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Dortch et al.

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(54) **SYSTEM AND METHOD FOR APPLYING USER-PREFERRED SETTINGS FOR EXTERNAL DEVICES**

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G06V 40/16 (2022.01)

(52) **U.S. Cl.**
CPC ***G06V 40/166*** (2022.01); ***G06V 40/162*** (2022.01); ***G06V 40/168*** (2022.01)

(58) **Field of Classification Search**
CPC G06V 40/166; G06V 40/162; G06V 40/168; G06V 40/193; G06V 40/176; G06V 40/11; G06V 40/113; G06V 40/175; G06V 40/28; G06V 40/174; G06V 40/20; G06V 40/161; G06V 40/172; G06V 40/16; G06V 40/18; G06V 40/197; G06V 20/52; G06V 40/171; G06V 40/19; G06V 10/141; G06V 10/70; G06V 10/762; G06V 10/82; G06V 10/95; G06V 30/2504; G06V 10/143; G06V 10/44; G06V 10/806; G06V 20/44; G06V 2201/07; G06V 40/165; G06V 40/173; G06V 40/23; G06V 40/70; G06V 20/20; G06V 10/25; G06V 10/40; G06V 20/48; G06V 10/764; G06V 10/758; G06V 20/80;
(Continued)

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(Continued)

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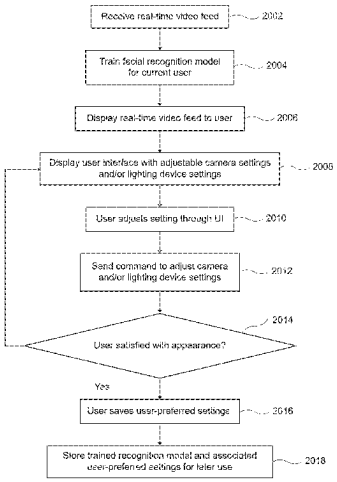
(74) *Attorney, Agent, or Firm* — Plumsea Law Group, LLC

(57) **ABSTRACT**

A system and method for training a system to recognize a user within a video feed and to automatically apply user-preferred device setting values to a camera and/or a lighting device. The method includes training the system to recognize the user's face and allowing the user to select user-preferred device setting values, which result in an optimal exposure for their face within the video feed. The method further includes detecting the face of the user, at a later time, and applying the user-preferred device setting values to a camera and/or lighting device. Such a system may be used in a variety of applications, including video calls.

20 Claims, 23 Drawing Sheets



(58) **Field of Classification Search**
CPC G06V 10/147; G06V 10/16; G06V 10/803; G06F 3/017; G06F 3/012; G06F 3/0304; G06F 3/013; G06F 3/011; G06F 3/005; G06F 3/0484; G06F 1/1686; G06F 21/32; G06F 3/016; G06F 18/22; G06F 21/60; G06F 16/55; G06F 21/31; G06F 1/3231; G06F 18/24; H04W 12/06; H04W 4/50; H04W 4/20; H04W 88/02; H04W 4/80; G06T 13/40; G06T 7/20; G06T 2207/30201; G06T 5/77; G06T 2200/24; G06T 7/73; G06T 1/00; G06T 5/50; G06T 7/00; G06T 5/80; G06T 7/70; G06T 11/80; G06T 13/80; G06T 11/00; G06T 2200/08; G06T 2207/20084; G06T 2207/30244; G06T 2210/22; G06T 3/04; G06T 3/18; G06T 2210/44; G06T 7/246; G06T 7/55; G06T 11/60; G06T 2207/10016; G06T 2207/10024; G06T 19/20; G06T 15/506; G06T 2207/10048; G06T 19/006; G06T 5/00; G06T 1/0007; G06T 2200/04; G06T 2207/10148; G06T 5/70; G06T 7/571; G06T 15/10; G06T 2207/30221; G06T 2207/20221; G06T 2207/20224; G06T 3/60; G06T 7/33; G06T 2207/20212; G06T 5/92; G06T 5/60; G06T 7/0012; G06T 7/80; G06T 7/97; G06N 20/00; G06N 3/045; H04M 1/0264; H04M 1/0266; H04M 1/0216; H04M 1/026; H04M 1/72439; H04M 1/72433; H04L 12/1831; H04L 51/10
See application file for complete search history.

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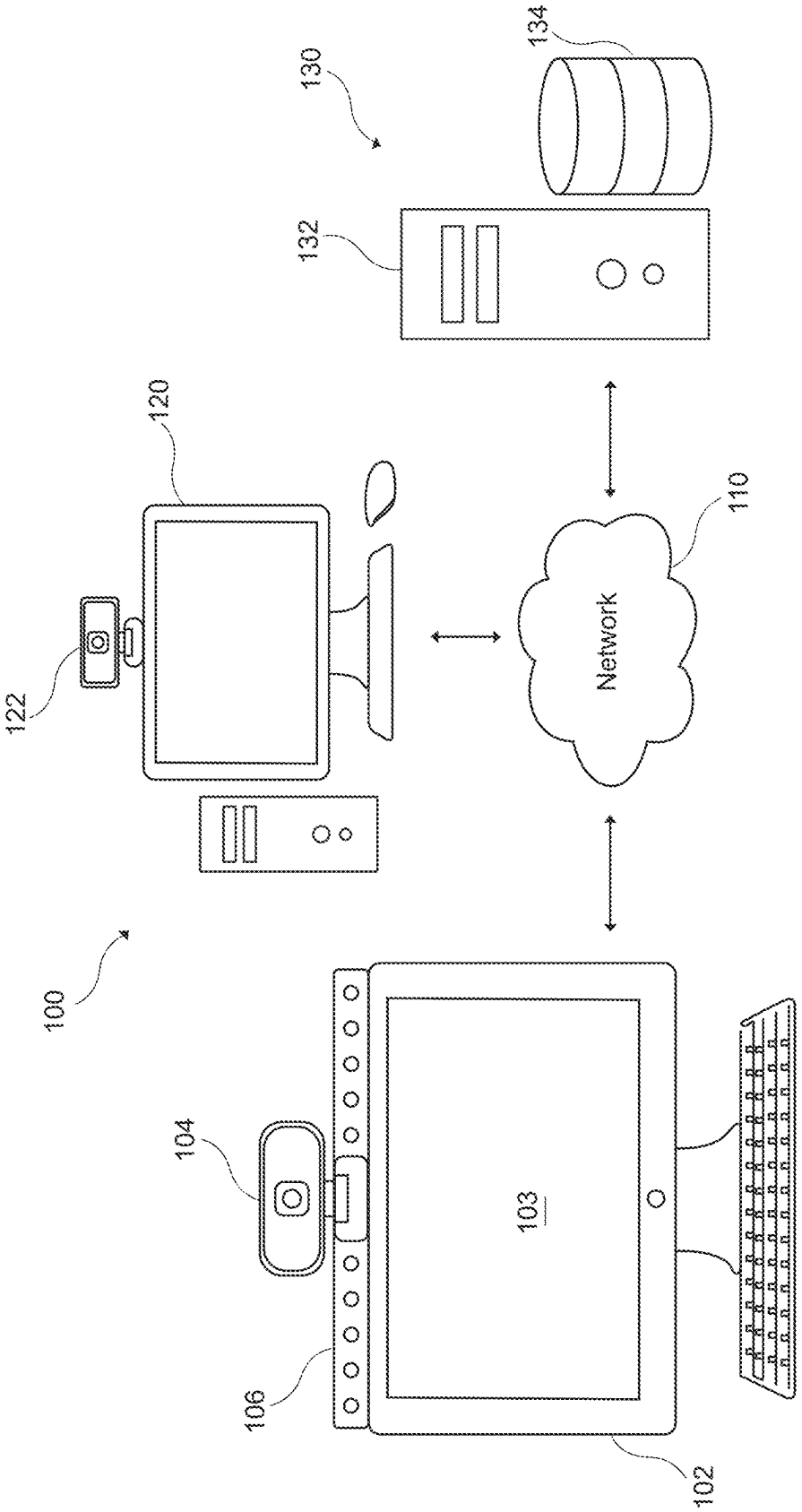

FIG. 1

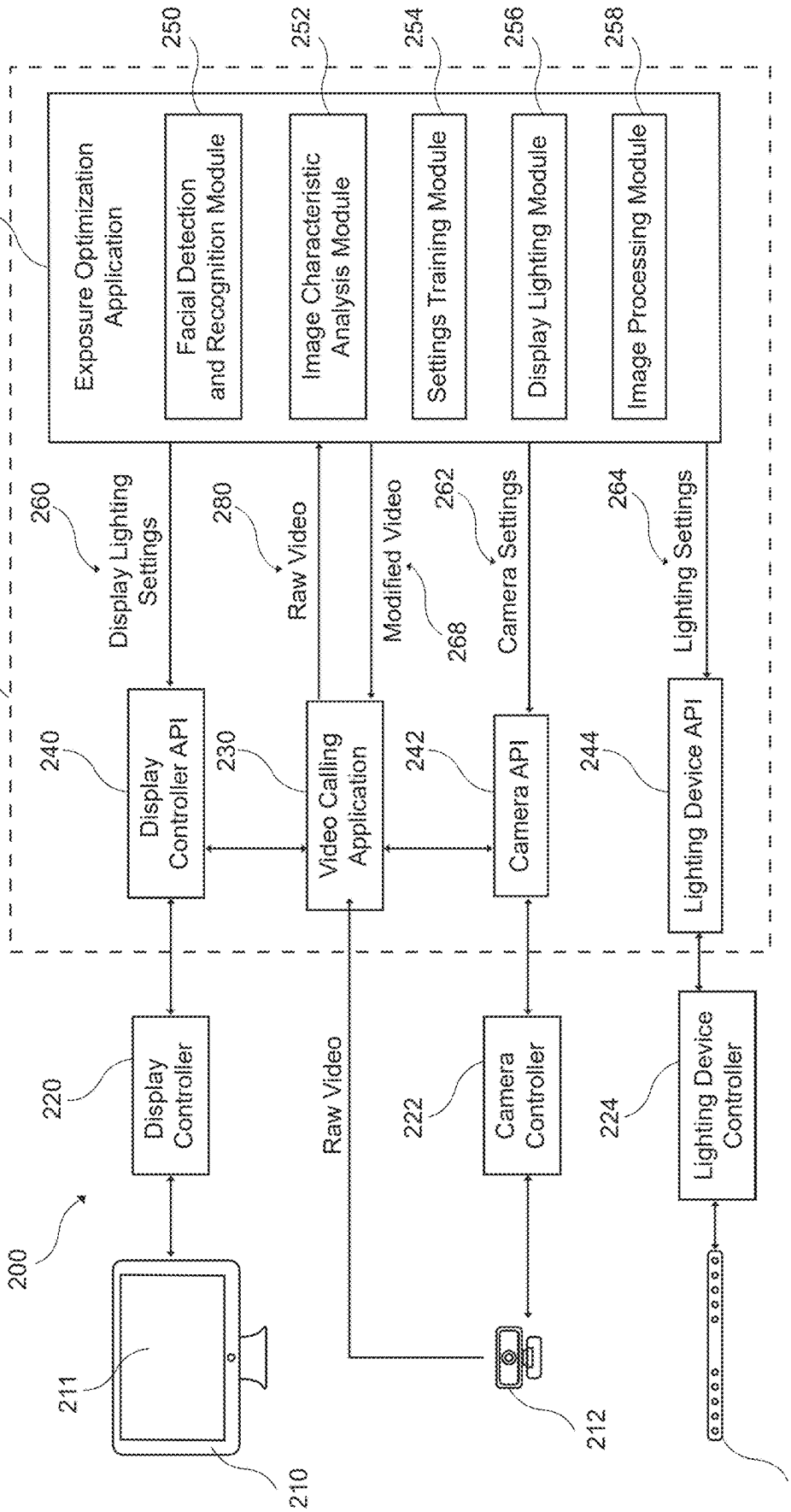
200
202
210
211
212
214
215
220
222
224
230
240
242
244
250
252
254
256
258
260
262
264
268
280
Exposure Optimization Application
Facial Detection and Recognition Module
Image Characteristic Analysis Module
Settings Training Module
Display Lighting Module
Image Processing Module
Display Lighting Settings
Raw Video
Modified Video
Camera Settings
Lighting Settings
Display Controller API
Video Calling Application
Camera API
Lighting Device API
Display Controller
Camera Controller
Lighting Device Controller
Raw Video

FIG. 2

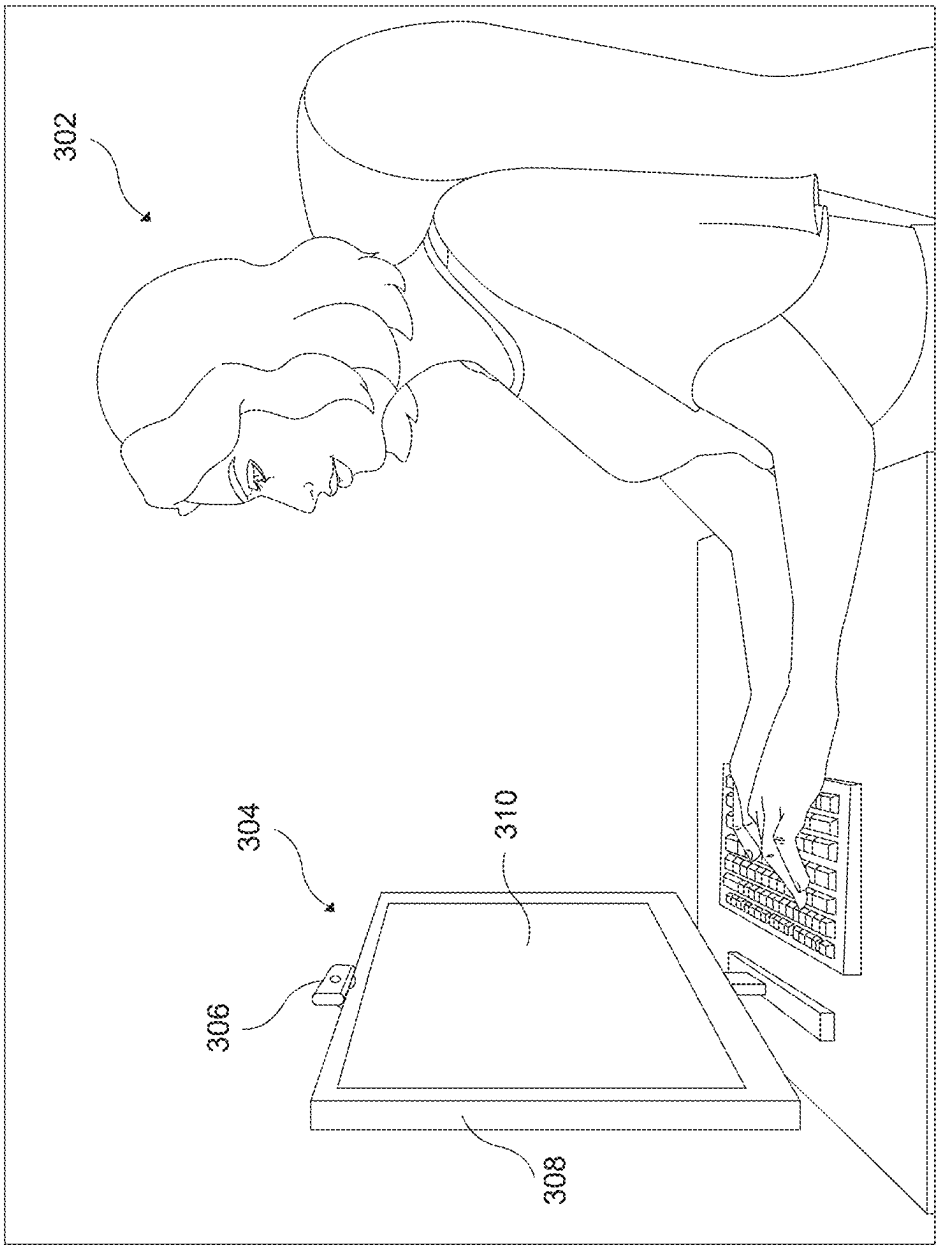

FIG. 3

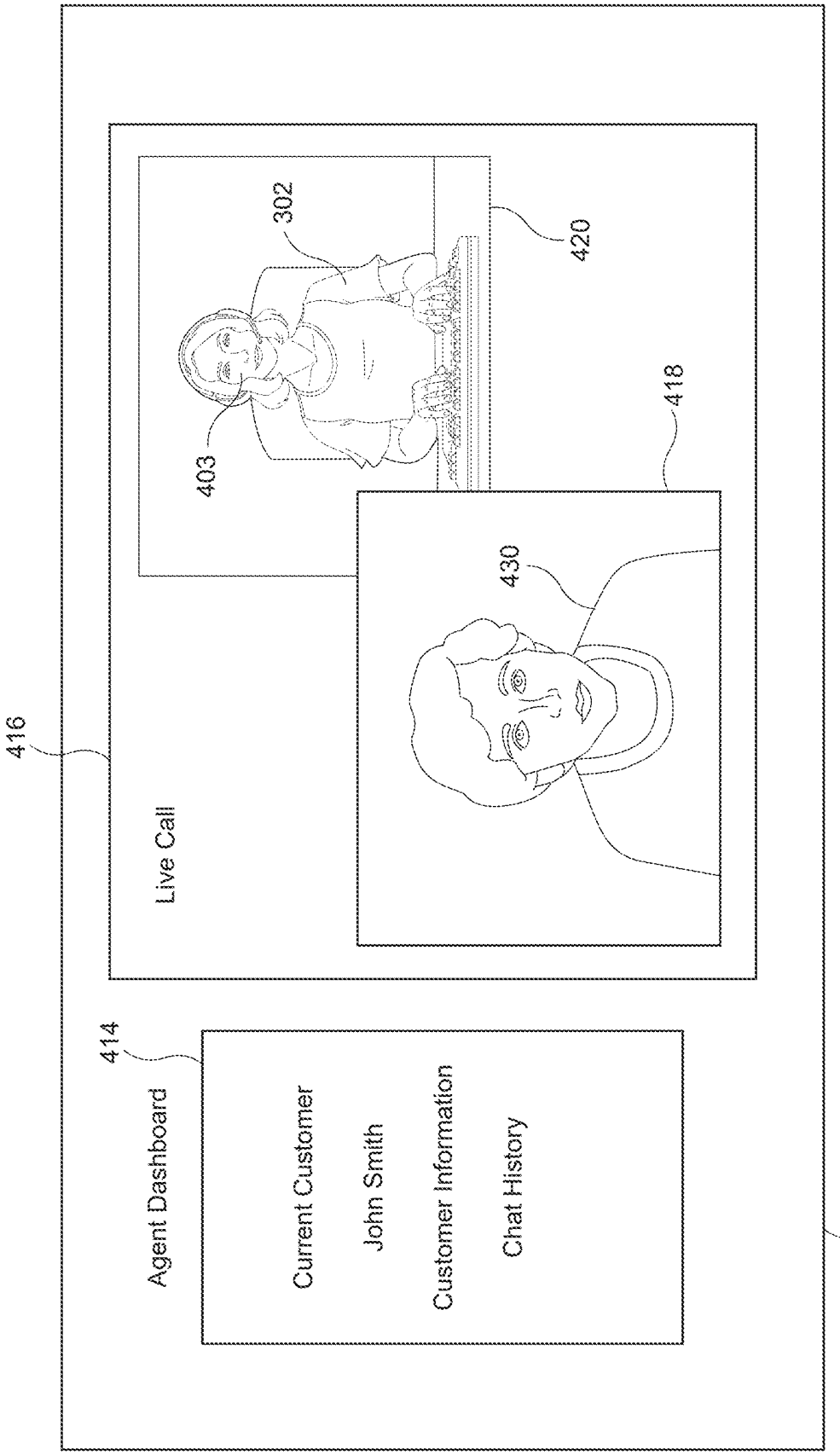
310
Agent Dashboard
414
Current Customer
John Smith
Customer Information
Chat History
416
Live Call
403
302
420
418
430

