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(71) Applicant: QUALCOMM INCORPORATED [US/US];
ATTN: International IP Administration, 5775 Morehouse
Drive, San Diego, California 92121-1714 (US).

(72) Inventors; and

(71) Applicants (for WS only): ZHANG, Nan [CN/CN];
5775 Morehouse Drive, San Diego, California 92121-1714
(US). YANG, Xinchao [CN/CN]; 5775 Morehouse Drive,
San Diego, California 92121-1714 (US). XU, Yongjun

[CN/CN]; 5775 Morehouse Drive, San Diego, California
92121-1714 (US).

(74) Agent: NTD PATENT & TRADEMARK AGENCY
LTD.; 10th Floor, Tower C, Beijing Global Trade Center 36
North Third Ring Road East, Dongcheng District, Beijing
100013 (CN).

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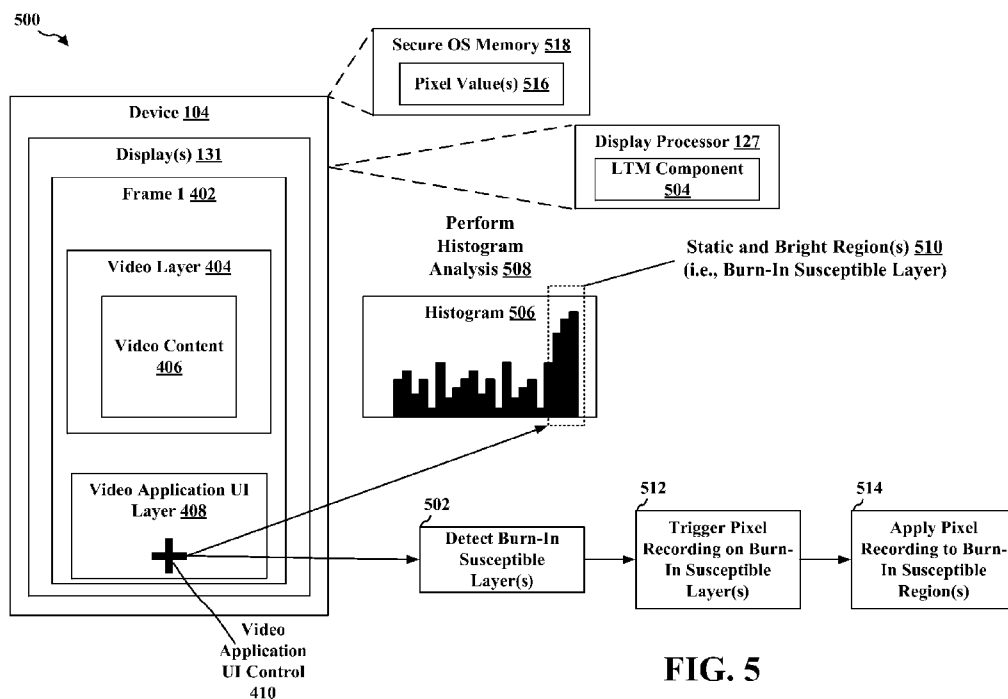


FIG. 5

(57) Abstract: This disclosure provides systems, devices, apparatus, and methods, including computer programs encoded on storage media, for a panel aging conditional recording strategy for OLED anti-aging. A display processor may detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. The display processor may perform, based on the detection, anti-aging pixel recording on the set of pixels. The display processor may adjust the values of the set of pixels based on the anti-aging pixel recording.

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PANEL AGING CONDITIONAL RECORDING STRATEGY FOR OLED ANTI-AGING

TECHNICAL FIELD

[0001] The present disclosure relates generally to processing systems, and more particularly, to one or more techniques for display processing.

INTRODUCTION

[0002] Computing devices often perform graphics and/or display processing (e.g., utilizing a graphics processing unit (GPU), a central processing unit (CPU), a display processor, etc.) to render and display visual content. Such computing devices may include, for example, computer workstations, mobile phones such as smartphones, embedded systems, personal computers, tablet computers, and video game consoles. GPUs are configured to execute a graphics processing pipeline that includes one or more processing stages, which operate together to execute graphics processing commands and output a frame. A central processing unit (CPU) may control the operation of the GPU by issuing one or more graphics processing commands to the GPU. Modern day CPUs are typically capable of executing multiple applications concurrently, each of which may need to utilize the GPU during execution. A display processor may be configured to convert digital information received from a CPU to analog values and may issue commands to a display panel for displaying the visual content. A device that provides content for visual presentation on a display may utilize a CPU, a GPU, and/or a display processor.

[0003] Current techniques for anti-aging pixel compensation may be associated with relatively high memory usage and/or relatively high power consumption at a device. There is a need for improved techniques for anti-aging pixel compensation.

BRIEF SUMMARY

[0004] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose

is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0005] In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus includes a memory; and a processor coupled to the memory and, based on information stored in the memory, the processor is configured to: detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period; perform, based on the detection, anti-aging pixel recording on the set of pixels; and adjust the values of the set of pixels based on the anti-aging pixel recording.

[0006] To the accomplishment of the foregoing and related ends, the one or more aspects include the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a block diagram that illustrates an example content generation system in accordance with one or more techniques of this disclosure.

[0008] FIG. 2 illustrates an example graphics processor (e.g., a graphics processing unit (GPU)) in accordance with one or more techniques of this disclosure.

[0009] FIG. 3 illustrates an example display framework including a display processor and a display in accordance with one or more techniques of this disclosure.

[0010] FIG. 4 is a diagram illustrating burn-in on a display panel in accordance with one or more techniques of this disclosure.

[0011] FIG. 5 is a diagram illustrating example aspects of a pixel anti-aging strategy in accordance with one or more techniques of this disclosure.

[0012] FIG. 6 is a diagram illustrating example aspects of adjusting values of pixels for anti-aging purposes in accordance with one or more techniques of this disclosure.

- [0013] FIG. 7 is a call flow diagram illustrating example communications between a display processor and a display panel in accordance with one or more techniques of this disclosure.
- [0014] FIG. 8 is a flowchart of an example method of display processing in accordance with one or more techniques of this disclosure.
- [0015] FIG. 9 is a flowchart of an example method of display processing in accordance with one or more techniques of this disclosure.

DETAILED DESCRIPTION

- [0016] Various aspects of systems, apparatuses, computer program products, and methods are described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of this disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of this disclosure is intended to cover any aspect of the systems, apparatuses, computer program products, and methods disclosed herein, whether implemented independently of, or combined with, other aspects of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. Any aspect disclosed herein may be embodied by one or more elements of a claim.
- [0017] Although various aspects are described herein, many variations and permutations of these aspects fall within the scope of this disclosure. Although some potential benefits and advantages of aspects of this disclosure are mentioned, the scope of this disclosure is not intended to be limited to particular benefits, uses, or objectives. Rather, aspects of this disclosure are intended to be broadly applicable to different wireless technologies, system configurations, processing systems, networks, and transmission protocols, some of which are illustrated by way of example in the figures and in the following description. The detailed description and drawings are merely illustrative

of this disclosure rather than limiting, the scope of this disclosure being defined by the appended claims and equivalents thereof.

[0018] Several aspects are presented with reference to various apparatus and methods. These apparatus and methods are described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, and the like (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0019] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors (which may also be referred to as processing units). Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), general purpose GPUs (GPGPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems-on-chip (SOCs), baseband processors, application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software can be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0020] The term application may refer to software. As described herein, one or more techniques may refer to an application (e.g., software) being configured to perform one or more functions. In such examples, the application may be stored in a memory (e.g., on-chip memory of a processor, system memory, or any other memory). Hardware described herein, such as a processor may be configured to execute the application. For example, the application may be described as including code that,

when executed by the hardware, causes the hardware to perform one or more techniques described herein. As an example, the hardware may access the code from a memory and execute the code accessed from the memory to perform one or more techniques described herein. In some examples, components are identified in this disclosure. In such examples, the components may be hardware, software, or a combination thereof. The components may be separate components or sub-components of a single component.

[0021] In one or more examples described herein, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can include a random access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

[0022] As used herein, instances of the term “content” may refer to “graphical content,” an “image,” etc., regardless of whether the terms are used as an adjective, noun, or other parts of speech. In some examples, the term “graphical content,” as used herein, may refer to a content produced by one or more processes of a graphics processing pipeline. In further examples, the term “graphical content,” as used herein, may refer to a content produced by a processing unit configured to perform graphics processing. In still further examples, as used herein, the term “graphical content” may refer to a content produced by a graphics processing unit.

[0023] Pixels (or subpixels) on a display panel (e.g., an organic light emitting diode (OLED) display panel) may be susceptible to burn-in. A pixel may refer to an area of illumination on a display panel. A subpixel may refer to a red (R), a green (G), or a blue (B) component of a pixel. In an example, each of the R component, the G component, and the B component may take on a value ranging from 0-255. Thus, a pixel may take on approximately 16.7 million possible values. Burn-in (which may

also be referred to as image retention) may refer to pixel(s) (or subpixel(s)) displaying unintended colors due to cumulative non-uniform usage of the pixel(s) (or the subpixel(s)) with respect to all pixel(s) (or subpixel(s)) on the display panel. Burn-in may include application static content burning and display long term brightness spatial inconsistency. Application static content burning may refer to a region of a display panel continuing to display graphical content associated with an application when display of the graphical content is unintended. In an example, a user interface (UI) control of an application may remain statically displayed each time the application is executed on a device. This may result in the UI control being subject to application static content burning when the application is used repeatedly over a period of time (e.g., several months, several years, etc.). For instance, a region of a display panel associated with the UI control may continue to display the UI control (or a faded instance of the UI control) even when the application is not being executed. Display long term brightness spatial inconsistency (which may also be referred to as mura) may refer to natural aging of pixels or subpixels of a display panel. For instance, display long term brightness spatial inconsistency may result in lines, spots, and cloudy areas on a display panel.

