(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 June 2024 (27.06.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/136998 A1

(51) International Patent Classification:
G06F 3/01 (2006.01) *G03B 15/02* (2021.01)
A61B 1/06 (2006.01) *H04M 1/02* (2006.01)
G02B 27/00 (2006.01) *H04N 23/74* (2023.01)
G02B 27/01 (2006.01)

(21) International Application Number:
PCT/US2023/037160

(22) International Filing Date:
10 November 2023 (10.11.2023)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/433,857 20 December 2022 (20.12.2022) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ,

(54) Title: GAZE CONTROLLED ADAPTIVE LED ILLUMINATION

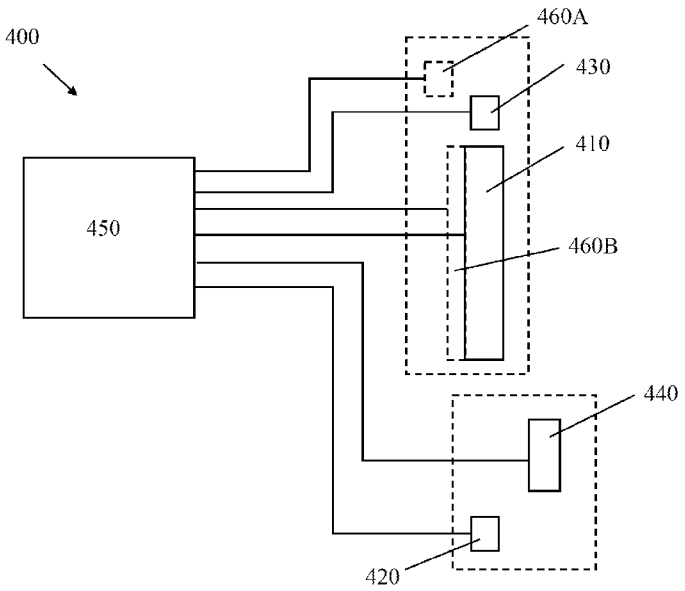


Figure 4

(57) Abstract: Adaptive illumination of a scene is controlled by the gaze of a user viewing the scene directly or viewing an image of the scene captured by a camera and displayed to the user.

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DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

GAZE CONTROLLED ADAPTIVE LED ILLUMINATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of priority to U.S. Provisional Patent Application 63/433,857 filed 20 December 2022, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The invention relates generally to gaze controlled adaptive LED illumination of a scene viewed directly by a user or imaged by a camera and displayed to the user.

BACKGROUND

[0003] Semiconductor light emitting diodes and laser diodes (collectively referred to herein as "LEDs") are among the most efficient light sources currently available. The emission spectrum of an LED typically exhibits a single narrow peak at a wavelength determined by the structure of the device and by the composition of the semiconductor materials from which it is constructed. By suitable choice of device structure and material system, LEDs may be designed to operate at ultraviolet, visible, or infrared wavelengths.

[0004] LEDs may be combined with one or more wavelength converting materials (generally referred to herein as "phosphors") that absorb light emitted by the LED and in response emit light of a longer wavelength. For such phosphor-converted LEDs ("pcLEDs"), the fraction of the light emitted by the LED that is absorbed by the phosphors depends on the amount of phosphor material in the optical path of the light emitted by the LED, for example on the concentration of phosphor material in a phosphor layer disposed on or around the LED and the thickness of the layer. Phosphor-converted LEDs may be designed so that all the light emitted by the LED is absorbed by one or more phosphors, in which case the emission from the pcLED is entirely from the phosphors. In such cases the phosphor may be selected, for example, to emit light in a narrow spectral region that is not efficiently generated directly by an LED. Alternatively, pcLEDs may be designed so that only a portion of the light emitted by the LED is absorbed by the phosphors, in which case the emission from the pcLED is a mixture of light emitted by the LED and light emitted by the phosphors. By suitable choice of LED, phosphors, and phosphor composition, such a pcLED may be designed to emit, for example, white light having a desired color temperature and desired color-rendering properties.

[0005] Inorganic LEDs and pcLEDs have been widely used to create different types of displays,

including displays for mobile phones, smart watches, smart glasses, monitors and TVs, augmented-reality (AR) displays, virtual-reality (VR) displays, and mixed-reality (MR) displays. Inorganic LEDs and pcLEDs have also been widely used for illumination, for example in automotive headlights and for cameras in mobile phones. Individual LEDs or pcLEDs in these display and illumination architectures can have an area of a few square millimeters down to a few square micrometers (e.g., microLEDs) depending on the matrix or display sized and its pixel per inch requirements.

[0006] This specification refers to LEDs and pcLEDs collectively as "LEDs"

SUMMARY

[0007] In one aspect of the invention an apparatus comprises a display viewable by a user, a first camera configured to provide an image of a scene to be shown on the display, a second camera configured to capture images of the user's face as the user views the display, an adaptive illumination system configured to illuminate the scene, and a control system. The adaptive illumination system comprises an array of independently operable LEDs and an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene. The control system is configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

[0008] The second camera, configured to capture images of the user's face as the user views the display, may be for example a color and/or IR sensitive camera. If the second camera is IR sensitive, the apparatus may comprise one or more infrared light sources arranged to illuminate the user's face as the user views the display.

[0009] The control system may be configured to determine from the images of the user's face the user's intention for illumination of the scene at least in part by determining from the images of the user's face the direction of the user's gaze. This specification uses "gaze" to refer to the direction the user is looking, for example at a portion of the scene as it is displayed to the user or directly at the scene. The control system may determine the direction of the user's gaze by, for example, tracking motion of the pupils of the user's eyes.

[0010] The control system may be configured to determine from the images of the user's face the user's intention for illumination of the scene at least in part using facial recognition and

analysis methods. These methods may be used, for example to determine the direction of the user's gaze.

