EYEWEAR DEVICE FACE TRACKING

Abstract

A wearable or a mobile device includes a camera to capture an image of a scene with a face and a display for displaying an image overlaid on the face. Execution of programming by a processor configures the device to perform functions, including functions to capture, via a camera of an eyewear device, an image of a scene including a face, identify the face in the image of the scene, track positional information of the face with respect to the eyewear device, generate an overlay image responsive the positional information, and present the overlay image on an image display.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a Continuation of U.S. application Ser. No. 18/378,268 filed on Oct. 10, 2023, which is a Continuation of U.S. application Ser. No. 16/950,045 filed on Nov. 17, 2020, now U.S. Pat. No. 11,789,527, and claims priority to U.S. Provisional Application Ser. No. 62/948,986 filed on Dec. 17, 2019, the contents of all of which are incorporated fully herein by reference.

TECHNICAL FIELD
[0002] The present subject matter relates to wearable devices, e.g., eyewear devices, and, more particularly, to facial detection and face tracking.
BACKGROUND
[0003] Wearable devices, including portable eyewear devices, such as smart glasses, headwear, and headgear, as well as mobile devices available today integrate image displays and cameras. Such devices are able to capture and present images.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0004] The drawing figures depict one or more implementations, by way of example only, not by way of limitations. In the figures, like reference numerals refer to the same or similar elements.
[0005] FIG. **1**A is a side view of an example hardware configuration of an eyewear device, which includes a visible light camera on a corner.
[0006] FIGS. **1**B and **1**C are rear views of example hardware configurations of the eyewear device of FIG. **1**A, including two different types of image displays.
[0007] FIG. **2** is a top cross-sectional view of a corner of the eyewear device of FIG. **1**A depicting the visible light camera and a circuit board.
[0008] FIG. **3**A is a high-level functional block diagram of an example face tracking system including the eyewear device, a mobile device, and a server system connected via various networks.
[0009] FIG. **3**B shows an example of a hardware configuration for the server system of the face tracking system of FIG. **3**A, in simplified block diagram form.
[0010] FIG. **3**C shows an example of an optimized hardware architecture configuration for the high-speed circuitry of the eyewear device of the face tracking system of FIGS. **3**A and **3**B, in simplified block diagram form.
[0011] FIG. **4** shows an example of a hardware configuration for the mobile device of the face tracking system of FIGS. **3**A and **3**B, in simplified block diagram form.
[0012] FIG. **5**A is a flowchart of the operation of a wearable device or a mobile device and other components of the face tracking system of FIGS. **3**A, **3**B, and **3**C.
[0013] FIG. **5**B is a flowchart of the operation of a wearable device or a mobile device and other components to track positional information of a face using a trained model in the face tracking system of FIGS. **3**A, **3**B, and **3**C.
[0014] FIG. **5**C is a flowchart of the operation of a wearable device or a mobile device and other

components to track positional information of a face using a two-dimensional (2D) image in the face tracking system of FIGS. **3**A, **3**B, and **3**C.

DETAILED DESCRIPTION

[0015] The following detailed description includes examples for tracking positional information of a face (e.g., including distance from a camera) for use in rendering image overlays on image displays of an eyewear device. In one example, a machine learning model is trained using images including faces having facial features with known positional information. The trained model can be applied to a face in an image to obtain positional information for that face in that image. The obtained positional information may then be used to create image overlays that track the face as the face moves in relation to the eyewear device.

[0016] In the following detailed description, numerous specific details are set forth by way of examples in order to provide a thorough understanding of the relevant teachings. However, it should be apparent to those skilled in the art that the present teachings may be practiced without such details. In other instances, description of well-known methods, procedures, components, and circuitry are set forth at a relatively high-level, without detail, in order to avoid unnecessarily obscuring aspects of the present teachings.

[0017] The term "coupled" as used herein refers to any logical, optical, physical, or electrical connection, link, or the like by which electrical signals produced or supplied by one system element are imparted to another coupled element. Unless described otherwise, coupled elements or devices are not necessarily directly connected to one another and may be separated by intermediate components, elements or communication media that may modify, manipulate, or carry the electrical signals. The term "on" means directly supported by an element or indirectly supported by the element through another element integrated into or supported by the element.

[0018] The orientations of the eyewear device, associated components and any complete devices incorporating a camera such as shown in any of the drawings, are given by way of example only, for illustration and discussion purposes. In operation for a particular face detection programming, the eyewear device may be oriented in any other direction suitable to the particular application of the eyewear device, for example up, down, sideways, or any other orientation. Also, to the extent used herein, any directional term, such as front, rear, inwards, outwards, towards, left, right, lateral, longitudinal, up, down, upper, lower, top, bottom and side, are used by way of example only, and are not limiting as to direction or orientation of any camera or component of a camera constructed as otherwise described herein.

[0019] Objects, advantages, and novel features of the examples will be set forth in part in the following description, and in part will become apparent to those skilled in the art upon examination of the following and the accompanying drawings or may be learned by production or operation of the examples. The objects and advantages of the present subject matter may be realized and attained by means of the methodologies, instrumentalities and combinations particularly pointed out in the appended claims.

[0020] Reference now is made in detail to the examples illustrated in the accompanying drawings and discussed below.

[0021] FIG. **1**A is a side view of an example hardware configuration of an eyewear device **100**, which includes at least one visible light camera **114** on a right corner **110**B for capturing images in a field of views. When a face is detected in the images, the face is tracked to create overlay images that may be overlaid on the face for presentation to a wearer of the eyewear device **100**.

[0022] In the example of FIG. **1**A, the visible light camera **114** is sensitive to the visible light range wavelength. As shown in the example, the visible light camera **114** has a front facing field of view from the perspective of a wearer. Examples of such a visible light camera **114** include a high-resolution complementary metal-oxide-semiconductor (CMOS) image sensor and a video graphic array (VGA) camera, such as 640 p (e.g., 640×480 pixels for a total of 0.3 m 3egapixels), 720 p, or 1080 p. The eyewear device **100** captures image sensor data from the visible light camera **114**, and

optionally other data such as geolocation data, digitizes the data using an image processor, and stores the digitized data in a memory.