[0024] Techniques for eliminating or reducing burn-in may be referred to as pixel anti-aging compensation techniques. That is, pixel anti-aging compensation techniques may be anti-burn-in techniques. One technique for pixel anti-aging compensation may involve recording historical values (i.e., values over a time period) for each pixel (or subpixel) on a display panel of a device. The device may adjust values of pixels associated with burn-in (or adjust values of neighboring pixels of the pixels) based on the recorded historical values in order to eliminate or mitigate burn-in. Recording historical values for each pixel (or subpixel) may be associated with a relatively high amount of memory usage (e.g., greater than 200 megabytes (MB)) and a relatively high amount of power consumption (e.g., greater than 10 milliamperes (mA)) at a device. Furthermore, recording the historical values for each pixel may involve security concerns, and as a result, the historical values for each pixel may be recorded in secure memory associated with an operating system (OS) of the device. However, an amount of the secure memory on a device may be limited due to computational and/or cost constraints.

- [0025]** Various technologies pertaining to a panel aging conditional recording strategy for OLED anti-aging by frame regional histogram analysis and guilty layer history are described herein. In an example, an apparatus (e.g., a display processor) detects that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. The apparatus (e.g., the display processor) performs, based on the detection, anti-aging pixel recording on the set of pixels. The apparatus (e.g., the display processor) adjusts the values of the set of pixels based on the anti-aging pixel recording. Vis-à-vis performing anti-aging pixel recording on a set of pixels on a display panel having values that (1) remain static over a time period and (2) exceed a threshold value over the time period, the above-described technologies may reduce memory usage and/or power consumption on a device in comparison to a device that performs anti-aging pixel recording on all pixels of a display panel of the device. Furthermore, determining that the values (1) remain static over the time period and (2) exceed the threshold value over the time period may be performed by a local tone mapping (LTM) element of a display processor, and hence the above-described technologies may be implemented in a manner that incurs little additional overhead in the display processor.
- [0026]** OLED anti-aging solutions may have high power consumption and memory usage characteristics. In one aspect, an apparatus may conditionally trigger display panel per pixel runtime recording by using a regional histogram analysis on layer / frame region run time behaviors. For example, if a layer or frame region is static for longer than a threshold amount of time, display panel per pixel runtime recording may be triggered. If a layer triggers the threshold, anti-aging recording may be performed on a frame or anti-aging recording may be performed on a layer or a frame region.
- [0027]** The examples describe herein may refer to a use and functionality of a graphics processing unit (GPU). As used herein, a GPU can be any type of graphics processor, and a graphics processor can be any type of processor that is designed or configured to process graphics content. For example, a graphics processor or GPU can be a specialized electronic circuit that is designed for processing graphics content. As an additional example, a graphics processor or GPU can be a general purpose processor that is configured to process graphics content.

[0028] FIG. 1 is a block diagram that illustrates an example content generation system 100 configured to implement one or more techniques of this disclosure. The content generation system 100 includes a device 104. The device 104 may include one or more components or circuits for performing various functions described herein. In some examples, one or more components of the device 104 may be components of a SOC. The device 104 may include one or more components configured to perform one or more techniques of this disclosure. In the example shown, the device 104 may include a processing unit 120, a content encoder/decoder 122, and a system memory 124. In some aspects, the device 104 may include a number of components (e.g., a communication interface 126, a transceiver 132, a receiver 128, a transmitter 130, a display processor 127, and one or more displays 131). Display(s) 131 may refer to one or more displays 131. For example, the display 131 may include a single display or multiple displays, which may include a first display and a second display. The first display may be a left-eye display and the second display may be a right-eye display. In some examples, the first display and the second display may receive different frames for presentment thereon. In other examples, the first and second display may receive the same frames for presentment thereon. In further examples, the results of the graphics processing may not be displayed on the device, e.g., the first display and the second display may not receive any frames for presentment thereon. Instead, the frames or graphics processing results may be transferred to another device. In some aspects, this may be referred to as split-rendering. In an example, the display(s) 131 may be or include organic light emitting diode (OLED) display(s). The display(s) 131 may also be referred to as panel(s) or display panel(s).

[0029] The processing unit 120 may include an internal memory 121. The processing unit 120 may be configured to perform graphics processing using a graphics processing pipeline 107. The content encoder/decoder 122 may include an internal memory 123. In some examples, the device 104 may include a processor, which may be configured to perform one or more display processing techniques on one or more frames generated by the processing unit 120 before the frames are displayed by the one or more displays 131. While the processor in the example content generation system 100 is configured as a display processor 127, it should be understood that the display processor 127 is one example of the processor and that other types of processors, controllers, etc., may be used as substitute for the display processor 127. The display

processor 127 may be configured to perform display processing. For example, the display processor 127 may be configured to perform one or more display processing techniques on one or more frames generated by the processing unit 120. The one or more displays 131 may be configured to display or otherwise present frames processed by the display processor 127. In some examples, the one or more displays 131 may include one or more of a liquid crystal display (LCD), a plasma display, an organic light emitting diode (OLED) display, a projection display device, an augmented reality display device, a virtual reality display device, a head-mounted display, or any other type of display device.

[0030] Memory external to the processing unit 120 and the content encoder/decoder 122, such as system memory 124, may be accessible to the processing unit 120 and the content encoder/decoder 122. For example, the processing unit 120 and the content encoder/decoder 122 may be configured to read from and/or write to external memory, such as the system memory 124. The processing unit 120 may be communicatively coupled to the system memory 124 over a bus. In some examples, the processing unit 120 and the content encoder/decoder 122 may be communicatively coupled to the internal memory 121 over the bus or via a different connection.

[0031] The content encoder/decoder 122 may be configured to receive graphical content from any source, such as the system memory 124 and/or the communication interface 126. The system memory 124 may be configured to store received encoded or decoded graphical content. The content encoder/decoder 122 may be configured to receive encoded or decoded graphical content, e.g., from the system memory 124 and/or the communication interface 126, in the form of encoded pixel data. The content encoder/decoder 122 may be configured to encode or decode any graphical content.

[0032] The internal memory 121 or the system memory 124 may include one or more volatile or non-volatile memories or storage devices. In some examples, internal memory 121 or the system memory 124 may include RAM, static random access memory (SRAM), dynamic random access memory (DRAM), erasable programmable ROM (EPROM), EEPROM, flash memory, a magnetic data media or an optical storage media, or any other type of memory. The internal memory 121 or the system memory 124 may be a non-transitory storage medium according to some examples. The term “non-transitory” may indicate that the storage medium is not embodied in a carrier wave or a propagated signal. However, the term “non-transitory” should not be interpreted to

mean that internal memory 121 or the system memory 124 is non-movable or that its contents are static. As one example, the system memory 124 may be removed from the device 104 and moved to another device. As another example, the system memory 124 may not be removable from the device 104.

[0033] The processing unit 120 may be a CPU, a GPU, a GPGPU, or any other processing unit that may be configured to perform graphics processing. In some examples, the processing unit 120 may be integrated into a motherboard of the device 104. In further examples, the processing unit 120 may be present on a graphics card that is installed in a port of the motherboard of the device 104, or may be otherwise incorporated within a peripheral device configured to interoperate with the device 104. The processing unit 120 may include one or more processors, such as one or more microprocessors, GPUs, ASICs, FPGAs, arithmetic logic units (ALUs), DSPs, discrete logic, software, hardware, firmware, other equivalent integrated or discrete logic circuitry, or any combinations thereof. If the techniques are implemented partially in software, the processing unit 120 may store instructions for the software in a suitable, non-transitory computer-readable storage medium, e.g., internal memory 121, and may execute the instructions in hardware using one or more processors to perform the techniques of this disclosure. Any of the foregoing, including hardware, software, a combination of hardware and software, etc., may be considered to be one or more processors.

[0034] The content encoder/decoder 122 may be any processing unit configured to perform content decoding. In some examples, the content encoder/decoder 122 may be integrated into a motherboard of the device 104. The content encoder/decoder 122 may include one or more processors, such as one or more microprocessors, application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), arithmetic logic units (ALUs), digital signal processors (DSPs), video processors, discrete logic, software, hardware, firmware, other equivalent integrated or discrete logic circuitry, or any combinations thereof. If the techniques are implemented partially in software, the content encoder/decoder 122 may store instructions for the software in a suitable, non-transitory computer-readable storage medium, e.g., internal memory 123, and may execute the instructions in hardware using one or more processors to perform the techniques of this disclosure. Any of the foregoing,

including hardware, software, a combination of hardware and software, etc., may be considered to be one or more processors.

[0035] In some aspects, the content generation system 100 may include a communication interface 126. The communication interface 126 may include a receiver 128 and a transmitter 130. The receiver 128 may be configured to perform any receiving function described herein with respect to the device 104. Additionally, the receiver 128 may be configured to receive information, e.g., eye or head position information, rendering commands, and/or location information, from another device. The transmitter 130 may be configured to perform any transmitting function described herein with respect to the device 104. For example, the transmitter 130 may be configured to transmit information to another device, which may include a request for content. The receiver 128 and the transmitter 130 may be combined into a transceiver 132. In such examples, the transceiver 132 may be configured to perform any receiving function and/or transmitting function described herein with respect to the device 104.

[0036] Referring again to FIG. 1, in certain aspects, the display processor 127 may include an anti-aging recorder 198 configured to detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period; perform, based on the detection, anti-aging pixel recording on the set of pixels; and adjust the values of the set of pixels based on the anti-aging pixel recording. Although the following description may be focused on display processing, the concepts described herein may be applicable to other similar processing techniques. Furthermore, although the following description may be focused on eliminating/mitigating burn-in associated with a video application, the concepts described herein may eliminate/mitigate burn-in associated with other types of applications. Furthermore, although the following description may be focused on eliminating/mitigating burn-in associated with an OLED display panel, the concepts described herein may be applicable to other types of display panels.