[0011] The control system may be configured to adapt the illumination beam according to the determination of the user's intention by, for example, steering it in the scene, increasing the brightness of a portion of the scene, and/or decreasing the brightness of a portion of the scene.

[0012] The first camera (providing an image to the display) and the adaptive illumination system may be located together remote from the display, the second camera, and the control system.

[0013] The apparatus summarized above may be utilized in, for example, AR or MR head gear (e.g., eye wear such as eyeglasses or goggles), other wearable devices, industrial apparatus, and medical devices. A medical device utilizing the apparatus may comprise a portion (e.g., a catheter or endoscope) adapted for insertion into a human or other animal body, in which case the first camera and the adaptive illumination system may be located remotely from the rest of the apparatus, in the portion of the medical device adapted for insertion into the body.

[0014] The apparatus summarized above may be utilized in a mobile device such as for example a smart phone. Such a mobile device may comprise, for example, a front surface and an oppositely positioned rear surface. The display and the second camera (configured to capture images of the user's face as the user views the display) may be disposed on the front surface, and the first camera (configured to provide an image of a scene to be shown on the display) and the adaptive illumination system may be disposed on the rear surface.

[0015] In another aspect of the invention an apparatus comprises a transparent infrared light source, an infrared sensitive camera configured to capture images of a user's face as the user looks through the transparent infrared light source at a scene, an adaptive illumination system configured to illuminate the scene, and a control system. The transparent infrared light source may comprise, for example, a sparse array of infrared emitting microLEDs disposed on a transparent substrate. The adaptive illumination system comprises an array of independently operable LEDs and an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene. The control system is configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination. The control system may operate for example as described above with respect to the first aspect of the invention.

[0016] In another aspect of the invention, an apparatus comprises eyewear, an adaptive illumination system, and a control system. The eyewear comprises a transparent substrate through which a user may view a scene and a camera configured to capture images of the user's face as the user views the scene through the transparent substrate. The adaptive illumination system is configured to illuminate the scene. The adaptive illumination system comprises an array of independently operable LEDs and an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene. The control system is configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

[0017] If the camera is IR sensitive, the eyewear may comprise one or more infrared light sources arranged to illuminate the user's face as the user views the scene. The one or more infrared light sources may, for example, be or comprise an array of one or more microLEDs configured to emit infrared light and disposed on the transparent substrate.

[0018] The eyewear may comprise a transparent display, for example disposed on or in the transparent substrate, on which images or information may be presented overlaying the user's view of the scene. This variation can support AR and/or MR applications, for example.

[0019] The adaptive illumination system may be incorporated into the eyewear or, alternatively, be remote from the eyewear.

[0020] The control system may be incorporated into the eyewear. The control system may operate for example as described above with respect to the first aspect of the invention.

[0021] These and other embodiments, features and advantages of the present invention will become more apparent to those skilled in the art when taken with reference to the following more detailed description of the invention in conjunction with the accompanying drawings that are first briefly described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Figure 1 shows a schematic cross-sectional view of an example adaptive illumination system comprising an LED array and a lens.

[0023] Figure 2 shows a schematic top view of an example LED array, which may be employed for example in the adaptive illumination system of Figure 1 or in the example display system of Figure 3.

[0024] Figure 3 shows a block diagram of an example display system.

[0025] Figure 4 shows a block diagram of an example apparatus according to an embodiment of the invention.

[0026] Figure 5A and Figure 5B show, respectively, front and rear views of an example mobile device incorporating an embodiment of the apparatus depicted in Figure 4.

[0027] Figure 6A and Figure 6b show, respectively, rear (user facing) and front views of example eyewear according to an embodiment of the invention.

DETAILED DESCRIPTION

[0028] The following detailed description should be read with reference to the drawings, in which identical reference numbers refer to like elements throughout the different figures. The drawings, which are not necessarily to scale, depict selective embodiments and are not intended to limit the scope of the invention. The detailed description illustrates by way of example, not by way of limitation, the principles of the invention.

[0029] Figure 1 shows a schematic cross-sectional view of an example adaptive illumination system 100 comprising an LED array 105, a lens 110 configured to form an output beam from light emitted by the LEDs in array 105, and an LED array controller 115.

[0030] Figure 2 shows a schematic top view of LED array 105, which in this example comprises 25 independently operable LEDs arranged in a square 5 x 5 array and identified by their location in the array by row and column as S(row, column) running from S11 to S55. More generally, array 105 may be for example a rectangular array or may approximate a non-rectangular (e.g., circular or oval) shape. Any suitably sized array may be used, for example a 3 x 3 array, a 5 x 5 array (as shown), a 7 x 7 array, or a 15 x 21 array. The LED or pcLED segments in the array can be of the same size, or of different sizes. For example, the central segment or segments could be larger than peripheral segments. The array may have dimensions in the plane of the array of, for example, about 1.5 mm x 1.5 mm to about 3 mm x 3 mm when used for example in an adaptive illumination system for a mobile device. Any suitable dimensions may be used for a particular application.

[0031] The LEDs in array 105 may have dimensions in the plane of the array (e.g., side lengths) of, for example, less than or equal to 500 microns, less than or equal to 200 microns, less than or equal to 100 microns, less than or equal to 50 microns, less than or equal to 10 microns, or less than or equal to 5 microns. LEDs having dimensions in the plane of the array of less than or

equal to about 50 microns are typically referred to as microLEDs, and an array of such microLEDs may be referred to as a microLED array.

[0032] Each LED in array 105 may comprise a semiconductor light emitting diode and optionally a wavelength converting structure that absorbs light emitted by the semiconducting light emitting diode and emits light of a longer wavelength (in which case the LED is a pcLED). The semiconductor light emitting diodes may be formed for example from II-VI, III-V, or other semiconductor material systems and may be configured to emit, for example, ultraviolet, visible, or infrared light, depending on the application.