FIG. 4

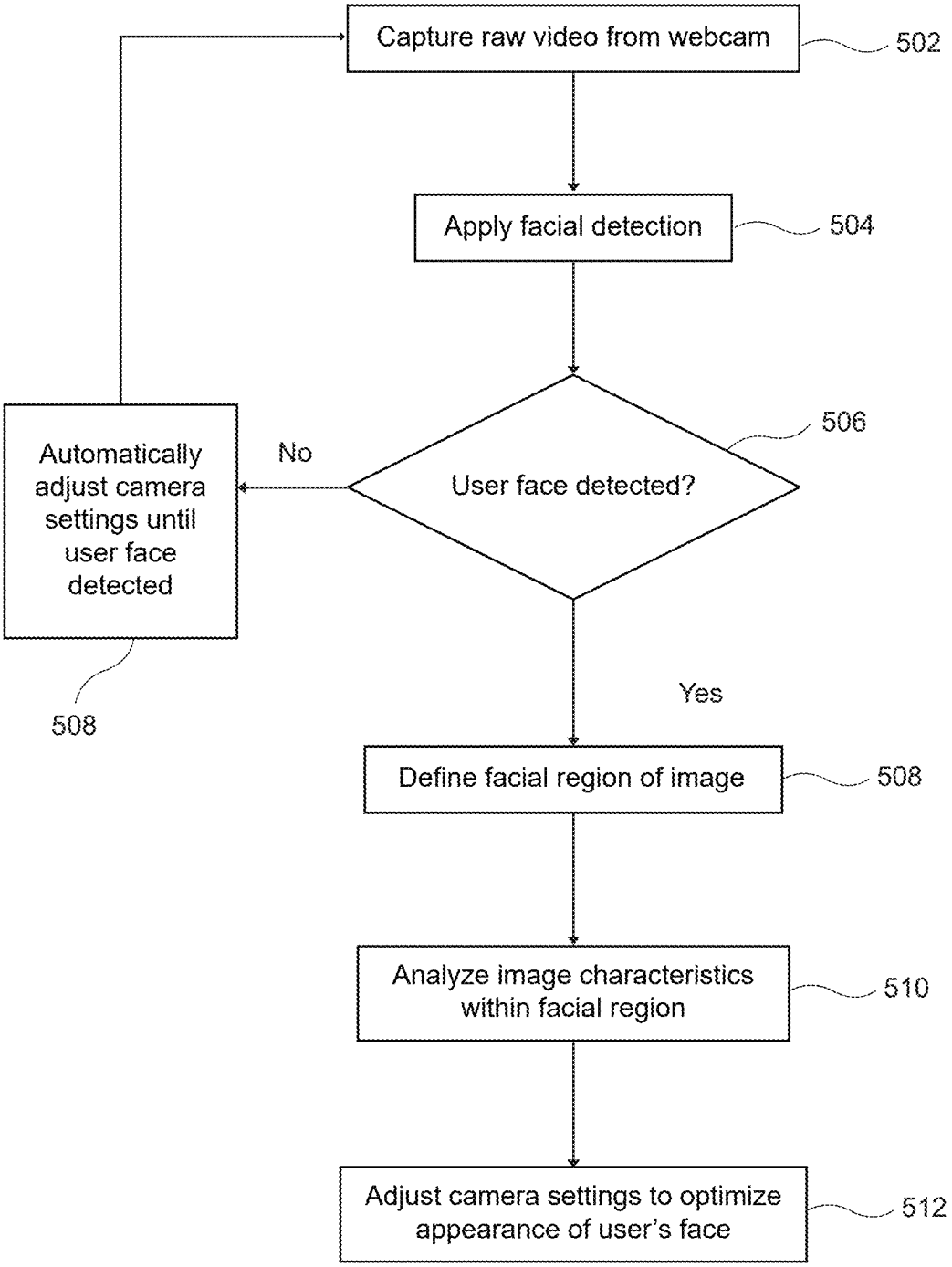
Capture raw video from webcam
502
Apply facial detection
504
User face detected?
506
No
Automatically adjust camera settings until user face detected
508
Yes
Define facial region of image
508
Analyze image characteristics within facial region
510
Adjust camera settings to optimize appearance of user's face
512

FIG. 5

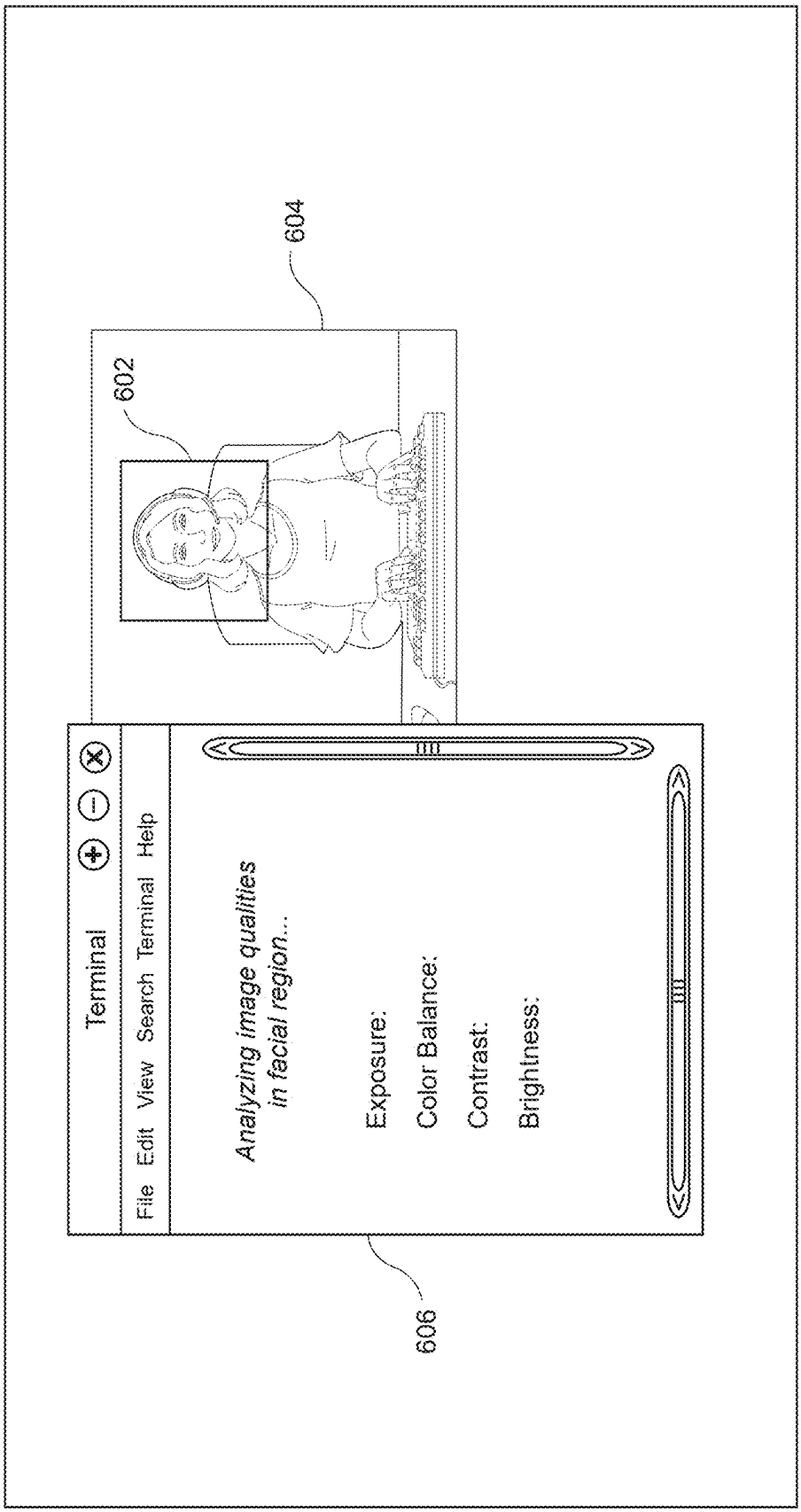
604
602
Terminal
File Edit View Search Terminal Help
Analyzing image qualities
in facial region...
Exposure:
Color Balance:
Contrast:
Brightness:
606

FIG. 6

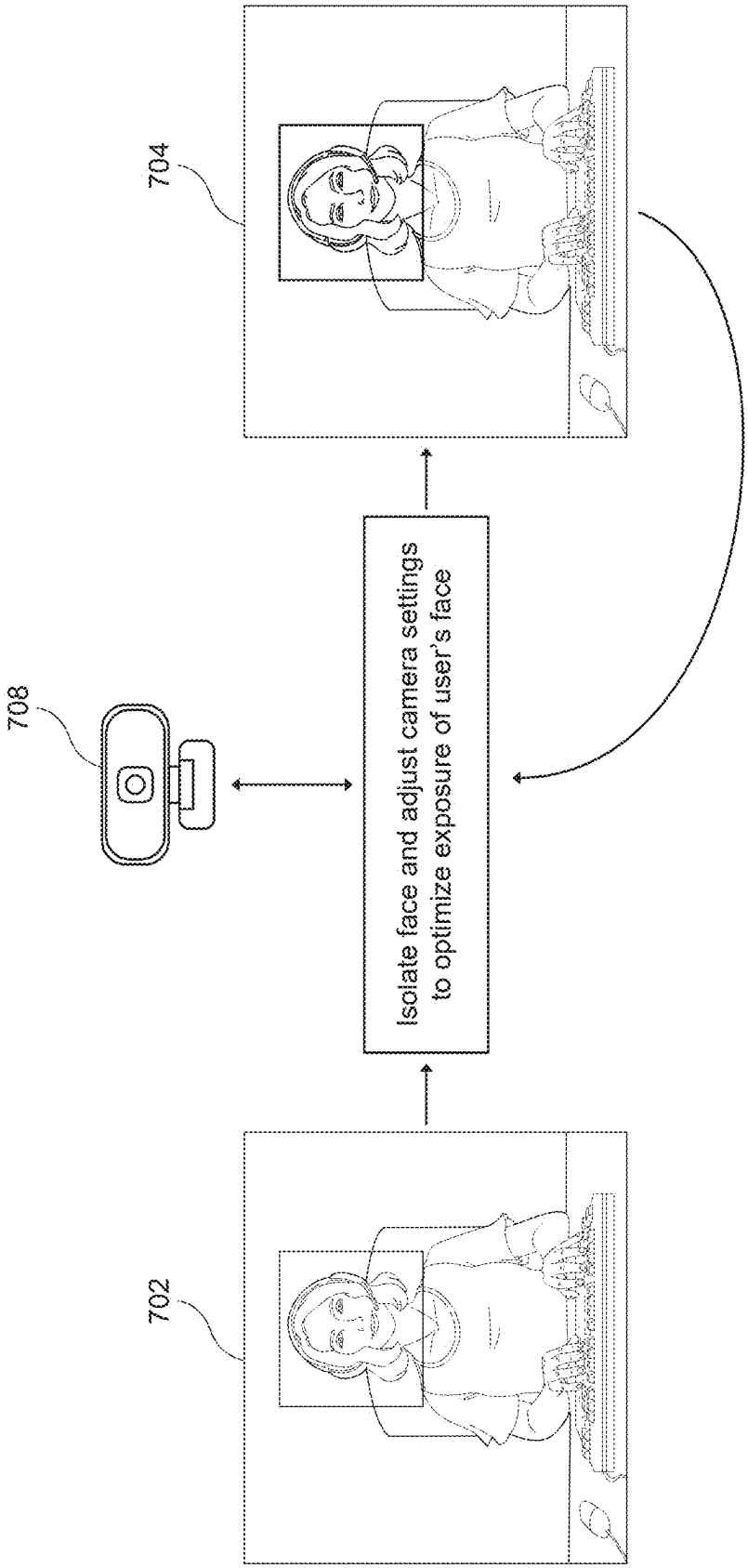
704
708
Isolate face and adjust camera settings to optimize exposure of user's face
702

FIG. 7

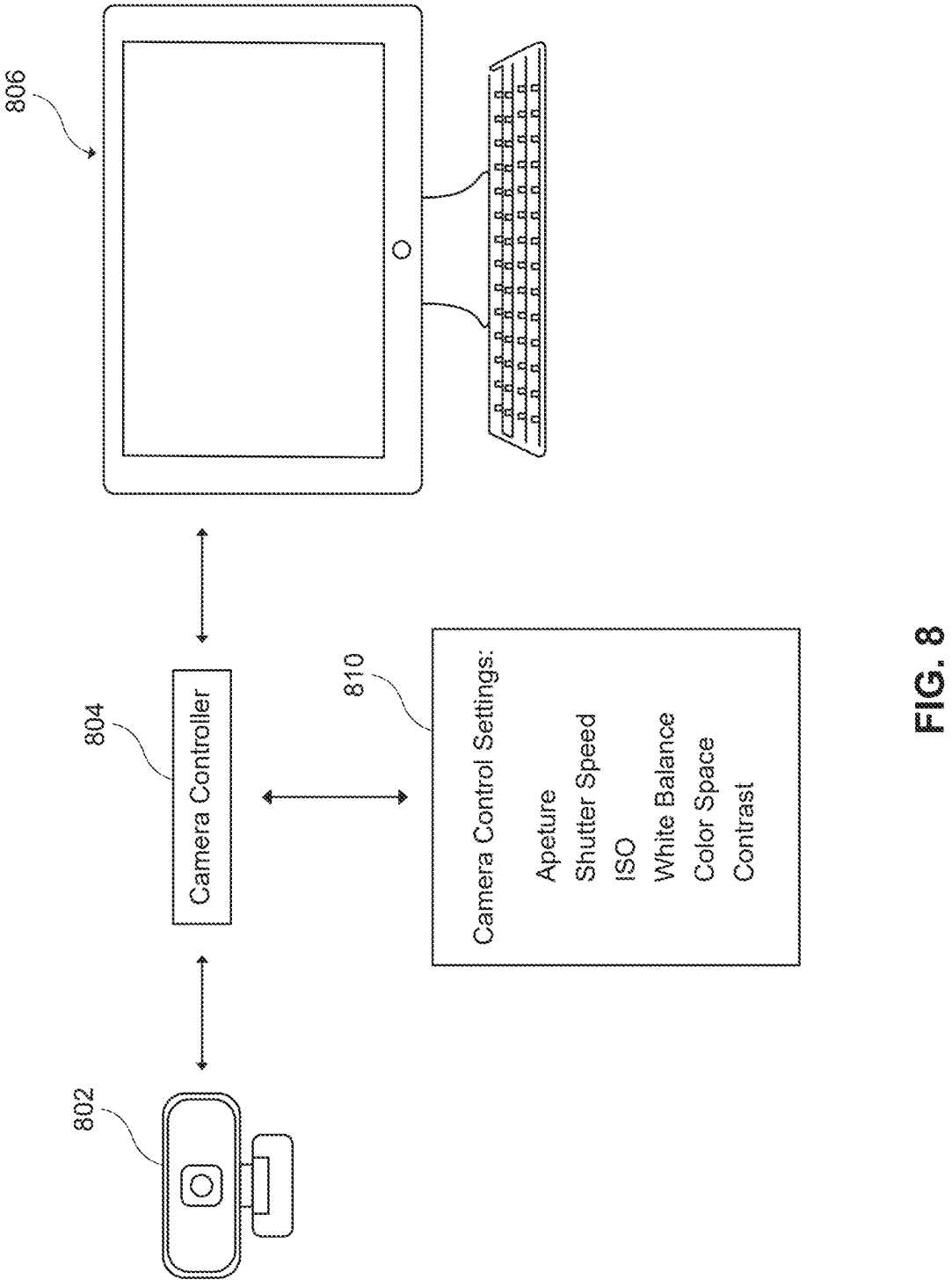
806
804
Camera Controller
810
Camera Control Settings:
Apeture
Shutter Speed
ISO
White Balance
Color Space
Contrast
802