[0037] A device, such as the device 104, may refer to any device, apparatus, or system configured to perform one or more techniques described herein. For example, a device may be a server, a base station, a user equipment, a client device, a station, an access point, a computer such as a personal computer, a desktop computer, a laptop computer, a tablet computer, a computer workstation, or a mainframe computer, an

end product, an apparatus, a phone, a smart phone, a server, a video game platform or console, a handheld device such as a portable video game device or a personal digital assistant (PDA), a wearable computing device such as a smart watch, an augmented reality device, or a virtual reality device, a non-wearable device, a display or display device, a television, a television set-top box, an intermediate network device, a digital media player, a video streaming device, a content streaming device, an in-vehicle computer, any mobile device, any device configured to generate graphical content, or any device configured to perform one or more techniques described herein. Processes herein may be described as performed by a particular component (e.g., a GPU) but in other embodiments, may be performed using other components (e.g., a CPU) consistent with the disclosed embodiments.

[0038] GPUs can process multiple types of data or data packets in a GPU pipeline. For instance, in some aspects, a GPU can process two types of data or data packets, e.g., context register packets and draw call data. A context register packet can be a set of global state information, e.g., information regarding a global register, shading program, or constant data, which can regulate how a graphics context will be processed. For example, context register packets can include information regarding a color format. In some aspects of context register packets, there can be a bit or bits that indicate which workload belongs to a context register. Also, there can be multiple functions or programming running at the same time and/or in parallel. For example, functions or programming can describe a certain operation, e.g., the color mode or color format. Accordingly, a context register can define multiple states of a GPU.

[0039] Context states can be utilized to determine how an individual processing unit functions, e.g., a vertex fetcher (VFD), a vertex shader (VS), a shader processor, or a geometry processor, and/or in what mode the processing unit functions. In order to do so, GPUs can use context registers and programming data. In some aspects, a GPU can generate a workload, e.g., a vertex or pixel workload, in the pipeline based on the context register definition of a mode or state. Certain processing units, e.g., a VFD, can use these states to determine certain functions, e.g., how a vertex is assembled. As these modes or states can change, GPUs may need to change the corresponding context. Additionally, the workload that corresponds to the mode or state may follow the changing mode or state.

- [0040] FIG. 2 illustrates an example GPU 200 in accordance with one or more techniques of this disclosure. As shown in FIG. 2, GPU 200 includes command processor (CP) 210, draw call packets 212, VFD 220, VS 222, vertex cache (VPC) 224, triangle setup engine (TSE) 226, rasterizer (RAS) 228, Z process engine (ZPE) 230, pixel interpolator (PI) 232, fragment shader (FS) 234, render backend (RB) 236, L2 cache (UCHE) 238, and system memory 240. Although FIG. 2 displays that GPU 200 includes processing units 220-238, GPU 200 can include a number of additional processing units. Additionally, processing units 220-238 are merely an example and any combination or order of processing units can be used by GPUs according to the present disclosure. GPU 200 also includes command buffer 250, context register packets 260, and context states 261.
- [0041] As shown in FIG. 2, a GPU can utilize a CP, e.g., CP 210, or hardware accelerator to parse a command buffer into context register packets, e.g., context register packets 260, and/or draw call data packets, e.g., draw call packets 212. The CP 210 can then send the context register packets 260 or draw call packets 212 through separate paths to the processing units or blocks in the GPU. Further, the command buffer 250 can alternate different states of context registers and draw calls. For example, a command buffer can simultaneously store the following information: context register of context N, draw call(s) of context N, context register of context N+1, and draw call(s) of context N+1.
- [0042] GPUs can render images in a variety of different ways. In some instances, GPUs can render an image using direct rendering and/or tiled rendering. In tiled rendering GPUs, an image can be divided or separated into different sections or tiles. After the division of the image, each section or tile can be rendered separately. Tiled rendering GPUs can divide computer graphics images into a grid format, such that each portion of the grid, i.e., a tile, is separately rendered. In some aspects of tiled rendering, during a binning pass, an image can be divided into different bins or tiles. In some aspects, during the binning pass, a visibility stream can be constructed where visible primitives or draw calls can be identified. A rendering pass may be performed after the binning pass. In contrast to tiled rendering, direct rendering does not divide the frame into smaller bins or tiles. Rather, in direct rendering, the entire frame is rendered at a single time (i.e., without a binning pass). Additionally, some types of GPUs can allow for both tiled rendering and direct rendering (e.g., flex rendering).

- [0043] In some aspects, GPUs can apply the drawing or rendering process to different bins or tiles. For instance, a GPU can render to one bin, and perform all the draws for the primitives or pixels in the bin. During the process of rendering to a bin, the render targets can be located in GPU internal memory (GMEM). In some instances, after rendering to one bin, the content of the render targets can be moved to a system memory and the GMEM can be freed for rendering the next bin. Additionally, a GPU can render to another bin, and perform the draws for the primitives or pixels in that bin. Therefore, in some aspects, there might be a small number of bins, e.g., four bins, that cover all of the draws in one surface. Further, GPUs can cycle through all of the draws in one bin, but perform the draws for the draw calls that are visible, i.e., draw calls that include visible geometry. In some aspects, a visibility stream can be generated, e.g., in a binning pass, to determine the visibility information of each primitive in an image or scene. For instance, this visibility stream can identify whether a certain primitive is visible or not. In some aspects, this information can be used to remove primitives that are not visible so that the non-visible primitives are not rendered, e.g., in the rendering pass. Also, at least some of the primitives that are identified as visible can be rendered in the rendering pass.
- [0044] In some aspects of tiled rendering, there can be multiple processing phases or passes. For instance, the rendering can be performed in two passes, e.g., a binning, a visibility or bin-visibility pass and a rendering or bin-rendering pass. During a visibility pass, a GPU can input a rendering workload, record the positions of the primitives or triangles, and then determine which primitives or triangles fall into which bin or area. In some aspects of a visibility pass, GPUs can also identify or mark the visibility of each primitive or triangle in a visibility stream. During a rendering pass, a GPU can input the visibility stream and process one bin or area at a time. In some aspects, the visibility stream can be analyzed to determine which primitives, or vertices of primitives, are visible or not visible. As such, the primitives, or vertices of primitives, that are visible may be processed. By doing so, GPUs can reduce the unnecessary workload of processing or rendering primitives or triangles that are not visible.
- [0045] In some aspects, during a visibility pass, certain types of primitive geometry, e.g., position-only geometry, may be processed. Additionally, depending on the position or location of the primitives or triangles, the primitives may be sorted into different bins or areas. In some instances, sorting primitives or triangles into different bins may

be performed by determining visibility information for these primitives or triangles. For example, GPUs may determine or write visibility information of each primitive in each bin or area, e.g., in a system memory. This visibility information can be used to determine or generate a visibility stream. In a rendering pass, the primitives in each bin can be rendered separately. In these instances, the visibility stream can be fetched from memory and used to remove primitives which are not visible for that bin.

[0046] Some aspects of GPUs or GPU architectures can provide a number of different options for rendering, e.g., software rendering and hardware rendering. In software rendering, a driver or CPU can replicate an entire frame geometry by processing each view one time. Additionally, some different states may be changed depending on the view. As such, in software rendering, the software can replicate the entire workload by changing some states that may be utilized to render for each viewpoint in an image. In certain aspects, as GPUs may be submitting the same workload multiple times for each viewpoint in an image, there may be an increased amount of overhead. In hardware rendering, the hardware or GPU may be responsible for replicating or processing the geometry for each viewpoint in an image. Accordingly, the hardware can manage the replication or processing of the primitives or triangles for each viewpoint in an image.

[0047] FIG. 3 is a block diagram 300 that illustrates an example display framework including the processing unit 120, the system memory 124, the display processor 127, and the display(s) 131, as may be identified in connection with the device 104.

[0048] A GPU may be included in devices that provide content for visual presentation on a display. For example, the processing unit 120 may include a GPU 310 configured to render graphical data for display on a computing device (e.g., the device 104), which may be a computer workstation, a mobile phone, a smartphone or other smart device, an embedded system, a personal computer, a tablet computer, a video game console, and the like. Operations of the GPU 310 may be controlled based on one or more graphics processing commands provided by a CPU 315. The CPU 315 may be configured to execute multiple applications concurrently. In some cases, each of the concurrently executed multiple applications may utilize the GPU 310 simultaneously. Processing techniques may be performed via the processing unit 120 output a frame over physical or wireless communication channels.

- [0049] The system memory 124, which may be executed by the processing unit 120, may include a user space 320 and a kernel space 325. The user space 320 (sometimes referred to as an “application space”) may include software application(s) and/or application framework(s). For example, software application(s) may include operating systems, media applications, graphical applications, workspace applications, etc. Application framework(s) may include frameworks used by one or more software applications, such as libraries, services (e.g., display services, input services, etc.), application program interfaces (APIs), etc. The kernel space 325 may further include a display driver 330. The display driver 330 may be configured to control the display processor 127. For example, the display driver 330 may cause the display processor 127 to compose a frame and transmit the data for the frame to a display.
- [0050] The display processor 127 includes a display control block 335 and a display interface 340. The display processor 127 may be configured to manipulate functions of the display(s) 131 (e.g., based on an input received from the display driver 330). The display control block 335 may be further configured to output image frames to the display(s) 131 via the display interface 340. In some examples, the display control block 335 may additionally or alternatively perform post-processing of image data provided based on execution of the system memory 124 by the processing unit 120.
- [0051] The display interface 340 may be configured to cause the display(s) 131 to display image frames. The display interface 340 may output image data to the display(s) 131 according to an interface protocol, such as, for example, the MIPI DSI (Mobile Industry Processor Interface, Display Serial Interface). That is, the display(s) 131, may be configured in accordance with MIPI DSI standards. The MIPI DSI standard supports a video mode and a command mode. In examples where the display(s) 131 is/are operating in video mode, the display processor 127 may continuously refresh the graphical content of the display(s) 131. For example, the entire graphical content may be refreshed per refresh cycle (e.g., line-by-line). In examples where the display(s) 131 is/are operating in command mode, the display processor 127 may write the graphical content of a frame to a buffer 350.
- [0052] In some such examples, the display processor 127 may not continuously refresh the graphical content of the display(s) 131. Instead, the display processor 127 may use a vertical synchronization (Vsync) pulse to coordinate rendering and consuming of

graphical content at the buffer 350. For example, when a Vsync pulse is generated, the display processor 127 may output new graphical content to the buffer 350. Thus, generation of the Vsync pulse may indicate that current graphical content has been rendered at the buffer 350.

