power wirelessly to other devices, batteries and other energy storage devices (e.g., capacitors), joysticks, buttons, and/or other components.

[0026] Electronic device **10** may have housing structures (e.g., housing walls, straps, etc.), as shown by illustrative support structures **26** of FIG. **1**. In configurations in which electronic device **10** is a head-mounted device (e.g., a pair of glasses, goggles, a helmet, a hat, etc.), support structures **26** may include head-mounted support structures (e.g., a helmet housing, head straps, temples in a pair of eyeglasses, goggle housing structures, and/or other head-mounted structures). The head-mounted support structures may be configured to be worn on a head of a user during operation of device **10** and may support display(s) **14**, sensors **16**, other components **24**, other input-output devices **22**, and control circuitry **12**.

[0027] FIG. **2** is a top view of electronic device **10** in an illustrative configuration in which electronic device **10** is a head-mounted device. As shown in FIG. **2**, electronic device **10** may include support structures (see, e.g., support structures **26** of FIG. **1**) that are used in housing the components of device **10** and mounting device **10** onto a user's head. These support structures may include, for example, structures that form housing walls and other structures for main unit **26-2** and straps or other supplemental support structures such as structures **26-1** that help to hold main unit **26-2** on a user's face so that the user's eyes are located within eye boxes **60**.

[0028] Display **14** may include left and right display panels (e.g., left and right pixel arrays, sometimes referred to as left and right displays) that are mounted respectively in left and right display modules **70** corresponding respectively to a user's left eye (and left eye box **60**) and right eye (and right eye box). Modules **70**, which may sometimes be referred to as lens support structures or lens housings, may be individually positioned relative to the housing wall structures of main unit **26-2** and relative to the user's eyes using respective left and right positioners **58** (e.g., stepper motors, piezoelectric actuators, motors, linear electromagnetic actuators, and/or other electronic components for adjusting position). Positioners **58** may be controlled by control circuitry **12** during operation of device **10**. For example, positioners **58** may be used to adjust the spacing between modules **70** (and therefore the lens-to-lens spacing between the lenses of modules **70**) to match the interpupillary distance IPD of a user's eyes.

[0029] Device **10** may include a non-removable lens system (sometimes referred to as a permanent lens system or fixed lens system) to which the user of device **10** may attach removable supplemental lenses to accommodate the user's vision (astigmatism, etc.). When the removable supplemental lenses are absent, a user may use the non-removable lens system. Users with particular visual defects (e.g., astigmatism), may benefit from the attachment of the removable supplemental lenses to the non-removable lenses. When the supplemental lenses are coupled to device **10** in alignment with the non-removable lenses, the supplemental lenses and non-removable lenses operate together to form a combined lens system with combined optical properties determined by both the non-removable lenses and the supplemental lenses.

[0030] As shown in FIG. **2**, for example, each lens module **70** may include a non-removable lens **72**. Lenses **72** may be Fresnel lenses, single-element or multiple-element lenses formed from clear materials such as glass or plastic, mirror lenses, catadioptric lenses, and/or lenses of other types. The position of lenses **72** along the X axis may be adjusted so that lenses **72** are separated by a distance that matches the user's interpupillary distance (distance IPD). The position of lenses **72** along the Z axis may be adjusted to help a user focus on display **14**.

[0031] The amount of travel available to lenses **72** may be limited and/or lenses **72** may have attributes that make it difficult for lenses **72** alone to be used to view content on display **14** by all users. For example, a user may have astigmatism or may be strongly nearsighted or farsighted. In situations such as these, lenses **72** when used alone may not be able to correct for the user's vision. To ensure that the user's vision is fully corrected, supplemental lenses **76** may be coupled to lenses **72** to provide further adjustments. For example, if a user is astigmatic, supplemental lenses **76** may be configured to compensate for the astigmatism of the user. If there are multiple users associated with device **10**, each of the multiple users may potentially have a different respective set of supplemental lenses **76**. Lenses **76** may be joined together to form a supplemental lens system based on a single supplemental lens module or may be housed in separate lens modules that form a multi-lens-module supplemental lens system.