FIG. 8

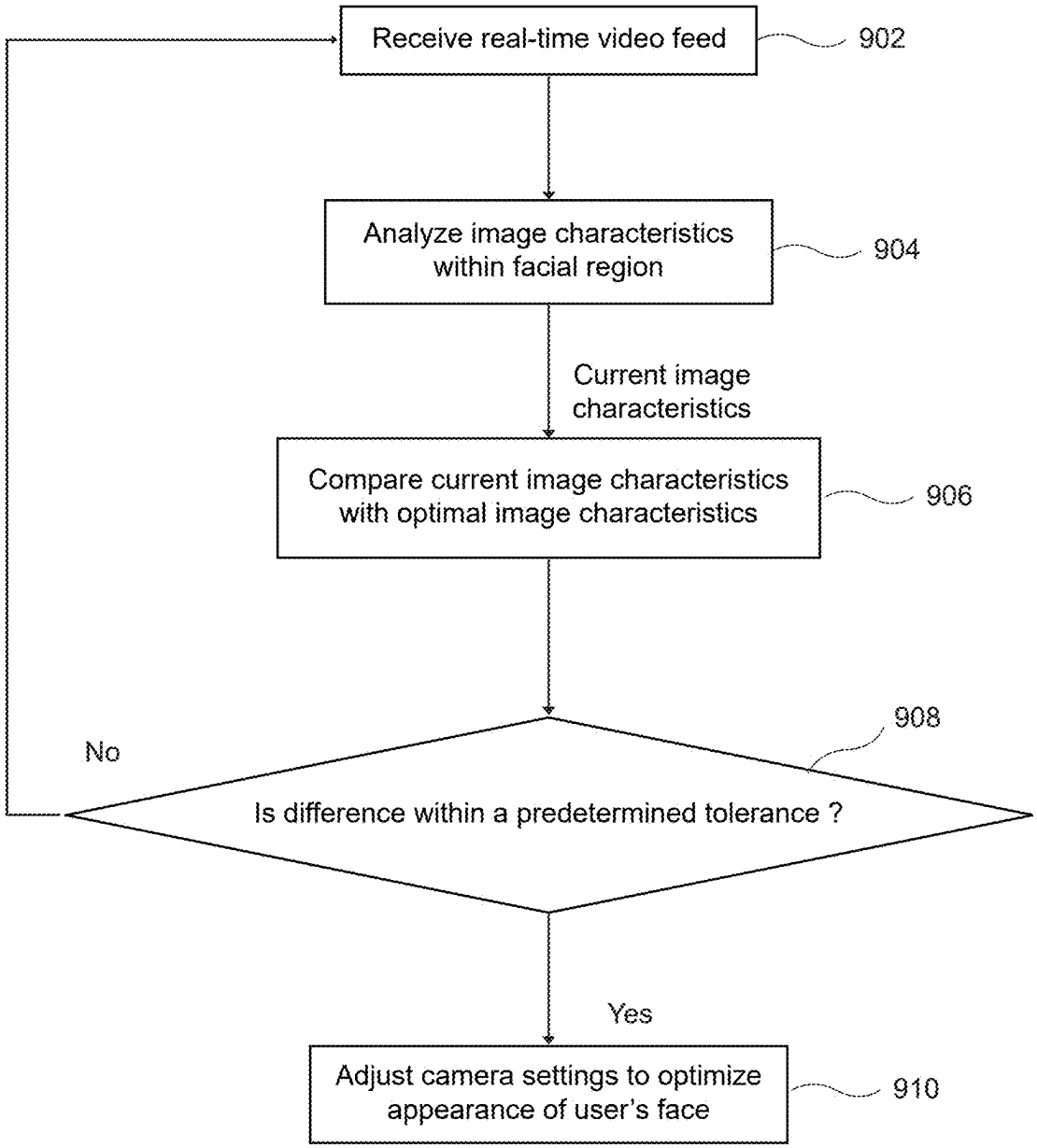
Receive real-time video feed
902
Analyze image characteristics within facial region
904
Current image characteristics
Compare current image characteristics with optimal image characteristics
906
908
No
Is difference within a predetermined tolerance ?
Yes
Adjust camera settings to optimize appearance of user's face
910

FIG. 9

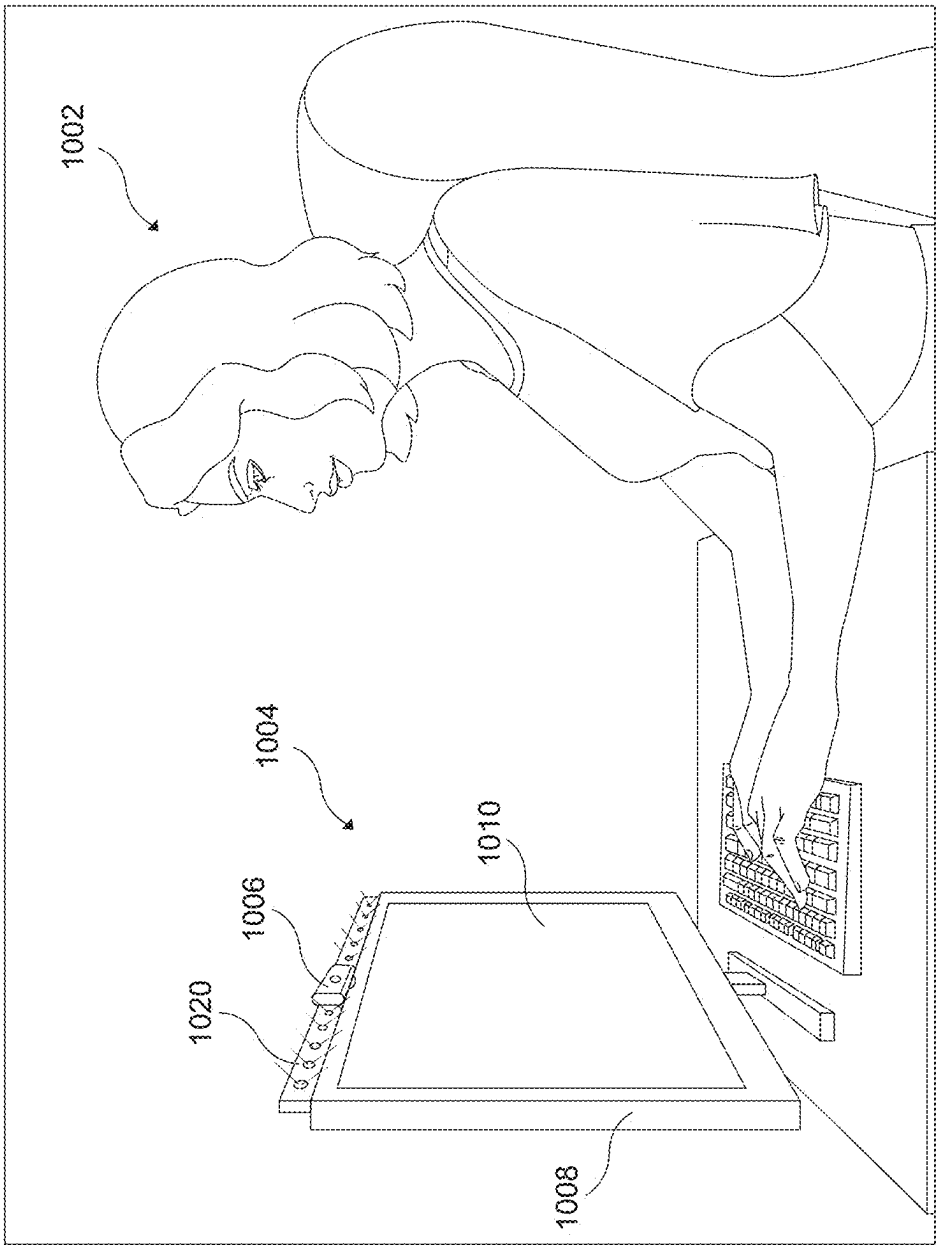

FIG. 10

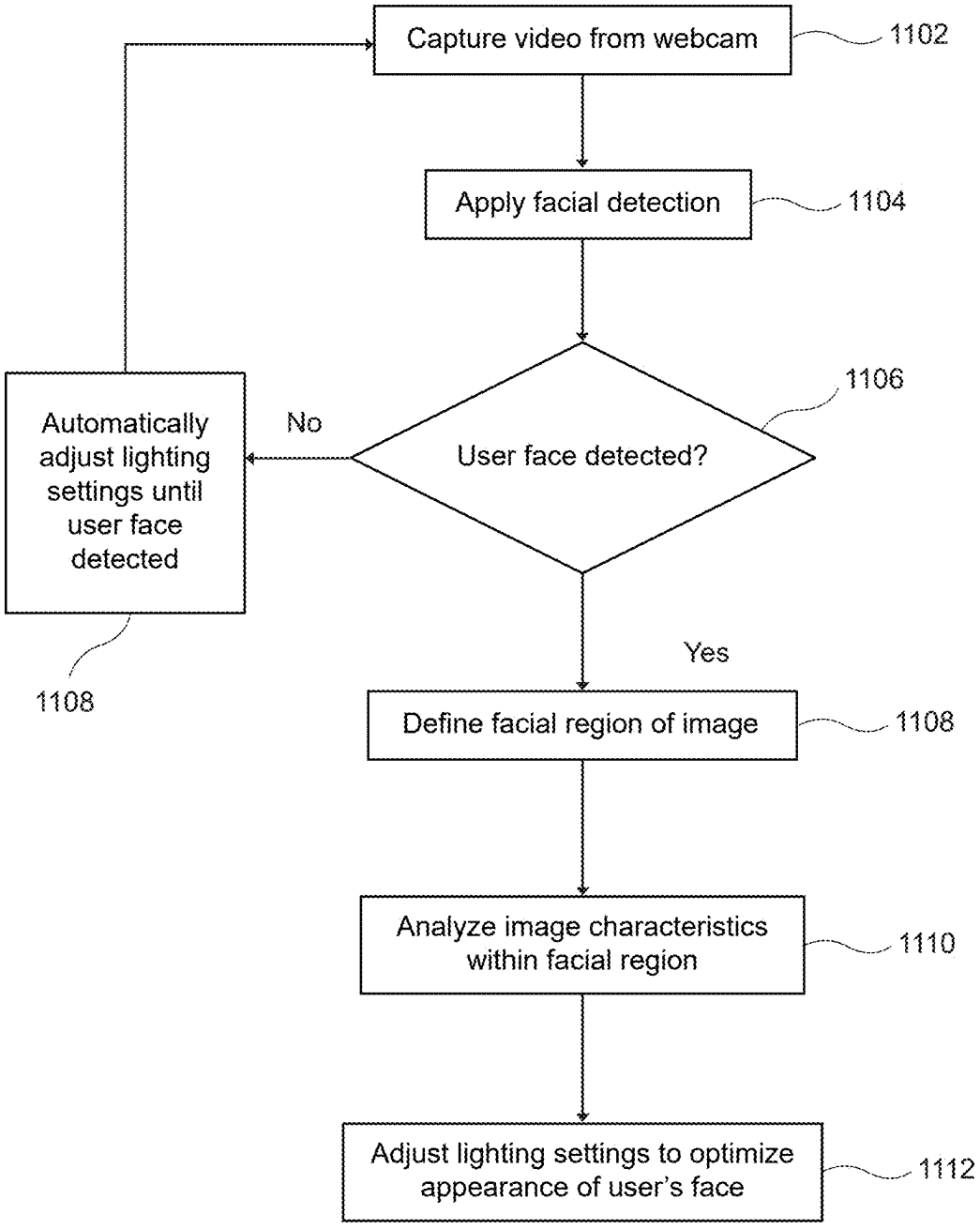
Capture video from webcam
1102
Apply facial detection
1104
User face detected?
1106
No
Automatically adjust lighting settings until user face detected
1108
Yes
Define facial region of image
1108
Analyze image characteristics within facial region
1110
Adjust lighting settings to optimize appearance of user's face
1112

FIG. 11

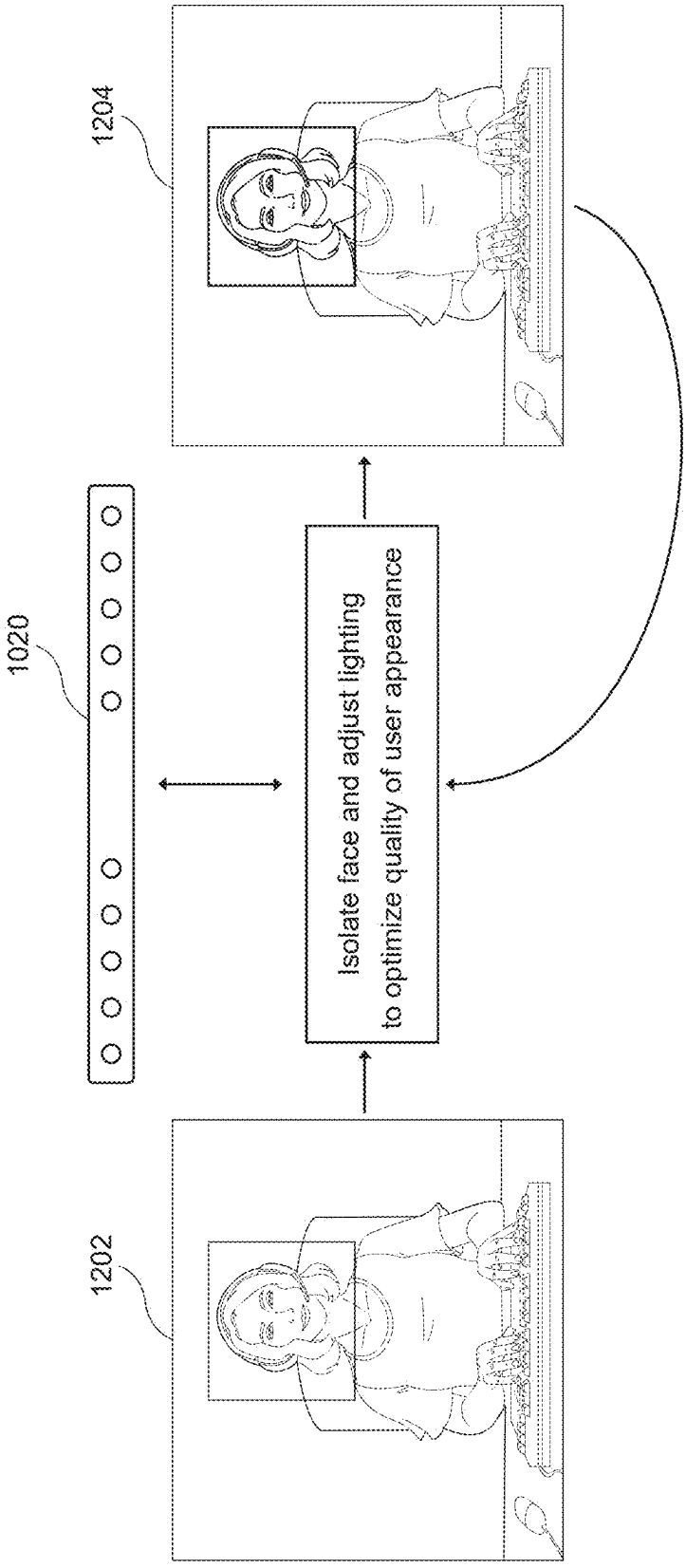
1204
1020
Isolate face and adjust lighting
to optimize quality of user appearance
1202

FIG. 12

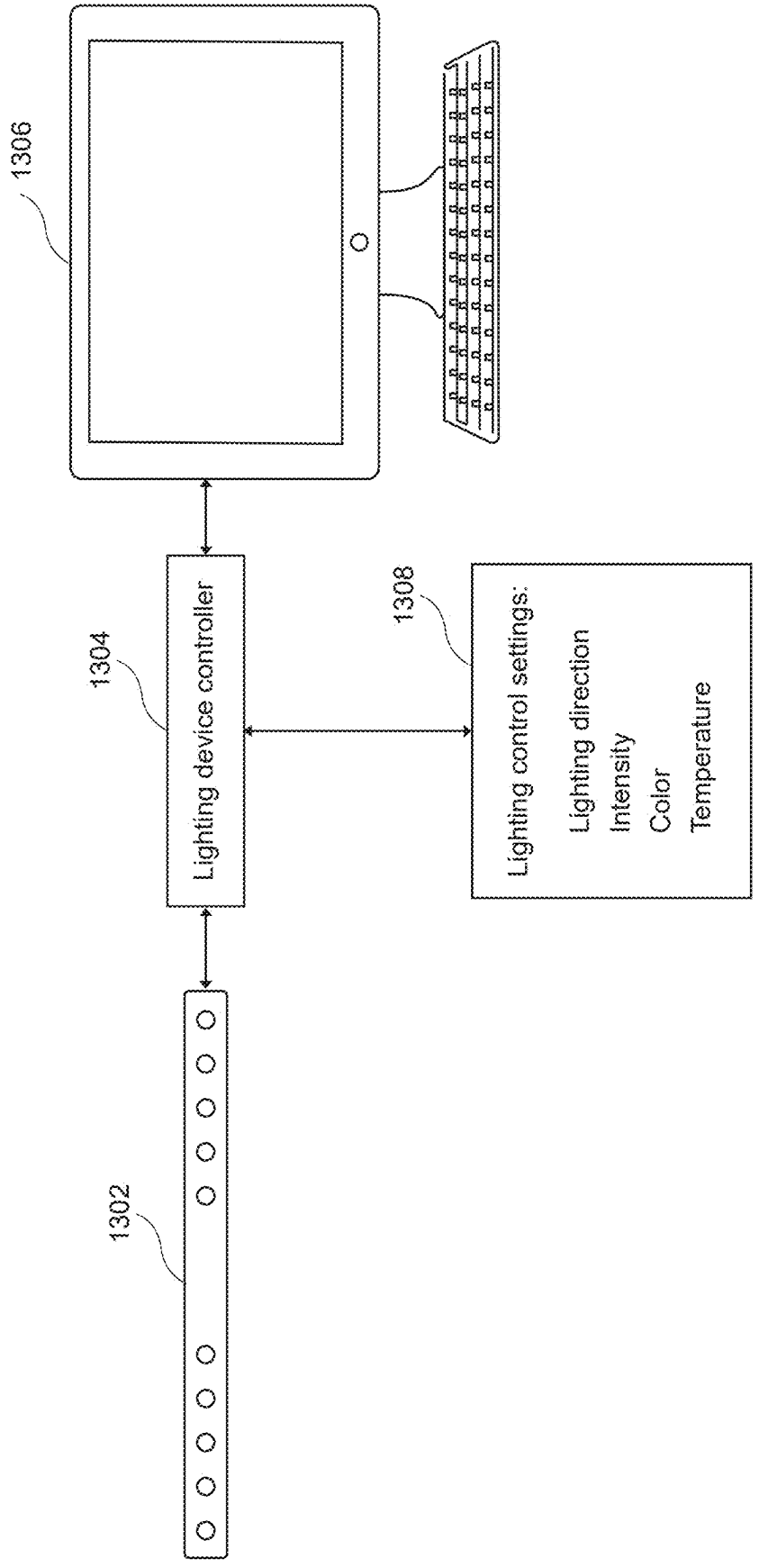
1306
1304
Lighting device controller
1308
Lighting control settings:
Lighting direction
Intensity
Color
Temperature
1302