[0053] Frames are displayed at the display(s) 131 based on a display controller 345, a display client 355, and the buffer 350. The display controller 345 may receive image data from the display interface 340 and store the received image data in the buffer 350. In some examples, the display controller 345 may output the image data stored in the buffer 350 to the display client 355. Thus, the buffer 350 may represent a local memory to the display(s) 131. In some examples, the display controller 345 may output the image data received from the display interface 340 directly to the display client 355.

[0054] The display client 355 may be associated with a touch panel that senses interactions between a user and the display(s) 131. As the user interacts with the display(s) 131, one or more sensors in the touch panel may output signals to the display controller 345 that indicate which of the one or more sensors have sensor activity, a duration of the sensor activity, an applied pressure to the one or more sensor, etc. The display controller 345 may use the sensor outputs to determine a manner in which the user has interacted with the display(s) 131. The display(s) 131 may be further associated with/include other devices, such as a camera, a microphone, and/or a speaker, that operate in connection with the display client 355.

[0055] Some processing techniques of the device 104 may be performed over three stages (e.g., stage 1: a rendering stage; stage 2: a composition stage; and stage 3: a display/transfer stage). However, other processing techniques may combine the composition stage and the display/transfer stage into a single stage, such that the processing technique may be executed based on two total stages (e.g., stage 1: the rendering stage; and stage 2: the composition/display/transfer stage). During the rendering stage, the GPU 310 may process a content buffer based on execution of an application that generates content on a pixel-by-pixel basis. During the composition and display stage(s), pixel elements may be assembled to form a frame that is transferred to a physical display panel/subsystem (e.g., the displays 131) that displays the frame.

- [0056] Instructions executed by a CPU (e.g., software instructions) or a display processor may cause the CPU or the display processor to search for and/or generate a composition strategy for composing a frame based on a dynamic priority and runtime statistics associated with one or more composition strategy groups. A frame to be displayed by a physical display device, such as a display panel, may include a plurality of layers. Also, composition of the frame may be based on combining the plurality of layers into the frame (e.g., based on a frame buffer). After the plurality of layers are combined into the frame, the frame may be provided to the display panel for display thereon. The process of combining each of the plurality of layers into the frame may be referred to as composition, frame composition, a composition procedure, a composition process, or the like.
- [0057] A frame composition procedure or composition strategy may correspond to a technique for composing different layers of the plurality of layers into a single frame. The plurality of layers may be stored in doubled data rate (DDR) memory. Each layer of the plurality of layers may further correspond to a separate buffer. A composer or hardware composer (HWC) associated with a block or function may determine an input of each layer/buffer and perform the frame composition procedure to generate an output indicative of a composed frame. That is, the input may be the layers and the output may be a frame composition procedure for composing the frame to be displayed on the display panel.
- [0058] Some aspects of display processing may utilize different types of mask layers, e.g., a shape mask layer. A mask layer is a layer that may represent a portion of a display or display panel. For instance, an area of a mask layer may correspond to an area of a display, but the entire mask layer may depict a portion of the content that is actually displayed at the display or panel. For example, a mask layer may include a top portion and a bottom portion of a display area, but the middle portion of the mask layer may be empty. In some examples, there may be multiple mask layers to represent different portions of a display area. Also, for certain portions of a display area, the content of different mask layers may overlap with one another. Accordingly, a mask layer may represent a portion of a display area that may or may not overlap with other mask layers.
- [0059] FIG. 4 is a diagram 400 illustrating burn-in on a display panel in accordance with one or more techniques of this disclosure. As noted above, a display panel (e.g., an OLED

display panel) may be susceptible to burn-in. In one example, an OLED display panel may be susceptible to application static content burning. For instance, a user may keep an application (e.g., a social media application, such as a video sharing social media application) running on a device for a number of hours (e.g., 2-5 hours) each day over a time period (e.g., several weeks, 2-3 months, etc.). As a result, there may be a region on the display panel that statically displays the same content (e.g., a UI control) for the number of hours each day. For instance, a frame region may include a UI control of the application. When burn-in occurs, the frame region may continue to display the content when the application is no longer running. For instance, a “ghosted” version of the UI control may be displayed on a home screen of a device when burn-in occurs. One approach to mitigating static content burning may be to change locations of statically displayed content (e.g., UI controls) for an application. However, users may expect and/or desire certain content (e.g., UI controls) to be displayed at certain locations on a display panel (e.g., a bottom portion of a display panel). Changing locations of the content may thus negatively affect user experience. An end user may wish to return a device that exhibits burn-in.

[0060] In another example, an OLED display panel may be susceptible to display long term brightness spatial inconsistency (which may be referred to as mura). Display long term brightness spatial inconsistency may be caused by natural aging of the OLED display panel over a period of time (e.g., months, years, etc.). Display long term brightness spatial inconsistency may be observed as lines, spots, and cloudy areas on an OLED display panel. In an example, display long term brightness spatial inconsistency may occur after a device (e.g., a smartphone) is used for one to two years. If display long term brightness spatial inconsistency does not occur until after three years of usage of a device, users may consider such a device as a “high quality” device. As display long term brightness spatial inconsistency is related to natural aging of a device, display long term brightness spatial inconsistency may not be able to be eliminated or mitigated by an application or by an operating system of a device.

[0061] In an example, a video application (e.g., a social media video application) executing on the device 104 may cause a first frame 402 to be presented on the display(s) 131 of the device 104. The first frame 402 may include a video layer 404 that displays video content 406. The first frame 402 may also include a video application UI layer 408 that displays a video application UI control 410. In an example, the video

application UI control 410 may be associated with controlling playback of the video content 406. For instance, the video application UI control 410 may be or include a play button, a pause button, a fast forward button, or a rewind button. In another example, the video application UI control 410 may be associated with uploading a recorded video corresponding to the video content 406. The video application UI control 410 may be a UI element. A UI element may refer to graphical data displayed for the purpose of facilitating user interaction with an application displayed on a display.

[0062] In an example, a user may utilize the video application on the device 104 for several hours a day over a time period (e.g., months, years, etc.). As a result, the video application UI control 410 may become burned-in on the display(s) 131. For instance, after the video application has been utilized on the device 104 over the time period, an operating system (OS) executing on the device 104 may cause a second frame 412 to be presented on the display(s) 131 of the device 104. The second frame 412 may include an OS layer 414 that display OS content 416 (e.g., application icons). Due to the aforementioned burn-in, a burned-in UI control 418 corresponding to the video application UI control 410 may be displayed on the display(s) 131 even when the video application is not being executed on the device 104. In an example, the burned-in UI control 418 may be an outline of the video application UI control 410. The burned-in UI control 418 may affect user experience with the device 104. In an example, the burned-in UI control 418 may be noticeable by a user when the device 104 is located in a dark environment.

[0063] One approach to eliminate or reduce burn-in (e.g., eliminate or mitigate the occurrence of the burned-in UI control 418) may be to configure the device 104 to record historical values of each pixel (or each subpixel) of the display(s) 131. The device 104 may then apply anti-aging pixel compensation based on the recorded historical values. For instance, the device 104 may adjust (e.g., reduce) values a subset of pixels associated with burn-in in order to eliminate or mitigate burn-in, or the device 104 may adjust values of neighbor pixels of the subset of pixels in order to eliminate or mitigate burn-in. In an example, adjusting a value of a pixel in the subset of pixels may include decreasing the value by 0.1% an original value of the pixel, 0.5% of the original value of the pixel, 1% of original value of the pixel, 5% of an original value of the pixel, or 10% of the original value of the pixel.