[0033] The wavelength converting structures if present include one or more wavelength converting materials which may be, for example, conventional phosphors, ceramic phosphors, organic phosphors, quantum dots, organic semiconductors, II-VI or III-V semiconductors, II-VI or III-V semiconductor quantum dots or nanocrystals, dyes, polymers, or other materials that luminesce. The wavelength converting materials absorb light emitted by the LED and in response emit light of a longer wavelength. Phosphors or other wavelength converting materials may be dispersed as luminescent particles in a binder material such as a silicone, for example, to form a wavelength converting structure. A wavelength converting structure may be or comprise a sintered ceramic phosphor plate.

[0034] The LEDs in array 105 may all emit light of the same color. Alternatively, different LEDs in the array may emit different colors of light. Independent operation of the segments may allow the color of light emitted by the array to be varied.

[0035] Array 105 may be, for example, a segmented monolithic device comprising independently operable LED segments S11– S55. In alternative variations array 105 may be formed from discrete LEDs or from two or more segmented monolithic devices.

[0036] By "segmented monolithic device" this disclosure refers to a monolithic semiconductor diode structure in which trenches passing partially but not entirely through the semiconductor diode structure define electrically isolated segments. The electrically isolated segments remain physically connected to each other by portions of the semiconductor structure. For example, in such a monolithic structure the active region and a first semiconductor layer of a first conductivity type (n or p) on one side of the active region may be segmented, and a second unsegmented semiconductor layer of the opposite conductivity type (p or n) positioned on the opposite side of the active region from the first semiconductor layer. The second semiconductor

layer may then physically and electrically connect the segmented structures to each other on one side of the active region, with the segmented structures otherwise electrically isolated from each other and thus separately operable as individual LEDs.

[0037] Referring again to Figure 1, in operation of adaptive illumination system 100 individual segments in array 105 may be operated by controller 115 to provide illumination adapted for a particular purpose. For example, illumination system 100 may provide illumination that varies by color and/or intensity across an illuminated scene or is aimed in a desired direction. Beam focus or steering of the output light beam emitted by the adaptive illumination system can be performed electronically by activating the LEDs in the array in groups of varying size or in sequence, to permit dynamic adjustment of the beam shape and/or direction without moving optics or changing the focus of the lens in the lighting apparatus.

[0038] Figure 3 shows a block diagram of an example display system 300 comprising a display 310 and a controller 320.

[0039] Display 310 comprises an array of LEDs that are individually operable or operable in groups. The array may be for example similar to array 105 shown in Figure 2 and described above, though typically physically larger than and including more LEDs than the example illustrated in Figure 2. The array may be a monolithic array, or comprise one or more monolithic arrays, as described above. The array may be monochromatic. Alternatively, the array may be a multicolor array in which different LEDs or pcLEDs in the array are configured to emit different colors of light, as described above. The array may therefore be or comprise a monolithic multicolor matrix of individually operable LED or pcLED light emitters, which may for example be microLEDs as described above. A single individually operable LED or pcLED or a group of adjacent such LEDs or pcLEDs in the array may correspond to a single pixel (picture element) in the display. For example, a group of three individually operable adjacent LEDs or pcLEDs comprising a red emitter, a blue emitter, and a green emitter may correspond to a single color-tunable pixel in the display. Similarly, to provide redundancy in the event of a defective LED or pcLED, a group of six individually operable adjacent LEDs or pcLEDs comprising two red emitters, two blue emitters, and two green emitters may correspond to a single color-tunable pixel in the display.

[0040] Controller 320 may receive input from a camera (not shown) and/or other data sources and in response operate the LEDs in display 310 to display images and/or other information.

[0041] Figure 4 shows a block diagram of an example apparatus 400 comprising a display 410 viewable by a user, a first camera 420 configured to provide an image of a scene to be shown on the display, a second camera 430 configured to capture images of the user's face as the user views the display, an adaptive illumination system 440 configured to illuminate the scene, and a control system 450.

[0042] Display 410 may be, for example, similar or identical to display 310 described above. Cameras 420 and 430 may be for example any suitable commercially available visible or infrared light sensitive camera. Adaptive illumination system 440 may be, for example, similar or identical to adaptive illumination system 100 describe above.

[0043] If camera 430 is sensitive to infrared light, apparatus 400 may also comprise optional infrared light sources 460A and/or 460B arranged to illuminate the user's face as the user views the display. Suitable infrared light sources may include, for example, infrared emitting LEDs. The infrared light sources may be located, for example (460A), proximate to (e.g., around the perimeter of) camera 430 and/or outside the perimeter of display 410.

[0044] Alternatively, or in addition, the infrared light sources may be located in or on display 410, for example in or on an area of the display in which the images of the scene are displayed to the user. The infrared light sources may be or comprise, for example, infrared emitting microLEDs in a transparent light source 460B disposed on the display. As used in this specification, transparent is intended to mean that the transparent light source allows light to pass through so that the display behind it can be distinctly seen. This may be accomplished for example using sufficiently sparse arrays (e.g., center to center pitch of $\geq$ 80 μm) of sufficiently small infrared emitting microLEDs (e.g., side lengths of 2 microns to 20 microns) arranged on a transparent substrate. Electrical leads providing power and/or control signals to the infrared emitting microLED arrays may be, for example, transparent or sufficiently thin (e.g., width $\leq$ 30 μm) to not obstruct a view through the infrared microLED array. As another example, the LED array in display 410 may comprise one or more infrared emitting LEDs (e.g., microLEDs) distributed among the visible light emitting LEDs and configured to illuminate the user's face.

[0045] Control system 450 is configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system 440 to adapt the illumination beam according to that determination. Control system 450 may also perform the functions of controller 115 (Figure 1) and controller 320

(Figure 3) and may be implemented with any suitable combination of computing hardware (e.g., a microprocessor), firmware, and/or software.