FIG. 13

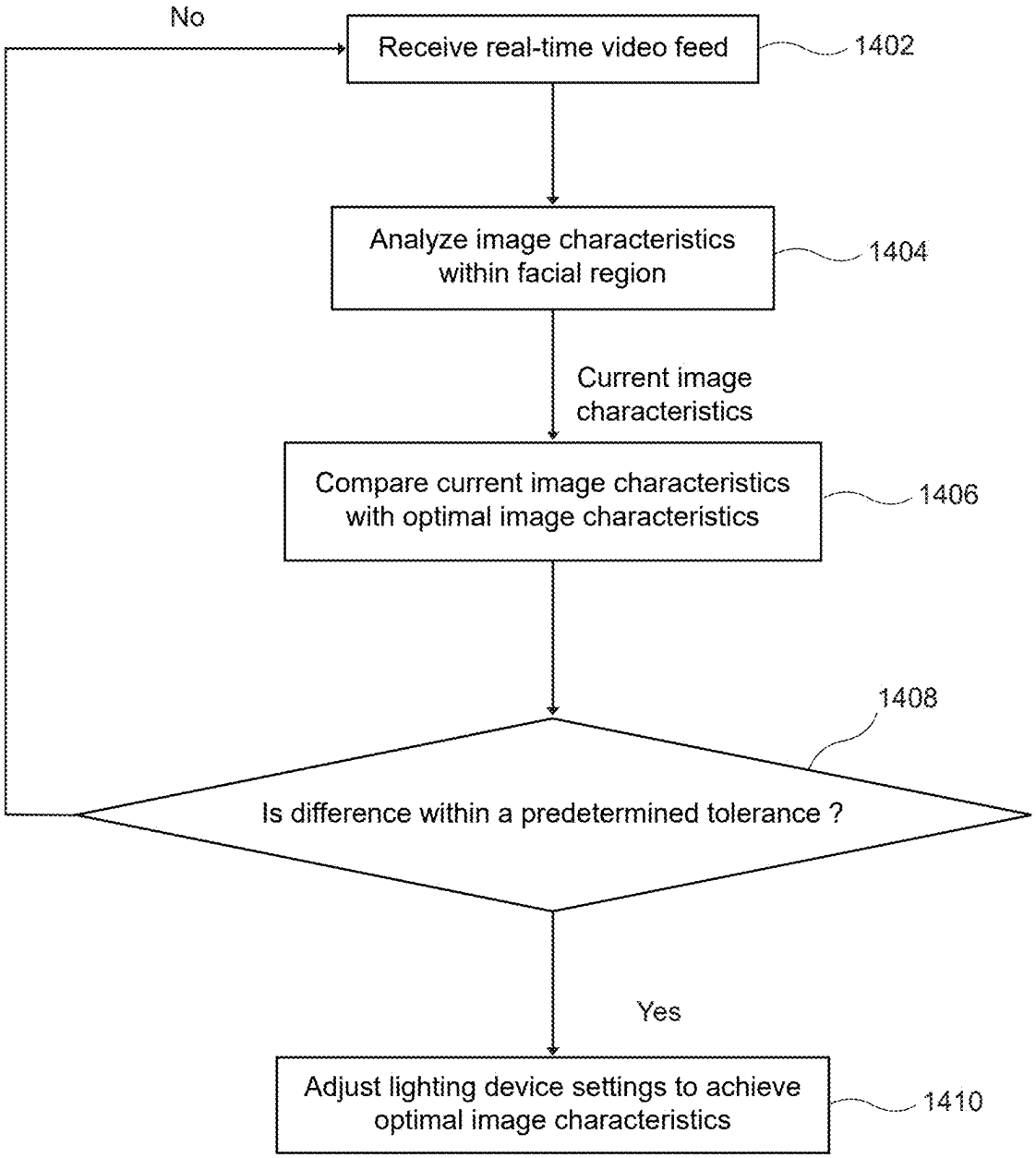
No
Receive real-time video feed
1402
Analyze image characteristics within facial region
1404
Current image characteristics
Compare current image characteristics with optimal image characteristics
1406
1408
Is difference within a predetermined tolerance ?
Yes
Adjust lighting device settings to achieve optimal image characteristics
1410

FIG. 14

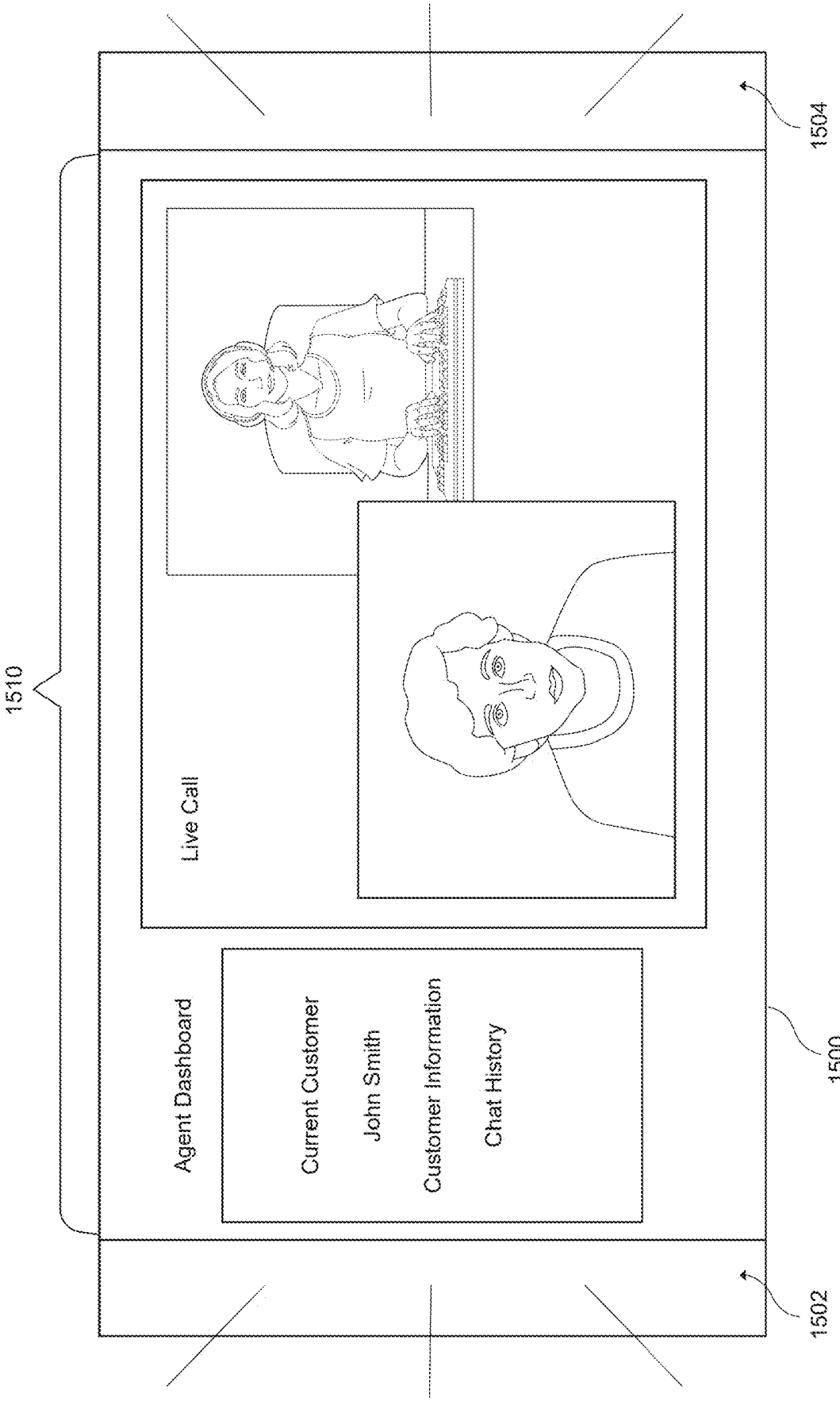
1504
1510
Live Call
Agent Dashboard
Current Customer
John Smith
Customer Information
Chat History
1500
1502

FIG. 15

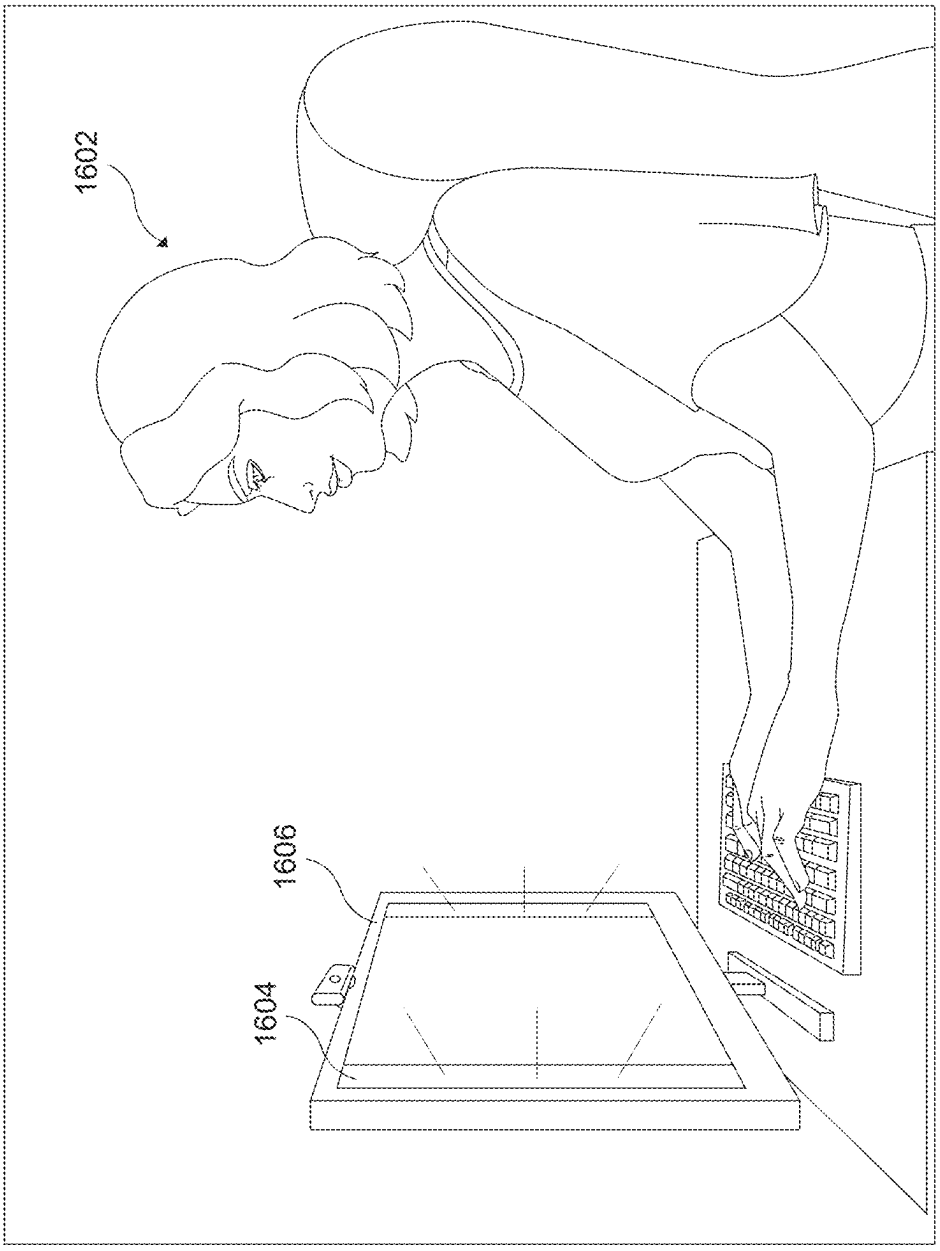

FIG. 16

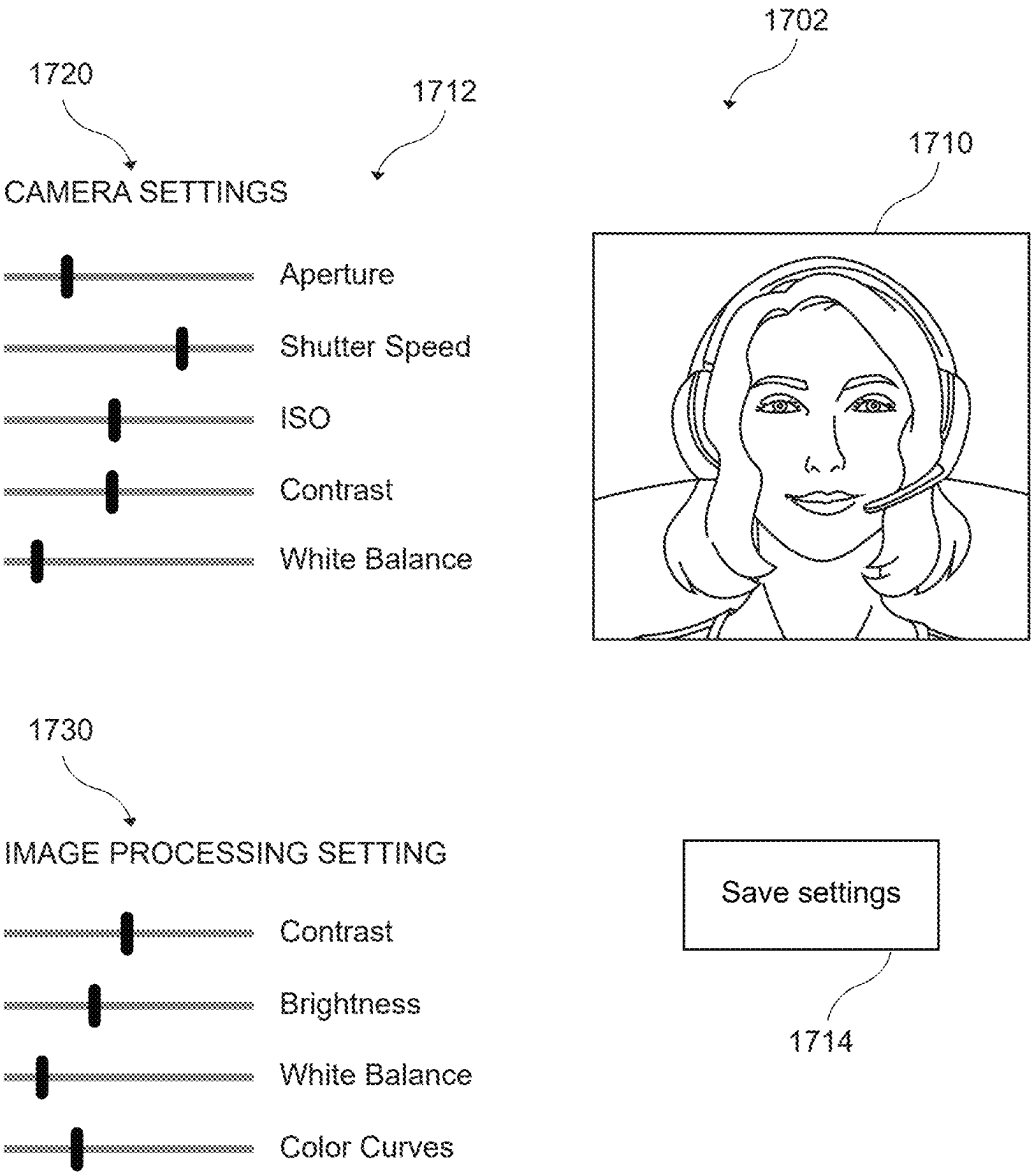
1702
1720
1712
1710
CAMERA SETTINGS
Aperture
Shutter Speed
ISO
Contrast
White Balance
1730
IMAGE PROCESSING SETTING
Contrast
Brightness
White Balance
Color Curves
Save settings
1714