[0023] Visible light camera **114** may be coupled to an image processor (element **312** of FIG. **3**A) for digital processing along with a timestamp in which the image of a scene is captured. Image processor **312** includes circuitry to receive signals from the visible light camera **114** and process those signals from the visible light camera **114** into a format suitable for storage in the memory **334**. The timestamp can be added by the image processor **312** or other processor, which controls operation of the visible light camera **114**. A coupled processor **343** uses algorithms to detect and extract facial features such as faces.

[0024] In an example, a system includes the eyewear device **100**. The eyewear device **100** includes a frame **105**, a right temple **110**B extending from a right lateral side **170**B of the frame **105**, and an image display (e.g., optical assembly **180**A and **180**B shown in FIGS. **1**B and **1**C) to present a graphical user interface to a user. The eyewear device **100** further includes a camera (e.g., visible light camera **114**) connected to the frame **105** or the right temple **110**B to capture an image of a scene including a face. Although not shown in FIGS. **1**A, **1**B, and **1**C, the system further includes a processor (element **343** of FIGS. **3**A and **3**C) coupled to the eyewear device **100** and connected to the camera **114**, a memory **334** accessible to the processor **343**, and programming in the memory **334**, for example in the eyewear device **100** itself or another part of the system.

[0025] Although not shown in FIG. **1**A, the system also includes a host computer (element **398** of FIGS. **3**A and **3**B) that generates a facial feature/parameter model utilizing a machine leaning model such as, for example, neural network programming. The neural network programming generates the facial feature/parameter model (e.g., trains the facial feature/parameter model) by learning features directly from sets of labeled image data without the need for manual feature extraction. The neural network programming executes on the host computer and outputs a model for storage.

[0026] As described in further detail below, the facial feature/parameter model, which is trained using detected facial features and associated parameters (e.g., comprising hundreds or thousands of extracted facial features and parameters), also or alternatively resides on the eyewear device **100**. The host computer **398** can transmit over the air updates to update the model. In one example, the model is trained using two-dimensional images. In another example, the model is trained using stereo imagery having overlapping fields of view.

[0027] In one example, a neural network is used to train the machine learning models. The neural network may be a pre-trained or untrained. An example of a suitable neural network is a convolutional neural network (CNN) running on the host computer that convolves facial features with distance parameters. The CNN may use two-dimensional convolutional layers. The CNN may extract features directly from images. The CNN can learn while the network trains on a collection of images of scenes.

[0028] During training of the machine learning model (e.g., neural network programming) of the host computer, multiple images of scenes with faces from various angles with different perspectives are fed into the host computer for processing. Images are also input with different lighting conditions and background scenes. Training the machine learning model examines multiple images and creates a facial feature and parameter model.

[0029] After the machine learning of the host computer builds the facial feature/parameter model, the face detection programming of the eyewear device **100** is executed. Execution of the programming by the processor **343** configures the eyewear device **100** to perform functions. The eyewear device **100** captures, via the camera **114**, an image of the scene with the face. The eyewear device **100** creates an overlay image; and produces visible output to the user via the graphical user interface presented on the image display (e.g., optical assembly **180**A-B) of the eyewear device **100** including the produced overlay.

[0030] Feature detection and feature extraction are combined in the machine learning (e.g., neural

network programming) of the host computer. Feature detection, feature extraction, and matching are combined in the face detection programming of the eyewear device **100**. Facial features can be detected and once detected, can be extracted. Facial feature extractions result in a feature descriptor or a feature vector for each extracted facial feature. N-jets and local histograms (e.g., scale-invariant feature transform), histogram of oriented gradients (HOG), speeded-up robust features (SURF), local binary patterns (LBP), Haar wavelets, color histograms, etc. can be utilized to extract and represent facial features. The facial detection and neural network programming described herein may store location coordinates of the extracted facial features in order to overlay a graphic (e.g., an overlay image) on the face or pinpoint the exact location facial features (including distance from the eyewear device **100**).

[0031] Facial detection programming of the eyewear device **100** runs repeatedly at certain time intervals, as long as the eyewear device **100** is powered and the user is active. Various optimizations to conserve battery power are implemented in the eyewear device **100**. The image capture interval is adjustable in order to optimize the power consumption. In one example, the face detection programming is not run (e.g., executed) if the eyewear device **100** is running another application. In another example, the face detection programming is not run if the environment is dark, for example, based on an ambient light sensor measurement. If no ambient light sensor is available in the eyewear device **100**, the time interval between which the face detection programming is run is increased. If no objects are detected in scenes over multiple images, the time interval between capturing images is also increased. If the eyewear device **100** finds a face, the time interval may be extended to 10 seconds or more.

[0032] The foregoing functionality can be embodied in programming instructions found in one or more components of the system as further described in FIGS. **3**A, **3**B, and **3**C. For example, the neural network programming **365** of the system server **398** and the face detection programming **344** of the eyewear device **100**.

[0033] As shown in FIGS. **1**A, **1**B, and **1**C, the eyewear device **100** is in a form for wearing by a user, which are eyeglasses in the example of FIGS. **1**A, **1**B, and **1**C. The eyewear device **100** can take other forms and may incorporate other types of frameworks, for example, a headgear, a headset, or a helmet. In the eyeglasses example, eyewear device **100** includes a frame **105** including a left rim **107**A connected to a right rim **107**B via a bridge **106** adapted for a nose of the user. The left and right rims **107**A-B include respective apertures **175**A-B, which hold a respective optical assembly **180**A-B. Optical assembly **180**A-B can include various optical layers **176**A-N and an image display device. The left and right temples **125**A-B extend from respective lateral sides of the frame **105**, for example, via respective left and right corners **110**A-B. A substrate or materials forming the temple **125**A-B can include plastic, acetate, metal, or a combination thereof. The corners **110**A-B can be integrated into or connected to the frame **105** on the lateral side.

[0034] FIGS. **1**B and **1**C are rear views of example hardware configurations of the eyewear device **100** of FIG. **1**A, including two different types of image displays. In one example, the image display of optical assembly **180**A-B includes an integrated image display. As shown in FIG. **1**B, the optical assembly **180**A-B includes a suitable display matrix **170** of any suitable type, such as a liquid crystal display (LCD), an organic light-emitting diode (OLED) display, or any other such display. The optical assembly **180**A-B also includes an optical layer or layers **176**, which can include lenses, optical coatings, prisms, mirrors, waveguides, optical strips, and other optical components in any combination.