[0032] As shown in FIG. **2**, for example, supplemental lenses **76** may be mounted in supplemental lens modules (sometimes referred to as supplemental lens support structures or housings) such as supplemental lens modules **74**. Lens modules **74** may be removably coupled to support structures **26** by using coupling structures **78** in non-removable lens modules **70** and corresponding coupling structures that mate with coupling structures **78** such as coupling structures **80** in removable lens modules **74** to couple lens modules **74** to lens modules **70**. Coupling structures **78** and **80** may be formed from magnetic couplers (e.g., magnets and/or magnetic structures such as iron bars), clips, hook-and-loop fasteners, snaps, screws and other threaded fasteners, temporary adhesive, spring-loaded engagement structures, and/or other coupling mechanisms.

[0033] Device **10** may include a gaze detection system that is configured to monitor a user's eyes in eye boxes **60**. The gaze detection system may, as an example, use optical eye monitoring components to monitor the user's direction of gaze as the user is using device **10**. With one illustrative configuration, a gaze tracker such a gaze tracker **86** may be located in each lens module **70**. In this position, the gaze tracker **86** in each lens module **70** may monitor a user's eye in a respective eye box **60** through a respective lens **72** and a respective mating supplemental lens **76**. Gaze trackers **86** may be placed at peripheral portions of lens modules **70** so that gaze trackers **86** do not block the user's view of display **14** through removable lenses **76** and non-removable lenses **72**.

[0034] If desired, the removable lens system of FIG. **2** (e.g., one or both of lens modules **74** and/or a single removable lens holder that is configured to support both of removable lenses **76**) may be provided with electronic storage such as storage **84**. Storage **84** may be programmable read-only memory (e.g., electrically programmable read-only memory, memory formed from laser-programmed fuses, and/or other programmable memory), may be formed from a pattern of metal traces and/or resistive elements (e.g., to encode information in the form of a pattern of conductive paths, a pattern of resistors and/or their associated resistance values, and/or other circuitry that is configured to serve as storage that stores data in the removable lenses for electrical retrieval by device **10**). Storage **84**, which may be formed as part of the removable lens system (e.g., as part of one or more of modules **74** and associated removable lenses **76**), may be used in storing lens information, user information, and/or other information electrically. When the removable lens system is coupled to the non-removable lens system (e.g., one or both lens modules **70** such as storage **84**), electrically stored information reader **82** may retrieve the data stored in storage **84**. Information reader **82** may be, for example, an electrically programmed read-only memory reader, a memory reader that reads laser-programmed storage or other programmable memory, circuitry that electrically measures storage **84** (e.g., to detect a pattern of conductive traces and/or resistive elements that are being used to store data), and/or other reader circuitry.

[0035] Information such as lens information, user information, and other information may also be stored using non-electrical storage. This storage may include, for example, bar codes, text, patterns of dots, and/or other information that can be detected optically. Optical data reading operations may be performed using infrared and/or visible cameras or other equipment (e.g., bar code scanning equipment) that reads optically encoded information. As an example, optical data reading equipment that reads data on the removable lens by imaging the removable lens such as infrared digital image sensors in gaze tracking sensors **86** and/or visible-light digital image sensors may be used in reading bar codes, text, and/or other optically encoded information.