FIG. 17

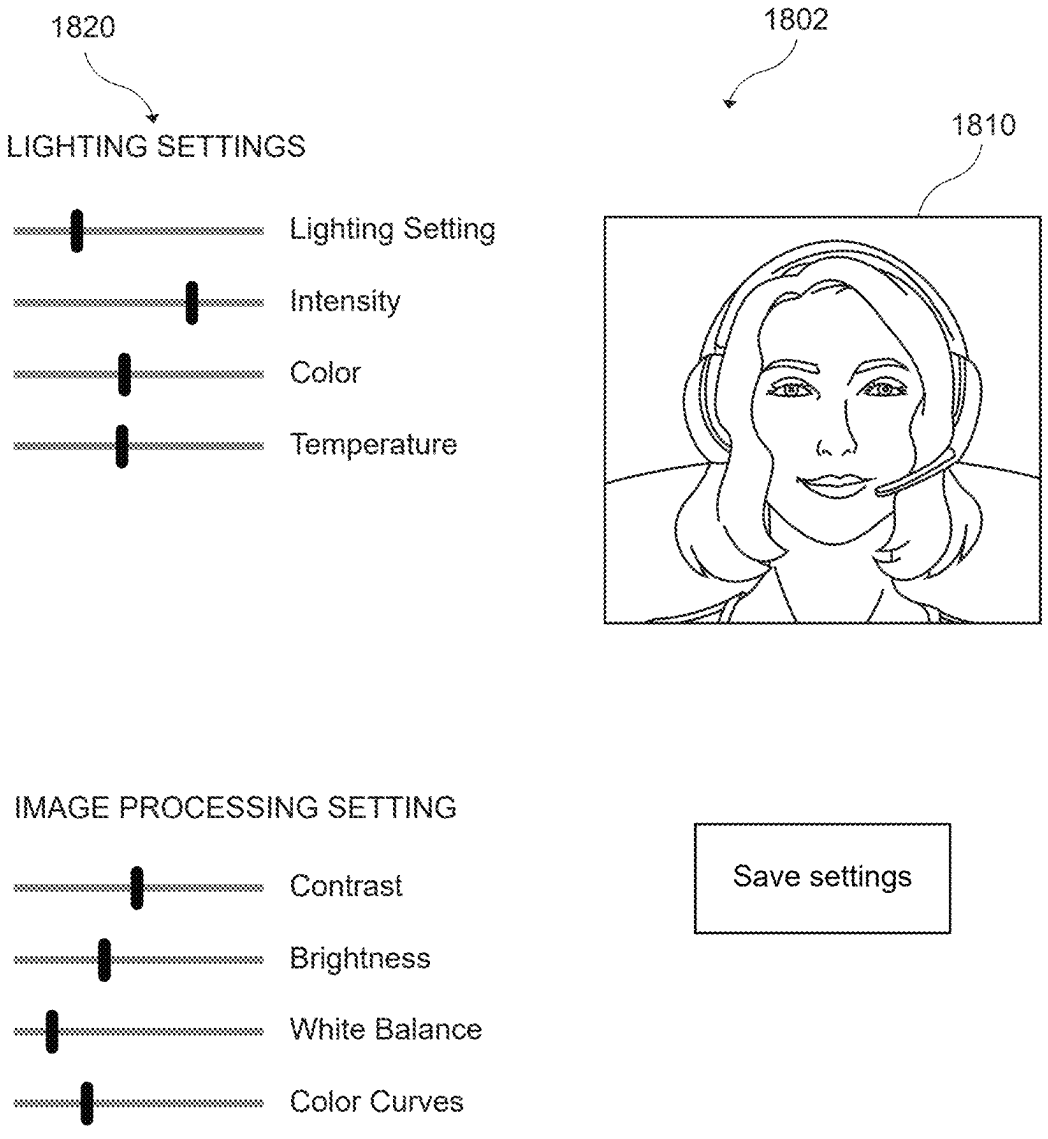
1820
1802
1810
LIGHTING SETTINGS
Lighting Setting
Intensity
Color
Temperature
IMAGE PROCESSING SETTING
Contrast
Brightness
White Balance
Color Curves
Save settings

FIG. 18

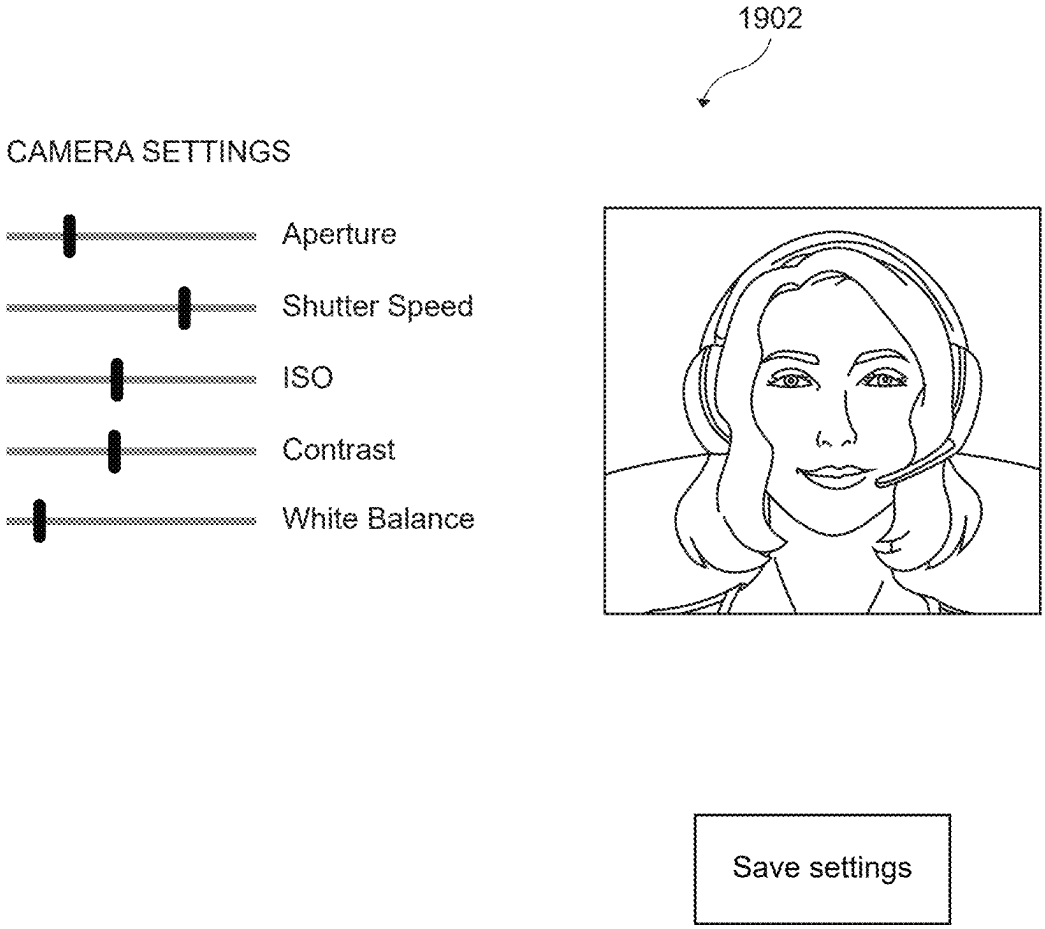
1902
CAMERA SETTINGS
Aperture
Shutter Speed
ISO
Contrast
White Balance
Save settings
LIGHTING SETTINGS
Lighting Setting
Intensity
Color
Temperature

FIG. 19

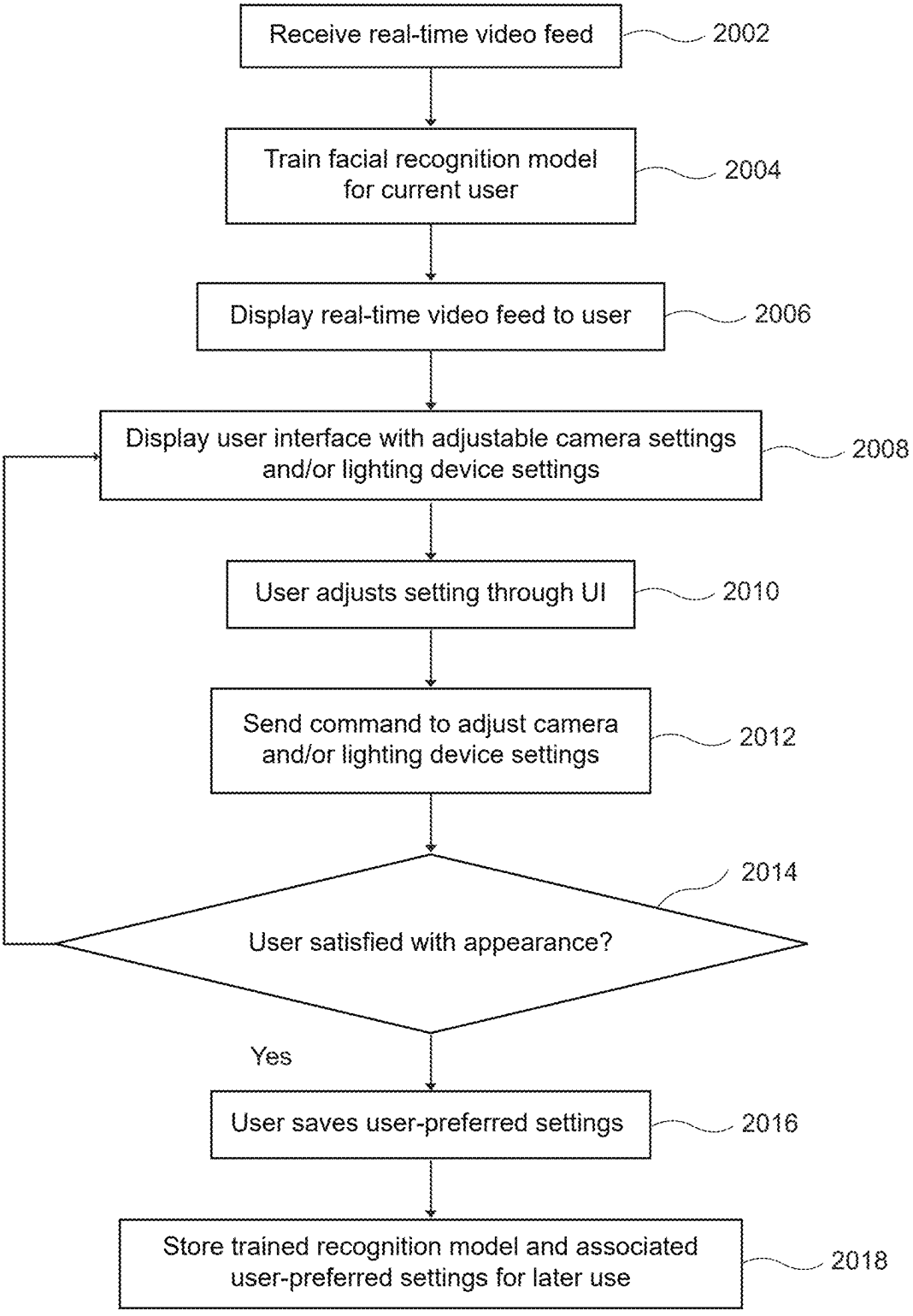
Receive real-time video feed
2002
Train facial recognition model for current user
2004
Display real-time video feed to user
2006
Display user interface with adjustable camera settings and/or lighting device settings
2008
User adjusts setting through UI
2010
Send command to adjust camera and/or lighting device settings
2012
User satisfied with appearance?
2014
Yes
User saves user-preferred settings
2016
Store trained recognition model and associated user-preferred settings for later use
2018

FIG. 20

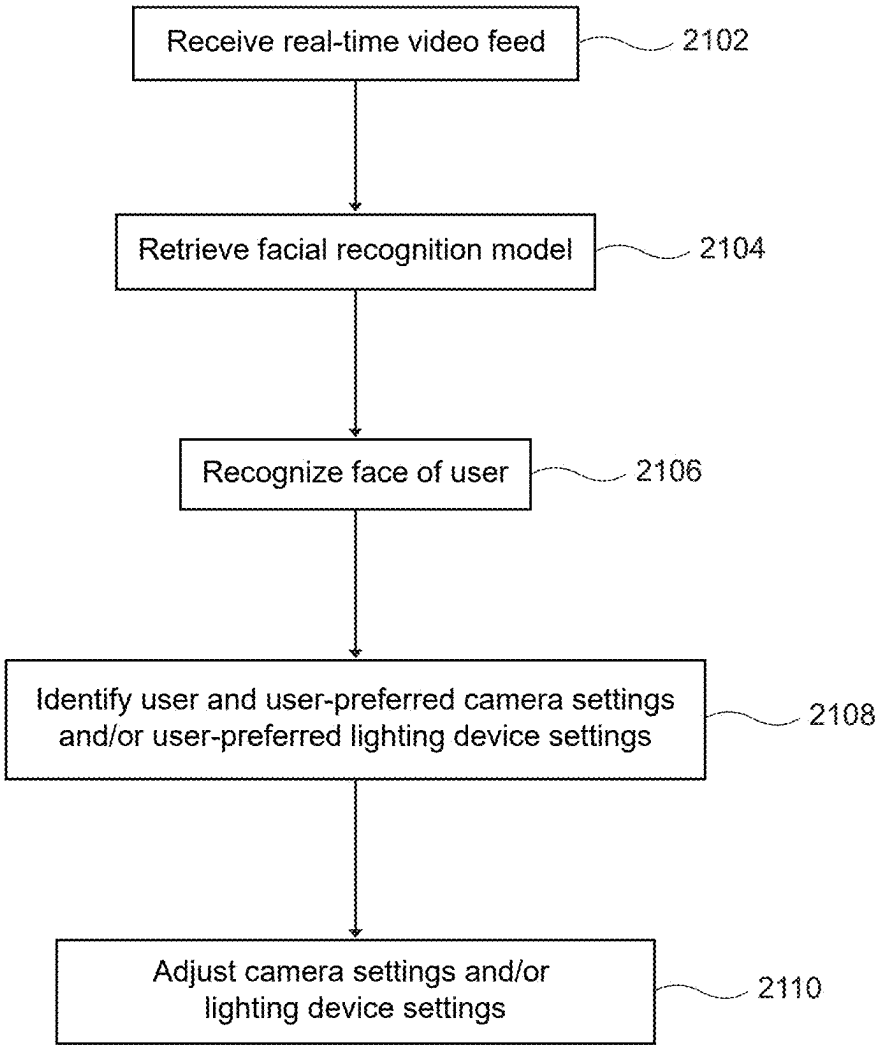
Receive real-time video feed
2102
Retrieve facial recognition model
2104
Recognize face of user
2106
Identify user and user-preferred camera settings and/or user-preferred lighting device settings
2108
Adjust camera settings and/or lighting device settings
2110

FIG. 21

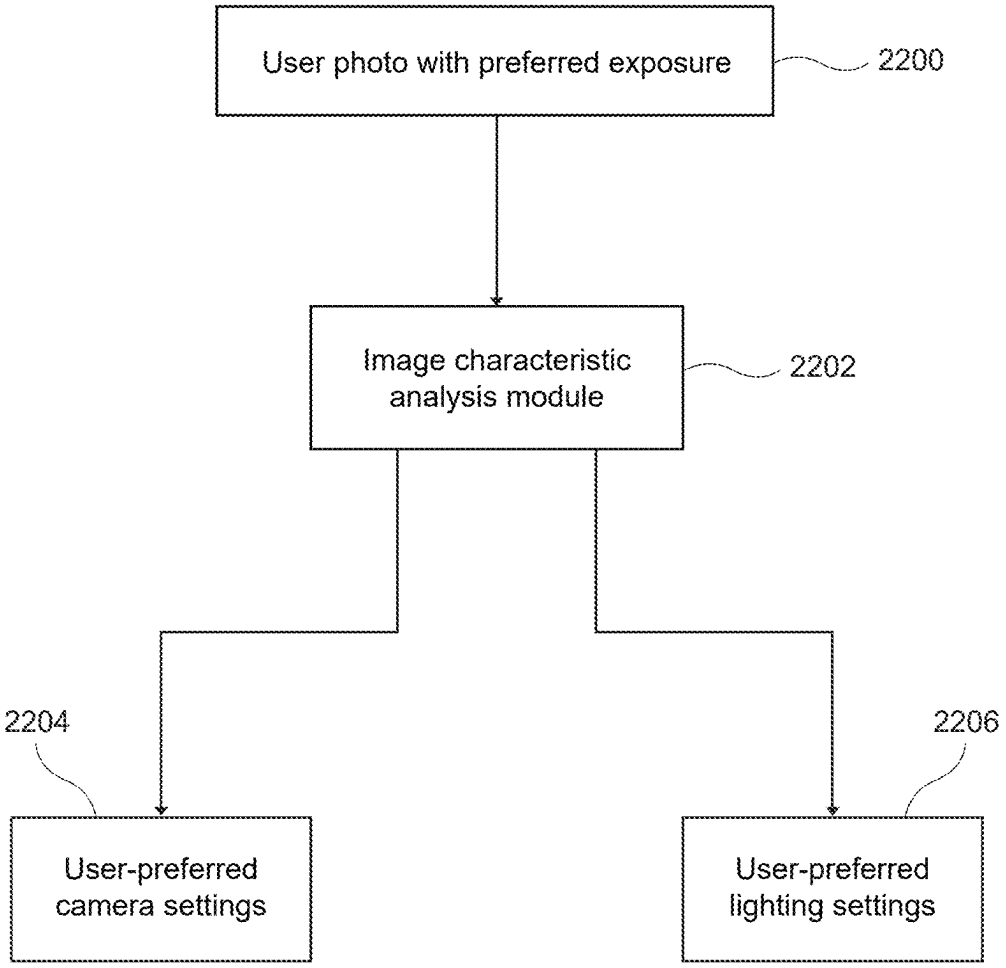
User photo with preferred exposure
2200
Image characteristic analysis module
2202
2204
2206
User-preferred camera settings
User-preferred lighting settings

FIG. 22

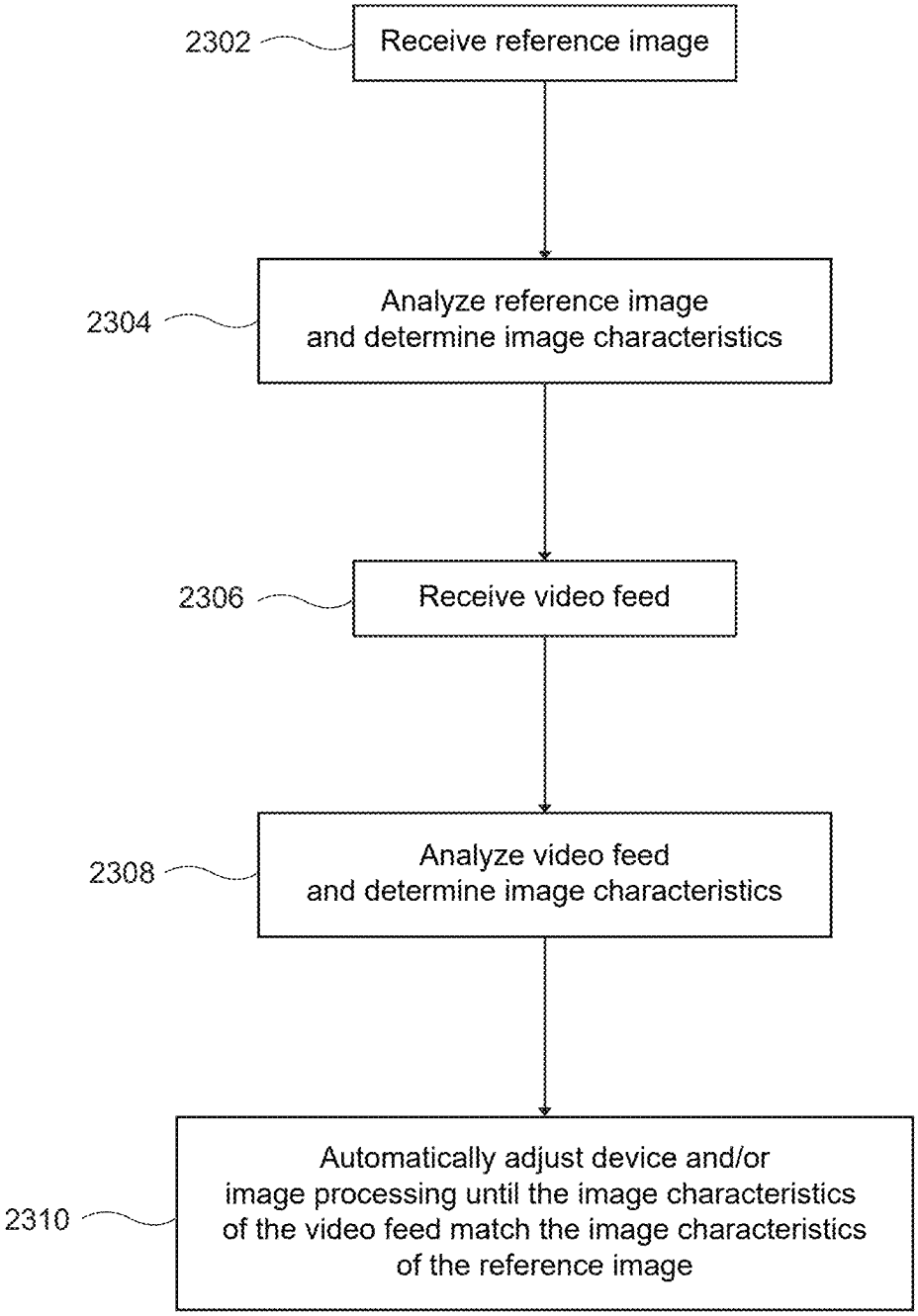
2302
Receive reference image
2304
Analyze reference image
and determine image characteristics
2306
Receive video feed
2308
Analyze video feed
and determine image characteristics
2310
Automatically adjust device and/or
image processing until the image characteristics
of the video feed match the image characteristics
of the reference image

FIG. 23

SYSTEM AND METHOD FOR APPLYING USER-PREFERRED SETTINGS FOR EXTERNAL DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Provisional Patent Application No. 63/250,278 filed Sep. 30, 2021, and titled "System and Method for Applying User-Preferred Settings for External Devices," which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present disclosure generally relates to video, and in particular to optimizing lighting qualities of a video.