- [0064] In an example, recording historical values for each pixel of the display(s) 131 may use (1) greater than 200 MB of secure storage space (e.g., secure memory associated with an OS of the device 104) of the device 104 and (2) greater than 10 mA of power of the device 104. Secure memory may refer to memory of a device having increased security in comparison to other memory of a device. However, the device 104 may not have sufficient secure storage space (e.g., greater than 200 MB) to store the recorded historical values and/or recording the historical values may utilize an undesirable amount (e.g., greater than 10 mA) of battery power. Thus, it may be difficult to implement anti-aging pixel compensation for the device 104.
- [0065] FIG. 5 is a diagram 500 illustrating example aspects of a pixel anti-aging strategy in accordance with one or more techniques of this disclosure. In one aspect, a display processor (e.g., the display processor 127) of a device (e.g., the device 104) may conditionally trigger display panel per pixel (or per subpixel) runtime recording according to the following steps. In a first step, the display processor may use a regional/local histogram to analyze layer/frame runtime behaviors. For instance, the display processor may determine whether a layer or a frame region of a frame are kept static for a time period. In an example, the regional/local histogram may be a red green blue (RGB) histogram, a hue saturation value (HSV) histogram, or a hue saturation lightness (HSL) histogram. In a second step, the display processor may use the regional/local histogram to analyze contents of layers/frames. For instance, the display processor may determine whether high luminance (i.e., high brightness) contents of the layers/frames are static by checking whether a HSV histogram is static. In a third step, the display processor may mark a layer (e.g., a UI layer for a social media application) as a static layer if values of the pixels of the layer remain static over a time period and if the values exceed a threshold luminance value over the time period. Luminance may refer to a photometric measure of luminous intensity per unit area of light travelling in a given direction. Marking the layer as a static layer may also be referred to as marking the layer as a “guilty layer.” In a fourth step, the display processor may trigger anti-aging pixel recording for the layer (and not other layers) if the layer is marked as guilty by a runtime regional histogram analysis. In one aspect, guilty layer lists may be managed by offline analysis in labs.
- [0066] In one aspect, per pixel or per subpixel recording may be conditionally applied to a subregion of a guilty layer/frame. For instance, the display processor, via an LTM

component, may mark static regions as being susceptible to burn-in. Marking the static regions as being susceptible to burn-in may also be referred to as marking the static regions as “dirty.” The display processor may record historical values of “dirty” region pixels (and not values of non-dirty region pixels). In one aspect, by tracking a guilty layer, anti-aging run time recording and anti-aging compensation may be applied to easily damaged devices and easily damaged region(s) of devices without applying anti-aging run time recording and anti-aging compensation to non-easily damaged devices or non-easily damaged region(s) of devices. In another aspect, by tracking a guilty layer and a dirty region, anti-aging run time recording and anti-aging compensation may be applied to easily damaged devices and easily damaged region(s) of devices without applying anti-aging run time recording and anti-aging compensation to non-easily damaged devices or non-easily damaged region(s) of devices.

[0067] In an example, a video application (e.g., a social media video application) executing on the device 104 may cause the first frame 402 to be presented on the display(s) 131 of the device 104. The first frame 402 may include the video layer 404 that displays video content 406. The first frame 402 may also include the video application UI layer 408 that displays the video application UI control 410. In an example, the video application UI control 410 may be associated with controlling playback of the video content 406. For instance, the video application UI control 410 may be or include a play button, a pause button, a fast forward button, or a rewind button. In another example, the video application UI control 410 may be associated with uploading a recorded video corresponding to the video content 406. As the video application continues to execute, the video application may cause additional frames (not depicted in FIG. 5) to be presented on the display(s) 131. In an example, the additional frames may include different video content in the video layer 404 and all or a majority of the additional frames may include the video application UI control 410.

[0068] At 502, the display processor 127 (e.g., via an LTM component 504) may detect burn-in susceptible layer(s) (e.g., the video application UI layer 408). For instance, the display processor 127 (e.g., via the LTM component 504) may determine that values of a set of pixels on the display(s) 131 (1) remain static over a time period and (2) exceed a threshold value (i.e., a luminance value) over the time period. The LTM component 504 may allow for tone mapping to be performed locally at the display

processor 127. In an example, the display processor 127 (e.g., via the LTM component 504) may generate a histogram 506 (or more than one histogram) based on the first frame 402 and the additional frames. The histogram 506 may store a number of pixels (or subpixels) of the display(s) 131 for each tonal value of a frame or frames. When displayed on a display, the histogram 506 may plot the number of pixels (or subpixels) for each tonal value of the frame or the frames. In an example, the histogram 506 may be a RGB histogram, a HSV histogram, or a HSL histogram. In an example, the histogram 506 may include a plurality of bars, where each bar is assigned to a different value (e.g., a RGB value, a hue value, etc.) of a pixel. A height of each bar in the histogram 506 may correspond to a number of times that a value of a pixel occurs in a frame (or frames). The histogram 506 may be a regional histogram or a local histogram. A regional histogram may refer to a histogram for a particular portion of a display. For instance, a display may be divided into a plurality of areas (e.g., 10 x 10), and each area may have an associated histogram (i.e., a regional histogram). A local histogram may be another name for a regional histogram. A global histogram may be a histogram for an entirety of a display.

[0069] At 508, the display processor 127 (e.g., via the LTM component 504) may perform a histogram analysis on the histogram 506 in order to identify static and bright region(s) 510 of the display(s) 131, that is, the display processor 127 may identify a burn-in susceptible layer (e.g., the video application UI layer 408) based on the histogram 506. In an example, the static and bright region(s) 510 may correspond to the video application UI layer 408 and/or the video application UI control 410. In an example, the static and bright region(s) 510 may correspond to a guilty layer (or layers) of a frame.

[0070] At 512, the display processor 127 (e.g., via the LTM component 504) may trigger pixel recording (i.e., anti-aging pixel recording) on burn-in susceptible layer(s) (e.g., the video application UI layer 408) based on detecting the burn-in susceptible layer(s) at 502. At 514, the display processor 127 (e.g., via the LTM component 504) may apply pixel recording to burn-in susceptible region(s) (e.g., a region corresponding to the video application UI control 410) of the display(s) 131 based on detecting the burn-in susceptible layer(s) at 502. Performing anti-aging pixel recording may refer to storing values of a set of pixels in storage (e.g., memory, a data store, secure OS memory, etc.) In an example, performing anti-aging pixel recording may include

storing values of the set of pixels (i.e., pixel value(s) 516) in secure OS memory 518. Alternatively, if the display processor 127 (e.g., via the LTM component 504) does not detect burn-in susceptible layers, the display processor 127 may not trigger pixel recording.

[0071] FIG. 6 is a diagram 600 illustrating example aspects of adjusting values of pixels for anti-aging purposes in accordance with one or more techniques of this disclosure. As discussed above in connection with FIG. 5, the display processor 127 (e.g., via the LTM component 504) may store the pixel value(s) 516 in the secure OS memory 518 as part of a pixel recording (i.e., an anti-aging pixel recording), where the pixel value(s) 516 may correspond to a burn-in susceptible layer or region. The pixel value(s) 516 may correspond to a set of pixels 602, where the set of pixels 602 may correspond to the video application UI control 410. In an example, the set of pixels 602 may include pixels with a first value (v1) and a second value (v2). The set of pixels 602 may be included in a plurality of pixels 604 of the display(s) 131. In an example, the plurality of pixels 604 may correspond to a display area of the display(s) 131. Each of the plurality of pixels 604 may have an associated value (not all values are depicted in FIG. 6). The plurality of pixels 604 may include a neighbor pixel 606, where the neighbor pixel 606 is adjacent to (or within a threshold distance 608) of the set of pixels 602. In an example, the threshold distance 608 may be a length of one pixel, a length of two pixels combined, a length of three pixels combined, etc. In an example a pixel may have a length of 0.01 to 0.1 mm. In an example, the neighbor pixel 606 may have a third value (v3).

[0072] After recording the values of the set of pixels 602, the display processor 127 (e.g., via the LTM component 504) may apply anti-aging pixel compensation 610 on the set of pixels 602 and/or the neighbor pixel 606, that is, the display processor 127 (e.g., via the LTM component 504) may adjust one or more values of the set of pixels 602 and/or the neighbor pixel 606. Adjusting the values may help to compensate for burn-in on the display(s) 131. In an example, the display processor 127 (e.g., via the LTM component 504) may adjust the values of the set of pixels 602 from the first value (v1) or the second value (v2) to a fourth value (v4). In another example, the display processor 127 (e.g., via the LTM component 504) may adjust the value of the neighbor pixel 606 from the third value (v3) to the fourth value (v4). In an example, the fourth

value (v4) may be less than the first value (v1), the second value (v2), or the third value (v3).

[0073] The above-described technologies may be associated with various advantages. In an example, recording values of all pixels of a display panel may utilize 200 MB of memory. However, utilizing the aspects described above in connection with FIG. 5 and FIG. 6, anti-aging memory usage may be reduced from 200 MB to less than 1 MB. Furthermore, for many devices, anti-aging per pixel recording may not be triggered at all. For instance, some devices may not be used in a manner that makes a display panel susceptible to burn-in. Utilizing the aspects described above in connection with FIG. 5 and FIG. 6 may not trigger anti-aging pixel recording for such devices and thus no additional memory cost may be incurred for such devices. Furthermore, an LTM component may already be running on a device, and thus utilizing an LTM component (e.g., the LTM component 504) to perform the aspects described above in connection with FIG. 5 and FIG. 6 may not incur an additional memory cost.

[0074] In another example, recording values of all pixels of a display panel may utilize 10 mA of power. However, utilizing the aspects described above in connection with FIG. 5 and FIG. 6, anti-aging power consumption may be reduced from 10 mA to less than 2 mA. Furthermore, for many devices, anti-aging per pixel may not be triggered at all. For instance, some devices may not be used in a manner that makes a display panel susceptible to burn-in. Utilizing the aspects described above in connection with FIG. 5 and FIG. 6 may not trigger anti-aging pixel recording for such devices and thus no additional power consumption cost may be incurred for such devices. Furthermore, an LTM component may already be running on a device, and thus utilizing an LTM component (e.g., the LTM component 504) to perform the aspects described above in connection with FIG. 5 and FIG. 6 may not incur an additional power cost. In one aspect, the LTM component may be modified to perform data analysis algorithms (in addition to performing local tone mapping) in order to perform the functionality described above in connection with FIG. 5 and FIG. 6.

[0075] Thus, the technologies described above may benefit both devices that are not susceptible to burn-in (e.g., by not triggering anti-aging pixel recording) and devices that are susceptible to burn-in (e.g., by triggering anti-aging pixel recording on pixels that are susceptible to burn-in and by not triggering anti-aging pixel recording on

pixels that are not susceptible to burn-in). For instance, the technologies described above may utilize local tone mapping to analyze layer behavior and to trigger per pixel recording for guilty layers (i.e., layers susceptible to burn-in). For instance, the technologies described above may conditionally apply per pixel or per subpixel recording on a guilty layer or a frame.