[0035] The optical layers **176**A-N can include a prism having a suitable size and configuration and including a first surface for receiving light from display matrix and a second surface for emitting light to the eye of the user. The prism of the optical layers **176**A-N extends over all or at least a portion of the respective apertures **175**A-B formed in the left and right rims **107**A-B to permit the user to see the second surface of the prism when the eye of the user is viewing through the corresponding left and right rims **107**A-B. The first surface of the prism of the optical layers **176**A-

N faces upwardly from the frame **105** and the display matrix overlies the prism so that photons and light emitted by the display matrix impinge on the first surface. The prism is sized and shaped so that the light is refracted within the prism and is directed towards the eye of the user by the second surface of the prism of the optical layers **176**A-N. In this regard, the second surface of the prism of the optical layers **176**A-N can be convex to direct the light towards the center of the eye. The prism can optionally be sized and shaped to magnify the image projected by the display matrix **170**, and the light travels through the prism so that the image viewed from the second surface is larger in one or more dimensions than the image emitted from the display matrix **170**.

[0036] In another example, the image display device of optical assembly **180**A and **180**B includes a projection image display as shown in FIG. **1**C. The optical assembly **180**A-B includes a laser projector **150**, which is a three-color laser projector using a scanning mirror or galvanometer. During operation, an optical source such as a laser projector **150** is disposed in or on one of the temples **125**A-B of the eyewear device **100**. Optical assembly **180**A and **180**B includes one or more optical strips **155**A-N spaced apart across the width of the lens of the optical assembly **180**A and **180**B or across a depth of the lens between the front surface and the rear surface of the lens.

[0037] As the photons projected by the laser projector **150** travel across the lens of the optical assembly **180**A and **180**B, the photons encounter the optical strips **155**A-N. When a particular photon encounters a particular optical strip, the photon is either redirected towards the user's eye, or it passes to the next optical strip. A combination of modulation of laser projector **150**, and modulation of optical strips, may control specific photons or beams of light. In an example, a processor controls optical strips **155**A-N by initiating mechanical, acoustic, or electromagnetic signals. Although shown as having two optical assemblies **180**A-B, the eyewear device **100** can include other arrangements, such as a single or three optical assemblies, or the optical assembly **180**A-B may have arranged different arrangement depending on the application or intended user of the eyewear device **100**.

[0038] As further shown in FIGS. **1**B and **1**C, eyewear device **100** includes a left corner **110**A adjacent the left lateral side **170**A of the frame **105** and a right corner **110**B adjacent the right lateral side **170**B of the frame **105**. The corners **110**A-B may be integrated into the frame **105** on the respective lateral sides **170**A-B (as illustrated) or implemented as separate components attached to the frame **105** on the respective sides **170**A-B. Alternatively, the corners **110**A-B may be integrated into temples **125**A-B attached to the frame **105**.

[0039] In one example, the produced visible output on the optical assembly **180**A-B of the eyewear device **100** may be an overlay image that overlays at least a portion of a face being tracked by the eyewear device **100**. In one example the optical assemblies **180**A-B are see-through displays that present the overlay image as an overlay on the face(s) that the wearer is viewing through the lenses of the optical assembly. In another example the optical assemblies **180**A-B are not see-through displays (e.g., are opaque displays) that present the overlay image by combining the overlay with images captured by the cameras **114** of the eyewear device for presentation to the user on the displays.

[0040] FIG. **2** is a top cross-sectional view of the corner of the eyewear device **100** of FIG. **1**A depicting the visible light camera **114** and a circuit board. As shown, the eyewear device **100** includes the visible light camera **114** and a circuit board, which may be a flexible printed circuit board (PCB) **240**. A right corner **110**B is connected to a right temple **125**B of the eyewear device **100** via the right hinge **126**B. In some examples, components of the visible light camera **114**, the flexible PCB **240**, or other electrical connectors or contacts may be located on the right temple **125**B or the right hinge **126**B. A left corner **110**A is connected to a left temple **125**A of the eyewear device **100** via the left hinge **126**A. In some examples, components of the visible light camera **114**, the flexible PCB **240**, or other electrical connectors or contacts may be located on the left temple **125**A or the left hinge **126**A.

[0041] The right corner **110**B includes corner body **211** and a corner cap, but the corner cap is

removed in the cross-section of FIG. **2**. Disposed inside the right corner **110**B are various interconnected circuit boards, such as PCBs or flexible PCBs, that include controller circuits for a visible light camera **114**, microphone(s), low-power wireless circuitry (e.g., for wireless short-range network communication via Bluetooth™), and high-speed wireless circuitry (e.g., for wireless local area network communication via WiFi).

[0042] The visible light camera **114** is coupled to or disposed on the flexible PCB **240** and covered by a visible light camera cover lens, which is aimed through opening(s) formed in the right corner **110**B. In some examples, the frame **105** connected to the right corner **110**B includes the opening(s) for the visible light camera cover lens. The frame **105** includes a front-facing side configured to face outward away from the eye of the user. The opening for the visible light camera cover lens is formed on and through the front-facing side. In the example, the visible light camera **114** has an outward facing field of view with a line of sight of the user of the eyewear device **100**. The visible light camera cover lens can also be adhered to an outward facing surface of the right corner **110**B in which an opening is formed with an outward facing field of view, but in a different outward direction. The coupling can also be indirect via intervening components.

[0043] Flexible PCB **240** is disposed inside the right corner **110**B and is coupled to one or more other components housed in the right corner **110**B. Although shown as being formed on the circuit boards of the right corner **110**B, the visible light camera **114** can be formed on the circuit boards of the left corner **110**A, the temples **125**A-B, or frame **105**.