BACKGROUND

Consumers are coming to rely on using cameras (and specifically, so-called "webcams"), to stream video during video calls for both remote work and personal social interactions. Most inexpensive cameras, including webcams, which may be used for remote work and other video calls aren't well calibrated to produce the best exposure for some user complexions. This can result in video feeds that are overexposed, or underexposed, especially with respect to the caller's face. In the context of remote work, or video conferencing, this can lead to differences in the image quality of video feeds for users with different complexions. This can cause frustration for user's whose video feeds are not properly exposed. In the context of remote work, such discrepancies in image quality can have a negative impact on a particular employee's ability to communicate while on video calls.

There is a need in the art for a system and method that addresses the shortcomings discussed above.

SUMMARY

In one aspect, a method of optimizing image quality for real-time video feeds using a camera connected to a computer system includes steps of receiving a video feed from the camera, the camera having a set of camera settings, training a facial recognition model, using the received video feed, to recognize a face of a user, and displaying the real-time video feed from the camera for a user. The method further includes steps of providing the user, through a user interface, with a set of adjustable camera settings and sending commands to a camera controller of the camera to adjust the set of camera settings according to changes to the set of adjustable camera settings made by the user through the user interface. The method also includes steps of receiving a set of user-preferred camera setting values, storing the trained facial recognition model and the set of user-preferred camera setting values, and receiving a new video feed from the camera, the new video feed being captured while the camera has a set of initial camera setting values. The method also includes steps of retrieving the facial recognition model, recognizing, using the facial recognition model, the face of the user, retrieving the set of user-preferred camera settings, and sending commands to the camera controller to change the set of camera settings from the set of initial camera setting values to the set of user-preferred camera setting values.

In another aspect, a method of optimizing image quality for real-time video feeds using a lighting device connected to a computer system includes steps of receiving a video feed from a camera, wherein the camera is also connected to the computer system, training a facial recognition model, using the received video feed, to recognize a face of a user, and displaying the real-time video feed from the camera for a user. The method also includes steps of providing the user with, through a user interface, a set of adjustable lighting settings for a lighting device, sending commands to a lighting device controller of the lighting device to adjust the set of lighting settings according to changes to the set of adjustable lighting settings made by the user through the user interface, receiving a set of user-preferred lighting setting values, and storing the trained facial recognition model and the set of user-preferred lighting setting values. The method also includes steps of receiving a new video feed from the camera, the new video feed being captured while the camera has a set of initial lighting setting values, retrieving the facial recognition model, recognizing, using the facial recognition model, the face of the user, retrieving the set of user-preferred lighting setting values, and sending commands to the lighting device controller to change the set of lighting settings from the set of initial lighting setting values to the set of user-preferred lighting setting values.

In another aspect, a system for optimizing image quality for real-time video feeds includes a computer system configured to receive a video feed from a camera. The computer system further includes a processor, memory comprising a non-transitory computer readable medium, the memory storing instructions that may be may be executed by the processor, a facial recognition module stored in memory, and a user interface comprising a viewing area for the video feed and a set of adjustable device settings that is stored in memory. The facial recognition module can be trained to recognize a face of a user at a first time. The user interface can be used to select a set of user-preferred device setting values selected by the user and corresponding to the set of adjustable device settings. the computer system is configured to automatically change an initial set of device setting values to the set of user-preferred device setting values when the facial recognition module recognizes the face of the user at a second time that is later than the first time.

Other systems, methods, features, and advantages of the disclosure will be, or will become, apparent to one of ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description and this summary, be within the scope of the disclosure, and be protected by the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. **1** is a schematic view of an arrangement of networked computer systems, according to an embodiment;

FIG. **2** is a schematic view of an architecture for a system that can be used to optimize the exposure of a face within a video feed, according to an embodiment;

FIG. **3** is a schematic view of an exemplary configuration in which a user has a computer system with a webcam, according to an embodiment;

FIG. **4** is a schematic view of a dashboard UI for a user that includes video feeds of an ongoing video call, according to an embodiment;

FIG. **5** is a schematic view of a process for automatically adjusting camera settings of a camera to optimize the appearance of a user's face, according to an embodiment;

FIG. **6** is a schematic view of a step of analyzing the image qualities of a facial region of a video feed, according to an embodiment;

FIG. **7** is a schematic view of a process for continuously analyzing images and adjusting camera settings to optimize the exposure of a user's face, according to an embodiment.

FIG. **8** is a schematic view of a camera controller and associated camera control settings, according to an embodiment;

FIG. **9** is a schematic view of a process for automatically adjusting camera settings until the resulting image characteristics are optimized, according to an embodiment;

FIG. **10** is a schematic view of an exemplary configuration in which a user has a computer system with a webcam and an external lighting device, according to an embodiment;

FIG. **11** is a schematic view of a process for automatically adjusting lighting settings to arrive at an optimal appearance for a user's face;

FIG. **12** is a schematic view of a process for continuously analyzing images and adjusting lighting settings to optimize the exposure of a user's face, according to an embodiment.

FIG. **13** is a schematic view of a lighting device controller and associated lighting control settings, according to an embodiment;

FIG. **14** is a schematic view of a process for automatically adjusting lighting settings until the resulting image characteristics of a video feed are optimized, according to an embodiment;

FIG. **15** is a schematic view of a display screen including two illuminating regions, according to an embodiment;

FIG. **16** is a schematic view of a configuration in which a user has a display screen with two illuminated regions, according to an embodiment;

FIGS. **17-19** are schematic views of user interfaces for controlling various device and/or image settings, according to some of the embodiments;

FIGS. **20-21** are schematic views of processes for receiving user-preferred settings and for selecting the user-preferred settings at a later time, according to an embodiment;

FIG. **22** is a schematic view of an image characteristic analysis module, including inputs and outputs, according to an embodiment; and

FIG. **23** is a schematic view of a process for automatically optimizing image characteristics of a video feed based on information from a reference image.

DESCRIPTION OF EMBODIMENTS

The embodiments provide systems and methods for improving the image quality of inexpensive video devices (such as webcams) by using computer vision to detect faces and by automatically adjusting camera settings and/or lighting settings in real-time.

The embodiments provide systems and methods for detecting a user's face within a video feed, analyzing the image quality of the user's face within the video feed, and automatically adjusting camera settings of the camera capturing the video feed to optimize the quality of the video. In some cases, the exposure of the user's face is optimized.

Other embodiments provide systems and methods for detecting a user's face within a video feed, analyzing the image quality of the user's face within the video feed, and automatically adjusting lighting settings of either an external lighting device, or lighting generated by a display screen, to optimize the quality of the video. In some cases, the exposure of the user's face is optimized.

Still other embodiments provide systems and methods for detecting a user's face within a video feed, analyzing the image quality of the user's face within the video feed, and automatically adjusting camera settings and lighting settings simultaneously, to optimize the quality of the video. In some cases, the exposure of the user's face is optimized.

Still other embodiments provide systems and methods for detecting and recognizing a user's face, and providing a user interface that allows the user to select user-preferred settings for a camera or a lighting device (or display screen). In some cases, the systems and methods also allow a user to select user-preferred image processing settings. The system can then retrieve the user-preferred settings whenever the user's face is detected within a video feed.

The embodiments describe digital cameras that may have one or more camera settings. Exemplary camera settings include, but are not limited to: shutter-speed, aperture, and ISO. The shutter-speed characterizes how quickly the camera shutter opens and closes, and thus the duration of time over which light can pass to the camera sensor. The aperture characterizes the size of the opening that the light passes through (when the shutter is open). The ISO setting of a digital camera controls how sensitive the camera's sensor is to light.

As used herein, the term "exposure" refers to the amount of light reaching a (digital) camera's sensor. Exposure varies according to (at least) the camera settings for aperture, shutter-speed, and ISO. One metric for evaluating the exposure for a given set of camera settings is known as the "Exposure Value," or simply "EV". The EV is a single number and can be calculated as a function of the aperture, shutter-speed, and ISO values. Moreover, there may be different sets of values (that is, values of shutter-speed, aperture, and ISO) that evaluate to the same exposure value. Each incremental increase of the exposure value (for example, 1, 2, 3) results in a doubling of the amount of light received at the camera's sensor. Each incremental decrease (for example, 2, 1, 0, −1) results in a halving of the amount of light received at the camera's sensor.

In some embodiments, a digital camera may have an exposure compensation setting, also referred to as an exposure control setting. That is, a user can set the value of the exposure compensation setting (or exposure control setting) in order to increase or decrease the exposure value. In such cases, the system may automatically select a set of shutter-speed, aperture, and ISO values to arrive at the desired exposure value. Alternatively, some digital cameras may require independent adjustments to shutter-speed, aperture, and ISO values to adjust the exposure value.

As used herein, the term "exposure setting" includes any camera settings that affect the exposure. Exposure settings include aperture, shutter-speed, ISO, as well as exposure compensation (or exposure control) settings.

In the description, the term "image characteristic," or "image property," refers to features of an image such as exposure, contrast, white balance, color balance, brightness, color, color temperature, opacity, as well as other suitable features of an image. An image characteristic (or image

property) may refer to a feature of an entire digital image, or to a feature of a portion (including, just a single pixel) of a digital image.

As used herein, the term "image lighting quality," or simply "image quality," refers to the quality of an image with respect to lighting, and can include exposure as well as other image characteristics such as contrast, brightness, white balance and so on. The embodiments describe systems and methods for optimizing the exposure or other image characteristics of a "facial region" that bounds a user's face within an image. An optimized exposure or other image characteristic may be determined according to suitable algorithms that analyze various image characteristics of the facial region and compare the values of the image characteristics to static or dynamic values, or ranges of values, which may be considered optimal for a given context. As described in further detail below, in some cases, optimal exposure and/or optimal values for various image characteristics may be provided as ranges. Moreover, in some cases, different values or ranges could be selected according to various inputs including information related to a user, such as information about the user's complexion.

Alternatively, in some embodiments, optimal exposure or other image characteristics can be determined by a user, who can select user-preferred settings for various devices (such as a camera or lighting device) that are automatically set whenever the system detects the user's face in a video feed.

All of these embodiments help solve the problem of exposure variability (and more broadly of image quality variability) among user's having different complexions.

FIG. **1** is a schematic view of a configuration **100** of networked computer systems that may be used to facilitate various user interactions, including video calls. The term "computer system" refers to the computing resources of a single computer, the partial computing resources of a single computer, a plurality of computers communicating with one another, or a network of remote servers. In the exemplary embodiment, a first computer system **102** is networked, via network **110**, to a second computer system **120**. In particular, using suitable software operating on first computer system **102** and second computer system **120**, users of the computer systems can communicate using audio and video calling.

The embodiments also show an exemplary third computing system **130**. Third computing system **130** may comprise a backend system that supports applications operating in first computer system **102** and/or second computer system **120**. In the embodiment of FIG. **1**, computer system **130** includes one or more computing devices **132** (for example, servers) that may be in communication with one or more databases **134**. Databases **134** could be co-located with computing devices **132** or could be remote databases that are accessible by computing devices **132** over a network, including network **110**. Databases **134** can include any kind of storage devices, including but not limited magnetic, optical, magneto-optical, and/or memory, including volatile memory and non-volatile memory.

A computer system interfacing directly with users, such as computer system **102**, could operate in a client-server relationship with one or more servers of third computer system **130**. For example, computer system **130** may include a server that communicates with first computer system **102** over network **110**. First computer system **102** may provide the front-end of a system that facilitates interactions between users. For example, in one embodiment, first computer system **102** may be configured to run software through a web browser, in which the client software, as well as user information and data may be hosted on a server of third computer system **130**. In other cases, first computer system **102** may run client software in the form of a native software application. In some cases, while the client software that allows users to perform various tasks may be run on first computer system **102**, the data may be retrieved from and stored on databases associated with third computer system **130**.

To facilitate interactions between users, each of computer system **102** and computer system **120** may include components to facilitate communication with external systems (for example, hardware and software components to enable communication over network **110**). Each computer system may generally include a processor, a data storage component and a display (for example, computer system **102** includes display **103**). Each computer system may further include one or more input devices. These could include a keyboard, mouse, or one or more physical buttons integrated into a case of the device. In some cases, a computer system includes touchscreen controls.

To enable video calls, each computer system could include a digital camera that is connected to the computer system. In the embodiment of FIG. **1**, for example, computer system **102** includes a webcam **104**. In the exemplary embodiment, webcam **104** is configured to attach (for example, clip) to display **103** of computer system **102**. In other embodiments, webcam **104** could be integrated directly into display **103**. In still other embodiments, a webcam could be a standalone camera. Moreover, the embodiments are not limited to using cameras that are configured specifically as webcams, and in other embodiments any suitable camera capable of capturing video can be used. For example, in another embodiment, a digital SLR camera could be used to capture video feeds and provide a real-time video feed to a connected computer system. In still another embodiment, a camera integrated into a smartphone could be used.

As described in further detail below, in some embodiments, a computer system could be connected to a lighting device. For example, in FIG. **1**, computer system **102** is equipped with a lighting device **106**. In this example, lighting device **106** is a light bar. As user herein, the term "light bar" refers to an elongated lighting device. In other embodiments, lighting devices with other suitable shapes or sizes could be used.

In the example of FIG. **1**, second computer system **120** also includes a webcam **122**. Although second computer system **120** does not include a lighting device, in other embodiments a lighting device could be connected to computer system **120**.

It may be appreciated that the principles and ideas described herein could be applied to a variety of different applications. More generally, the principles and ideas described herein could be useful in any application where two or more users are participating in a video call.

Although the embodiments show computer systems comprising desktop computers, other embodiments could comprise any suitable computer systems, such as laptops, tablet computers, smart phones, or other suitable computer systems.

As already discussed, the embodiments provide systems and methods for improving the appearance of one or more users on a video call. More specifically, the embodiments provide systems and methods that can modify the exposure (and related image characteristics) of a video feed. In some contexts, this could be used to ensure that users with darker complexions are shown with an optimal exposure.

FIG. **2** is a schematic view of an architecture **200** that facilitates optimizing the exposure of a video feed for different users, each of which may have different complexions.

In FIG. **2**, a system **202** may include various components, including applications, modules, and APIs for receiving, processing, and sending information to external components. In this example, the external components include a display **210**, a webcam **212**, and a lighting device **214**. In one embodiment, system **202** could comprise a single computer system. In other cases, some of the applications, modules, and APIs could be performed by two or more computer systems that may be networked together.

Each of the external devices connected to system **202** could include associated controllers. As user herein, the term "controller" refers to any combination of hardware and/or software that can be used to control one or more features of a device. In some cases, controllers could comprise drivers for a device.

In FIG. **2**, display **210** is associated with a display controller **220**, which includes various functionality for displaying data generated by system **202** as visual information (such as text and images) on the screen **211** of display **210**. Webcam **212** is associated with a camera controller **222**, which includes various functionality for controlling aspects of webcam **212**. In particular, camera controller **222** may be used to change the settings of webcam **212**, which could include an aperture setting, a shutter speed setting, and an ISO setting (the ISO setting of a digital camera controls how sensitive the camera's sensor is to light), as well as other suitable settings that are described in further detail below.

Lighting device **214** is associated with a lighting device controller **224**. Lighting device controller **224** includes functionality for controlling settings of a lighting device. These can include the lighting direction, intensity, color, temperature, as well as other suitable lighting settings.

In some embodiments, a device controller can be disposed within a centralized computer system, such as system **202**. In other embodiments, a device controller could be integrated into the corresponding device. For example, a camera controller could be integrated into a webcam. Moreover, in a given embodiment some device controllers may be disposed in a centralized computing device, while other device controllers could be integrated directly into the controlled devices. In still other embodiments, a device controller could be disposed within an intermediate system that is independent of the device and the computer system running various applications that rely on controlling the device.

