



(11) **EP 4 439 534 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.10.2024 Bulletin 2024/40

(51) International Patent Classification (IPC):
G09G 3/20 ^(2006.01)

(21) Application number: **23211093.2**

(52) Cooperative Patent Classification (CPC):
G09G 3/20; G09G 2320/0626; G09G 2330/021;
G09G 2360/144; G09G 2360/16

(22) Date of filing: **21.11.2023**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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(30) Priority: **31.03.2023 US 202318129446**

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(54) **TECHNOLOGIES FOR DISPLAY CONTRAST ENHANCEMENT**

(57) Techniques for display contrast enhancement are disclosed. In an illustrative embodiment, an ambient light sensor determines an amount of ambient light in the environment of the compute device. The display of the compute device has a reflectivity that causes some of the ambient light to be reflected off of the display. The reflected ambient light reduces the contrast ratio of the display. In order to compensate, the compute device can increase the brightness of the backlight based on the reflectivity of the display. In this manner, the compute device can adjust the contrast, such as by achieving a certain target ambient contrast ratio, based on the reflectivity of the display and without unnecessarily increasing the brightness of the backlight, conserving power. This approach can be used with other contrast-enhancing and/or power-saving algorithms, such as localized adaptive contrast enhancement (LACE) and/or display power savings technology (DPST).

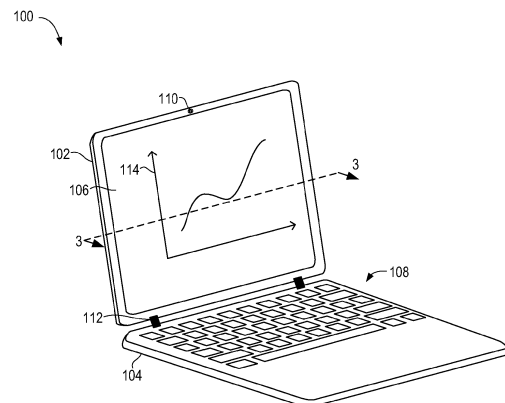


FIG. 1

Description**BACKGROUND**

[0001] Laptop computers have become an essential tool for both personal and professional use. As the use of laptops continues to grow, the importance of display quality has also increased significantly. One of the critical factors affecting the display quality is the ambient lighting conditions in which the laptop is being used.

[0002] In low-light environments, a relatively low brightness of the laptop display can be used. However, in bright environments, such as direct sunlight and a brightly lit indoor environment, the display may appear washed out, and the contrast ratio may be reduced. The brightness of the display can be increased in such conditions, but that also increases the energy usage of the display.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The concepts described herein are illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. Where considered appropriate, reference labels have been repeated among the figures to indicate corresponding or analogous elements.

FIG. 1 is a simplified drawing of at least one embodiment of a compute device in low-ambient-light conditions.

FIG. 2 is a simplified drawing of at least one embodiment of the compute device of claim 1 in higher-ambient-light conditions.

FIG. 3 is a cross-sectional view of one embodiment of the display of the compute device of FIG. 1.

FIG. 4 is a simplified block diagram of at least one embodiment of the compute device of FIG. 1.

FIG. 5 is a simplified block diagram of at least one embodiment of an environment that may be established by the compute device of FIG. 1.

FIG. 6 is a simplified flow diagram of at least one embodiment of a method for adjusting display brightness based on display reflectivity.

FIG. 7 is a picture with uneven contrast and histograms showing image contrast distribution.

FIG. 8 is a picture with equalized contrast and histograms showing image contrast distribution.

FIG. 9 is one embodiment of a simplified data flow diagram for adjusting display brightness based on display reflectivity.

DETAILED DESCRIPTION OF THE DRAWINGS

[0004] In the illustrative embodiment and as discussed below in more detail, a compute device such as a laptop has a display that reflects some of the light incident on it. In bright ambient conditions, the reflected light adds background light relative to light generated by the display, reducing the effective contrast. The contrast can be increased by increasing the brightness of the display. As the effective contrast can depend on the reflectivity of the display, the compute device can control the brightness at least partially based on the reflectivity of the display.

[0005] While the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will be described herein in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives consistent with the present disclosure and the appended claims.

[0006] References in the specification to "one embodiment," "an embodiment," "an illustrative embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may or may not necessarily include that particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. Additionally, it should be appreciated that items included in a list in the form of "at least one A, B, and C" can mean (A); (B); (C); (A and B); (A and C); (B and C); or (A, B, and C). Similarly, items listed in the form of "at least one of A, B, or C" can mean (A); (B); (C); (A and B); (A and C); (B and C); or (A, B, and C).

[0007] The disclosed embodiments may be implemented, in some cases, in hardware, firmware, software, or any combination thereof. The disclosed embodiments may also be implemented as instructions carried by or stored on a transitory or non-transitory machine-readable (e.g., computer-readable) storage medium, which may be read and executed by one or more processors. A machine-readable storage medium may be embodied as any storage device,

mechanism, or other physical structure for storing or transmitting information in a form readable by a machine (e.g., a volatile or non-volatile memory, a media disc, or other media device).

[0008] In the drawings, some structural or method features may be shown in specific arrangements and/or orderings. However, it should be appreciated that such specific arrangements and/or orderings may not be required. Rather, in some embodiments, such features may be arranged in a different manner and/or order than shown in the illustrative figures. Additionally, the inclusion of a structural or method feature in a particular figure is not meant to imply that such feature is required in all embodiments and, in some embodiments, may not be included or may be combined with other features.

[0009] Referring now to FIGS. 1 and 2, an illustrative compute device 100 includes a lid portion 102 and a base portion 104. The lid portion 102 includes a display 106, and the base portion 104 includes a keyboard 108. An ambient light sensor 110, which may be a camera, can detect the amount of ambient light in the environment of the compute device 100. FIG. 1 shows an environment with relatively low ambient light, and FIG. 2 shows an environment with ambient light 204 from, e.g., the sun 202 or other light source. In low ambient light conditions, an image such as a graph 114 on the display 106 has a relatively high contrast and is easy to view. In high ambient conditions and with the same display settings, the graph 114 on the display 106 may have a relatively low contrast and is more difficult to view. The decrease in contrast is in part due to light reflected off of the display 106.

[0010] In the illustrative embodiment, the brightness of the display 106 can be adjusted to improve the contrast in different ambient light conditions. As the contrast depends on the reflectivity of the display 106, the compute device 100 can adjust the brightness of the display 106 at least partially based on the reflectivity of the display, as described below in more detail.

[0011] The illustrative compute device 100 is embodied as a laptop with a clamshell configuration. The illustrative compute device 100 can be in an open configuration (shown in FIGS. 1 and 2) or a closed configuration, with the lid portion 102 positioned on top of the base portion 104 with the display 106 facing downwards toward the base portion 104. Additionally or alternatively, the compute device 100 may be embodied as a laptop with additional configurations. For example, the compute device 100 may be a laptop with a display that can rotate up to 360°, allowing the compute device 100 to be in a book configuration, a tablet configuration, etc. The compute device 100 may be a 2-in-1 device, with a lid portion 102 that can separate from the base portion 104. In the illustrative embodiment, one or more hinges 112 joins the base portion 104 and the lid portion 102.

[0012] The illustrative lid portion 102 has a display 106. The display 106 may be any suitable size and/or resolution, such as a 5-18 inch display, with a resolution from 340 x 480 to 3820 x 2400. The display 106 may use any suitable display technology, such as light-emitting diode (LED), organic light-emitting diode (OLED), quantum dot light-emitting diode (QD-LED), electronic paper display, etc. The display 106 may be a touchscreen display. The lid portion 102 may also include a camera 110. The camera 110 may include one or more fixed or adjustable lenses and one or more image sensors. The image sensors may be any suitable type of image sensors, such as a CMOS or CCD image sensor. The camera 110 may have any suitable aperture, focal length, field of view, etc. For example, the camera 110 may have a field of view of 60-110° in the azimuthal and/or elevation directions. In some embodiments, the camera 110 has a field of view that can capture the entire overlay component 106. In some embodiments, the compute device 100 may use the camera 110 as an ambient light sensor. In other embodiments, the sensor 110 may be an ambient light sensor, and the compute device 100 may include a separate camera or may not include a camera.