[0044] FIG. **3**A is a high-level functional block diagram of an example face tracking system **300**. The face tracking system **300** includes a wearable device, which is the eyewear device **100** in the example. The wearable device can communicate via one or more wireless networks or wireless links with mobile device **390** or server system **398**. The face tracking system **300** further includes a mobile device **390** and server system **398**. Mobile device **390** may be a smartphone, tablet, laptop computer, access point, or any other such device capable of connecting with eyewear device **100** using both a low-power wireless connection **325** and a high-speed wireless connection **337**. Mobile device **390** is connected to server system **398** and network **395**. The network **395** may include any combination of wired and wireless connections.

[0045] Eyewear device **100** includes a visible light camera **114**, image display of the optical assembly **180**, image display driver **342**, image processor **312**, low-power circuitry **320**, and high-speed circuitry **330**. The components shown in FIG. **3**A for the eyewear device **100** are located on one or more circuit boards, for example a PCB or flexible PCB, in the temples. Alternatively, or additionally, the depicted components can be located in the corners, frames, hinges, or bridge of the eyewear device **100**. Visible light camera **114** can include digital camera elements such as a complementary metal-oxide-semiconductor (CMOS) image sensor, charge coupled device, a lens, or any other respective visible or light capturing elements that may be used to capture data, including images of scenes with unknown objects. Memory **334** includes face detection programming **344**, a face tracker **345**, and a facial feature/parameter model **346** to perform the functions described herein for face tracking. Memory **334** additionally includes a rendering engine **348** for rendering overlay images over the face(s) on the displays **180**A and **180**B using image processor **312** and image display driver **342**.

[0046] In one example, face detection programming **344** and face tracker **345** implement instructions to cause the eyewear device **100** to capture, via the visible light camera **114**, an image of a scene including a face and to track the face(s) as it moves with respect to the eyewear device **100**. Initially, one or more anchor points on the face are acquired. The tasks of acquiring a face, related anchor points, and their locations are performed according to any of a variety of conventional face detection/tracking algorithms. Face tracking is accomplished by establishing a three-dimensional coordinate system and searching for and identifying a face and its location relative to the coordinate system. Any of a variety of face tracking applications to perform face tracking are available on different kinds of devices. A suitable face tracking application locates and

tracks the motion of a face relative to six degrees of freedom; in other words, motion in relation to six axes (x, y, z, pitch, roll, yaw). After the face is acquired, the face tracking application keeps track of the location and orientation of the face using any of a variety of available tracking techniques, generally referred to as simultaneous localization and mapping (SLAM). SLAM can, for example, be used to track the location and orientation of a user in motion relative to a virtual reality; for example, a virtual world. SLAM can also be used to track the location and orientation of a user in motion relative to augmented reality, in which one or more virtual objects are overlaid or otherwise displayed together with a physical reality.

[0047] As shown in FIG. **3**A, high-speed circuitry **330** includes high-speed processor **343**, memory **334**, and high-speed wireless circuitry **336**. In the example, the image display driver **342** is coupled to the high-speed circuitry **330** and operated by the high-speed processor **343** in order to drive the image display of the optical assembly **180**. High-speed processor **343** may be any processor capable of managing high-speed communications and operation of any general computing system needed for eyewear device **100**. High-speed processor **343** includes processing resources needed for managing high-speed data transfers on high-speed wireless connection **337** to a wireless local area network (WLAN) using high-speed wireless circuitry **336**. In some examples, the high-speed processor **343** executes an operating system such as a LINUX operating system or other such operating system of the eyewear device **100** and the operating system is stored in memory **334** for execution. In addition to any other responsibilities, the high-speed processor **343** executing a software architecture for the eyewear device **100** is used to manage data transfers with high-speed wireless circuitry **336**. In some examples, high-speed wireless circuitry **336** is configured to implement Institute of Electrical and Electronic Engineers (IEEE) 802.11 communication standards, also referred to herein as Wi-Fi. In other examples, other high-speed communications standards may be implemented by high-speed wireless circuitry **336**.

[0048] Low-power wireless circuitry **324** and the high-speed wireless circuitry **336** of the eyewear device **100** can include short range transceivers (Bluetooth™) and wireless wide, local, or wide area network transceivers (e.g., cellular or WiFi). Mobile device **390**, including the transceivers communicating via the low-power wireless connection **325** and high-speed wireless connection **337**, may be implemented using details of the architecture of the eyewear device **100**, as can other elements of network **395**.

[0049] Memory **334** includes any storage device capable of storing various data and applications, including, among other things, camera data generated by the visible light camera **114** and the image processor **312**, as well as images generated for display by the image display driver **342** on the image display of the optical assembly **180**. While memory **334** is shown as integrated with high-speed circuitry **330**, in other examples, memory **334** may be an independent standalone element of the eyewear device **100**. In some examples, electrical routing lines may provide a connection through a chip that includes the high-speed processor **343** from the image processor **312** or low-power processor **323** to the memory **334**. In other examples, the high-speed processor **343** may manage addressing of memory **334** such that the low-power processor **323** will boot the high-speed processor **343** any time that a read or write operation involving memory **334** is needed.

[0050] As further shown in FIG. **3**B, server system **398** may be one or more computing devices as part of a service or network computing system, for example, that include a processor **360**, a memory **362**, and network communication interface **361** to communicate over the network **395** with the mobile device **390** and eyewear device **100**. The memory **362** includes a facial feature/parameter model **364** and neural network programming **365**. Execution of the neural network programming **365** by the processor **360** configures the server system **398** to perform some or all of the functions described herein.

[0051] In one example, server system **398** receives, via the network **395**, the image of the scene with the face from the eyewear device **100** via the mobile device **390**. In another example, server system **398** connects, via the network communication interface **361**, to the eyewear device **100** via

the mobile device **390**, the wearable device **399**, or another computing device of a different user over the network **395**.

[0052] The facial feature/parameter model **346** of the eyewear device **100** can be a mirror image of the facial feature/parameter model **364** of the server system **398**. Facial feature/parameter model **345** of the eyewear device **100** is stored locally in a read-only memory (ROM), erasable programmable read-only memory (EPROM), or flash memory of high-speed circuitry **330**.