[0046] The control system may for example be configured to determine from the images of the user's face the user's intention for illumination of the scene at least in part by determining from the images of the user's face the direction of the user's (e.g., prolonged) gaze. Alternatively, or in addition, the control system may for example be configured to determine from the images of the user's face the user's intention for illumination of the scene at least in part by identifying from the images of the user's face other signals such as, for example, (e.g., prolonged) eye blinks. These determinations may be made, for example, under infrared or visible light illumination of the user's face (particularly the eyes) using any suitable pupil-tracking methodology known to one of ordinary skill in the art or modifications thereof and/or any suitable facial recognition and analysis methodology known to one of ordinary skill in the art or modifications thereof.

[0047] Control system 450 may comprise a mechanical, electronic (e.g., touch pad), or voice sensitive switch or other control interface (not shown) by which the function of determining the user's intention for illumination of the scene may be turned on, turned off, or modified. For example, the meaning of particular facial signals (e.g., gaze, blinks) may be alterable through such an interface.

[0048] Control system 450 may optionally control display 410 to provide a visual indication (e.g., a pointer, crosshair, or highlighted area) indicating the portion of the display to which the user's gaze is directed. Control system 450 may in addition, or alternatively, similarly indicate on the display the portion of the scene shown on the display to which a light beam from the adaptive illumination system is directed.

[0049] Upon determination of the user's intention, the control system may be configured to adapt the illumination beam to, for example, steer it to an area of the displayed scene to which the user's attention (e.g., gaze) is directed, increase the brightness of the illumination beam in an area of the displayed scene to which the user's attention is directed, decrease a brightness of the illumination beam in an area of the displayed scene to which the user's attention is directed, increase the brightness of the illumination beam in areas of the displayed scene to which the user's attention is not directed, and/or decrease a brightness of the illumination beam in areas of the displayed scene to which the user's attention is not directed.

[0050] In some variations, the first camera 420 and adaptive illumination system 440 (shown together within a dashed box in Figure 4) may be located together remote from the display, the second camera, and the control system (shown together within another dashed box in Figure 4). In other variations, adaptive illumination system 440 may be located remote from the rest of apparatus 400. Elements of apparatus 400 that are remote from control system 450 may communicate with control system 450 wirelessly, for example.

[0051] Apparatus 400 may be utilized in, for example, AR or MR head gear (e.g., eye goggles), industrial apparatus, and medical devices. A medical device utilizing apparatus 400 may comprise a portion (e.g., a catheter or endoscope) adapted for insertion into a human or other animal body, in which case the first camera 420 and the adaptive illumination system 440 may be located remote from the rest of the apparatus, in the portion of the medical device adapted for insertion into the body. In some variations, first camera 420 and adaptive illumination system 440 may be disposed in a remotely controlled vehicle which may be used, for example, to image a scene remote from the user and the display.

[0052] In some variations apparatus 400 lacks display 410 and first camera 420, and the user views the scene directly. In such variations the second camera and the optional infrared light sources (if present) may for example by disposed on or in a device (e.g., eyewear such as eyeglasses or goggles) worn over the user's eyes. The infrared light sources may be disposed for example in a transparent infrared light source, as described above, through which the user views the scene. The system may otherwise operate similarly or identically to as described above. In such a variation the adaptive illumination system 440 may be remote from the rest of the system, for example disposed in a hand-held torch.

[0053] Figure 5A and Figure 5B show, respectively, front and rear views of a mobile device 500 (e.g., a smart phone) comprising an apparatus 400 as described above. Display 410, second camera 430, and (optional) infrared light source 460A are disposed on the front of the mobile device. First camera 420 and adaptive illumination system 440 are disposed on the rear of the mobile device. In this example, adaptive illumination system 440 may also provide illumination for conventional image capture using first camera 420.

[0054] Referring now to Figure 6A and Figure 6B, another apparatus comprises eyewear 600, an adaptive illumination system 640, and a control system 650. Adaptive illumination system 640 may be similar or identical to adaptive illumination system 440 described above. Control system

650 may operate similarly or identically to control system 450 described above.

[0055] Figure 6A and Figure 6b show, respectively, rear (user facing) and front views of example eyewear 600. Eyewear 600 comprises a frame 605 holding a transparent substrate 610 through which a user views a scene, and a camera 630 mounted in or on the frame 605 (e.g., on the user facing side of the eyewear) and configured to capture images of the user's face as the user views the scene through the transparent substrate. Adaptive illumination system 640 may be incorporated into the eyewear (e.g., in or on the front side of frame 605, as illustrated), or be remote from the eyewear. Control system 650 may be incorporated into or attached to the eyewear (e.g., as illustrated), or be remote from the eyewear. The control system is configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

[0056] If the camera 630 is IR sensitive, eyewear 600 may comprise one or more infrared light sources (660A, 660B) arranged to illuminate the user's face as the user views the display. The one or more infrared light sources may, for example (660A), be mounted in or on frame 605. In addition, or alternatively, the one or more infrared light sources may for example be or comprise one or more transparent sparse arrays (660B) of infrared emitting microLEDs disposed in or on transparent substrate 610. In the example illustrated in Figure 6A, the microLEDs in sparse arrays 660B are not shown to scale but instead exaggerated in size for clarity. If present, these microLEDs would be sufficiently small and spaced sufficiently far apart for the arrays to be transparent as defined above.

[0057] Eyewear 600 may comprise a transparent display, for example disposed on or in the transparent substrate 610, on which images or information may be presented overlaying the user's view of the scene. This variation can support AR and/or MR applications, for example.

[0058] If eyewear 600 comprises a display, a camera 620 configured to provide images to be shown on the display may be incorporated into the eyewear (e.g., in or on the front side of frame 605 as illustrated) or be remote from the eyewear.