[0013] Referring now to FIG. 3, in one embodiment, a cross-sectional view of the lid portion 102 is shown. The lid portion 102 includes a display 106 and a cover 302. The display 106 includes several layers, as shown in the zoomed-in section of FIG. 3. The display 106 may include a backlight layer 304, a first polarizer layer 306, a liquid crystal layer 308, a second polarizer layer 310, a touch layer 312, and a cover glass layer 314. The various layers of the display 106 may include one or more sublayers. For example, the backlight layer 304 may include an enhanced diffuser reflector, a light guide plate, a quantum dot enhancement film, a bottom brightness enhancement film, a top brightness enhancement film, a diffuser, and an advanced polarizing film. Each polarizer layer 306, 310 may include a first tri-acetyl cellulose (TAC) film, a polarizing element, a second TAC film, and a pressure sensitive adhesive.

[0014] Unless a more specific description is explicitly used, the reflectivity of the display 106 as used herein may refer to any suitable metric for the reflectivity of the display 106, such as the proportion of incident ambient light reflected off of the top surface of the cover glass 314 or the total proportion of incident ambient light reflected off of all of the layers of the display 106. The reflectivity of the display 106 may depend on the material of the cover glass 314, the presence or type of anti-reflection coating on the cover glass 314 or other layers, whether the touch layer is in-cell or on-cell, etc.

[0015] In user, ambient light 316 is incident on the cover glass layer 314. Some light 318 is reflected off of the cover glass layer 314. Additionally, light 320 is generated by the display 106. The ambient contrast ratio may be defined as

$$ACR = \frac{L_{ON} + L_{AMBIENT}R}{L_{OFF} + L_{AMBIENT}R}$$
, where ACR is the ambient contrast ratio, L_{ON} is the light emitted by a pixel of the display 106 when that pixel is on, L_{OFF} is the light emitted by a pixel of the display 106 when the pixel is off, $L_{AMBIENT}$ is the

amount of ambient light, and R is the reflectivity of the display 106.

[0016] For displays 106 with a higher reflectivity, the ACR will be reduced. For example, Table 1 below shows the ambient light and ACR for different lighting conditions and different display 106 reflectivity. The light values are shown in nits. As can be seen from the table, the ACR depends on the reflectivity of the display 106. In order to compensate for the change in contrast, the compute device 100 can take into account both the amount of ambient light as well as the display reflectivity.

Table 1:

Reflectivity of display	2%	3%	4%	5%
LCD Peak Brightness	556	556	556	556
Contrast ratio of panel	1:1234	1:1234	1:1234	1:1234
Home lighting condition	63.8	63.8	63.8	63.8
Sunlight	31837	31837	31837	31837
Cloud	318.37	318.37	318.37	318.37
Reflected light under home condition	1.273	1.91	2.55	3.44
Reflected light under cloudy	6.367	9.551	12.73	17.19
Reflected light under outdoor condition	636.7	955.1	1273	1719
ACR in home light condition	323.2	236.3	186	143.9
ACR in sunlight	1.87	1.58	1.43	1.32
ACR in cloudy	82.48	56.5	43.13	32.49

[0017] Referring now to FIG. 4, in one embodiment, a compute device 102 for display contrast enhancement is shown. In the illustrative embodiment, the compute device 100 is a laptop in a clamshell configuration. In other embodiments, the compute device 100 may be embodied as any type of compute device. For example, the compute device 100 may be embodied as or otherwise be included in, without limitation, a server computer, an embedded computing system, a System-on-a-Chip (SoC), a multiprocessor system, a processor-based system, a consumer electronic device, a smartphone, a cellular phone, a desktop computer, a tablet computer, a notebook computer, a laptop computer, a networked computer, a wearable computer, a handset, a messaging device, a camera device, and/or any other compute device. In some embodiments, the compute device 100 may be located in a data center, such as an enterprise data center (e.g., a data center owned and operated by a company and typically located on company premises), managed services data center (e.g., a data center managed by a third party on behalf of a company), a colocated data center (e.g., a data center in which data center infrastructure is provided by the data center host and a company provides and manages their own data center components (servers, etc.)), cloud data center (e.g., a data center operated by a cloud services provider that host companies applications and data), and an edge data center (e.g., a data center, typically having a smaller footprint than other data center types, located close to the geographic area that it serves).

[0018] The illustrative compute device 100 includes a processor 402, a memory 404, an input/output (I/O) subsystem 406, data storage 408, a communication circuit 410, a touch sensor 412, a display 414, a camera 416, and one or more peripheral devices 418. In some embodiments, one or more of the illustrative components of the compute device 100 may be incorporated in, or otherwise form a portion of, another component. For example, the memory 404, or portions thereof, may be incorporated in the processor 402 in some embodiments. In some embodiments, one or more of the illustrative components may be physically separated from another component.

[0019] The processor 402 may be embodied as any type of processor capable of performing the functions described herein. For example, the processor 402 may be embodied as a single or multi-core processor(s), a single or multi-socket processor, a digital signal processor, a graphics processor, a neural network compute engine, an image processor, a microcontroller, or other processor or processing/controlling circuit. Similarly, the memory 404 may be embodied as any type of volatile or non-volatile memory or data storage capable of performing the functions described herein. In operation, the memory 404 may store various data and software used during operation of the compute device 100 such as operating systems, applications, programs, libraries, and drivers. The memory 404 is communicatively coupled to the processor 402 via the I/O subsystem 406, which may be embodied as circuitry and/or components to facilitate input/output operations with the processor 402, the memory 404, and other components of the compute device 100. For example, the I/O subsystem 406 may be embodied as, or otherwise include, memory controller hubs, input/output control hubs, firmware devices, communication links (i.e., point-to-point links, bus links, wires, cables, light guides, printed circuit board traces,

etc.) and/or other components and subsystems to facilitate the input/output operations. The I/O subsystem 406 may connect various internal and external components of the compute device 100 to each other with use of any suitable connector, interconnect, bus, protocol, etc., such as an SoC fabric, PCIe®, USB2, USB3, USB4, NVMe®, Thunderbolt®, and/or the like. In some embodiments, the I/O subsystem 406 may form a portion of a system-on-a-chip (SoC) and be incorporated, along with the processor 402, the memory 404, and other components of the compute device 100 on a single integrated circuit chip.

[0020] The data storage 408 may be embodied as any type of device or devices configured for the short-term or long-term storage of data. For example, the data storage 408 may include any one or more memory devices and circuits, memory cards, hard disk drives, solid-state drives, or other data storage devices.

[0021] The communication circuit 410 may be embodied as any type of interface capable of interfacing the compute device 100 with other compute devices, such as over one or more wired or wireless connections. In some embodiments, the communication circuit 410 may be capable of interfacing with any appropriate cable type, such as an electrical cable or an optical cable. The communication circuit 410 may be configured to use any one or more communication technology and associated protocols (e.g., Ethernet, Bluetooth®, Wi-Fi®, WiMAX, near field communication (NFC), etc.). The communication circuit 410 may be located on silicon separate from the processor 402, or the communication circuit 410 may be included in a multi-chip package with the processor 402, or even on the same die as the processor 402. The communication circuit 410 may be embodied as one or more add-in-boards, daughtercards, network interface cards, controller chips, chipsets, specialized components such as a field programmable gate array (FPGA) or application specific integrated circuit (ASIC), or other devices that may be used by the compute device 402 to connect with another compute device. In some embodiments, communication circuit 410 may be embodied as part of a system-on-a-chip (SoC) that includes one or more processors, or included on a multichip package that also contains one or more processors. In some embodiments, the communication circuit 410 may include a local processor (not shown) and/or a local memory (not shown) that are both local to the communication circuit 410. In such embodiments, the local processor of the communication circuit 410 may be capable of performing one or more of the functions of the processor 402 described herein. Additionally or alternatively, in such embodiments, the local memory of the communication circuit 410 may be integrated into one or more components of the compute device 100 at the board level, socket level, chip level, and/or other levels.

[0022] The camera 416 may be similar to the camera 110, a description of which will not be repeated in the interest of clarity. In some embodiments, the camera 416 may act as an ambient light sensor, or the sensor 416 may be an ambient light sensor 110.

[0023] In some embodiments, the compute device 100 may include other or additional components, such as those commonly found in a compute device. For example, the compute device 100 may also have peripheral devices 418, such as a keyboard, a mouse, a speaker, an external storage device, etc. In some embodiments, the compute device 100 may be connected to a dock that can interface with various devices, including peripheral devices 418. The compute device 100 may include several additional components, such as a battery, one or more antennas, one or more connectors (such as one or more USB2 connectors, one or more USB3 connectors, an SD card slot, a headphone and/or microphone jack, a power connector, etc.), etc. Each of the various components of the compute device 100 may be in the lid portion 102 and/or the base portion 104, as appropriate.