[0076] FIG. 7 is a call flow diagram 700 illustrating example communications between a display processor 702 and a display panel 704 in accordance with one or more techniques of this disclosure. In an example, the display processor 702 may be or include the display processor 127. In an example, the display panel 704 may be or include the display(s) 131.

[0077] At 705, the display processor 702 may obtain a frame associated with a set of pixels. At 706, the display processor 702 may detect that values of a set of pixels displayed on the display panel 704 remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. At 708, the display processor 702 may mark, based on the detection, the set of pixels as static pixels. At 710, the display processor 702 may perform, based on the detection, anti-aging pixel recording on the set of pixels. At 712, the display processor 702 may adjust the values of the set of pixels based on the anti-aging pixel recording. At 714, the display processor 702 may output an indication of the adjusted values of the set of pixels. For instance, at 714A, the display processor 702 may store, in a memory or a cache, the indication of the adjusted values of the set of pixels. For instance, at 714B, the display processor 702 may transmit, to the display panel 704, the indication of the adjusted values of the set of pixels. The display panel 704 may display the frame, where the frame may include pixels having the adjusted values.

[0078] FIG. 8 is a flowchart 800 of an example method of display processing in accordance with one or more techniques of this disclosure. The method may be performed by an apparatus, such as an apparatus for display processing, a display processing unit (DPU) or other display processor (e.g., the display processor 127), a wireless communication device, and the like, as used in connection with the aspects of FIGs. 1-7. In an example, the method may be associated with reduced memory usage and/or power consumption at a device (e.g., the device 104). In an example, the method may be performed by the anti-aging recorder 198.

- [0079]** At 802, the apparatus (e.g., a display processor) detects that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. For example, FIG. 7 at 706 shows that the display processor 702 may detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. In an example, the set of pixels may be or include the set of pixels 602. In an example, the display panel may be or include the display(s) 131 of the device 104. In an example, detecting that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period may include aspects described above in connection with FIG. 5, such as FIG. 5 at 502. In an example, the values of the set of pixels may correspond to v1 and/or v2 in FIG. 6. In an example, 802 may be performed by the anti-aging recorder 198.
- [0080]** At 804, the apparatus (e.g., a display processor) performs, based on the detection, anti-aging pixel recording on the set of pixels. For example, FIG. 7 at 710 shows that the display processor 702 may perform, based on the detection, anti-aging pixel recording on the set of pixels. Performing the anti-aging pixel recording may include aspects described above in connection with FIG. 5, such as FIG. 5 at 512 and/or at 514. In an example, 804 may be performed by the anti-aging recorder 198.
- [0081]** At 806, the apparatus (e.g., a display processor) adjusts the values of the set of pixels based on the anti-aging pixel recording. For example, FIG. 7 at 712 shows that the display processor 702 may adjust the values of the set of pixels based on the anti-aging pixel recording. In an example, FIG. 6 shows that values (v1, v2) of the set of pixels 602 may be adjusted from v1 or v2 to v4. In an example, 806 may be performed by the anti-aging recorder 198.
- [0082]** FIG. 9 is a flowchart 900 of an example method of display processing in accordance with one or more techniques of this disclosure. The method may be performed by an apparatus, such as an apparatus for display processing, a display processing unit (DPU) or other display processor (e.g., the display processor 127), a wireless communication device, and the like, as used in connection with the aspects of FIGS. 1-7. In an example, the method may be associated with reduced memory usage and/or power consumption at a device (e.g., the device 104). In an example, the method

(including the various aspects detailed below) may be performed by the anti-aging recorder 198.

[0083] At 902, the apparatus (e.g., a display processor) detects that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. For example, FIG. 7 at 706 shows that the display processor 702 may detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. In an example, the set of pixels may be or include the set of pixels 602. In an example, the display panel may be or include the display(s) 131 of the device 104. In an example, detecting that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period may include aspects described above in connection with FIG. 5, such as FIG. 5 at 502. In an example, the values of the set of pixels may correspond to v1 and/or v2 in FIG. 6. In an example, 902 may be performed by the anti-aging recorder 198.

[0084] At 906, the apparatus (e.g., a display processor) performs, based on the detection, anti-aging pixel recording on the set of pixels. For example, FIG. 7 at 710 shows that the display processor 702 may perform, based on the detection, anti-aging pixel recording on the set of pixels. Performing the anti-aging pixel recording may include aspects described above in connection with FIG. 5, such as FIG. 5 at 512 and/or at 514. In an example, 906 may be performed by the anti-aging recorder 198.

[0085] At 908, the apparatus (e.g., a display processor) adjusts the values of the set of pixels based on the anti-aging pixel recording. For example, FIG. 7 at 712 shows that the display processor 702 may adjust the values of the set of pixels based on the anti-aging pixel recording. In an example, FIG. 6 shows that values (v1, v2) of the set of pixels 602 may be adjusted from v1 or v2 to v4. In an example, 908 may be performed by the anti-aging recorder 198.

[0086] In one aspect, at 910, the apparatus (e.g., a display processor) may output an indication of the adjusted values of the set of pixels. For example, FIG. 7 at 714 shows that the display processor 702 may output an indication of the adjusted values of the set of pixels. In an example, 910 may be performed by the anti-aging recorder 198.

[0087] In one aspect, outputting the indication of the adjusted values of the set of pixels may include transmitting, to the display panel, the indication of the adjusted values of the

set of pixels. For example, FIG. 7 at 714B shows that outputting the indication of the adjusted values of the set of pixels may include transmitting, to the display panel 704, the indication of the adjusted values of the set of pixels.

[0088] In one aspect, outputting the indication of the adjusted values of the set of pixels may include storing, in a memory or a cache, the indication of the adjusted values of the set of pixels. For example, FIG. 7 at 714A shows that outputting the indication of the adjusted values of the set of pixels may include storing, in a memory or a cache, the indication of the adjusted values of the set of pixels.

[0089] In one aspect, adjusting the values of the set of pixels based on the anti-aging pixel recording may include: adjusting, based on the anti-aging pixel recording, the values of a set of neighboring pixels that is within a threshold distance of one of the set of pixels, where each of the set of neighboring pixels may be adjacent to one of the set of pixels. For example, the set of neighboring pixels may include the neighbor pixel 606 and the threshold distance may be the threshold distance 608. Furthermore, FIG. 6 shows that a value of the neighbor pixel 606 may be adjusted from v3 to v4 based on the anti-aging pixel recording.

[0090] In one aspect, the set of pixels may be included in a plurality of pixels displayed on the display panel, where the set of pixels may include a first number of pixels and the plurality of pixels may include a second number of pixels, and where the first number may be less than the second number. For example, the plurality of pixels may be or include the plurality of pixels 604. Furthermore, FIG. 6 shows that the set of pixels 602 may include less pixels than pixels in the plurality of pixels 604.

[0091] In one aspect, detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period may include: generating a histogram based on first values of the plurality of pixels over the time period. For example, the histogram may be or include the histogram 506. Furthermore, generating the histogram based on the first values of the plurality of pixels over the time period may include aspects described above in connection with FIG. 5.

[0092] In one aspect, detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period may include: identifying the set of pixels based on the

histogram. For example, identifying the set of pixels based on the histogram may include performing the histogram analysis at 508 in FIG. 5.

[0093] In one aspect, the histogram may be a regional histogram based on at least one region of the display panel, or the histogram may be a local histogram. For example, the histogram 506 may be a regional histogram or a local histogram. In another example, the at least one region may be the static and bright region(s) 510. In a further example, the at least one region may correspond to the video application UI layer 408 and/or the video application UI control 410.

[0094] In one aspect, the set of pixels may be associated with at least one of a frame or a layer displayed on the display panel over the time period. For example, the set of pixels may be associated with the first frame 402 or the video application UI layer 408.

[0095] In one aspect, detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period may include determining, by way of a local tone mapping (LTM) component of a display processor, that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period. For example, the LTM component may be the LTM component 504 and the display processor may be the display processor 127.

[0096] In one aspect, performing the anti-aging pixel recording on the set of pixels may include storing the values of the set of pixels in a secure memory associated with an operating system (OS) of a device. For example, the secure memory may be the secure OS memory 518. In another example, the values of the set of pixels may be or include the pixel value(s) 516.

[0097] In one aspect, the set of pixels may correspond to a user interface (UI) element displayed on the display panel. For example, the set of pixels may correspond to the video application UI control 410.

[0098] In one aspect, detecting that the values of the set of pixels displayed on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period may include detecting that first values of a set of subpixels displayed on the display panel remain static over the time period and that the first values of the set of subpixels exceed the threshold value over the time

period, performing the anti-aging pixel recording on the set of pixels may include performing the anti-aging pixel recording on the set of subpixels, and adjusting the values of the set of pixels based on the anti-aging pixel recording may include adjusting the first values of the set of subpixels based on the anti-aging pixel recording. For example, the detecting performed at 706, the anti-aging pixel recording performed at 710, and the adjustment performed at 712 may be performed on a set of subpixels instead of a set of pixels.

[0099] In one aspect, at 904, the apparatus (e.g., a display processor) may mark, based on the detection, the set of pixels as static pixels, where performing the anti-aging pixel recording on the set of pixels may be based on the set of pixels being marked as the static pixels. For example, FIG. 7 at 708 shows that the display processor 702 may mark, based on the detection at 706, the set of pixels as static pixels, where performing the anti-aging pixel recording on the set of pixels may be based on the set of pixels being marked as the static pixels. In an example, marking a set of pixels as static pixels may refer to storing, in data storage (e.g., memory, secure OS memory, a data store, etc.), identifiers for the set of pixels and at least one indication of a static pixel, where the at least one indication of the static pixel is associated with the set of pixels. In one example, the identifiers for the set of pixels may be stored in a data structure (e.g., a list) and a static pixel identifier may be stored in association with the list. In another example, the identifiers for the set of pixels may be stored in a data structure, where each identifier for each pixel in the set of pixels may include an indication that a pixel is a static pixel. In an example, 904 may be performed by the anti-aging recorder 198.