Each device controller may be configured to communicate with an associated API of system **202**. In the exemplary embodiment, system **202** uses a display controller API **240** (or simply "display API **240**") to communicate with display controller **220**. Additionally, system **202** uses a camera controller API **242** ("camera API **242**") to communicate with camera controller **222**. In addition, system **202** uses a lighting device controller API **244** ("lighting device API **244**") to communicate with lighting device controller **224**. Using the appropriate APIs, the applications and/or modules of system **202** may receive information from the device controllers, and/or send commands to the device controllers. In some cases, the various APIs shown in FIG. **2** could be replaced directly with device controllers, and corresponding APIs could be integrated into various applications running on system **202**.

System **202** may further include a video calling application **230** that facilitates video calling between two or more users. Video calling application **230** could use any suitable software or protocol. Video calling application **230** may receive raw video directly from webcam **212**. As used herein, the term "raw video" refers to video data as it is generated by a camera. In particular, raw video has not been processed by any software operating externally to the camera.

After processing raw video, video calling application **230** may pass the output video data to display controller API **240**, so that the video data can be viewed by a user at display **210**. In some embodiments, video calling application **230** may also communicate directly with camera API **242**.

To help achieve optimal exposures for different users, system **202** may also include an exposure optimization application **215** ("optimization app **215**"). In some cases, optimization app **215** could be integrated directly into video calling application **230** (or vice versa). However, in some embodiments, optimization app **215** can be a stand-alone application that communicates with video calling application **230** using any suitable application programming interfaces ("APIs").

Optimization app **215** may include various modules for facilitating processing of video data. These include a facial recognition module and detection module **250**, an image characteristic analysis module **252**, a settings training module **254**, and a display lighting module **256**.

Facial detection and recognition module **250** facilitates detecting and, in some cases, recognizing, user faces. Facial detection refers to the process of identifying a face within an image (or video feed), while facial recognition refers to the process of identifying a face as belonging to a particular person/user. As described in further detail below, the systems and methods may try to optimize the image characteristics (such as exposure) in a region surrounding the face of a user, rather than optimizing image characteristics across the whole image. Facial detection and recognition module **250** may make use of any suitable facial detection algorithms as well as any suitable facial recognition algorithms.

Image characteristic analysis module **252** facilitates identifying properties of an image (or of a region within an image) including, but not limited to: exposure, white balance, color balance, contrast, brightness, and color temperature.

Settings training module **254** facilitates training a system to recognize a user and to automatically implement user-preferred settings for devices (such as a camera or lighting device). The user-preferred settings may generally be settings for a device that optimize a particular image characteristic of a video feed.

Display lighting module **256** facilitates implementing a display-based light source. That is, a light source created by adjusting the visual properties of a portion of a display screen. Display lighting module **256** may include functionality for designating particular regions of the screen for illumination, while designating other regions for use by other applications running on the computer system, such as a video calling application.

In operation, raw video **280** from webcam **212** is fed into video calling application **230**, which outputs at least some of the video information to the display via the display API **240**. When optimization app **215** is being used, video calling application **230** may also feed some or all of the raw video data to optimization app **215**.

Optimization app **215** processes the raw video data, using one or more of the modules described above. Based on this processing, optimization app **215** may generate various commands to change the settings of one or more external

devices. For example, optimization app **215** can generate display lighting settings **260** and deliver those settings to display controller API **240**. Likewise, optimization app **215** can generate camera settings **262** and deliver those settings to camera API **242**. Moreover, optimization app **215** can generate lighting settings **264** and deliver those settings to lighting device API **244**. The downstream effects of adjusting the settings of one or more external devices is a change in the image characteristics of the raw video data generated by webcam **212**. Moreover, these changes may be made incrementally and/or continuously to arrive at a high quality video feed that is optimally exposed to improve the appearance of users depending on complexion, background lighting conditions, or other factors.

It may be appreciated that in different embodiments, optimization app **215** can operate to modify the settings of different external devices. Moreover, in some embodiments, some of the modules comprising optimization app **215** may be optional.

In some embodiments, exposure optimization application **215** may further include an optional image processing module **258**. Image processing module **258** may be used to modify one or more images received as part of a raw video feed. The modified images could then be delivered to video calling application **230**, which passes the modified video data ("modified video **268**") on to display **210** via display controller API **240**. However, in embodiments where image processing is not used, the video feed displayed for a user may be raw video, a subset of the raw video (for example, a portion of the full video resolution), or a suitably compressed version of the raw video. In particular, when the system changes only camera or lighting settings and does not apply image processing to the raw feed that is output from the camera, the exposure and/or image characteristics such as contrast, brightness, color, color temperature, white balance, color balance, or other suitable characteristics are modified by the camera itself, or by modifying the external lighting shone on the user. In such configurations, significant computational processing time can be saved since the computer system is not required to render or otherwise transform images (apart from any transformations done by the video calling application itself).

It may be appreciated that the present architecture could be deployed at any computer system participating in a video call.

FIG. **3** is a schematic view of an exemplary scenario in which a user **302** is interacting with another user (not shown) through a video calling application running on computer system **304**. In this exemplary scenario, user **302** could be a customer service agent or representative on a video call with a customer. The embodiment of FIG. **3** includes a webcam **306** connected to computer system **304**. Computer system **304** also includes a display **308** with a display screen **310**.

FIG. **4** is a schematic view of the content displayed on display screen **310**, which is visible to user **302**. Specifically, display screen **310** shows an agent dashboard application, which further includes a customer window **414** and a live call window **416**. Within live call window **416**, user **302** can see a first video feed **418** showing a customer **430**. In addition, live call window **416** may show a second video feed **420** of user **302**.

Using conventional webcam technology, users with darker complexions may face problems with exposure in the video feed showing the user. For example, in FIG. **4**, second video feed **420** may be poorly exposed, so that it is difficult to make out features of face **403** of user **302**. This may happen because the default settings on webcam **306** are not optimized to create an exposure for video feed **420** that accurately renders face **403** with respect to contrast, brightness, temperature color, or other suitable image characteristics.

In order to modify the exposure of second video feed **420**, the embodiments provide systems and methods for automatically analyzing the image characteristics of second video feed **420** and for automatically adjusting camera settings for webcam **306** to produce a modified video feed with an exposure that is optimized to better show face **403** of user **302**.

In order to optimize the exposure of a user's face within a video feed, the embodiments may utilize facial detection technology to automatically identify a face within a video feed. However, facial detection algorithms may rely on a video feed having a suitable exposure for a given subject in order to identify features of a face that stand out against a background. For users with darker complexions, the default exposure of a video feed may result in images where the face is not sufficiently distinct from the background to be detected by the facial detection algorithm.

The embodiments may provide systems and methods that can automatically identify faces when the default camera exposure is poor. This is accomplished by automatically adjusting contrast and/or other camera settings until a facial recognition algorithm is able to identify a face within a video feed.

FIG. **5** is a schematic view of a method for automatically adjusting camera settings to first identify a user's face, and then to achieve an optimal exposure and/or appearance for a user's face within a video feed. It may be appreciated that one or more of the following systems could be performed by any suitable system running an exposure optimization algorithm, such as system **202** described above and shown in FIG. **2**.

Starting in step **502**, system **202** may capture raw video from a webcam. Next, in step **504**, system **202** may apply one or more facial detection algorithms to the raw video in order to detect a user's face within the image. In step **506**, system **202** determines if a face has been detected. If no face has been detected, system **202** proceeds to step **508**.

In step **508**, system **202** may automatically adjust camera settings until a user's face has been detected. For example, system **202** could automatically adjust the contrast setting of a camera and reanalyze the resulting raw video until the facial detection algorithm detects a face. Alternatively, system **202** could automatically adjust brightness, white balance, or other camera settings until a face can be detected. In some cases, system **202** could automatically adjust the aperture, shutter speed, and/or ISO settings of a camera until a face can be detected.

Once a face has been detected in step **506**, system **202** proceeds to step **508**. In step **508**, system **202** defines a facial region of the image. This may be any region with a suitable boundary that encloses the face detected in step **504**. For example, the facial region could be a circular region around the face, a square region around the face, or any other suitably shaped region. Once the face has been detected, the facial region can be configured to "follow" the face whenever the user moves around within the video feed.

Next, in step **510**, system **202** may analyze the image characteristics of the video feed within the defined facial region. In some cases, the image analysis could be performed by an image characteristics analysis module (such as image characteristics analysis module **252** of FIG. **2**). As already mentioned, analyzing the image characteristics within the facial region, as opposed to analyzing the image

characteristics of the whole video feed, may help in optimizing the exposure of the video feed so that the user's face can properly exposed.

As an example, FIG. **6** shows a schematic view of a facial region **602** within a video feed **604**, which is being analyzed. In this example, the analysis, represented schematically as a script running in terminal window **606**, processes the pixels within facial region **602** to determine numerical values for one or more image characteristics. In this example, the process analyzes "Exposure", "Color Balance," "Contrast," and "Brightness." However, it may be appreciated that in other embodiments any suitable image characteristics could be analyzed.

Referring back to FIG. **5**, in step **512**, system **202** may automatically adjust the camera settings to optimize the appearance of the user's face. In some cases, this includes optimizing the exposure of the user's face.

FIG. **7** is a schematic view showing how the exemplary system may continuously analyze images and adjust camera settings to optimize the exposure of a user's face. In this case, an initial video feed **702** is received. This initial video feed is then processed by isolating a face within the video and automatically adjusting the camera settings to optimize the exposure of the user's face. The changes in the camera settings cause changes in the image characteristics of the video feed, represented in FIG. **7** as modified video feed **704**. It may be appreciated that both initial video feed **702** and modified video feed **704** comprise raw video feeds output by camera **708**. The distinction between the two feeds is that the camera settings have been modified so that the resulting raw images have different exposures (indicated schematically in the figures using different line weights).

FIG. **8** is a schematic view showing various camera settings for a camera **802** that can be adjusted by an application running on a computing device **806** using a camera controller **804**. These camera control settings **810** include, but are not limited to "Aperture", "Shutter Speed," "ISO," "White Balance," "Color Space," and "Contrast." It may be appreciated that different digital cameras could provide different customizable settings. Moreover, some of the camera controls correspond to direct control of electro-mechanical aspects of the camera, such as shutter speed, ISO, and aperture, while others may correspond to indirect controls. In some cases, some camera settings may not be independent, so that a camera may automatically adjust multiple camera settings to achieve a user selected value for another setting. For example, the system could automatically adjust aperture, shutter speed and ISO to achieve a user selected value for a contrast control.

FIG. **9** is a schematic view of a process for automatically modifying camera settings to achieve an optimal appearance for a user's face, according to an embodiment. Starting in step **902**, system **202** could receive a real-time video feed from a webcam. Next, in step **904**, system **202** could analyze image characteristics within a previously defined facial region. In step **906**, system **202** may compare the current image characteristics (outputs of step **904**) with a set of optimal image characteristics. The optimal image characteristics can be specific camera settings, or ranges of settings, that have been found to improve the exposure of a user's face, and may apply to users of various complexions.

In some cases, it may be appreciated, optimal image characteristics could be determined as a function of one or more inputs, which may include the current image characteristics. In particular, in some cases, the optimal image characteristics could vary according to information gathered from the video feed about the user's complexion. Thus, in some cases, the system could retrieve a first set of optimal image characteristics for user's having a first complexion, and a second set of optimal image characteristics for user's having a second complexion. In still other embodiments, the system could receive inputs from a user that are indicative of the user's complexion.

In step **908**, the system checks to see if the difference between the current image characteristics and the optimal image characteristics is within a predetermined tolerance. If so, the system returns to step **902** to continue analyzing the video feed for deviations from the optimal image characteristics.

If the difference between the current image characteristics and optimal image characteristics is greater than the predetermined tolerance, than system **202** may proceed to step **910**. In step **910**, system **202** may automatically adjust the camera settings to achieve an optimal appearance (or exposure) for the user's face.

In one possible implementation of the exemplary system and method, a system may calculate an exposure for a facial region according to the following steps: first, the facial region is converted to greyscale. Next, the arithmetic mean of all the pixels in the face image may be found, yielding a number between 0 and 255. In some cases, the system could impose a threshold of 127, which corresponds to the halfway point between 0 and 255. If the arithmetic mean of the facial region is below 127, the image is determined to be too dark and the system proceeds accordingly to increase the exposure by adjusting the camera settings. If the arithmetic mean of the facial region is above 127, the image is determined to be too bright, and the system proceeds accordingly to decrease the exposure by adjusting the camera settings. In this way, the camera settings may be continuously adjusted until the arithmetic mean of the (grey-scaled) facial region is exactly 127. In still other implementations, the ideal exposure value could be defined in a range, or band, around 127. For example, the camera settings can be adjusted until the exposure of the facial region has a value between 125 and 129. In still other embodiments, other suitable ranges of values could be used.

In still other embodiments, instead of using the arithmetic mean of pixels in the facial region, another suitable function on the pixels could be used. Moreover, in some cases, the value of 127 (and a suitable band around 127) may be adjustable by users, so that users can opt to have generally lighter or darker images.

Similar calculations could be performed for adjusting other image characteristics. For example, if a system automatically adjusts camera settings to achieve a particular color temperature in the facial region of the resulting video feed, the system could apply suitable functions (such as the arithmetic mean) to the hue and/or saturation values of pixels in the facial region.

Moreover it may be appreciated that these same methods for trying to identify ideal exposure values or ranges of exposure values for the facial region within a video feed may be applied to later embodiments, including embodiments where lighting settings (rather than camera settings) are adjusted to change the exposure of the video feed.

In some embodiments, a system could make use of a lighting device to adjust the exposure of a video feed, and thus provide an optimal appearance for a user's face.

FIG. **10** is a schematic view of another exemplary scenario in which a user **1002** is interacting with another user (not shown) though a video calling application running on computer system **1004**. In this exemplary scenario, user **1002** could be a customer service agent or representative on

a video call with a customer. The embodiment of FIG. **10** includes a webcam **1006** connected to computer system **1004**. Computer system **1004** also includes a display **1008** with a display screen **1010**. Additionally, in the embodiment of FIG. **10**, a lighting device **1020** is connected with computer system **1004**. Lighting device **1020** may be positioned on display **1008** so that lighting device **1020** can be used to illuminate the face of user **1002**. By adjusting the lighting properties of lighting device **1020**, an application running on computer system **1004** can automatically adjust the exposure of the video feed captured by webcam **1006**.

In order to optimize the exposure of user's face within a video feed, the embodiments may utilize facial detection technology to automatically identify a face within a video feed. However, facial detection algorithms may rely on a video feed having a suitable exposure for a given subject in order to identify features of a face that stand out against a background. For users with darker complexions, the default exposure of a video feed may result in images where the face is not sufficiently distinct from the background to be recognized by the facial detection algorithm.

The embodiments may provide systems and methods that can automatically identify faces when the default camera exposure poor. This is accomplished by automatically adjusting lighting settings of a lighting device that is configured to illuminate a user's face. This adjustment may be done repeatedly until a facial recognition algorithm is able to identify a face within a video feed.

FIG. **11** is a schematic view of a method for automatically adjusting camera settings to first identify a user's face, and then to achieve an optimal exposure and/or appearance for a user's face within a video feed. It may be appreciated that one or more of the following systems could be performed by any suitable system running an exposure optimization algorithm, such as system **202** described above and shown in FIG. **2**.

Starting in step **1102**, system **202** may capture raw video from a webcam. Next, in step **1104**, system **202** may apply one or more facial recognition algorithms to the raw video in order to detect a user's face within the image. In step **1106**, system **202** determines if a face has been detected. If not face has been detected, system **202** proceeds to step **1108**.

In step **1108**, system **202** may automatically adjust the lighting settings of a lighting device until a user's face has been detected. For example, system **202** could automatically adjust the intensity of the light and reanalyze the resulting raw video until the facial detection algorithm detects a face. Alternatively, system **202** could automatically adjust the color, direction, or other properties of the lighting settings until a face can be detected.

Once a face has been detected in step **1106**, system **202** proceeds to step **1108**. In step **1108**, system **202** defines a facial region of the image. This may be any region with a suitable boundary that encloses the face detected in step **1104**. For example, the facial region could be a circular region around the face, a square region around the face, or any other suitably shaped region. Once the face has been detected, the facial region can be configured to "follow" the face whenever the user moves around within the video feed.

Next, in step **1110**, system **202** may analyze the image characteristics of the video feed within the defined facial region. In some cases, the image analysis could be performed by an image characteristics analysis module (such as image characteristics analysis module **252**). As already mentioned, analyzing the image characteristics within the facial region, as opposed to analyzing the image characteristics of the whole video feed, may help in optimizing the exposure of the video feed so that the user's face can properly exposed. In step **1112**, system **202** may automatically adjust the lighting settings of a lighting device to optimize the appearance of the user's face.

As described in further detail below, lighting can be provided by illuminating regions of a user's display. In such embodiments, the method of detecting a user's face automatically can be achieved by adjusting the lighting settings of the illuminated regions of the user's display.

FIG. **12** is a schematic view showing how the exemplary system may continuously analyze images and adjust lighting settings to optimize the exposure of a user's face. In this case, an initial video feed **1202** is received. This initial video feed is then processed by isolating a face within the video and automatically adjusting the lighting settings to optimize the exposure of the user's face. The changes in the camera settings cause changes in the image characteristics of the video feed, represented in FIG. **12** as modified video feed **1204**. It may be appreciated that both initial video feed **1202** and modified video feed **1204** comprise raw video feeds output by webcam (such as webcam **1006** of FIG. **10**). The distinction between the two feeds is that the lighting settings have been modified so that the resulting raw images have different exposures (indicated schematically in the figures using different line weights).

FIG. **13** is a schematic view showing various lighting control settings (or, simply, "lighting settings") for a lighting device **1302** that can be adjusted by an application running on a computer system **1306** using a lighting device controller **1304**. The lighting control settings **1308** include, but are not limited to "Lighting direction," "intensity," "color," and "temperature." It may be appreciated that different lighting devices could provide different customizable settings. In some cases, a lighting device could be configured with a single light source, which is either rounded or elongated, for example. In other cases, a lighting device could be configured with multiple light sources (for example, multiple LED bulbs) that may be arranged in any suitable configuration. Exemplary configurations include light sources arranged in a linear configuration or in a ring-like configuration. In some cases including multiple light sources, the lighting device controller may allow for independent control of each light source. This would allow a system to automatically adjust the intensity, color, temperature, direction, or other features of each light source.