[0024] Referring now to FIG. 5, in an illustrative embodiment, the compute device 100 establishes an environment 500 during operation. The illustrative environment 500 includes an image analyzer 502, an image adapter 504, and a backlight controller 506. The various modules of the environment 500 may be embodied as hardware, software, firmware, or a combination thereof. For example, the various modules, logic, and other components of the environment 500 may form a portion of, or otherwise be established by, the processor 402, the memory 404, the data storage 408, or other hardware components of the compute device 100. As such, in some embodiments, one or more of the modules of the environment 500 may be embodied as circuitry or collection of electrical devices (e.g., image analyzer circuitry 502, image adapter circuitry 504, backlight controller circuitry 506, etc.). It should be appreciated that, in such embodiments, one or more of the circuits (e.g., the image analyzer adapter circuitry 502, the image adapter circuitry 504, the backlight controller circuitry 506, etc.) may form a portion of one or more of the processor 402, the memory 404, the I/O subsystem 406, the data storage 408, and/or other components of the compute device 100. For example, in some embodiments, some or all of the modules may be embodied as the processor 402, as well as the memory 404 and/or data storage 408 storing instructions to be executed by the processor 402. In some embodiments, some or all of the functionality of the image analyzer 502, the image adapter 504, and the backlight controller 506 may be implemented by a graphics driver, display engine, and/or the like. Additionally, in some embodiments, one or more of the illustrative modules may form a portion of another module and/or one or more of the illustrative modules may be independent of one another. Further, in some embodiments, one or more of the modules of the environment 400 may be embodied as virtualized hardware components or emulated architecture, which may be established and maintained by the processor 402 or other components of the compute device 100. It should be appreciated that some of the functionality of one or more of the modules of the environment 400 may require a hardware implementation, in which case embodiments of modules that implement

such functionality will be embodied at least partially as hardware.

[0025] The image analyzer 502, which may be embodied as hardware, firmware, software, virtualized hardware, emulated architecture, and/or a combination thereof as discussed above, is configured to analyze images being sent to the display 106. The image analyzer 502 may generate a histogram showing the distribution of the brightness of different parts of the image. For example, the frame of display data may be an image 702 of a woman, as shown in FIG. 7. The image 702 may be broken up into many different bins, based on the luminance of each pixel. The total brightness of each bin is calculated. A histogram 706 shows how common each brightness level is. A cumulative histogram 704 shows the fraction of bins that are at or below a given brightness level.

[0026] The image adapter 505, which may be embodied as hardware, firmware, software, virtualized hardware, emulated architecture, and/or a combination thereof as discussed above, is configured to adapt images based on parameters such as ambient light, display reflectivity, distribution of brightness in different regions of the image, user input such as input from brightness hot keys, user and platform policy, etc.

[0027] In one embodiment, the image adapter 505 may implement localized adaptive contrast enhancement (LACE). The image adapter 505 may use the histogram 706 and the cumulative histogram 708 generated by the image analyzer 502 to equalize the contrast of the image. To do so, the image adapter 505 may adjust the brightness of individual bins of pixels in a manner that evens out the distribution of brightness of different parts of the image. For example, the bins of the image 702 may have their brightness adjusted to result in the brightness histogram shown in histogram 806, with resulting cumulative histogram 804. The brightness of the various bins are adjusted so that the cumulative histogram 804 is approximately a straight line from zero to full brightness, resulting in the contrast equalized image 802.

[0028] Additionally or alternatively, in one embodiment, the image adapter 504 may implement Intel® Display Power Savings Technology (DPST). DPST can achieve platform average power savings by dynamically decreasing the display backlight brightness while boosting the pixel values in the displayed frames proportionally. DPST can provide equivalent end user perceived image quality at a decreased backlight power level. In some cases, DPST may introduce distortion to brighter pixels of displayed frames. Users can control the amount of distortion by selecting DPST aggressiveness.

[0029] Consider, for example, a brightness of a given pixel of an image. The brightness of the pixel is given by

$$I = BL \times \left(\frac{Pixel}{255} \right)^{\gamma}$$
, where *Pixel* is the pixel brightness (from 0-255), γ is a parameter for gamma correction, *BL* is the backlight intensity, and *I* is the final pixel intensity. The parameter γ implements gamma correction and may be any suitable value, such as 2.2. If the *Pixel* value is less than the maximum brightness (i.e., less than 255), the equivalent final pixel brightness can be achieved by increasing the *Pixel* value and decreasing the *BL* value. The pixel brightness

I may then also be expressed as
$$I = BL_{Dim} \times \left(\frac{Pixel_{Enhanced}}{255} \right)^{\gamma}$$
, leading to the equation

$$\frac{BL_{Dim}}{BL} = \left(\frac{Pixel}{Pixel_{Enhanced}} \right)^{\gamma}$$
, wherein *Pixel_{Enhanced}* is the new value of the pixel and *BL_{Dim}* is the new backlight level.

[0030] The backlight controller 506, which may be embodied as hardware, firmware, software, virtualized hardware, emulated architecture, and/or a combination thereof as discussed above, is configured to control the brightness of the backlight 304 and, in particular, control the backlight 304 to provide an ACR based on ambient brightness and reflectivity of the display 106. The backlight controller 506 may use any suitable algorithm to determine the backlight level. For example, in one embodiment, the backlight controller 506 may use the formula for the ACR, as

$$ACR = \frac{L_{ON} + L_{AMBIENT} R}{L_{OFF} + L_{AMBIENT} R}$$
, to achieve e.g., the same ACR regardless of the reflectivity *R*.

[0031] It should be appreciated that, in some embodiments, a backlight may not be used. In such embodiments, the reflectivity of the display 106 may be taken into account in a different manner. For example, in some embodiments, the backlight controller 506 may adjust the brightness of each pixel in a similar manner as the backlight controller 506 adjusts the entire backlight. In such a manner, the reflectivity of the display 106 can be used to improve the ACR while limiting power usage even without a backlight.

[0032] Referring now to FIG. 6, in use, the compute device 100 may execute a method 600 for display contrast enhancement. The method 600 may correspond to the data flow 900 shown in FIG. 9. The method 600 begins in block 602, in which the compute device 100 determines a reflectivity of the display 106. In the illustrative embodiment, the compute device 100 access a parameter stored on the compute device 100 that indicates the reflectivity of the display 106 (e.g., includes a value of the reflectivity of the display 106). The display reflectivity may be stored in a display reflectivity register 906, as shown in FIG. 9. In other embodiments, the compute device 100 may determine the reflectivity of the display 106 in another manner, such as by accessing a remote compute that has the value of the reflectivity of the display 106.

[0033] In block 604, the compute device 100 determines the next frame of display data, such as by accessing a graphics frame buffer 902. In block 606, the compute device 100 generates a histogram showing the distribution of the brightness of different parts of the image, which may be done in image analysis 910. For example, the frame of display data may be an image 702 of a woman, as shown in FIG. 7. The image 702 may be broken up into many different bins, such as bins of size, e.g., 10 by 10 pixels each. The total brightness of each bin is calculated. A histogram 706 shows how common each brightness level is. A cumulative histogram 704 shows the fraction of bins that are at or below a given brightness level.

[0034] In block 608, the compute device 100 compares the histogram for the current frame to the histogram for the previous frame. In block 610, the compute device 100 determines whether there is a change in any histogram bin by at least a threshold amount. The threshold amount may be, e.g., any value from 0-10%. For the first frame, when there is no previous histogram to compare to, the compute device 100 always determines that the change is above the threshold amount.

[0035] In block 612, if the change is not more than a threshold amount, the method 600 loops back to block 604 to determine the next frame of display data. If the change is more than a threshold amount, the method 600 proceeds to block 614, in which the compute device modifies the pixel values of each pixel. In the illustrative embodiment, the compute device 100 implements an algorithm such as Intel® Display Power Savings Technology (DPST), which can be used to reduce the backlight intensity while maintaining a high contrast. The pixels may be modified as described above in regard to the image adapter 502. The pixels may be modified at the image adaptation block 908.