[0100] In one aspect, detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period may include detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period further based on historical analysis data. For example, FIG. 7 at 706 shows that detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period may include detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over

the time period further based on historical analysis data. In an example, the historical analysis data may be usage data for one or more applications used by one or more users over a relatively long period of time. In an example, historical analysis data may indicate that one or more regions on a display panel are likely to remain static over the time period.

[0101] In one aspect, the values of the set of pixels may include luminance values, where the threshold value may include a threshold luminance value, and where detecting that the values of the set of pixels exceed the threshold value over the time period may include comparing the luminance values to the threshold luminance value. For example, FIG. 7 at 706 shows that the threshold value may be a luminance value. In an example, the threshold value may be a weighted luminance value based on a weighted sum of a R component (ranging from 0-255), a G component (ranging from 0-255), and a B component (ranging from 0-255), where a weight for the R component may be approximately 0.3, a weight for the G component may be approximately 0.59, and a weight for the B component may be approximately 0.11. In another example, the threshold value may be a percentage (e.g., 80%, 90%, etc.) of a maximum brightness of a display panel and the values of the set of pixels may be percentages (e.g., 85%, 95%, etc.) of the maximum brightness of the display panel.

[0102] In configurations, a method or an apparatus for display processing is provided. The apparatus may be a DPU, a display processor, or some other processor that may perform display processing. In aspects, the apparatus may be the display processor 127 within the device 104, or may be some other hardware within the device 104 or another device. The apparatus may include means for detecting that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period. The apparatus may further include means for performing, based on the detection, anti-aging pixel recording on the set of pixels. The apparatus may include means for adjusting the values of the set of pixels based on the anti-aging pixel recording. The apparatus may include means for outputting an indication of the adjusted values of the set of pixels. The apparatus may include means for marking, based on the detection, the set of pixels as static pixels, where performing the anti-aging pixel recording on the set of pixels is based on the set of pixels being marked as the static pixels.

- [0103]** It is understood that the specific order or hierarchy of blocks/steps in the processes, flowcharts, and/or call flow diagrams disclosed herein is an illustration of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of the blocks/steps in the processes, flowcharts, and/or call flow diagrams may be rearranged. Further, some blocks/steps may be combined and/or omitted. Other blocks/steps may also be added. The accompanying method claims present elements of the various blocks/steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.
- [0104]** The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, where reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects.
- [0105]** Unless specifically stated otherwise, the term “some” refers to one or more and the term “or” may be interpreted as “and/or” where context does not dictate otherwise. Combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is

explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.” Unless stated otherwise, the phrase “a processor” may refer to “any of one or more processors” (e.g., one processor of one or more processors, a number (greater than one) of processors in the one or more processors, or all of the one or more processors) and the phrase “a memory” may refer to “any of one or more memories” (e.g., one memory of one or more memories, a number (greater than one) of memories in the one or more memories, or all of the one or more memories).

[0106] In one or more examples, the functions described herein may be implemented in hardware, software, firmware, or any combination thereof. For example, although the term “processing unit” has been used throughout this disclosure, such processing units may be implemented in hardware, software, firmware, or any combination thereof. If any function, processing unit, technique described herein, or other module is implemented in software, the function, processing unit, technique described herein, or other module may be stored on or transmitted over as one or more instructions or code on a computer-readable medium.

[0107] Computer-readable media may include computer data storage media or communication media including any medium that facilitates transfer of a computer program from one place to another. In this manner, computer-readable media generally may correspond to: (1) tangible computer-readable storage media, which is non-transitory; or (2) a communication medium such as a signal or carrier wave. Data storage media may be any available media that can be accessed by one or more computers or one or more processors to retrieve instructions, code, and/or data structures for implementation of the techniques described in this disclosure. By way of example, and not limitation, such computer-readable media may include RAM, ROM, EEPROM, compact disc-read only memory (CD-ROM), or other optical disk storage, magnetic disk storage, or other magnetic storage devices. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc, where disks usually reproduce data magnetically, while discs usually reproduce data optically with lasers. Combinations

of the above should also be included within the scope of computer-readable media. A computer program product may include a computer-readable medium.

- [0108]** The techniques of this disclosure may be implemented in a wide variety of devices or apparatuses, including a wireless handset, an integrated circuit (IC) or a set of ICs, e.g., a chip set. Various components, modules or units are described in this disclosure to emphasize functional aspects of devices configured to perform the disclosed techniques, but do not necessarily need realization by different hardware units. Rather, as described above, various units may be combined in any hardware unit or provided by a collection of inter-operative hardware units, including one or more processors as described above, in conjunction with suitable software and/or firmware. Accordingly, the term “processor,” as used herein may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described herein. Also, the techniques may be fully implemented in one or more circuits or logic elements.
- [0109]** The following aspects are illustrative only and may be combined with other aspects or teachings described herein, without limitation.
- [0110]** Aspect 1 is a method of display processing, including: detecting that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period; performing, based on the detection, anti-aging pixel recording on the set of pixels; and adjusting the values of the set of pixels based on the anti-aging pixel recording.
- [0111]** Aspect 2 may be combined with aspect 1 and further comprises: outputting an indication of the adjusted values of the set of pixels.
- [0112]** Aspect 3 may be combined with aspect 2 and comprises that outputting the indication of the adjusted values of the set of pixels includes transmitting, to the display panel, the indication of the adjusted values of the set of pixels.
- [0113]** Aspect 4 may be combined with any of aspects 2-3 and comprises that outputting the indication of the adjusted values of the set of pixels includes storing, in a memory or a cache, the indication of the adjusted values of the set of pixels.
- [0114]** Aspect 5 may be combined with any of aspects 1-4 and comprises that adjusting the values of the set of pixels based on the anti-aging pixel recording includes: adjusting, based on the anti-aging pixel recording, the values of a set of neighboring pixels that

is within a threshold distance of one of the set of pixels, wherein each of the set of neighboring pixels is adjacent to one of the set of pixels.

- [0115]** Aspect 6 may be combined with any of aspects 1-5 and comprises that the set of pixels is included in a plurality of pixels displayed on the display panel, wherein the set of pixels includes a first number of pixels and the plurality of pixels includes a second number of pixels, and wherein the first number is less than the second number.
- [0116]** Aspect 7 may be combined with aspect 6 and comprises that detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period includes: generating a histogram based on first values of the plurality of pixels over the time period; and identifying the set of pixels based on the histogram.
- [0117]** Aspect 8 may be combined with aspect 7 and comprises that the histogram is a regional histogram based on at least one region of the display panel, or wherein the histogram is a local histogram.
- [0118]** Aspect 9 may be combined with any of aspects 1-8 and comprises that the set of pixels is associated with at least one of a frame or a layer displayed on the display panel over the time period.
- [0119]** Aspect 10 may be combined with any of aspects 1-9 and comprises that detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period includes detecting, by way of a local tone mapping (LTM) component of a display processor, that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period.
- [0120]** Aspect 11 may be combined with any of aspects 1-10 and comprises that performing the anti-aging pixel recording on the set of pixels includes storing the values of the set of pixels in a secure memory associated with an operating system (OS) of a device.
- [0121]** Aspect 12 may be combined with any of aspects 1-11 and comprises that the set of pixels corresponds to a user interface (UI) element displayed on the display panel.
- [0122]** Aspect 13 may be combined with any of aspects 1-12 and comprises that detecting that the values of the set of pixels displayed on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period includes detecting that first values of a set of subpixels displayed on

the display panel remain static over the time period and that the first values of the set of subpixels exceed the threshold value over the time period, wherein performing the anti-aging pixel recording on the set of pixels including performing the anti-aging pixel recording on the set of subpixels, and wherein adjusting the values of the set of pixels based on the anti-aging pixel recording includes adjusting the first values of the set of subpixels based on the anti-aging pixel recording.

[0123] Aspect 14 may be combined with any of aspects 1-13 and further comprises: marking, based on the detection, the set of pixels as static pixels, wherein performing the anti-aging pixel recording on the set of pixels is based on the set of pixels being marked as the static pixels.

[0124] Aspect 15 may be combined with any of aspects 1-14 and comprises that detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period includes detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period further based on historical analysis data.

[0125] Aspect 16 is may be combined with any of aspects 1-15 and comprises that the values of the set of pixels comprise luminance values, wherein the threshold value comprises a threshold luminance value, and wherein detecting that the values of the set of pixels exceed the threshold value over the time period comprises comparing the luminance values to the threshold luminance value.

[0126] Aspect 17 is an apparatus for display processing comprising a processor coupled to a memory and, based on information stored in the memory, the processor is configured to implement a method as in any of aspects 1-16.

[0127] Aspect 18 may be combined with aspect 17 and comprises that the apparatus is a wireless communication device comprising at least one of a transceiver or an antenna coupled to the processor, where the processor is configured to obtain a frame associated with the set of pixels via at least one of the transceiver or the antenna.

[0128] Aspect 19 is an apparatus for display processing comprising means for implementing a method as in any of aspects 1-16.

[0129] Aspect 20 is a computer-readable medium (e.g., a non-transitory computer readable-medium) storing computer executable code, the computer executable code, when

executed by a processor, causes the processor to implement a method as in any of aspects 1-16.

[0130] Various aspects have been described herein. These and other aspects are within the scope of the following claims.