[0053] Eyewear device **100** further includes an ambient light sensor **333** and detects, via the ambient light sensor **333**, the illuminance of the environment in which the eyewear device **100** is located. The eyewear device **100** determines whether the detected illuminance of the environment exceeds an illuminance brightness threshold or is below an illuminance darkness threshold. Upon determining that the detected illuminance exceeds the illuminance brightness threshold or is below the illuminance darkness threshold, the eyewear device **100** throttles back the sampling interval of the capturing, via the camera **114**, the image of the scene with the face. The ambient light-based adjustment to the sampling interval for capturing the image of the scene with the face may be implemented in the application layer of the face detection programming **344**. Although not shown, eyewear device **100** can also include a proximity sensor, which detects if the user is currently wearing the eyewear device **100**, to optimize power consumption.

[0054] Eyewear device **100** is connected with a host computer. For example, the eyewear device **100** is paired with the mobile device **390** via the high-speed wireless connection **337** or connected to the server system **398** via the network **395**. In one example, eyewear device **100** receives images that can be overlaid with a face being tracked with the eyewear device **100**.

[0055] Output components of the eyewear device **100** include visual components, such as the image display of optical assembly **180** as described in FIGS. **1**B and **1**C (e.g., a display such as a liquid crystal display (LCD), a plasma display panel (PDP), a light emitting diode (LED) display, a projector, or a waveguide). The image display of the optical assembly **180** is driven by the image display driver **342**. The output components of the eyewear device **100** further include acoustic components (e.g., speakers), haptic components (e.g., a vibratory motor), other signal generators, and so forth. The input components of the eyewear device **100**, the mobile device **390**, and server system **398**, may include alphanumeric input components (e.g., a keyboard, a touch screen configured to receive alphanumeric input, a photo-optical keyboard, or other alphanumeric input components), point-based input components (e.g., a mouse, a touchpad, a trackball, a joystick, a motion sensor, or other pointing instruments), tactile input components (e.g., a physical button, a touch screen that provides location and force of touches or touch gestures, or other tactile input components), audio input components (e.g., a microphone), and the like.

[0056] Face tracking system **300** may optionally include additional peripheral device elements **319**. Such peripheral device elements **319** may include biometric sensors, additional sensors, or display elements integrated with eyewear device **100**. For example, peripheral device elements **319** may include any I/O components including output components, motion components, position components, or any other such elements described herein.

[0057] For example, the biometric components of the face tracking system **300** include components to detect expressions (e.g., hand expressions, facial expressions, vocal expressions, body gestures, or eye tracking), measure biosignals (e.g., blood pressure, heart rate, body temperature, perspiration, or brain waves), identify a person (e.g., voice identification, retinal identification, facial identification, fingerprint identification, or electroencephalogram based identification), and the like. The motion components include acceleration sensor components (e.g., accelerometer), gravitation sensor components, rotation sensor components (e.g., gyroscope), and so forth. The position components include location sensor components to generate location coordinates (e.g., a Global Positioning System (GPS) receiver component), WiFi or Bluetooth™ transceivers to generate positioning system coordinates, altitude sensor components (e.g., altimeters or barometers that detect air pressure from which altitude may be derived), orientation sensor components (e.g.,

magnetometers), and the like. Such positioning system coordinates can also be received over wireless connections **325** and **337** from the mobile device **390** via the low-power wireless circuitry **324** or high-speed wireless circuitry **336**.

[0058] FIG. **3**C shows an example of an optimized hardware architecture configuration for the high-speed circuitry **330** of the eyewear device **100** of the face tracking system **300** of FIG. **3**A, in simplified block diagram form. To enhance runtime optimization and speed of execution, the face detection programming **344** may include a subset of instruction (instructions **344**A) in firmware and another subset of instructions (instructions **344**B) in the application layer. In this example of FIG. **3**C, an additional optimization is shown.

[0059] As shown in FIG. **3**C, the high-speed circuitry **330** of the eyewear device **100** includes at least two systems on a chip (SOCs) **331**A-B. The first SOC **331**A is a dedicated graphics processing unit (GPU) or a vision processing unit (VPU), which includes a first processor **343**A; a first memory **334**A (e.g., firmware); and firmware programming in the first memory **334**A. Execution of the firmware layer of the face detection programming **344**A by the first processor **343**A of the dedicated GPU or VPU **331**A configures the eyewear device **100** to: capture, via the visible light camera **114**, the images of the scene with the face and track positional information of the face in the images. The high-speed circuitry **330** further includes another second system on a chip (SOC) unit **331**B. The second SOC **331**B of the high-speed circuitry **330** is a main SOC which includes a second processor **343**B, a second memory **334**B, and application layer of face detection programming **344**B in the second memory **334**B. Execution of the application layer of the face detection programming **344**B by the second processor **343**B configures the eyewear device **100** to generate an overlay responsive to the positional information. The dedicated GPU or VPU SOC **331**B of the high-speed circuitry **330** has access to the visible light camera **114** via direct memory access (DMA).

[0060] In one example, image processor **312** comprises a microprocessor integrated circuit (IC) customized for processing image sensor data from the visible light camera **114**, along with volatile memory used by the microprocessor to operate. In order to reduce the amount of time that image processor **312** takes when powering on to processing data, a non-volatile read only memory (ROM) may be integrated on the IC with instructions for operating or booting the image processor **312**. This ROM may be minimized to match a minimum size needed to provide basic functionality for gathering sensor data from visible light camera **114**, such that no extra functionality that would cause delays in boot time are present. The ROM may be configured with direct memory access (DMA) to the volatile memory of the microprocessor of image processor **312**. DMA allows memory-to-memory transfer of data from the ROM to system memory of the image processor **312** independent of operation of a main controller of image processor **312**. Providing DMA to this boot ROM further reduces the amount of time from power on of the image processor **312** until sensor data from the visible light camera **114** can be processed and stored. In some examples, minimal processing of the camera signal from the visible light camera **114** is performed by the image processor **312**, and additional processing may be performed by applications operating on the mobile device **390** or server system **398**.

[0061] Low-power circuitry **320** includes low-power processor **323** and low-power wireless circuitry **324**. These elements of low-power circuitry **320** may be implemented as separate elements or may be implemented on a single IC as part of a system on a single chip. Low-power processor **323** includes logic for managing the other elements of the eyewear device **100**. Low-power processor **323** is configured to receive input signals or instruction communications from mobile device **390** via low-power wireless connection **325**. Additional details related to such instructions are described further below. Low-power wireless circuitry **324** includes circuit elements for implementing a low-power wireless communication system via a short-range network. Bluetooth™ Smart, also known as Bluetooth™ low energy, is one standard implementation of a low power wireless communication system that may be used to implement low-power wireless circuitry **324**.