[0036] In block 616, the compute device 100 determines an amount of ambient light. The compute device 100 may sense the amount of ambient light from an ambient light sensor or a camera. In block 618, the compute device 100 calculates a new backlight level based on the histogram statistics, the amount of ambient light, and the reflectivity of the display 106. The backlight level may be determined in the processing block 912. The user and platform policy 904 may affect the processing, such as by affecting how aggressively the DPST or other algorithm is used to reduce backlight power. The LED controller 918 may take into account input from the user provided by backlight hot-keys 914. For example, if the user has pressed a backlight hot key to increase the brightness, the LED controller 918 may increase the brightness of the backlight. If the user has pressed a backlight hot key to decrease the brightness, the LED controller 918 may decrease the brightness of the backlight. The LED controller 918 controls the backlight 922 of the panel 920. The compute device 100 may use any suitable algorithm to determine the backlight level. For example, in one embodiment,

the compute device 100 may use the formula for the ACR, as

$$ACR = \frac{L_{ON} + L_{AMBIENT}R}{L_{OFF} + L_{AMBIENT}R}$$

, to achieve e.g., the same ACR regardless of the reflectivity R.

[0037] In block 620, the compute device 100 phases in the backlight level change so that the user of the compute device 100 does not observe flickering or other artifacts. For example, the backlight level may be limited to a change rate of 1% per frame. The method 600 then loops back to block 604 to determine the next frame of display data.

[0038] It should be appreciated that the algorithm described above is merely one possible algorithm, and any suitable algorithm or combination of algorithms may be used. For example, the compute device 100 may implement any suitable combination of DPST, localized adaptive contrast enhancement (LACE), content adaptive backlight control (CABC). Any of those algorithms or combination of algorithms may be modified to include adjusting the backlight and/or pixel brightness based at least partially on the reflectivity of the display 106.

EXAMPLES

[0039] Illustrative examples of the technologies disclosed herein are provided below. An embodiment of the technologies may include any one or more, and any combination of, the examples described below.

[0040] Example 1 includes a compute device comprising a display; an ambient light sensor to determine an amount of ambient light in an environment of the compute device; and backlight controller circuitry to determine a brightness parameter at least partially based on the amount of ambient light and a reflectivity parameter of the display of the compute device, wherein the reflectivity parameter of the display is at least partially based on a proportion of incident ambient light reflected off of a top surface of a cover glass layer of the display; and adjust the display based on the brightness parameter.

[0041] Example 2 includes the subject matter of Example 1, and wherein the brightness parameter is a backlight brightness, wherein to adjust the display comprises to adjust a backlight of the display.

[0042] Example 3 includes the subject matter of any of Examples 1 and 2, and wherein the display is an organic light-emitted diode display, wherein to adjust the display based on the brightness parameter comprises to adjust a brightness of a plurality of pixels of the organic light-emitting diode display based on the brightness parameter.

[0043] Example 4 includes the subject matter of any of Examples 1-3, and wherein the backlight controller circuitry is to determine the reflectivity parameter by accessing a parameter saved on the compute device.

[0044] Example 5 includes the subject matter of any of Examples 1-4, and further including image analyzer circuitry to process frame data to be displayed on the display; and image adapter circuitry to adapt the frame data to equalize a contrast of the frame data based on the processing of the frame data, wherein the backlight controller circuitry is to display the adapted frame data on the display at a brightness based on the brightness parameter.

[0045] Example 6 includes the subject matter of any of Examples 1-5, and wherein to adapt the frame data comprises to apply a localized adaptive contrast enhancement (LACE) algorithm.

[0046] Example 7 includes the subject matter of any of Examples 1-6, and further including image analyzer circuitry to process frame data to be displayed on the display; and image adapter circuitry to adapt the frame data to increase an average pixel brightness, wherein the backlight controller circuitry is to display the adapted frame data on the display at a brightness based on the brightness parameter.

[0047] Example 8 includes the subject matter of any of Examples 1-7, and wherein to adapt the frame data comprises to apply a display power savings technology (DPST) algorithm.

[0048] Example 9 includes the subject matter of any of Examples 1-8, and wherein the backlight controller circuitry is further to determine a target ambient contrast ratio, wherein to determine the brightness parameter for the display comprises to determine the brightness parameter at least partially based on the amount of ambient light and the reflectivity parameter to achieve the target ambient contrast ratio, wherein to adjust the display based on the brightness parameter comprises to adjust the display to achieve the target ambient contrast ratio.

[0049] Example 10 includes the subject matter of any of Examples 1-9, and wherein the compute device is a laptop comprising a lid portion and a base portion, wherein the lid portion comprises the display.

[0050] Example 11 includes a method comprising determining, by a compute device, an amount of ambient light in an environment of the compute device; determining, by the compute device, a brightness parameter for a display of the compute device at least partially based on the amount of ambient light and a reflectivity parameter of the display of the compute device, wherein the reflectivity parameter of the display is at least partially based on a proportion of incident ambient light reflected off of a top surface of a cover glass layer of the display; and adjusting, by the compute device, the display based on the brightness parameter.

[0051] Example 12 includes the subject matter of Example 11, and wherein the brightness parameter is a backlight brightness, wherein adjusting the display comprises adjusting a backlight of the display.

[0052] Example 13 includes the subject matter of any of Examples 11 and 12, and wherein the display is an organic light-emitted diode display, wherein adjusting the display based on the brightness parameter comprises adjusting a brightness of a plurality of pixels of the organic light-emitting diode display based on the brightness parameter.

[0053] Example 14 includes the subject matter of any of Examples 11-13, and further including determining, by the compute device, the reflectivity parameter by accessing a parameter saved on the compute device.

[0054] Example 15 includes the subject matter of any of Examples 11-14, and further including processing, by the compute device, frame data to be displayed on the display; adapting, by the compute device, the frame data to equalize a contrast of the frame data based on the processing of the frame data; and displaying, by the compute device, the adapted frame data on the display at a brightness based on the brightness parameter.

[0055] Example 16 includes the subject matter of any of Examples 11-15, and wherein adapting the frame data comprises applying a localized adaptive contrast enhancement (LACE) algorithm.

[0056] Example 17 includes the subject matter of any of Examples 11-16, and further including processing, by the compute device, frame data to be displayed on the display; adapting, by the compute device, the frame data to increase an average pixel brightness; and displaying, by the compute device, the adapted frame data on the display at a brightness based on the brightness parameter.

[0057] Example 18 includes the subject matter of any of Examples 11-17, and wherein adapting the frame data comprises applying a display power savings technology (DPST) algorithm.

[0058] Example 19 includes the subject matter of any of Examples 11-18, and further including determining a target ambient contrast ratio, wherein determining the brightness parameter for the display comprises determining the brightness parameter at least partially based on the amount of ambient light and the reflectivity parameter to achieve the target ambient contrast ratio, wherein adjusting the display based on the brightness parameter comprises adjusting the display to achieve the target ambient contrast ratio.

[0059] Example 20 includes the subject matter of any of Examples 11-19, and wherein the compute device is a laptop comprising a lid portion and a base portion, wherein the lid portion comprises the display.

[0060] Example 21 includes a compute device comprising means for determining, by a compute device, an amount of ambient light in an environment of the compute device; means for determining a brightness parameter for a display of the compute device at least partially based on the amount of ambient light and a reflectivity parameter of the display of the compute device, wherein the reflectivity parameter of the display is at least partially based on a proportion of incident ambient light reflected off of a top surface of a cover glass layer of the display; and means for adjusting the display based on the brightness parameter.

[0061] Example 22 includes the subject matter of Example 21, and wherein the brightness parameter is a backlight

brightness, wherein the means for adjusting the display comprises means for adjusting a backlight of the display.

[0062] Example 23 includes the subject matter of any of Examples 21 and 22, and wherein the display is an organic light-emitted diode display, wherein the means for adjusting the display based on the brightness parameter comprises means for adjusting a brightness of a plurality of pixels of the organic light-emitting diode display based on the brightness parameter.

[0063] Example 24 includes the subject matter of any of Examples 21-23, and further including means for determining the reflectivity parameter by accessing a parameter saved on the compute device.

[0064] Example 25 includes the subject matter of any of Examples 21-24, and further including means for processing frame data to be displayed on the display; means for adapting the frame data to equalize a contrast of the frame data based on the processing of the frame data; and means for displaying the adapted frame data on the display at a brightness based on the brightness parameter.

[0065] Example 26 includes the subject matter of any of Examples 21-25, and wherein the means for adapting the frame data comprises means for applying a localized adaptive contrast enhancement (LACE) algorithm.