[0059] This disclosure is illustrative and not limiting. Further modifications will be apparent to one skilled in the art in light of this disclosure and are intended to fall within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. An apparatus comprising:

a display viewable by a user;

a first camera configured to provide an image of a scene to the display;

a second camera configured to capture images of the user's face as the user views the display;

an adaptive illumination system configured to illuminate the scene, the adaptive illumination system comprising:

an array of independently operable LEDs; and

an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene;

and a control system configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

2. The apparatus of claim 1, wherein the display comprises a segmented monolithic array of independently controllable microLEDs.

3. The apparatus of claim 1, wherein the second camera is a color sensitive camera.

4. The apparatus of claim 1, comprising one or more infrared light sources arranged to illuminate the user's face as the user views the display, wherein the second camera is an infrared sensitive camera.

5. The apparatus of claim 4, wherein:

the display comprises an array of independently controllable microLEDs;

at least one of the microLEDs is configured to emit infrared light; and

the one or more infrared light sources arranged to illuminate the user's face are or comprise the one or more microLEDs configured to emit infrared light.

6. The apparatus of claim 4, wherein:

the one or more infrared light sources are or comprise an array of one or more microLEDs configured to emit infrared light and disposed on a transparent substrate, and

the transparent substrate is disposed on the display.

7. The apparatus of claim 1, wherein the array of independently operable LEDs in the adaptive illumination system is or comprises a segmented monolithic array of independently operable LEDs.

8. The apparatus of claim 7, wherein the LEDs in the segmented monolithic array are microLEDs.

9. The apparatus of claim 1, wherein the control system is configured to determine from the images of the user's face the user's intention for illumination of the scene at least in part by determining from the images of the user's face the direction of the user's gaze.

10. The apparatus of claim 9, wherein the control system determines the direction of the user's gaze by tracking motion of the pupils of the user's eyes.

11. The apparatus of claim 10, comprising one or more infrared light sources arranged to illuminate the user's face as the user views the display, wherein the second camera is an infrared sensitive camera.

12. The apparatus of claim 1, wherein the control system is configured to use facial recognition to determine from the images of the user's face the user's intention for illumination of the scene.

13. The apparatus of claim 1, wherein the control system is configured to adapt the illumination beam by steering it in the scene according to the determination of the user's intention.

14. The apparatus of claim 1, wherein the control system is configured to adapt the illumination beam to increase the brightness of a portion of the scene according to the determination of the user's intention.

15. The apparatus of claim 1, wherein the control system is configured to adapt the illumination beam to decrease the brightness of a portion of the scene according to the determination of the user's intention.

16. The apparatus of claim 1, wherein the first camera and the adaptive illumination system are remote from the display and the second camera.

17. A mobile device comprising

a front surface comprising a display viewable by a user;

a first camera configured to provide an image of a scene to the display, the first camera disposed on a rear surface oppositely positioned from the front surface;

a second camera disposed on the front surface and configured to capture images of the user's face as the user views the display;

an adaptive illumination system disposed on the rear surface and configured to illuminate the scene, the adaptive illumination system comprising:

an array of independently operable LEDs; and

an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene;

and a control system configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

18. The mobile device of claim 17, wherein the second camera is a color sensitive camera.

19. The mobile device of claim 17, comprising one or more infrared light sources arranged to illuminate the user's face as the user views the display, wherein the second camera is an infrared sensitive camera.

20. An apparatus comprising

a transparent infrared light source configured to illuminate a user's face as the user looks through the transparent infrared light source at a scene;

an infrared sensitive camera configured to capture images of the user's face as the user looks through the transparent infrared light source at the scene;

an adaptive illumination system configured to illuminate the scene, the adaptive illumination system comprising:

an array of independently operable LEDs; and

an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene;

and a control system configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

21. An apparatus comprising:

eyewear comprising a transparent substrate through which a user views a scene and a camera configured to capture images of the user's face as the user views the scene;

an adaptive illumination system configured to illuminate the scene, the adaptive illumination system comprising:

an array of independently operable LEDs; and

an optic or optical system arranged to form an illumination beam from light emitted by the LEDs and direct the illumination beam onto the scene;

and a control system configured to determine from the images of the user's face the user's intention for illumination of the scene and to control operation of the LEDs in the adaptive illumination system to adapt the illumination beam according to that determination.

22. The apparatus of claim 21, wherein the eyewear comprises one or more infrared light sources arranged to illuminate the user's face as the user views the display and the camera is an infrared sensitive camera.

23. The apparatus of claim 22, wherein the one or more infrared light sources are or comprise an array of one or more microLEDs configured to emit infrared light and disposed on the transparent substrate.

24. The apparatus of claim 21, wherein the eyewear comprises a transparent display on which images or information may be presented overlaying the user's view of the scene.