[0036] Gaze trackers **86** (sometimes referred to as gaze monitoring systems, gaze tracking systems, eye monitoring systems, etc.) may monitor the eyes of the user in eye boxes **60** during operation of device **10**. Gaze trackers **86** may include light sources and light-detecting components such as image sensors. Each gaze tracker **86** may, as an example, include a light source such as a light-emitting diode light source or laser light source that produces an array of light beams (e.g., infrared light beams that do not interfere with the vision of the user). Blanket (flood) illumination at infrared and/or visible wavelengths may also be provided. Each gaze tracker **86** may also include a respective infrared image sensor (and/or visible-light image sensor) that faces a user's eye in a respective eye box **60** and capture images of the user's eye through lenses **72** and lenses **76** while the user's eye is being illuminated with the light beams from the light source of that gaze tracker. During normal operation, control circuitry **20** may use gaze trackers **86** to track a user's gaze (e.g., so that images being displayed on displays **14** can be adjusted based on the direction of the user's gaze, etc.). When it is desired to read information in the removable lens system that has been optically stored (e.g., by encoding the information in the form of a bar code, text, etc.), one or more image sensors such as one or more infrared image sensors in one or more gaze trackers **86** may optically read the information from the supplemental lens system (e.g., from one or more lens modules **74**).

[0037] FIG. **3** is a front view of an illustrative removable lens module showing arrangements that may be used to store information in the lens module. As shown in FIG. **3**, lens module **74** may include lens support structures **74**H. Support structures **74**H may be formed from polymer, metal, and/or other materials and may surround or otherwise support lens **76** to form lens module **74**. Coupling structures **80** may be supported by support structures **74**H, so that coupling structures **80** hold lens module **74** to lens module **70** and support structures **26** when coupling structures **80** are coupled to mating coupling structures **78** in lens module **70**.

[0038] Lens information, user information, and other information can be stored in removable lens module **74** using one or more approaches. With one illustrative arrangement, electrical storage **84** is included in lens module **74**. Data may be stored in electrical storage **84**. When removable lens module **74** is coupled to non-removable lens module **70**, reader **82** may couple to electrical storage **84** and may retrieve the stored data from electrical storage **84**.

[0039] With another illustrative arrangement, a bar code such as bar code **92** may be included in lens module **74**. Bar code **92** may, as an example, be an infrared bar code that is formed from an ink that is visibly transparent while being opaque to infrared light (e.g., infrared light at the wavelength emitted by an infrared light source in gaze tracker **86**) or other bar code structure that is transparent to visible light and opaque at infrared wavelengths. With this type of arrangement, bar code **92** will be transparent to the user and will not interfere with the user's viewing of content on display **14**, even though bar code **92** is formed on lens **76**. At the same time, gaze tracker **86** is pointed towards lens **76** so that gaze tracker **86** may capture an image of bar code **92** at infrared wavelengths.

[0040] Bar codes, text information, or other visible-light (and/or infrared light) markings may be formed from laser markings, patterned ink, patterned metal coatings, and/or other markings formed in regions such as region **90**. Visible-light-encoded information of this type (e.g., information stored optically) may be read by a visible light image sensor in lens module **70** or an image sensor elsewhere in device **10** (e.g., a visible light image sensor in sensors **16**). In some situations, visible-light-encoded information such as text, icons, or other optically readable patterns may contain information that is recognizable to a user (e.g., text that a user can read such as the user's name or user name, an icon that a user can recognize, etc.). User recognizable information may be used to label lens modules **74** so that lens modules that belong to different users are not mixed up. An image sensor in device **10** (e.g., an image sensor in gaze tracker **87** and/or other image sensors) may optically read text, icons, or other patterned structures on the removable lens system that are also recognizable to the user and/or the image sensor may read patterns such as bar codes and other patterns that do not contain user-recognizable text or icons.

[0041] In some situations, it may be desirable to encrypt the information that is being stored in removable lens module **74**. Stored information may be encrypted using a cryptographic key. Control circuitry **12** can decrypt the encrypted information using a corresponding cryptographic

key suitable for decryption (which may be the same as the encrypting key or may be related to the encrypting key). Control circuitry **12** can obtain the key from the user (e.g., using input-output devices **22**). If desired, control circuitry **12** can obtain the key from a remote server (e.g., an online service). A user password, username, or other information may, if desired, be gathered from the user and/or storage in device **10** and may be used by control circuitry **12** in obtaining the key from the online service. In some arrangements, keys may be stored in control circuitry **12** for use in decrypting encrypted information stored in lens module **74** (e.g., when device **10** is only used by the members of a single household). These illustrative arrangements and/or other arrangements for encrypting and decrypting the information stored in removable lens module **74** may be used to enhance privacy for stored user information.