In some embodiments, it may be helpful to add a highlight color to a face using a lighting device in order to create an ideal exposure or otherwise improve the image quality. For example, a lighting device could be configured to shine a blue or magenta light on some portions of a user's face. In some cases, the highlight color could be projected only onto to one (or both) sides of a user's face, and may not be projected directly onto the front of the user's face.

FIG. **14** is a schematic view of a process for automatically modifying lighting settings to achieve an optimal appearance for a user's face, according to an embodiment. In some cases, the lighting settings may be used to control a discrete lighting device that is connected to a computer system. In other cases, the lighting settings may be used to control an illuminated region of a display screen.

Starting in step **1402**, system **202** could receive a real-time video feed from a webcam. Next, in step **1404**, system **202** could analyze image characteristics within a previously defined facial region. In step **1406**, system **202** may compare the current image characteristics (outputs of step **1404**) with a set of optimal image characteristics. The optimal image

characteristics can be specific lighting settings, or ranges of settings, that have been found to improve the exposure of a user's face, and may apply to users of various complexions.

In some cases, it may be appreciated, optimal image characteristics could be determined as a function of one or more inputs, which may include the current image characteristics. In particular, in some cases, the optimal image characteristics could vary according to information gathered from the video feed about the user's complexion. Thus, in some cases, the system could retrieve a first set of optimal image characteristics for user's having a first complexion, and a second set of optimal image characteristics for user's having a second complexion. In still other embodiments, the system could receive inputs from a user that are indicative of the user's complexion.

In step **1408**, the system checks to see if the difference between the current image characteristics and the optimal image characteristics is within a predetermined tolerance. If so, the system returns to step **1402** to continue analyzing the video feed for deviations from the optimal image characteristics.

If the difference between the current image characteristics and optimal image characteristics is greater than the predetermined tolerance, than system **202** may proceed to step **1410**. In step **1410**, system **202** may automatically adjust the lighting settings to achieve an optimal appearance (or exposure) for the user's face.

It may be appreciated that a comparison between image characteristics detected in a video feed and optimal image characteristics may include comparing the difference to a predetermined threshold, as above, or using any other suitable metric for comparing the detected image characteristics with optimal image characteristics. In another embodiment, for example, a system could store a range of values for each optimal image characteristic, and the method could include checking to see if the detected image characteristic has a value that is in the range of values associate with an optimal image characteristic.

In some embodiments, rather than control the lighting settings of a stand-alone lighting device, a system could be configured to control an illuminated region of a display screen. Referring back to FIG. **2**, system **202** may include display lighting module **256** that can automatically generate one or more illuminated regions on a display screen. Moreover, display lighting module **256** can adjust lighting settings associated with the illuminated regions. For example, display lighting module **256** could adjust the direction, intensity, color, and color temperature of illuminated regions. The illuminated regions could then project light onto the user's face that is captured by a camera and therefore can be used to adjust the image characteristics (such as exposure) of the raw video.

FIG. **15** is a schematic view of a display screen **1500**, in which the screen includes two illuminated regions, according to an embodiment. Specifically, display screen **1500** includes a first illuminated region **1502** and a second illuminated region **1504**. Each of the illuminated regions comprises a region of the display screen (that is, a region of pixels) that can be adjusted to change the way a user's face is illuminated. Specifically, a user **1602** facing the display screen may be illuminated by the illuminated regions **1604** of a display screen **1606**, as shown schematically in FIG. **16**.

It may be appreciated that the entirety of a display screen may provide light that illuminates a user to some extent. However, the term "illumination region" as used herein, refers to a region or portion of a display screen that is controlled for the primary purpose of generating light. By contrast, other regions of the display screen may be used to display information for a user. Thus, it may be appreciated, that with respect to informational content, an illuminated region of a display screen is a region with no informational content for the user.

As shown in FIG. **15**, first illuminated region **1502** and second illuminated region **1504** comprise rectangular strips that are disposed on opposing lateral sides of display screen **1500**. Moreover, the strips bound a central region **1510**, which is used to convey visual information to a user. In other embodiments, each illuminated region could have any suitable shape and size. Moreover, the number of illuminated regions could vary, and may include one, two, three, four, or more illuminated regions. In some cases, the shapes, sizes, and total number of illuminated regions could vary according to the dimensions, resolution, display type (for example, LCD, LED, or OLED), or other suitable features of a display screen.

It should be appreciated that the various methods for modifying the exposure or other image characteristics of a video feed using a lighting device could be applied using illuminated regions of a display screen instead. Moreover, in some cases, a combination of separate lighting devices and illuminated regions of a display screen could be used to adjust the exposure or other image characteristics of a video feed.

In some embodiments, a system can be trained to recognize particular users and apply user-preferred camera, lighting, or image processing settings. In such an embodiment, the process may comprise two phases: a training phase and an deployment phase. In the training phase, each user can interact with the system to train a facial recognition algorithm to identify the user's face. For example, a system could capture multiple images of a user (for example, "John Smith") and train a facial recognition model to recognize the user's face and identify it with his name or other credentials. During the training phase, the user could also interact with the system to select user-preferred (that is, customized) settings. Depending on the configuration of the system, these could include camera settings, lighting settings, and/or image processing settings. Here, image processing settings refer to settings that may be applied after the raw video feed from the camera has been received. By contrast, camera settings and lighting settings are used to control external devices, which may cause direct changes to the raw video feed.

FIGS. **17-19** depict schematic views of different user interfaces that allow a user to try different device (or image processing) settings, and then save those settings as user-preferred settings. Starting with FIG. **17**, a user interface **1702** ("UI **1702**") comprises a video feed region **1710**, a settings region **1712** and a save settings button **1714**.

A system may display the current raw video feed, and/or a post-processed video feed within video feed region **1710**. The image characteristics of the video feed may be influenced by camera settings **1720** and/or image processing settings **1730**. For purposes of illustration, the embodiments depict several possible settings for a camera and/or an image processing subsystem (such as image processing module **258**). However, it may be appreciated that any suitable camera settings or image processing settings could be provided through a UI in other embodiments.

Using UI **1702**, a user can adjust various settings to create a preferred exposure, or preferred appearance, for their face as shown in video feed region **1710**. In some cases, only a previously defined facial region may be shown, since the system may be configured to provide an optimal (or pre-

ferred) exposure for the user's face. However, in other embodiments, the entirety of a video feed can be shown and a user can be instructed to focus on the exposure of their face.

In the exemplary embodiment, a user can adjust camera settings corresponding to "aperture," "shutter speed," "ISO," "contrast," and "white balance." However, it may be appreciated that in other embodiments any other suitable camera settings could be adjusted by a user through UI **1702**.

In the exemplary embodiment, a user can adjust image processing settings corresponding to "Contrast," "brightness," "white balance," and "color curves." However, it may be appreciated that in other embodiments any other suitable image processing settings could be adjusted by a user through UI **1702**.

Once a user has selected a preferred set of camera settings and/or image processing settings, the user can choose to save those settings using save settings button **1714**. When this button is clicked, the system may automatically store the current settings as a set of "user-preferred settings". Moreover, these user-preferred settings may be identified with the facial recognition model previously associated with the user, as described above.

In another embodiment, a user interface can provide a user with a way to select user-preferred lighting settings. In FIG. **18**, UI **1802** includes similar provisions to UI **1702** of FIG. **17**. However, rather than having a user customize camera settings, the user can customize lighting settings **1820**. As the user adjusts the lighting settings within UI **1802**, the lighting settings of a lighting device and/or illuminated regions of the user's display screen may change, thereby resulting in a modified exposure or other image characteristics in video feed region **1810**.

In the exemplary embodiment, a user can adjust lighting settings corresponding to "Lighting direction," "intensity," "color," and "temperature." However, it may be appreciated that in other embodiments any other suitable lighting settings could be adjusted by a user through UI **1802**.

FIG. **19** depicts yet another embodiment, in which a user can adjust both camera settings and lighting settings simultaneously using UI **1902**. By adjusting both camera settings and lighting settings simultaneously, the system can provide a wider range of possible exposures than might be achievable using only camera settings or lighting settings alone.

FIGS. **20-21** are schematic processes for a training phase and a deployment phase, respectively, of an exposure optimization system according to an embodiment. FIG. **20** is a schematic view of a process for a system of training a system to recognize a user and to associate user-preferred settings with the user. Starting in step **2002**, system **202** can receive a real-time video feed. In step **2004**, system **202** can train a facial recognition model for the current user. In some cases, this may include prompting the user to move their head so that a webcam may capture their face from different angles in order to build a robust three-dimensional model of the face. Next, in step **2006**, system **202** can display a real-time video feed to the user.

In step **2008**, system **202** can display a user interface with adjustable camera settings and/or adjustable light settings, as shown in FIGS. **17-19**. In some cases, a UI can also provide adjustable image processing settings.

A user may interact with the UI and adjust the settings in step **2010**. In particular, using the real-time video feed that is displayed, the user can observe changes to the exposure or other image characteristics of the video feed in real time as the settings are changed, as in step **2012**.

If, in step **2014**, the user is satisfied with their appearance as viewed in the real-time video feed, the user may save their user-preferred settings (for example, using button **1714** of FIG. **17**) in step **2016**. Otherwise, this process may return to step **2008** and continue until the user is satisfied with their appearance at step **2014**.

Once the user chooses to save their user-preferred settings, system **202** may proceed to step **2018**. In step **2018**, system **202** can store a trained facial recognition model and the associated user-preferred settings for later use. In some cases, the trained model and/or user-preferred settings could be stored locally, for example on a user's computer system. In other cases, the trained model and/or user-preferred settings could be stored remotely.

FIG. **21** is a schematic view of a process for automatically recognizing a user and applying the user's preferred settings for a camera, lighting device, and/or image processing to optimize their exposure on the video feed.

In step **2102**, system **202** receives a real-time video feed. In step **2104**, system **202** retrieves a facial recognition model that can be used to recognize faces from images and/or videos. In step **2106**, system **202** may recognize a user's face. Following this, in step **2108**, system **202** can identify the user (that is, associated the recognized face with some other identifying information) and retrieve the user-preferred camera settings and/or user-preferred lighting device settings. Alternatively, in some cases, the system could retrieve user-preferred image processing settings.

Finally, in step **2110**, system **202** can adjust camera settings, lighting device settings, and/or image processing settings based on the user-preferred settings retrieved in step **2108**.

FIG. **22** depicts an alternative embodiment, in which rather than having a user select particular device settings to achieve an optimal exposure, the user can provide a reference image that is optimally exposed for their face. The reference image **2200** can be analyzed by an image characteristic analysis module **2202**. Based on this analysis, the system can automatically generate user-preferred camera settings **2204** and/or user preferred lighting settings **2206**.

FIG. **23** is an exemplary process for generating user-preferred device settings (camera and/or lighting) to match exposure conditions of a reference image. Starting in step **2302**, system **202** may receive a reference image (or video) from a user. This could include a professionally taken photograph, for example. In step **2304**, system **202** can analyze the reference image and determine image characteristics associated with the image. Next, in step **2306**, system **202** can receive a video feed, which may include images of the user. In step **2308**, system **202** may analyze the video feed and determine image characteristics for the video feed. In step **2310**, system **202** can automatically adjust device settings (for example, a camera and/or lighting device) and/or image processing settings until the image characteristics of the video feed match the image characteristics of the reference image. In some cases, the image characteristics of a video feed may match those of a reference image when the values of the image characteristics are within a predetermined tolerance.

The processes and methods of the embodiments described in this detailed description and shown in the figures can be implemented using any kind of computing system having one or more central processing units (CPUs) and/or graphics processing units (GPUs). The processes and methods of the embodiments could also be implemented using special purpose circuitry such as an application specific integrated circuit (ASIC). The processes and methods of the embodi-

ments may also be implemented on computing systems including read only memory (ROM) and/or random access memory (RAM), which may be connected to one or more processing units. Examples of computing systems and devices include, but are not limited to: servers, cellular phones, smart phones, tablet computers, notebook computers, e-book readers, laptop or desktop computers, all-in-one computers, as well as various kinds of digital media players.

The processes and methods of the embodiments can be stored as instructions and/or data on non-transitory computer-readable media. Examples of media that can be used for storage include erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memories (EEPROM), solid state drives, magnetic disks or tapes, optical disks, CD ROM disks and DVD-ROM disks.

The embodiments may utilize any kind of network for communication between separate computing systems. A network can comprise any combination of local area networks (LANs) and/or wide area networks (WANs), using both wired and wireless communication systems. A network may use various known communications technologies and/or protocols. Communication technologies can include, but are not limited to: Ethernet, 802.11, worldwide interoperability for microwave access (WiMAX), mobile broadband (such as CDMA, and LTE), digital subscriber line (DSL), cable internet access, satellite broadband, wireless ISP, fiber optic internet, as well as other wired and wireless technologies. Networking protocols used on a network may include transmission control protocol/Internet protocol (TCP/IP), multiprotocol label switching (MPLS), User Datagram Protocol (UDP), hypertext transport protocol (HTTP) and file transfer protocol (FTP) as well as other protocols.

Data exchanged over a network may be represented using technologies and/or formats including hypertext markup language (HTML), extensible markup language (XML), Atom, JavaScript Object Notation (JSON), YAML, as well as other data exchange formats. In addition, information transferred over a network can be encrypted using conventional encryption technologies such as secure sockets layer (SSL), transport layer security (TLS), and Internet Protocol security (Ipsec).

For each of the exemplary processes described above including multiple steps, it may be understood that other embodiments some steps may be omitted and/or reordered. In some other embodiments, additional steps could also be possible.

While various embodiments of the invention have been described, the description is intended to be exemplary, rather than limiting, and it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents. Also, various modifications and changes may be made within the scope of the attached claims.

The invention claimed is:

1. A method of optimizing image quality for real-time video feeds using a camera connected to a computer system, the method comprising:

receiving a video feed from the camera, the camera having a set of camera settings;

training a facial recognition model, using the received video feed, to recognize a face of a user;

displaying the video feed from the camera for a user;

providing the user, through a user interface, with a set of adjustable camera settings;

sending commands to a camera controller of the camera to adjust the set of camera settings according to changes to the set of adjustable camera settings made by the user through the user interface;

receiving a set of user-preferred camera setting values;

storing the trained facial recognition model and the set of user-preferred camera setting values;

receiving a new video feed from the camera, the new video feed being captured while the camera has a set of initial camera setting values;

retrieving the facial recognition model;

recognizing, using the facial recognition model, the face of the user;

retrieving the set of user-preferred camera settings; and

sending commands to the camera controller to change the set of camera settings from the set of initial camera setting values to the set of user-preferred camera setting values.

2. The method according to claim **1**, wherein the set of adjustable camera settings include an aperture setting.

3. The method according to claim **1**, wherein the set of adjustable camera settings include a shutter speed setting.

4. The method according to claim **1**, wherein the set of adjustable camera settings include an ISO setting.

5. The method according to claim **1**, wherein the set of adjustable camera settings include a contrast setting.

6. The method according to claim **1**, wherein the set of adjustable camera settings include a white balance setting.

7. The method according to claim **1**, wherein the set of adjustable camera settings include an exposure setting.

8. A method of optimizing image quality for real-time video feeds using a lighting device connected to a computer system, the method comprising:

receiving a video feed from a camera, wherein the camera is also connected to the computer system;

training a facial recognition model, using the received video feed, to recognize a face of a user;

displaying the real-time video feed from the camera for a user;

providing the user with, through a user interface, a set of adjustable lighting settings for a lighting device;

sending commands to a lighting device controller of the lighting device to adjust the set of lighting settings according to changes to the set of adjustable lighting settings made by the user through the user interface;

receiving a set of user-preferred lighting setting values;

storing the trained facial recognition model and the set of user-preferred lighting setting values;

receiving a new video feed from the camera, the new video feed being captured while the camera has a set of initial lighting setting values;

retrieving the facial recognition model;

recognizing, using the facial recognition model, the face of the user;

retrieving the set of user-preferred lighting setting values; and

sending commands to the lighting device controller to change the set of lighting settings from the set of initial lighting setting values to the set of user-preferred lighting setting values.

9. The method according to claim **8**, wherein the set of adjustable lighting settings include an intensity setting.

10. The method according to claim **8**, wherein the set of adjustable lighting settings include a lighting direction setting.

11. The method according to claim **8**, wherein the set of adjustable lighting settings include a lighting color setting.

12. The method according to claim 8, wherein the set of adjustable lighting settings include a temperature color setting.

13. The method according to claim 8, wherein the method further comprises providing the user with, with a user interface, a set of adjustable image processing settings; and automatically adjusting the video feed provided to the user according to changes in the set of adjustable image processing settings.

14. A system for optimizing image quality for real-time video feeds, the system comprising:

a computer system, the computer system further comprising:

a processor to:

receive a video feed from a camera in communication with the computer system, the camera having a set of camera settings;

train a facial recognition model, using the received video feed, to recognize a face of a user;

display the video feed from the camera for a user;

provide the user, through a user interface, with a set of adjustable camera settings;

send commands to a camera controller of the camera to adjust the set of camera settings according to changes to the set of adjustable camera settings made by the user through the user interface;

receive a set of user-preferred camera setting values;

store the trained facial recognition model and the set of user-preferred camera setting values;

receive a new video feed from the camera, the new video feed being captured while the camera has a set of initial camera setting values;

retrieve the facial recognition model;

recognize, using the facial recognition model, the face of the user;

retrieve the set of user-preferred camera settings; and

send commands to the camera controller to change the set of camera settings from the set of initial camera setting values to the set of user-preferred camera setting values.

15. The system according to claim 14, wherein the set of camera settings includes an aperture setting.

16. The system according to claim 14, wherein the set of camera settings includes a shutter speed setting.

17. The system according to claim 14, wherein the set of camera settings includes a contrast setting.

18. The system according to claim 14, wherein the set of camera settings includes an ISO setting.

19. The system according to claim 14, wherein the set of camera settings includes a white balance setting.

20. The system according to claim 14, wherein the set of camera settings includes an exposure setting.

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