25. The apparatus of claim 21, wherein the eyewear comprises the adaptive illumination system.

26. The apparatus of claim 21, wherein the adaptive illumination system is remote from the eyewear.

27. The apparatus of claim 21, wherein the eyewear comprises the control system.

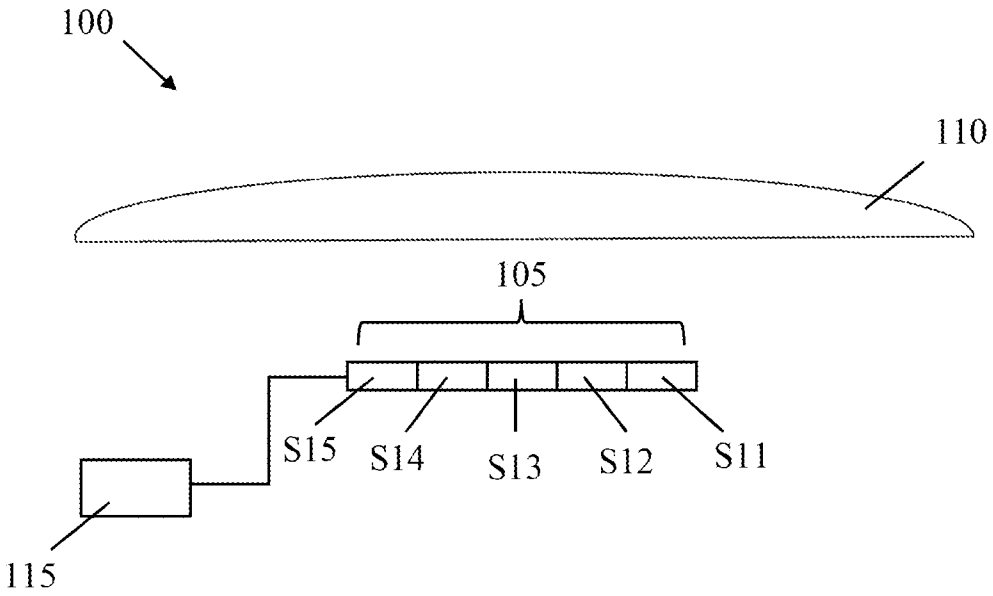


Figure 1

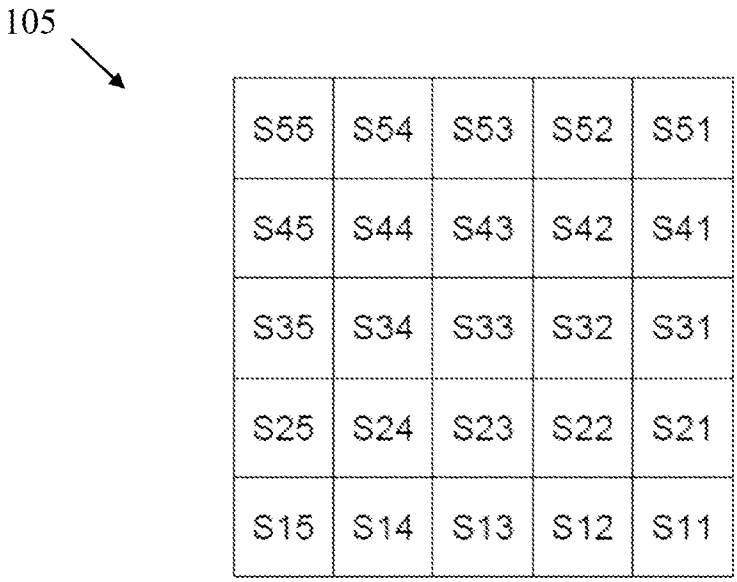


Figure 2

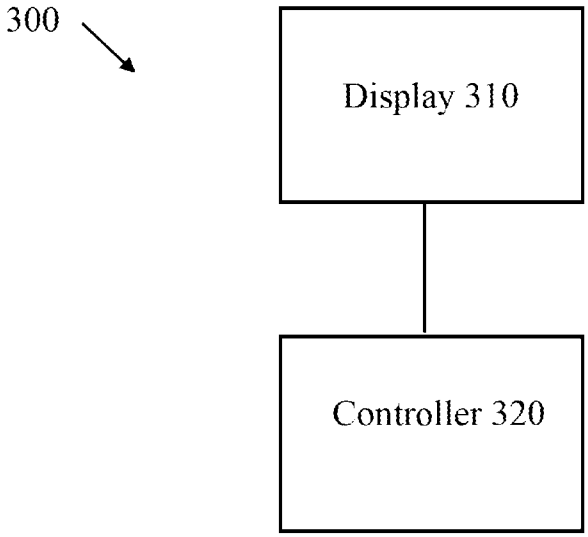


Figure 3

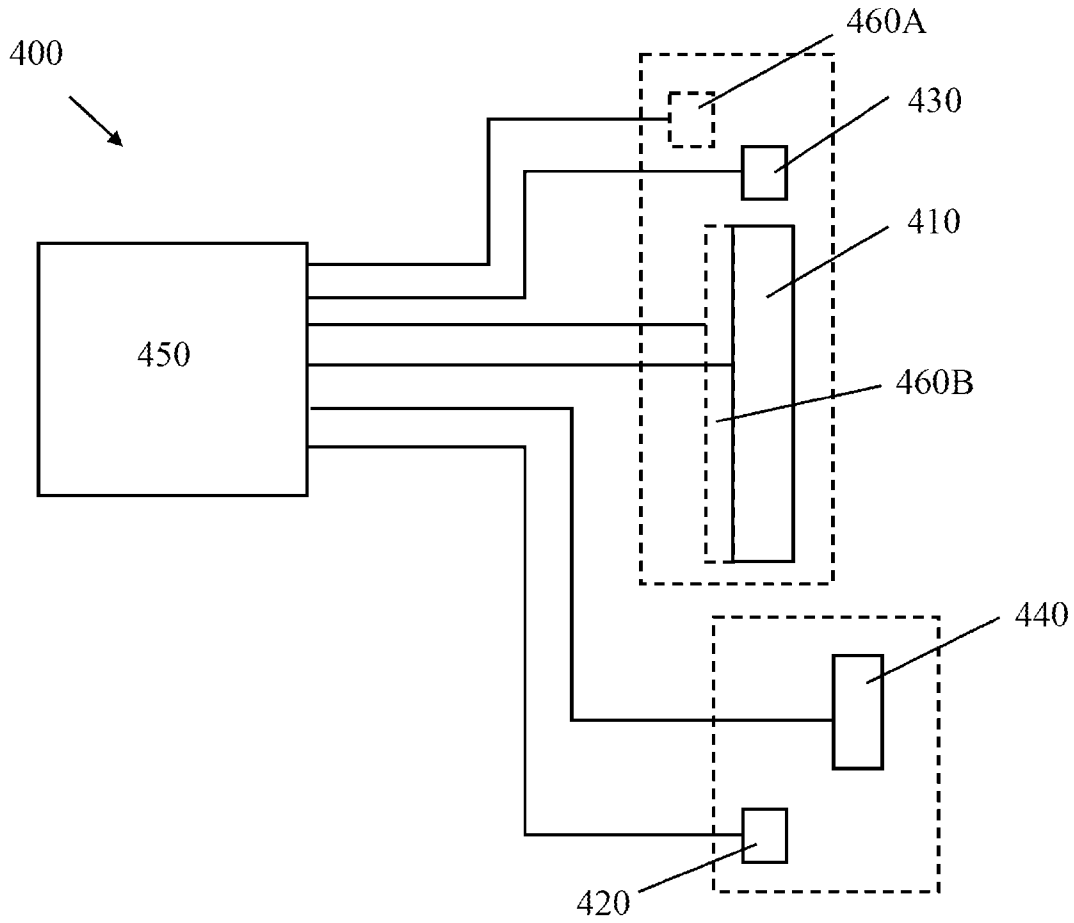


Figure 4

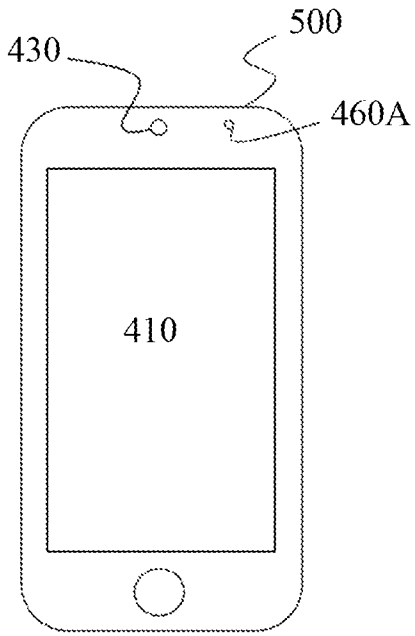


Figure 5A

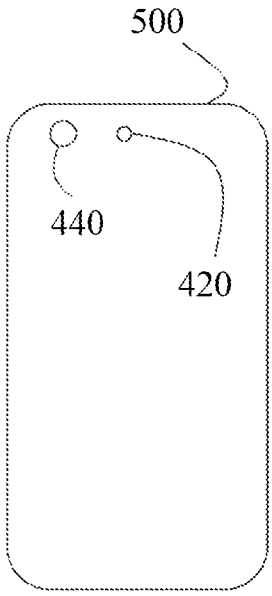


Figure 5B

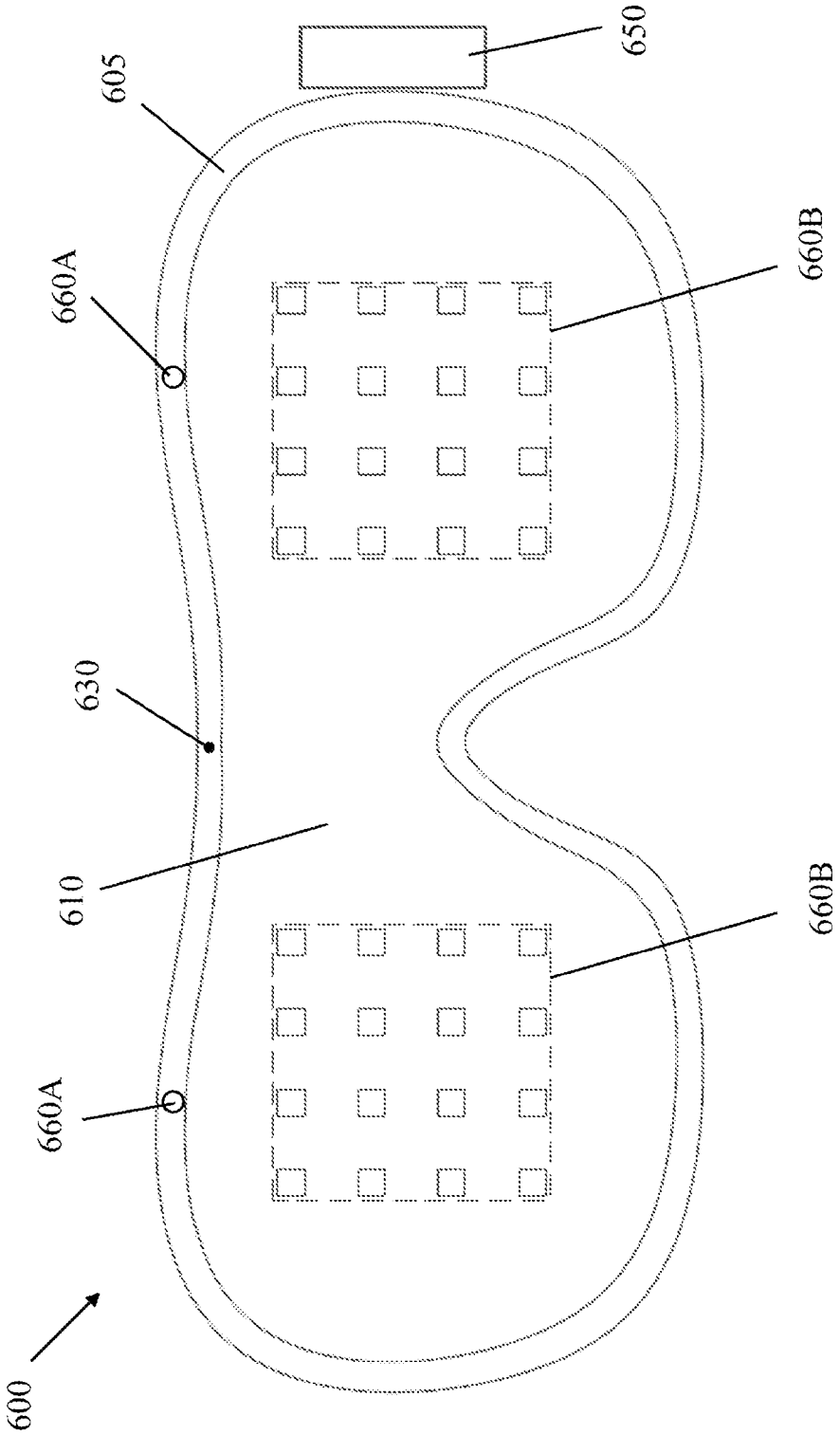


Figure 6A

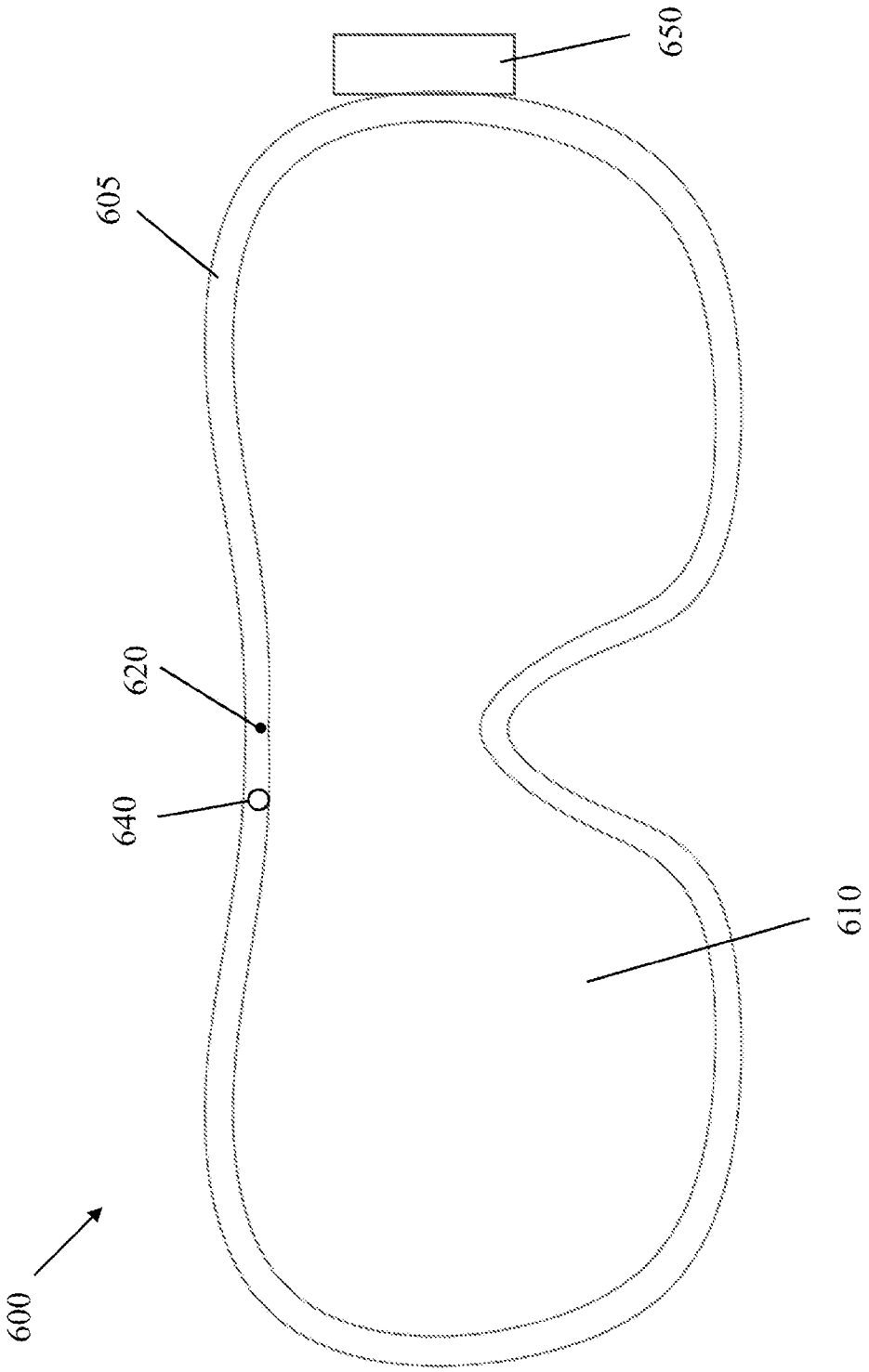


Figure 6B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/037160