[0042] Illustrative steps involved in using system **8** are shown in FIG. **4**.

[0043] During the operations of block **100**, a user who desires to use device **10** but who has specific visual defects (astigmatism, etc.) may attach a removable lens system that is associated with that user to device **10**. During attachment of the removable lens system, removable lens support structures such as lens modules **74** may be aligned with non-removable lens support structures such as lens modules **70**, so that lenses **76** are aligned with corresponding lenses **72**. Coupling structures **82** and **84** may be used to hold lens modules **74** and **72** together. The presence of lenses **76** in alignment with lenses **72** allows the optical properties of lenses **76** to modify the optical properties of lenses **72** (e.g., to increase or decrease lens power, to add lens asymmetry to compensate for user astigmatism, etc.). In this way, the optical system of device **10** may be tailored to the user's vision.

[0044] During the operations of block **102**, control circuitry **12** of head-mounted device **10** may read information that has been stored in the removable lens system (e.g., using gaze trackers **86**, a visible-light image sensor, a memory reader such as reader **82**, etc.). The information that is read may be stored using a bar code, text, other optically readable patterns (e.g., patterned ink, patterned metal, or other patterned structures), and/or using electrical data storage arrangements (see, e.g., bar code **92**, visible information **90**, and electrically stored information in storage **84** of FIG. **3**).

[0045] In general, any suitable data may be stored in the removable lens system. This information may include, for example, information regarding the user that is associated with the removable lens system such as the user's eyeglass prescription (e.g., the spherical component of the user's prescription to be handled by spherical lens power, the astigmatic component of the user's prescription to be handled by an aspherical lens power, and/or the interpupillary distance of the user's prescription), the date of the prescription, the expiration date of the prescription, the user's username and other user credentials, manufacturing information such as the date of manufacture of the removable lens system, the name of the manufacturer, a serial number, a lot number, and a model name or other model type information, lens materials for lenses **76**, lens powers (e.g., spherical lens power and/or aspherical lens power) and/or other optical characteristics of lenses **76** such as known aberrations that can be later corrected using compensating image warping operations performed by control circuitry **12** during video playback, and/or other information.

[0046] After reading this information from the removable lens system during the operations of block **102**, control circuitry **12** may, if desired, make adjustments to the components in device **10**. These adjustments may be made based on real-time measurements from gaze trackers **86** and/or based on the stored data obtained from the removable lens system. For example, control circuitry **12** may use positioners **58** to adjust lens-to-lens spacing based on real-time measurements of the user's interpupillary distance determined from the positions of the user's pupils measured with gaze trackers **86** and/or based on stored interpupillary distance information for the user that is obtained from removable lens modules **74**. Control circuitry **12** may also adjust the positions of the lenses in device **10** along the Z axis of FIG. **2** to place lenses **72** and associated supplemental lenses **76** in a satisfactory location to allow the user to view content on displays **14**. These focusing adjustments with lenses **72** and **76** may be made based on the user's prescription, the powers of lenses **76**, and other information obtained using the stored information in lenses **76**. In arrangements in which lenses **72** have adjustable power (e.g., when lenses **72** are tunable lenses), control circuitry **12** can adjust lenses **72** to implement the spherical component of the user's prescription. The asymmetric component of a user's prescription may be handled using the asymmetric portion of supplemental lenses **76** (as an example).

[0047] After making adjustments to device **10** based on information from the supplemental lens system formed from lenses **76**, a user may place device **10** on the user's head.

[0048] During the operations of block **104**, control circuitry **12** may make further adjustments to the components in device **10**. For example, control circuitry **12** may use positioners **58** to adjust the lens-to-lens separation of left and right lenses **72** (and left and right lenses **76**) based on information from sensors in device **10** (e.g., based on a measured interpupillary distance gathered using gaze trackers **86**).