[0066] Example 27 includes the subject matter of any of Examples 21-26, and further including means for processing frame data to be displayed on the display; means for adapting the frame data to increase an average pixel brightness; and means for displaying the adapted frame data on the display at a brightness based on the brightness parameter.

[0067] Example 28 includes the subject matter of any of Examples 21-27, and wherein the means for adapting the frame data comprises means for applying a display power savings technology (DPST) algorithm.

[0068] Example 29 includes the subject matter of any of Examples 21-28, and further including means for determining a target ambient contrast ratio, wherein the means for determining the brightness parameter for the display comprises means for determining the brightness parameter at least partially based on the amount of ambient light and the reflectivity parameter to achieve the target ambient contrast ratio, wherein the means for adjusting the display based on the brightness parameter comprises means for adjusting the display to achieve the target ambient contrast ratio.

[0069] Example 30 includes the subject matter of any of Examples 21-29, and wherein the compute device is a laptop comprising a lid portion and a base portion, wherein the lid portion comprises the display.

[0070] Example 31 includes one or more computer-readable media comprising a plurality of instructions stored thereon that, when executed, causes a compute device to determine an amount of ambient light in an environment of the compute device; determine a brightness parameter for a display of the compute device at least partially based on the amount of ambient light and a reflectivity parameter of the display of the compute device, wherein the reflectivity parameter of the display is at least partially based on a proportion of incident ambient light reflected off of a top surface of a cover glass layer of the display; and adjust the display based on the brightness parameter.

[0071] Example 32 includes the subject matter of Example 31, and wherein the brightness parameter is a backlight brightness, wherein to adjust the display comprises to adjust a backlight of the display.

[0072] Example 33 includes the subject matter of any of Examples 31 and 32, and wherein the display is an organic light-emitted diode display, wherein to adjust the display based on the brightness parameter comprises to adjust a brightness of a plurality of pixels of the organic light-emitting diode display based on the brightness parameter.

[0073] Example 34 includes the subject matter of any of Examples 31-33, and wherein the plurality of instructions further cause the compute device to determine the reflectivity parameter by accessing a parameter saved on the compute device.

[0074] Example 35 includes the subject matter of any of Examples 31-34, and wherein the plurality of instructions further cause the compute device to process frame data to be displayed on the display; adapt the frame data to equalize a contrast of the frame data based on the processing of the frame data; and display the adapted frame data on the display at a brightness based on the brightness parameter.

[0075] Example 36 includes the subject matter of any of Examples 31-35, and wherein to adapt the frame data comprises to apply a localized adaptive contrast enhancement (LACE) algorithm.

[0076] Example 37 includes the subject matter of any of Examples 31-36, and wherein the plurality of instructions further cause the compute device to process frame data to be displayed on the display; adapt the frame data to increase an average pixel brightness; and display the adapted frame data on the display at a brightness based on the brightness parameter.

[0077] Example 38 includes the subject matter of any of Examples 31-37, and wherein to adapt the frame data comprises to apply a display power savings technology (DPST) algorithm.

[0078] Example 39 includes the subject matter of any of Examples 31-38, and wherein the plurality of instructions further causes the compute device to determine a target ambient contrast ratio, wherein to determine the brightness parameter for the display comprises to determine the brightness parameter at least partially based on the amount of ambient light and the reflectivity parameter to achieve the target ambient contrast ratio, wherein to adjust the display based on the brightness parameter comprises to adjust the display to achieve the target ambient contrast ratio.

[0079] Example 40 includes the subject matter of any of Examples 31-39, and wherein the compute device is a laptop comprising a lid portion and a base portion, wherein the lid portion comprises the display.

Claims

1. A compute device comprising:

a display;
an ambient light sensor to determine an amount of ambient light in an environment of the compute device; and
backlight controller circuitry to:

determine a brightness parameter at least partially based on the amount of ambient light and a reflectivity parameter of the display of the compute device, wherein the reflectivity parameter of the display is at least partially based on a proportion of incident ambient light reflected off of a top surface of a cover glass layer of the display; and
adjust the display based on the brightness parameter.

2. The compute device of claim 1, wherein the brightness parameter is a backlight brightness, wherein to adjust the display comprises to adjust a backlight of the display.

3. The compute device of claim 1, wherein the display is an organic light-emitted diode display, wherein to adjust the display based on the brightness parameter comprises to adjust a brightness of a plurality of pixels of the organic light-emitting diode display based on the brightness parameter.

4. The compute device of any of claims 1-3, wherein the backlight controller circuitry is to determine the reflectivity parameter by accessing a parameter saved on the compute device.

5. The compute device of any of claims 1-4, further comprising:

image analyzer circuitry to process frame data to be displayed on the display; and
image adapter circuitry to adapt the frame data to equalize a contrast of the frame data based on the processing of the frame data,
wherein the backlight controller circuitry is to display the adapted frame data on the display at a brightness based on the brightness parameter.

6. The compute device of claim 5, wherein to adapt the frame data comprises to apply a localized adaptive contrast enhancement (LACE) algorithm.

7. The compute device of any of claims 1-4, further comprising:

image analyzer circuitry to process frame data to be displayed on the display; and
image adapter circuitry to adapt the frame data to increase an average pixel brightness,
wherein the backlight controller circuitry is to display the adapted frame data on the display at a brightness based on the brightness parameter.

8. The compute device of claim 7, wherein to adapt the frame data comprises to apply a display power savings technology (DPST) algorithm.

9. The compute device of any of claims 1-8, wherein the backlight controller circuitry is further to determine a target ambient contrast ratio,

wherein to determine the brightness parameter for the display comprises to determine the brightness parameter at least partially based on the amount of ambient light and the reflectivity parameter to achieve the target ambient contrast ratio,
wherein to adjust the display based on the brightness parameter comprises to adjust the display to achieve the target ambient contrast ratio.

10. The compute device of any of claims 1-9, wherein the compute device is a laptop comprising a lid portion and a base portion, wherein the lid portion comprises the display.

11. A method comprising:

determining, by a compute device, an amount of ambient light in an environment of the compute device;
determining, by the compute device, a brightness parameter for a display of the compute device at least partially
based on the amount of ambient light and a reflectivity parameter of the display of the compute device, wherein
the reflectivity parameter of the display is at least partially based on a proportion of incident ambient light reflected
off of a top surface of a cover glass layer of the display; and
adjusting, by the compute device, the display based on the brightness parameter.

12. The method of claim 11, further comprising:

processing, by the compute device, frame data to be displayed on the display;
adapting, by the compute device, the frame data to equalize a contrast of the frame data based on the processing
of the frame data; and
displaying, by the compute device, the adapted frame data on the display at a brightness based on the brightness
parameter.

13. The method of claim 11, further comprising:

processing, by the compute device, frame data to be displayed on the display;
adapting, by the compute device, the frame data to increase an average pixel brightness; and
displaying, by the compute device, the adapted frame data on the display at a brightness based on the brightness
parameter.

14. The method of any of claims 11-13, further comprising determining a target ambient contrast ratio,

wherein determining the brightness parameter for the display comprises determining the brightness parameter
at least partially based on the amount of ambient light and the reflectivity parameter to achieve the target ambient
contrast ratio,
wherein adjusting the display based on the brightness parameter comprises adjusting the display to achieve
the target ambient contrast ratio.

15. One or more computer-readable media comprising a plurality of instructions stored thereon that, when executed,
causes a compute device to perform the method of any of claims 11-14.