In other examples, other low power communication systems may be used.

[0062] Mobile device **390** and elements of network **395**, low-power wireless connection **325**, and high-speed wireless architecture **337** may be implemented using details of the architecture of mobile device **390**, for example utilizing the short range XCVRs and WWAN XCVRs of mobile device **390** described in FIG. **4**.

[0063] FIG. **4** is a high-level functional block diagram of an example of a mobile device **390** that provides processing for the face tracking system **300** of FIGS. **3**A and **3**B. Shown are elements of a touch screen type of mobile device **390** having face detection programming **344** loaded along with other applications such as chat application **453**. Examples of touch screen type mobile devices that may be used include (but are not limited to) a smart phone, a personal digital assistant (PDA), a tablet computer, a laptop computer, or other portable device. However, the structure and operation of the touch screen type devices is provided by way of example; and the subject technology as described herein is not intended to be limited thereto. For purposes of this discussion, FIG. **4** therefore provides a block diagram illustration of the example mobile device **390** having a touch screen display for displaying content and receiving user input as (or as part of) the user interface. Mobile device **390** also includes a camera(s) **470**, such as visible light camera(s).

[0064] As shown in FIG. **4**, the mobile device **390** includes at least one digital transceiver (XCVR) **410**, shown as WWAN XCVRs, for digital wireless communications via a wide area wireless mobile communication network. The mobile device **390** also includes additional digital or analog transceivers, such as short range XCVRs **420** for short-range network communication, such as via NFC, VLC, DECT, ZigBee, Bluetooth™, or WiFi. For example, short range XCVRs **420** may take the form of any available two-way wireless local area network (WLAN) transceiver of a type that is compatible with one or more standard protocols of communication implemented in wireless local area networks, such as one of the Wi-Fi standards under IEEE 802.11 and WiMAX.

[0065] To generate location coordinates for positioning of the mobile device **390**, the mobile device **390** can include a global positioning system (GPS) receiver. Alternatively, or additionally the mobile device **390** can utilize either or both the short range XCVRs **420** and WWAN XCVRs **410** for generating location coordinates for positioning. For example, cellular network, WiFi, or Bluetooth™ based positioning systems can generate very accurate location coordinates, particularly when used in combination. Such location coordinates can be transmitted to the eyewear device **100** over one or more network connections via XCVRs **420**.

[0066] The transceivers **410**, **420** (network communication interfaces) conform to one or more of the various digital wireless communication standards utilized by modern mobile networks. Examples of WWAN transceivers **410** include (but are not limited to) transceivers configured to operate in accordance with Code Division Multiple Access (CDMA) and 3rd Generation Partnership Project (3GPP) network technologies including, for example and without limitation, 3GPP type 2 (or 3GPP2) and LTE, at times referred to as "4G." For example, the transceivers **410**, **420** provide two-way wireless communication of information including digitized audio signals, still image and video signals, web page information for display as well as web related inputs, and various types of mobile message communications to/from the mobile device **390** for user authorization strategies.

[0067] Several of these types of communications through the transceivers **410**, **420** and a network, as discussed previously, relate to protocols and procedures in support of communications with the eyewear device **100** or the server system **398** for facial detection. Such communications, for example, may transport packet data via the short range XCVRs **420** over the wireless connections **325** and **337** to and from the eyewear device **100** as shown in FIGS. **3**A-C. Such communications, for example, may also transport data utilizing IP packet data transport via the WWAN XCVRs **410** over the network (e.g., Internet) **395** shown in FIGS. **3**A-C. Both WWAN XCVRs **410** and short range XCVRs **420** connect through radio frequency (RF) send-and-receive amplifiers (not shown) to an associated antenna (not shown).

[0068] The mobile device **390** further includes a microprocessor, shown as CPU **430**, sometimes referred to herein as the host controller. A processor is a circuit having elements structured and arranged to perform one or more processing functions, typically various data processing functions. Although discrete logic components could be used, the examples utilize components forming a programmable CPU. A microprocessor, for example, includes one or more integrated circuit (IC) chips incorporating the electronic elements to perform the functions of the CPU. The processor **430**, for example, may be based on any known or available microprocessor architecture, such as a Reduced Instruction Set Computing (RISC) using an ARM architecture, as commonly used today in mobile devices and other portable electronic devices. Of course, other processor circuitry may be used to form the CPU **430** or processor hardware in smartphone, laptop computer, and tablet.

[0069] The microprocessor **430** serves as a programmable host controller for the mobile device **390** by configuring the mobile device **390** to perform various operations, for example, in accordance with instructions or programming executable by processor **430**. For example, such operations may include various general operations of the mobile device, as well as operations related to facial detection communications with the eyewear device **100** and server system **398**. Although a processor may be configured by use of hardwired logic, typical processors in mobile devices are general processing circuits configured by execution of programming.

[0070] The mobile device **390** includes a memory or storage device system, for storing data and programming. In the example, the memory system may include a flash memory **440**A and a random access memory (RAM) **440**B. The RAM **440**B serves as short term storage for instructions and data being handled by the processor **430**, e.g., as a working data processing memory. The flash memory **440**A typically provides longer term storage.

[0071] Hence, in the example of mobile device **390**, the flash memory **440**A is used to store programming or instructions for execution by the processor **430** to implement the functions described herein for facial detection. Depending on the type of device, the mobile device **390** stores and runs a mobile operating system through which specific applications, which may include the face detection programming **344** are executed. However, in some implementations, the face detection programming **344** and facial feature/parameter model **346** may be implemented in firmware or a combination of firmware and an application layer as described with the eyewear device **100**. For example, the instructions to capture the image of the scene with the face, track positional information for the face, and generate an overlay may reside in firmware (e.g., with a dedicated GPU or VPU SOC) like that described with reference to the eyewear device in FIGS. **3**A, **3**B, and **3**C. Instructions to produce the visible output to the user may reside in an application. Applications, like the face detection programming **344** and other applications, may be a native application, a hybrid application, or a web application (e.g., a dynamic web page executed by a web browser) that runs on mobile device **390**. Examples of mobile operating systems include Google Android, Apple iOS (I-Phone or iPad devices), Windows Mobile, Amazon Fire OS, RIM BlackBerry operating system, or the like.