[0049] During the operations of block **104**, an iris scanner, fingerprint sensor, input-output devices that gather username and password information, or other components may be used in authenticating the user. The user may, for example, be directed to supply a username and password so that control circuitry **12** can establish a communications link with an online service that provides media content (block **108**). If the user is not authenticated by control circuitry **12** (e.g., if the user' username and password or other credentials (biometric information, etc.) are not authenticated, control circuitry **12** can, during the operations of block **110**, prevent the user from accessing the online service, selectively block content, and/or take other suitable action. If desired, the user may be allowed to override the authentication process at block **110** and/or additional authentication techniques may be used in scenarios in which the user fails authentication during the operations block **106**.

[0050] In some configurations of device **10**, lenses **76** may carry user information (e.g., user game preferences, user movie preferences, etc.). In these configurations, control circuitry **12** can refrain from decoding this information until the user has been authenticated during the operations of block **106** and an appropriate decryption key has been obtained (e.g., the user's password).

[0051] In some embodiments, user information is stored by control circuitry **12**. The user information may include information on a user's eye glasses prescription (e.g., a

required optical prescription strength). The information stored in lenses **76** may include information on the optical prescription strength of lenses **76**. After determining the user of device **10** and retrieving the user's stored prescription from control circuitry **12**, control circuitry **12** may compare this retrieved user prescription information with the prescription of lenses **76** to determine if there is a satisfactory match. In the event that the prescription of lenses **76** does not match the user's prescription, control circuitry **12** may use display **14** and/or other output circuitry to issue a visible and/or audible alert for the user and may, if desired, decline to display content on display **14**.

[0052] In scenarios in which optical aberration information is included in the information stored in lenses **76** (e.g., information indicating that lenses **76** have a particular amount of barrel distortion, pincushion distortion, spherical aberration, chromatic aberration, etc.), control circuitry **12** may, during the playback operations of block **108**, apply geometric transformations or other video processing to the content being displayed on display **14** that compensates for this distortion. In this way, a user may view content that is free or nearly free of aberrations. If, as an example, lenses **76** exhibit pincushion distortion of a particular amount, information on this amount of pincushion distortion can be stored in lenses **76**. During playback operations, control circuitry **12** can apply compensating (barrel) image warping to the content for display **14** to ensure that the displayed content exhibits low distortion and aberrations, thereby enhancing the content viewing experience for the user. In general, control circuitry **12** may apply any image processing correction that helps enhance image quality and the user's viewing experience. For example, corrections can be applied to correct for chromatic aberration, spherical aberration, etc.

[0053] As described above, one aspect of the present technology is the gathering and use of information gathered from a removable supplemental lens to enhance operation of a head-mounted display. The present disclosure contemplates that in some instances, this gathered data may include personal information data that uniquely identifies or can be used to contact or locate a specific person. Such personal information data can include demographic data, location-based data, telephone numbers, email addresses, twitter ID's, home addresses, data or records relating to a user's health or level of fitness (e.g., vital signs measurements, medication information, exercise information), date of birth, eyeglasses prescription, username, password, biometric information, interpupillary distance, or any other identifying or personal information.

[0054] The present disclosure recognizes that the use of such personal information, in the present technology, can be used to the benefit of users. For example, the personal information data can be used to deliver targeted content that is of greater interest to the user. Accordingly, use of such personal information data enables users to calculated control of the delivered content. Further, other uses for personal information data that benefit the user are also contemplated by the present disclosure. For instance, health and fitness data may be used to provide insights into a user's general wellness, or may be used as positive feedback to individuals using technology to pursue wellness goals.

[0055] The present disclosure contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining personal information data private and secure. Such policies should be easily accessible by users, and should be updated as the collection and/or use of data changes. Personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection/sharing should occur after receiving the informed consent of the users. Additionally, such entities should consider taking any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices. In addition, policies and practices should be adapted for the particular types of personal information data being collected and/or accessed and adapted to applicable laws and standards, including jurisdiction-specific considerations. For instance, in the United States, collection of or access to certain health data may be governed by federal and/or state laws, such as the Health Insurance Portability and Accountability Act (HIPAA), whereas health data in other countries may be subject to other regulations and policies and should be handled accordingly. Hence different privacy practices should be maintained for different personal data types in each country.