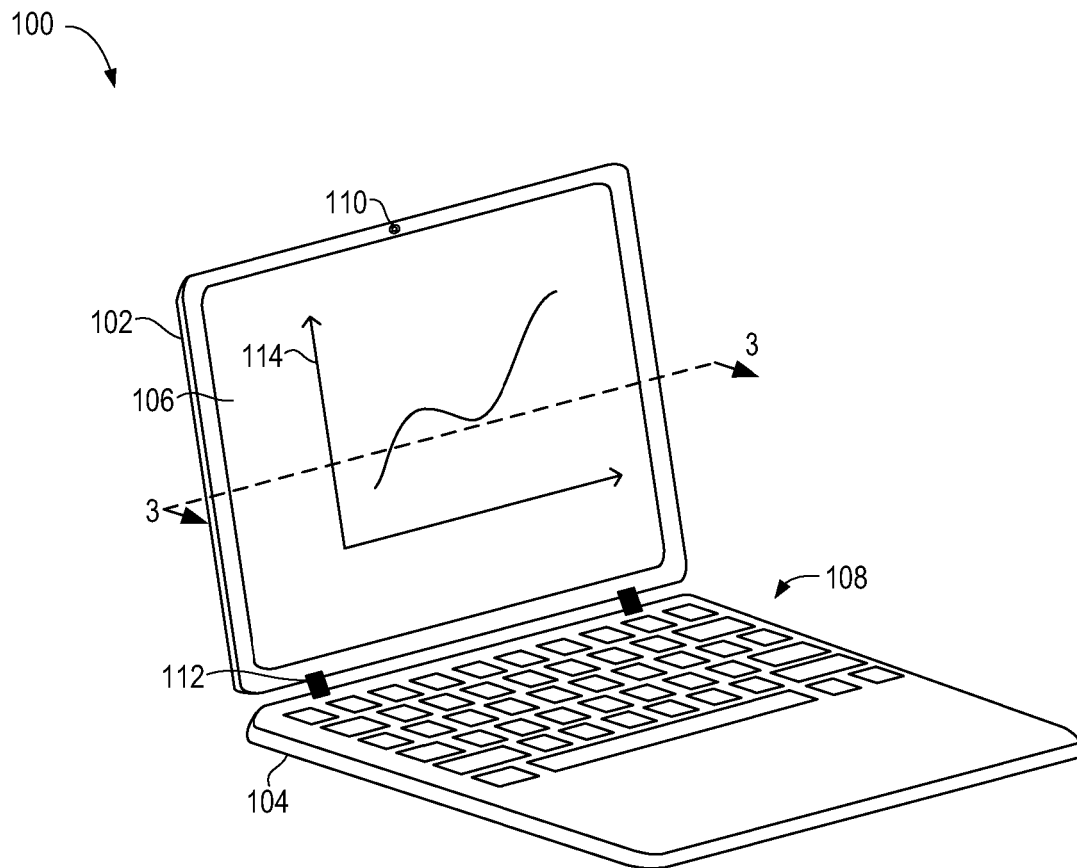


FIG. 1

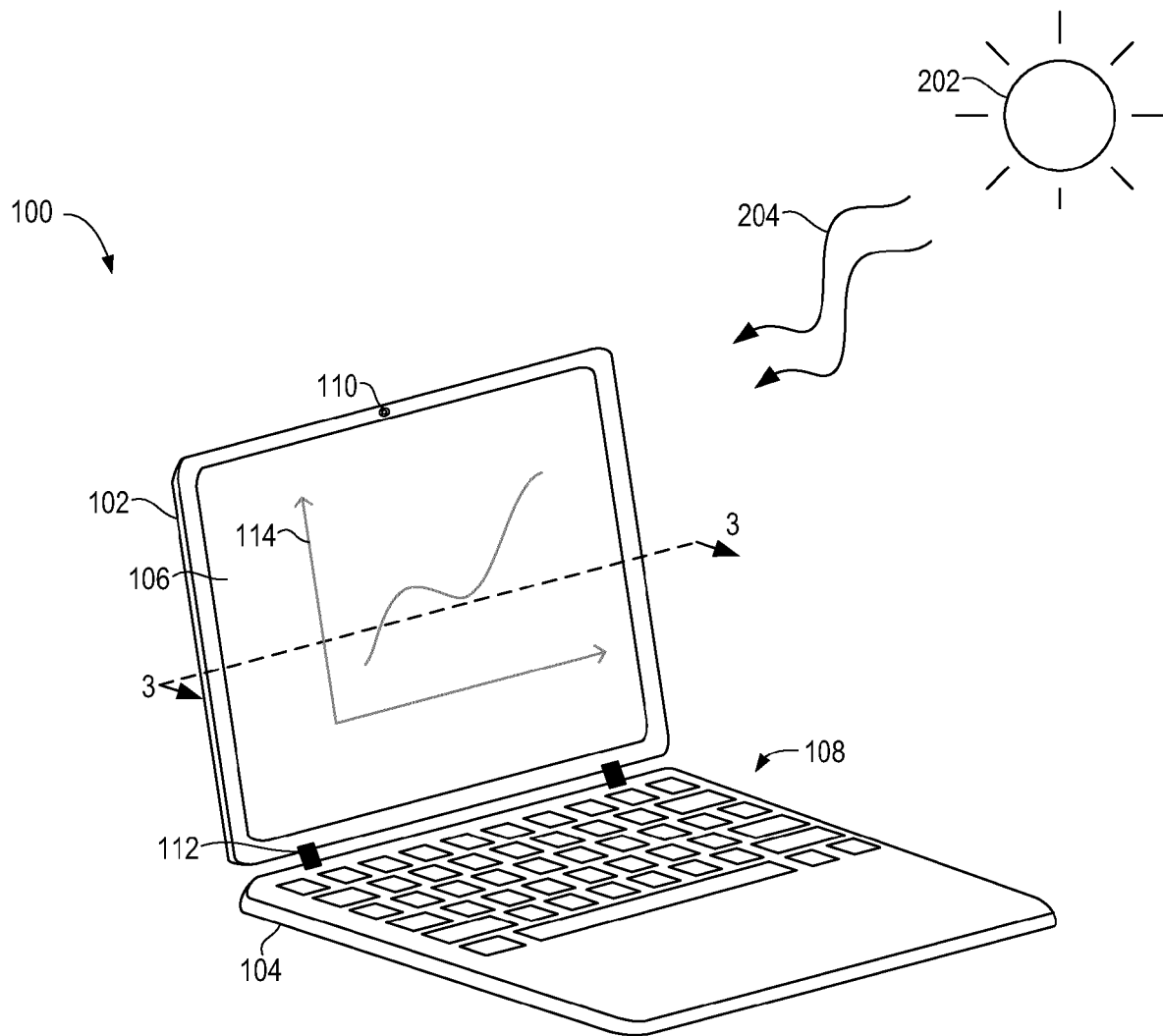


FIG. 2

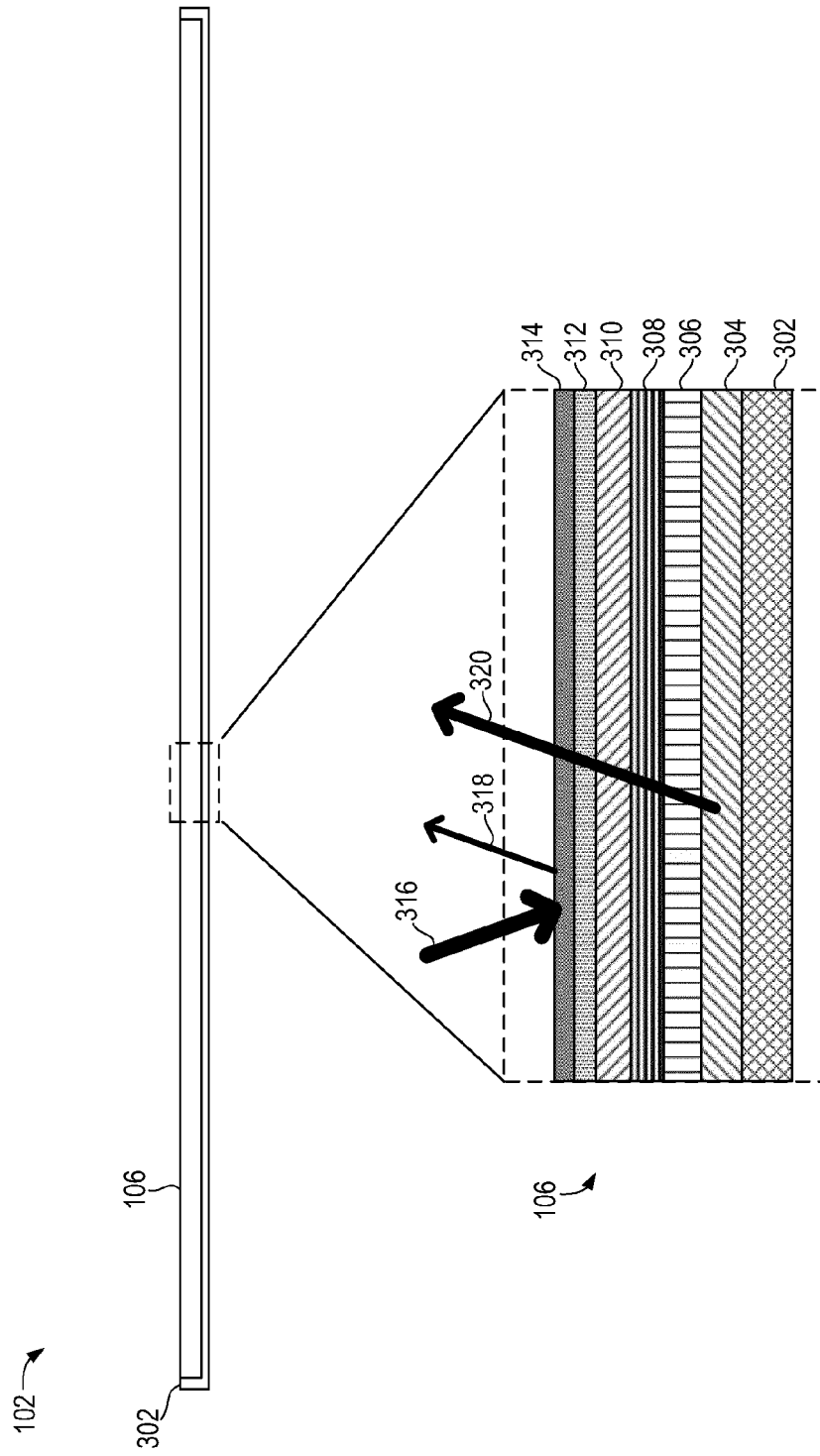


FIG. 3

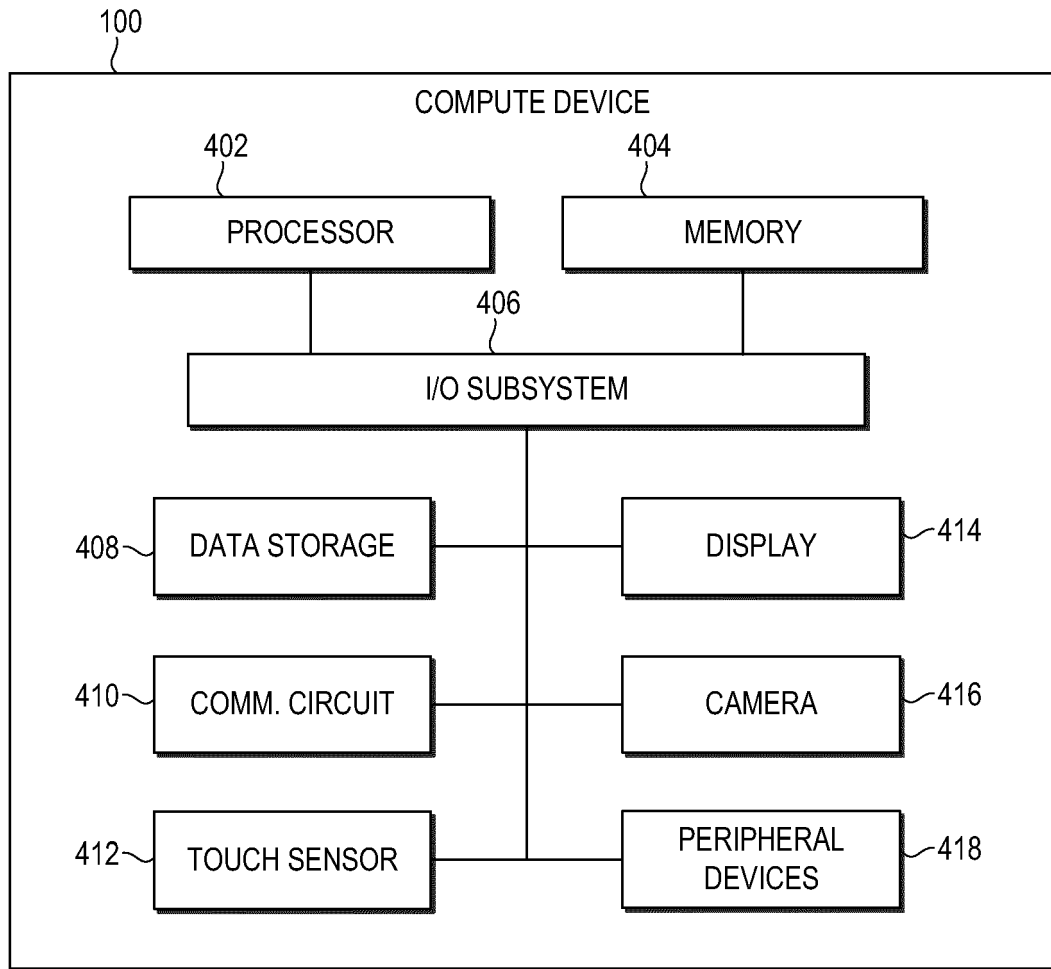


FIG. 4

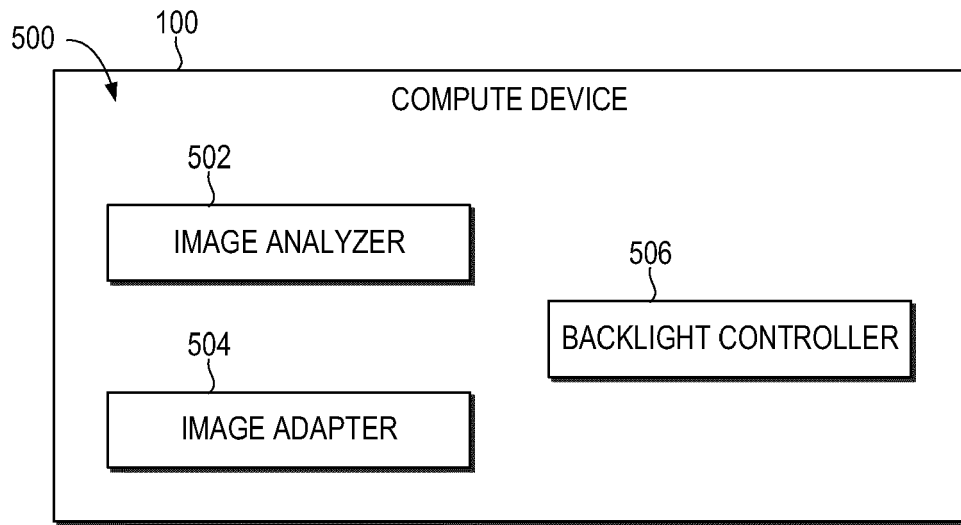


FIG. 5