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F3/01 A61B1/06 G02B27/00 G02B27/01 G03B15/02
H04M1/02 H04N23/74
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
G06F G03D A61B H04M H04N G02B G03B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 2022 0061614 A (LG ELECTRONICS INC [KR]) 13 May 2022 (2022-05-13)	1,3,4, 9-19,21, 22,24-27
Y	abstract; figures 1-8 paragraphs [0004], [0009], [0010], [0023] - [0025], [0036] - [0042], [0065], [0070] - [0072], [0079] - [0090], [0098] - [0121]	2,5-8, 20,23
X	US 2021/112195 A1 (DIKEN ERKAN [NL] ET AL) 15 April 2021 (2021-04-15)	1,3,4, 9-15, 17-19
Y	abstract; figures 1-5 paragraphs [0011] - [0018], [0029] - [0032]	2,5-8

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[X] Further documents are listed in the continuation of Box C.
[X] See patent family annex.

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"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 January 2024	12/02/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Köhn, Andreas

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/220291 A1 (HORNING ROBERT D [US] ET AL) 2 September 2010 (2010-09-02) abstract; figures 1-3 paragraphs [0006], [0015] - [0019]	20
Y	US 2022/146079 A1 (TAMMA VENKATA ANANTH [US] ET AL) 12 May 2022 (2022-05-12) abstract; figures 1-10 paragraphs [0016] - [0028], [0052], [0053]	2,5,7,8, 23
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A	US 2020/081529 A1 (RICHMOND ROBERT L [US] ET AL) 12 March 2020 (2020-03-12) abstract; figures 1-6 paragraphs [0091], [0097], [0100]	9,12

2

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