[0056] Despite the foregoing, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services or anytime thereafter. In another example, users can select not to provide certain types of user data. In yet another example, users can select to limit the length of time user-specific data is maintained. In addition to providing "opt in" and "opt out" options, the present disclosure contemplates providing notifications relating to the access or use of personal information. For instance, a user may be notified upon downloading an application ("app") that their personal information data will be accessed and then reminded again just before personal information data is accessed by the app.

[0057] Moreover, it is the intent of the present disclosure that personal information data should be managed and handled in a way to minimize risks of unintentional or unauthorized access or use. Risk can be minimized by limiting the collection of data and deleting data once it is no longer needed. In addition, and when applicable, including in certain health related applications, data de-identification can be used to protect a user's privacy. De-identification may be facilitated, when appropriate, by removing specific identifiers (e.g., date of birth, etc.), controlling the amount or specificity of data stored (e.g., collecting location data at a city level rather than at an address level), controlling how data is stored (e.g., aggregating data across users), and/or other methods.

[0058] Therefore, although the present disclosure broadly covers use of personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing such personal information data. That is, the various embodiments of the present technology are not rendered inoperable due to the lack of all or a portion of such personal information data.

[0059] In accordance with an embodiment, a system is provided that includes a head-mounted support structure, a display coupled to the head-mounted support structure, control circuitry configured to supply content using the display, a non-removable lens coupled to the head-mounted support structure that is configured to present the content from the display in an eye box, and a removable supplemental lens removably coupled to head-mounted support structure between the non-removable lens and the eye box, the removable supplemental lens is configured to store information that is retrieved by the control circuitry.

[0060] In accordance with another embodiment, the system includes a gaze tracking system having a light emitter and an infrared image sensor, the removable supplemental lens has a bar code that stores the information, the bar code is opaque at infrared wavelengths and transparent at visible wavelengths, and the image sensor is configured to read the bar code while the removable supplemental lens is removably coupled to the head-mounted support structure.

[0061] In accordance with another embodiment, the bar code includes infrared-opaque-and-visible-light-transparent ink on a clear lens element in the removable supplemental lens.

[0062] In accordance with another embodiment, the information includes information selected from the group consisting of an eyeglass prescription, an eyeglass prescription date of expiration, a username, a manufacturing date, a manufacturer, a serial number, a manufacturing lot number, a model name, a model type, and information on optical characteristics of the removable supplemental lens.

[0063] In accordance with another embodiment, the system includes a data reading device coupled to the head-mounted support structure, the control circuitry is configured to use the data reading device to obtain the information from the removable supplemental lens.

[0064] In accordance with another embodiment, the information includes an eyeglasses prescription.

[0065] In accordance with another embodiment, the removable supplemental lens includes memory and the data reading device is configured to obtain the information from the memory.

[0066] In accordance with another embodiment, the removable supplemental lens includes text and the data reading device is configured to obtain the information by optically reading the text.

[0067] In accordance with another embodiment, the removable supplemental lens includes circuitry configured to store data and the data reading device is configured to obtain the information from the circuitry.

[0068] In accordance with another embodiment, the removable supplemental lens includes programmable read only memory, the data reading device is configured to obtain the information from the programmable read only memory, and the information includes a lens characteristics of the removable supplemental lens.

[0069] In accordance with another embodiment, the lens characteristic includes a lens power associated with the removable supplemental lens.

[0070] In accordance with another embodiment, the lens characteristic includes an aspherical lens power associated with the removable supplemental lens.

[0071] In accordance with another embodiment, the lens characteristic includes an optical aberration associated with the removable supplemental lens.

[0072] In accordance with another embodiment, the control circuitry is configured to obtain the information when the removable supplemental lens is coupled to the head-mounted support structure.