[0072] FIGS. **5**A, **5**B, and **5**C are flowcharts **500**, **520**, and **540**, respectively, illustrating example operation of a wearable device (e.g., an eyewear device **100**) or a mobile device **390** and other components of the face tracking system **300**. Although shown as occurring serially, one or more of the blocks in flow charts **500**, **520**, and/or **540** may be reordered or parallelized depending on the implementation.

[0073] At block **502**, capture an image of a scene including a face. The image processor **312** may capture the image using visible light camera **114**. In one example, image processor **312** captures images from one visible light camera **114**. In another example, image processor **312** captures images from two visible light cameras **114** having overlapping fields of view.

[0074] At block **504**, identify the face in the image of the scene. The high-speed circuitry **330** may identify the face using face detection programming **344** stored in memory **334**.

[0075] At block **506**, track positional information of the face with respect to the eyewear device.

The high-speed circuitry **330** may track positional information using face tracker **345** and facial feature/parameter model **346**. In one example, positional information includes distances from the camera **114** to features on the face (e.g., eyes, cheek bones).

[0076] Tracking positional information may include identifying facial feature parameters of the face in the initial image (block **522**) and tracking the positional information of the face by comparing the identified facial feature parameters to a model trained using a plurality of images including faces having facial features with known positional information (block **524**). Alternatively, tracking positional information may include identifying facial feature parameters of the face in the initial image corresponding to an apparent size of the face in the initial image (block **542**) and tracking the positional information of the face based on the identified parameters corresponding to the apparent size of the face (block **544**).

[0077] At block **508**, generate an overlay image responsive to the positional information. The high-speed circuitry **330** may generate the overlay image taking into account the positional information. In one example, overlay images are skewed to conform to the face if the positional information for features on the face indicate the face is turned or tilted with respect to the eyewear device **100**. In another example, the size of the overlay images is adjusted based on positional information with the size being reduced if the face is further away and increased if the face is closer.

[0078] At block **510**, present the overlay image on an image display. The high-speed circuitry **330** may present the overlay image to a wearer of the eyewear device **100** on optical displays **180** of the eyewear device **100**. In one example, the overlay image is presented over the face being tracked. In another example, the overlay image is presented adjacent a face being tracked. In accordance with this example, audio produced by a face of a speaker being tracked may be captured by microphones and converted from speech to text (e.g., using a speech to text converter) with the resultant text presented as an overlay to a side of the speaker (e.g., above/below/right/left).

[0079] Any of the method described herein such as the facial tracking and rendering methods for the eyewear device **100**, mobile device **390**, and server system **398** can be embodied in one or more methods as method steps or in one or more applications as described previously.

[0080] According to some examples, an "application," "applications," or "firmware" are program(s) that execute functions defined in the program, such as logic embodied in software or hardware instructions. Various programming languages can be employed to create one or more of the applications, structured in a variety of manners, such as object-oriented programming languages (e.g., Objective-C, Java, or C++) or procedural programming languages (e.g., C or assembly language). In a specific example, a third-party application (e.g., an application developed using the ANDROID™ or IOS™ software development kit (SDK) by an entity other than the vendor of the particular platform) may be mobile software running on a mobile operating system such as IOS™, ANDROID™, WINDOWS® Phone, or another mobile operating system. In this example, the third-party application can invoke application programming interface (API) calls provided by the operating system to facilitate functionality described herein. The applications can be stored in any type of computer readable medium or computer storage device and be executed by one or more general-purpose computers. In addition, the methods and processes disclosed herein can alternatively be embodied in specialized computer hardware or an application specific integrated circuit (ASIC), field programmable gate array (FPGA) or a complex programmable logic device (CPLD).

[0081] Program aspects of the technology may be thought of as "products" or "articles of manufacture" typically in the form of executable code and/or associated data that is carried on or embodied in a type of machine-readable medium. For example, programming code could include code for user authorization, navigation, facial tracking, or other functions described herein. "Storage" type media include any or all of the tangible memory of the computers, processors or the like, or associated modules thereof, such as various semiconductor memories, tape drives, disk drives and the like, which may provide non-transitory storage at any time for the software

programming. All or portions of the software may at times be communicated through the Internet or various other telecommunication networks. Such communications, for example, may enable loading of the software from one computer or processor into another, for example, from the server system **398** or host computer of the service provider into the computer platforms of the eyewear device **100** and mobile device **390**. Thus, another type of media that may bear the programming, media content or meta-data files includes optical, electrical, and electromagnetic waves, such as used across physical interfaces between local devices, through wired and optical landline networks and over various air-links. The physical elements that carry such waves, such as wired or wireless links, optical links, or the like, also may be considered as media bearing the software. As used herein, unless restricted to "non-transitory," "tangible," or "storage" media, terms such as computer or machine "readable medium" refer to any medium that participates in providing instructions or data to a processor for execution.

[0082] Hence, a machine-readable medium may take many forms of tangible storage medium. Non-volatile storage media include, for example, optical or magnetic disks, such as any of the storage devices in any computer(s) or the like, such as may be used to implement the client device, media gateway, transcoder, etc. shown in the drawings. Volatile storage media include dynamic memory, such as main memory of such a computer platform. Tangible transmission media include coaxial cables; copper wire and fiber optics, including the wires that comprise a bus within a computer system. Carrier-wave transmission media may take the form of electric or electromagnetic signals, or acoustic or light waves such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media therefore include for example: a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD or DVD-ROM, any other optical medium, punch cards paper tape, any other physical storage medium with patterns of holes, a RAM, a PROM and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave transporting data or instructions, cables or links transporting such a carrier wave, or any other medium from which a computer may read programming code and/or data. Many of these forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to a processor for execution.