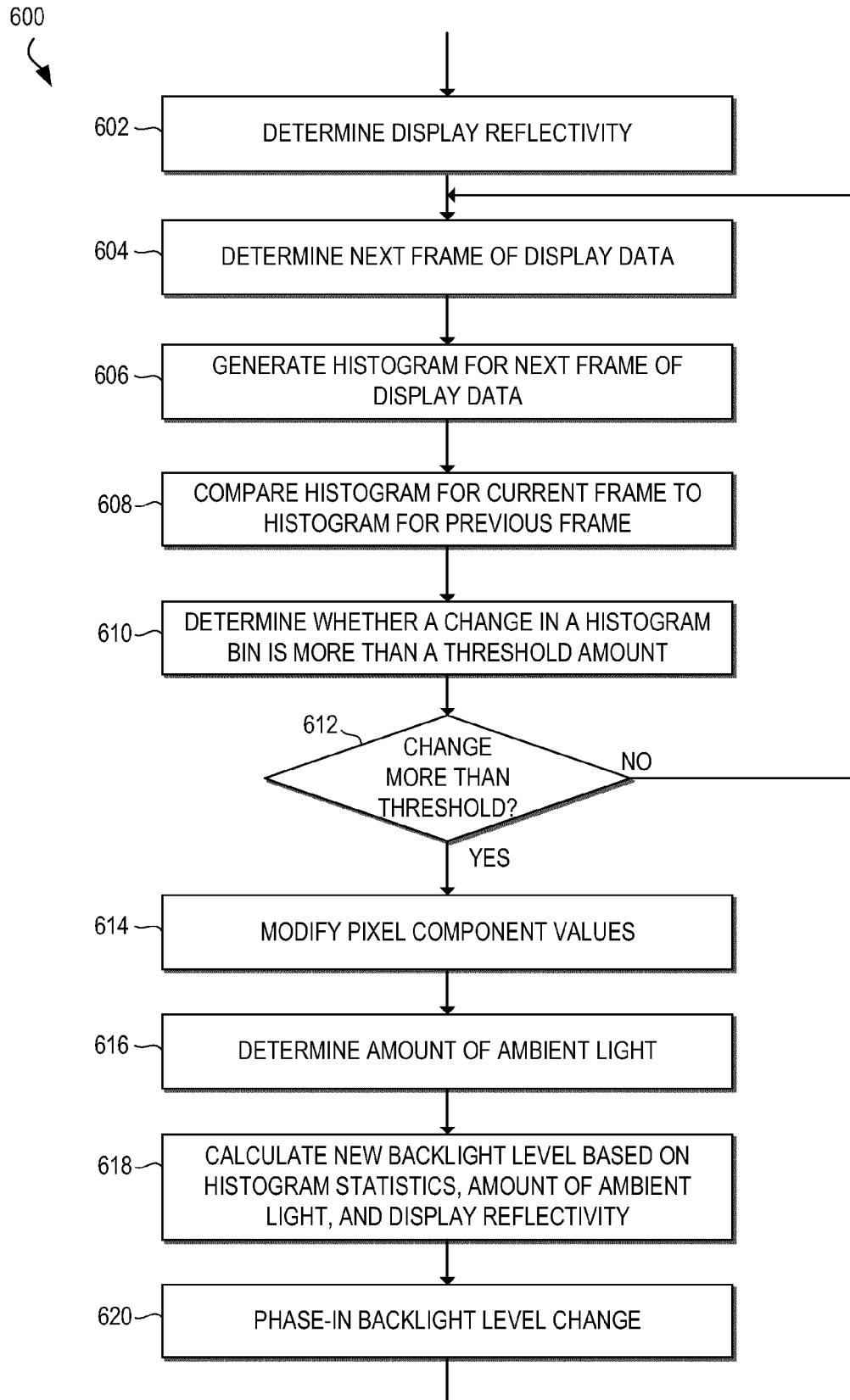


FIG. 6



FIG. 7

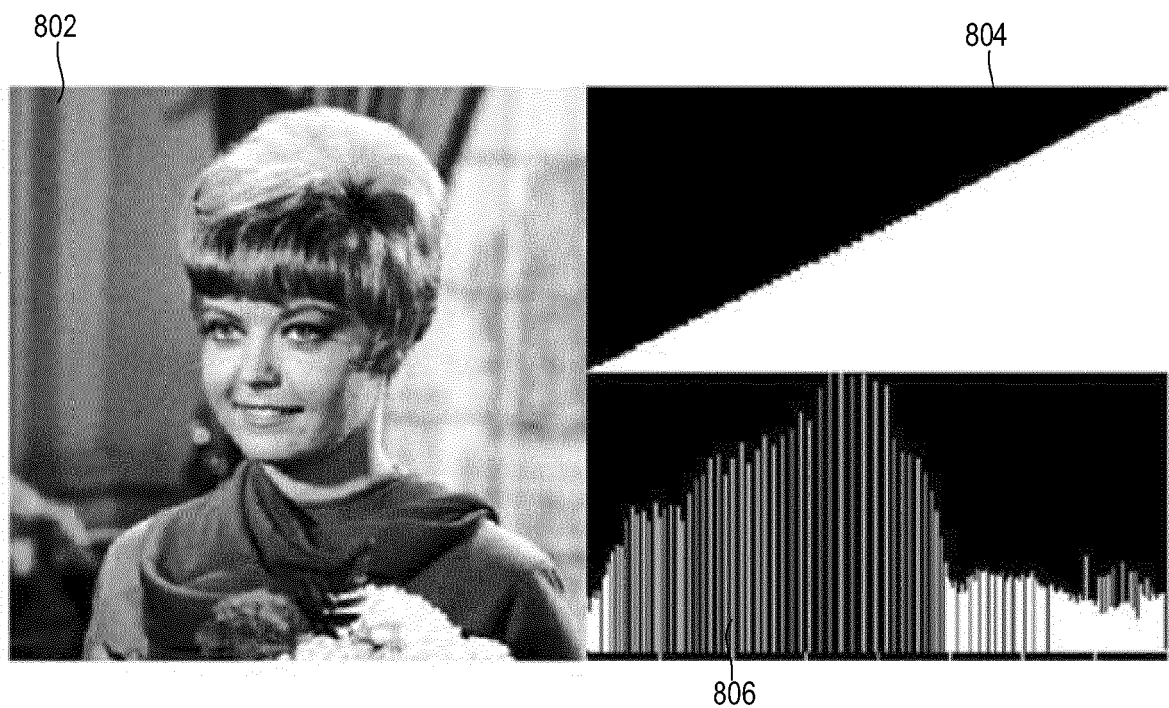


FIG. 8

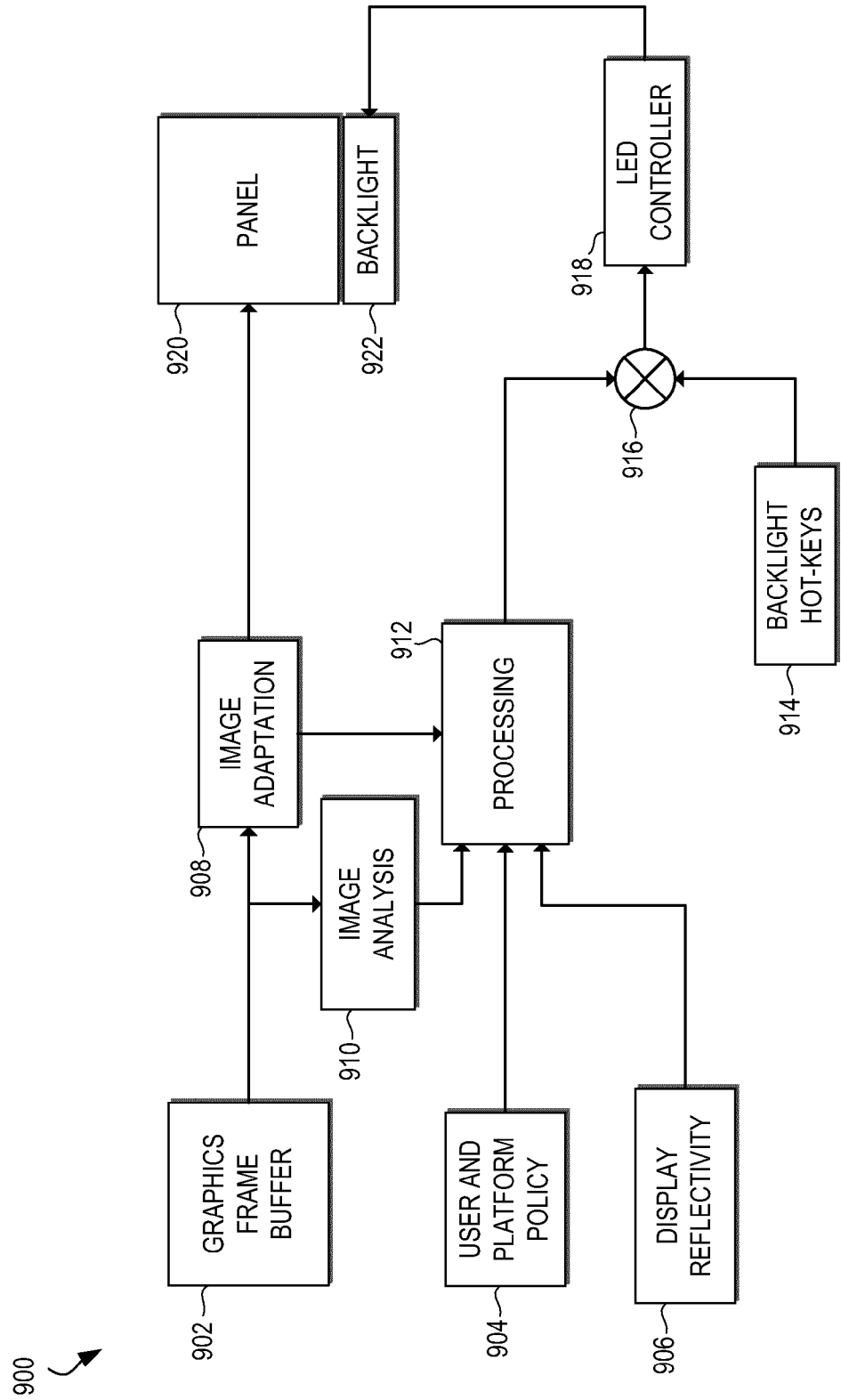


FIG. 9



EUROPEAN SEARCH REPORT

Application Number

EP 23 21 1093

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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		15 April 2024	Harke, Michael
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ON EUROPEAN PATENT APPLICATION NO.

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15-04-2024

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