[0073] In accordance with another embodiment, the information includes information selected from the group consisting of a username, a serial number, optical characteristics of the removable supplemental lens, and eyeglass prescription information.

[0074] In accordance with an embodiment, a head-mounted device, is provided that includes head-mounted support structures, a display configured to display content, left and right positioners, a non-removable lens system having left and right lenses that are positioned respectively by the left and right positioners, a removable lens system with removable supplemental left and right lenses that are removably coupled to the head-mounted support structures in alignment respectively with the right and left lenses, and control circuitry configured to obtain information stored in the removable lens system.

[0075] In accordance with another embodiment, the information includes an interpupillary distance for a user and the control circuitry is configured to use the left and right positioners to adjust a lens-center-to-lens-center spacing associated with the left and right lenses to match the interpupillary distance.

[0076] In accordance with another embodiment, the head-mounted device includes an optically readable pattern on the removable lens system that stores the information.

[0077] In accordance with another embodiment, the head-mounted device includes an image sensor that optically reads the optically readable pattern to retrieve the information from the removable lens system.

[0078] In accordance with another embodiment, the image sensor includes an infrared image sensor in a gaze tracking system.

[0079] In accordance with another embodiment, the information includes a user's eyeglass prescription and the control circuitry is configured to adjust the left and right positioners based on the user's eyeglass prescription.

[0080] In accordance with an embodiment, an electronic device configured to operate with a removable supplemental lens system is provided that includes a display that displays content, control circuitry, a non-removable lens system configured to allow the display content to be viewed from eye boxes, a removable supplemental lens system, and head-mounted support structures that support the display and that support the non-removable lens system between the eye boxes and the display, the removable supplemental lens system is configured to be supported between the non-removable lenses and the eye boxes, the removable supplemental lens system is configured to store information, and the control circuitry is configured to obtain the information from the removable supplemental lens system when the

removable supplemental lens system is between the non-removable lenses and the eye boxes.

[0081] In accordance with another embodiment, the electronic device includes lens positioners, the control circuitry is configured to use the lens positioners to adjust a lens-to-lens spacing associated with left and right lenses in the non-removable lens system based on the information obtained from the removable supplemental lens system.

[0082] In accordance with another embodiment, the information includes an optical prescription associated with the removable supplemental lens system and the control circuitry is configured to issue an alert to a user in response to determining that there is a mismatch between the user's prescription and the optical prescription associated with the removable supplemental lens system.

[0083] In accordance with another embodiment, the information includes distortion information specifying an optical distortion associated with the supplemental lens system and the control circuitry is configured to apply a compensating correction to the content being displayed on the display based on the distortion information.

[0084] The foregoing is merely illustrative and various modifications can be made to the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. A system, comprising:

a head-mounted support structure;

a display coupled to the head-mounted support structure;

control circuitry configured to supply content using the display;

a non-removable lens coupled to the head-mounted support structure that is configured to present the content from the display in an eye box; and

a removable supplemental lens removably coupled to head-mounted support structure between the non-removable lens and the eye box, wherein the removable supplemental lens is configured to store information that is retrieved by the control circuitry.

2. The system defined in claim **1** further comprising:

a gaze tracking system having a light emitter and an infrared image sensor, wherein the removable supplemental lens has a bar code that stores the information, wherein the bar code is opaque at infrared wavelengths and transparent at visible wavelengths, and wherein the image sensor is configured to read the bar code while the removable supplemental lens is removably coupled to the head-mounted support structure.

3. The system defined in claim **2** wherein the bar code comprises infrared-opaque-and-visible-light-transparent ink on a clear lens element in the removable supplemental lens.

4. The system defined in claim **3** wherein the information comprises information selected from the group consisting of: an eyeglass prescription, an eyeglass prescription date of expiration, a username, a manufacturing date, a manufacturer, a serial number, a manufacturing lot number, a model name, a model type, and information on optical characteristics of the removable supplemental lens.