[0083] The scope of protection is limited solely by the claims that now follow. That scope is intended and should be interpreted to be as broad as is consistent with the ordinary meaning of the language that is used in the claims when interpreted in light of this specification and the prosecution history that follows and to encompass all structural and functional equivalents. Notwithstanding, none of the claims are intended to embrace subject matter that fails to satisfy the requirement of Sections 101, 102, or 103 of the Patent Act, nor should they be interpreted in such a way. Any unintended embracement of such subject matter is hereby disclaimed.

[0084] Except as stated immediately above, nothing that has been stated or illustrated is intended or should be interpreted to cause a dedication of any component, step, feature, object, benefit, advantage, or equivalent to the public, regardless of whether it is or is not recited in the claims.

[0085] It will be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein. Relational terms such as first and second and the like may be used solely to distinguish one entity or action from another without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms "comprises," "comprising," "includes," "including," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises or includes a list of elements or steps does not include only those elements or steps but may include other elements or steps not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by "a" or "an" does not, without further constraints, preclude the existence of additional identical elements in the

process, method, article, or apparatus that comprises the element.

[0086] Unless otherwise stated, any and all measurements, values, ratings, positions, magnitudes, sizes, and other specifications that are set forth in this specification, including in the claims that follow, are approximate, not exact. Such amounts are intended to have a reasonable range that is consistent with the functions to which they relate and with what is customary in the art to which they pertain. For example, unless expressly stated otherwise, a parameter value or the like may vary by as much as ±10% from the stated amount.

[0087] In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various examples for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed examples require more features than are expressly recited in each claim. Rather, as the following claims reflect, the subject matter to be protected lies in less than all features of any single disclosed example. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

[0088] While the foregoing has described what are considered to be the best mode and other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that they may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all modifications and variations that fall within the true scope of the present concepts.

Claims

1. A system comprising: an eyewear device including a camera configured to capture images of a scene viewed through the eyewear device; a processor coupled to the eyewear device and connected to the camera; a memory accessible to the processor; and programming in the memory, wherein execution of the programming by the processor configures the system to perform functions, including functions to: capture, via the camera, the images of the scene on a time interval; determine if a face is present in one or more of the images of the scene; and adjust the time interval responsive to whether the face is determined to be present in the one or more of the images of the scene.

2. The system of claim 1, wherein the time interval is adjusted by increasing the time interval.

3. The system of claim 2, wherein the time interval is increased by ten seconds or more.

4. The system of claim 1, wherein the eyewear device further comprises a see-through display and execution of the programming by the processor configures the system to: generate an overlay image; and present the overlay image on the see-through display over or adjacent the face in the scene.

5. The system of claim 4, wherein execution of the programming by the processor to generate the overlay image configures the eyewear device to perform functions to: track positional information of the face with respect to the eyewear device by comparing identified facial feature parameters in the images to a model trained using a plurality of images including faces having facial features with known positional information; and skew the overlay image to conform to the face responsive to the positional information for features on the face indicating the face is turned or tilted with respect to the eyewear device.

6. The system of claim 4, wherein execution of the programming by the processor to generate the overlay image configures the eyewear device to perform functions to: track positional information of the face with respect to the eyewear device by comparing identified facial feature parameters in the images to a model trained using a plurality of images including faces having facial features with known positional information; and adjust the size of the overlay image based on the positional information.

7. The system of claim 6, wherein execution of the programming by the processor to adjust the size configures the eyewear device to perform functions to: reduce the size of the overlay image if the positional information indicates the face is relatively far; and increase the size of the overlay image if the positional information indicates the face is relatively close.

8. The system of claim 1, wherein the eyewear device further comprises an opaque display and execution of the programming by the processor further configures the system to perform functions to: generate an overlay image; merge the overlay image and one or more of the images captured by the camera to generate a merged overlay image; and present the merged overlay image on the opaque display.

9. A method comprising: capturing, via a camera of an eyewear device, images of a scene on a time interval; determine if a face is present in one or more of the images of the scene; and adjust the time interval responsive to whether the face is determined to be present in the one or more of the images of the scene.

10. The method of claim 9, wherein the time interval is adjusted by increasing the time interval.

11. The method of claim 10, wherein the time interval is increased by ten seconds or more.

12. The method of claim 9, further comprising: generating an overlay image; and presenting the overlay image on a see-through display of the eyewear device over or adjacent the face.

13. The method of claim 12, further comprising: tracking positional information of the face with respect to the eyewear device by comparing identified facial feature parameters in the image to a model trained using a plurality of images including faces having facial features with known positional information; and skewing the overlay image to conform to the face responsive to the positional information for features on the face indicating the face is turned or tilted with respect to the eyewear device.

14. The method of claim 12, wherein generating the overlay image comprises: tracking positional information of the face with respect to the eyewear device by comparing identified facial feature parameters in the image to a model trained using a plurality of images including faces having facial features with known positional information; and adjusting the size of the overlay image based on the positional information.

15. The method of claim 14, wherein adjusting the size comprises: reducing the size of the overlay image if the positional information indicates the face is relatively far; and increasing the size of the overlay image if the positional information indicates the face is relatively close.

16. The method of claim 9, further comprising: generating an overlay image; merging the overlay image and one or more of the image captured by the camera to generate a merged overlay image; and presenting the merged overlay image on an opaque display of the eyewear device.

17. A non-transitory computer-readable medium storing program code which, when executed, is operative to cause an electronic processor to perform steps comprising: capturing, via a camera of an eyewear device, images of a scene on a time interval; determining if a face is present in one or more of the images of the scene; and adjusting the time interval responsive to whether the face is determined to be present in the one or more of the images of the scene.

18. The non-transitory computer-readable medium of claim 17, wherein the time interval is adjusted by increasing the time interval.

19. The non-transitory computer-readable medium of claim 17, wherein the eyewear device further comprises a see-through display and execution of the program code by the electronic processor causes the electronic processor to perform the step of: generating an overlay image; and presenting, via the see-through display of the eyewear device, an overlay image over or adjacent the face.

20. The non-transitory computer-readable medium of claim 17, wherein the eyewear device further comprises an opaque display and execution of the program code by the electronic processor causes the electronic processor to perform the steps of: generating an overlay image; merging the overlay image and one or more images captured by the camera to generate a merged overlay image; and presenting the merged overlay image on the opaque display of the eyewear device.