5. The system defined in claim **1** further comprising a data reading device coupled to the head-mounted support structure, wherein the control circuitry is configured to use the data reading device to obtain the information from the removable supplemental lens.

6. The system defined in claim **5** wherein the information comprises an eyeglasses prescription.

7. The system defined in claim **5** wherein the removable supplemental lens includes memory and wherein the data reading device is configured to obtain the information from the memory.

8. The system defined in claim **5** wherein the removable supplemental lens comprises text and wherein the data reading device is configured to obtain the information by optically reading the text.

9. The system defined in claim **5** wherein the removable supplemental lens includes circuitry configured to store data and wherein the data reading device is configured to obtain the information from the circuitry.

10. The system defined in claim **5** wherein the removable supplemental lens includes programmable read only memory, wherein the data reading device is configured to obtain the information from the programmable read only memory, and wherein the information comprises a lens characteristics of the removable supplemental lens.

11. The system defined in claim **10** wherein the lens characteristic comprises a lens power associated with the removable supplemental lens.

12. The system defined in claim **10** wherein the lens characteristic comprises an aspherical lens power associated with the removable supplemental lens.

13. The system defined in claim **10** wherein the lens characteristic comprises an optical aberration associated with the removable supplemental lens.

14. The system defined in claim **1** wherein the control circuitry is configured to obtain the information when the removable supplemental lens is coupled to the head-mounted support structure.

15. The system defined in claim **14** wherein the information comprises information selected from the group consisting of a username, a serial number, optical characteristics of the removable supplemental lens, and eyeglass prescription information.

16. A head-mounted device, comprising:

head-mounted support structures;

a display configured to display content;

left and right positioners;

a non-removable lens system having left and right lenses that are positioned respectively by the left and right positioners;

a removable lens system with removable supplemental left and right lenses that are removably coupled to the head-mounted support structures in alignment respectively with the right and left lenses; and

control circuitry configured to obtain information stored in the removable lens system.

17. The head-mounted device defined in claim **16** wherein the information comprises an interpupillary distance for a user and wherein the control circuitry is configured to use the left and right positioners to adjust a lens-center-to-lens-center spacing associated with the left and right lenses to match the interpupillary distance.

18. The head-mounted device defined in claim **17** further comprising an optically readable pattern on the removable lens system that stores the information.

19. The head-mounted device defined in claim **18** further comprising an image sensor that optically reads the optically readable pattern to retrieve the information from the removable lens system.

20. The head-mounted device defined in claim **19** wherein the image sensor comprises an infrared image sensor in a gaze tracking system.

21. The head-mounted device defined in claim **16** wherein the information comprises a user's eyeglass prescription and wherein the control circuitry is configured to adjust the left and right positioners based on the user's eyeglass prescription.

22. An electronic device configured to operate with a removable supplemental lens system, comprising:

a display that displays content;

control circuitry;

a non-removable lens system configured to allow the display content to be viewed from eye boxes;

a removable supplemental lens system; and

head-mounted support structures that support the display and that support the non-removable lens system between the eye boxes and the display, wherein the removable supplemental lens system is configured to be supported between the non-removable lenses and the eye boxes, wherein the removable supplemental lens system is configured to store information, and wherein the control circuitry is configured to obtain the information from the removable supplemental lens system when the removable supplemental lens system is between the non-removable lenses and the eye boxes.

23. The electronic device defined in claim **22** further comprising lens positioners, wherein the control circuitry is configured to use the lens positioners to adjust a lens-to-lens spacing associated with left and right lenses in the non-removable lens system based on the information obtained from the removable supplemental lens system.

24. The electronic device defined in claim **22** wherein the information comprises an optical prescription associated with the removable supplemental lens system and wherein the control circuitry is configured to issue an alert to a user in response to determining that there is a mismatch between the user's prescription and the optical prescription associated with the removable supplemental lens system.

25. The electronic device defined in claim **22** wherein the information includes distortion information specifying an optical distortion associated with the supplemental lens system and wherein the control circuitry is configured to apply a compensating correction to the content being displayed on the display based on the distortion information.

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