CLAIMS

WHAT IS CLAIMED IS:

1. An apparatus for display processing, comprising:
a memory; and
a processor coupled to the memory and, based on information stored in the memory, the processor is configured to:
detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period;
perform, based on the detection, anti-aging pixel recording on the set of pixels; and
adjust the values of the set of pixels based on the anti-aging pixel recording.
2. The apparatus of claim 1, wherein the processor is further configured to:
output an indication of the adjusted values of the set of pixels.
3. The apparatus of claim 2, wherein to output the indication of the adjusted values of the set of pixels, the processor is configured to transmit, to the display panel, the indication of the adjusted values of the set of pixels.
4. The apparatus of claim 2, wherein to output the indication of the adjusted values of the set of pixels, the processor is configured to store, in the memory or a cache, the indication of the adjusted values of the set of pixels.
5. The apparatus of claim 1, wherein to adjust the values of the set of pixels based on the anti-aging pixel recording, the processor is configured to:
adjust, based on the anti-aging pixel recording, the values of a set of neighboring pixels that is within a threshold distance of one of the set of pixels, wherein each of the set of neighboring pixels is adjacent to one of the set of pixels.
6. The apparatus of claim 1, wherein the set of pixels is included in a plurality of pixels displayed on the display panel, wherein the set of pixels comprises a first number

of pixels and the plurality of pixels comprises a second number of pixels, and wherein the first number is less than the second number.

7. The apparatus of claim 6, wherein to detect that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period, the processor is configured to:

generate a histogram based on first values of the plurality of pixels over the time period; and

identify the set of pixels based on the histogram.

8. The apparatus of claim 7, wherein the histogram is a regional histogram based on at least one region of the display panel, or wherein the histogram is a local histogram.

9. The apparatus of claim 1, wherein the set of pixels is associated with at least one of a frame or a layer displayed on the display panel over the time period.

10. The apparatus of claim 1, wherein to detect that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period, the processor is configured to detect, by way of a local tone mapping (LTM) component of a display processor, that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period.

11. The apparatus of claim 1, wherein to perform the anti-aging pixel recording on the set of pixels, the processor is configured to store the values of the set of pixels in a secure memory associated with an operating system (OS) of a device.

12. The apparatus of claim 1, wherein the set of pixels corresponds to a user interface (UI) element displayed on the display panel.

13. The apparatus of claim 1, wherein to detect that the values of the set of pixels displayed on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period, the processor is

configured to detect that first values of a set of subpixels displayed on the display panel remain static over the time period and that the first values of the set of subpixels exceed the threshold value over the time period, wherein to perform the anti-aging pixel recording on the set of pixels, the processor is configured to perform the anti-aging pixel recording on the set of subpixels, and wherein to adjust the values of the set of pixels based on the anti-aging pixel recording, the processor is configured to adjust the first values of the set of subpixels based on the anti-aging pixel recording.

14. The apparatus of claim 1, wherein the processor is further configured to:

mark, based on the detection, the set of pixels as static pixels, wherein to perform the anti-aging pixel recording on the set of pixels, the processor is configured to perform the anti-aging pixel recording on the set of pixels based on the set of pixels being marked as the static pixels.

15. The apparatus of claim 1, wherein to detect that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period, the processor is configured to detect that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period further based on historical analysis data.

16. The apparatus of claim 1, wherein the values of the set of pixels comprise luminance values, wherein the threshold value comprises a threshold luminance value, and wherein to detect that the values of the set of pixels exceed the threshold value over the time period, the processor is configured to compare the luminance values to the threshold luminance value.

17. The apparatus of claim 1, wherein the apparatus is a wireless communication device comprising at least one of a transceiver or an antenna coupled to the processor, wherein the processor is configured to obtain a frame associated with the set of pixels via at least one of the transceiver or the antenna.

18. A method of display processing, comprising:

detecting that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period;

performing, based on the detection, anti-aging pixel recording on the set of pixels;
and

adjusting the values of the set of pixels based on the anti-aging pixel recording.

19. The method of claim 18, further comprising:

outputting an indication of the adjusted values of the set of pixels.

20. The method of claim 19, wherein outputting the indication of the adjusted values of the set of pixels comprises transmitting, to the display panel, the indication of the adjusted values of the set of pixels.

21. The method of claim 19, wherein outputting the indication of the adjusted values of the set of pixels comprises storing, in a memory or a cache, the indication of the adjusted values of the set of pixels.

22. The method of claim 18, wherein adjusting the values of the set of pixels based on the anti-aging pixel recording comprises:

adjusting, based on the anti-aging pixel recording, the values of a set of neighboring pixels that is within a threshold distance of one of the set of pixels, wherein each of the set of neighboring pixels is adjacent to one of the set of pixels.

23. The method of claim 18, wherein the set of pixels is included in a plurality of pixels displayed on the display panel, wherein the set of pixels comprises a first number of pixels and the plurality of pixels comprises a second number of pixels, and wherein the first number is less than the second number.

24. The method of claim 23, wherein detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period comprises:

generating a histogram based on first values of the plurality of pixels over the time period; and

identifying the set of pixels based on the histogram.

25. The method of claim 24, wherein the histogram is a regional histogram based on at least one region of the display panel, or wherein the histogram is a local histogram.

26. The method of claim 18, wherein the set of pixels is associated with at least one of a frame or a layer displayed on the display panel over the time period.

27. The method of claim 18, wherein detecting that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period comprises detecting, by way of a local tone mapping (LTM) component of a display processor, that the values of the set of pixels on the display panel remain static over the time period and that the values of the set of pixels exceed the threshold value over the time period.

28. The method of claim 18, wherein performing the anti-aging pixel recording on the set of pixels comprises storing the values of the set of pixels in a secure memory associated with an operating system (OS) of a device.

29. The method of claim 18, wherein the set of pixels corresponds to a user interface (UI) element displayed on the display panel.

30. A computer-readable medium storing computer executable code, the computer executable code, when executed by a processor, causes the processor to:

detect that values of a set of pixels displayed on a display panel remain static over a time period and that the values of the set of pixels exceed a threshold value over the time period;

perform, based on the detection, anti-aging pixel recording on the set of pixels;
and

adjust the values of the set of pixels based on the anti-aging pixel recording.

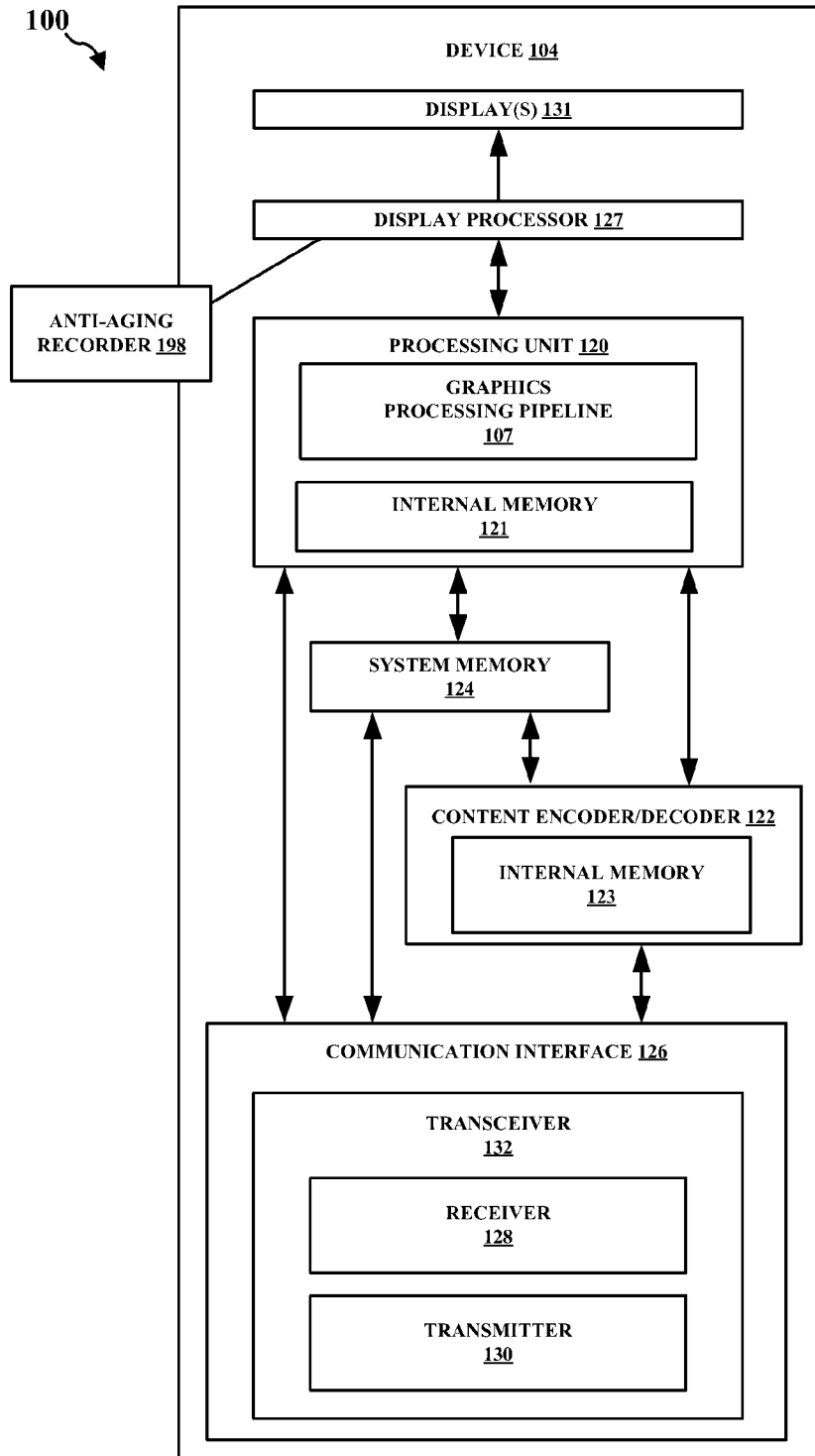
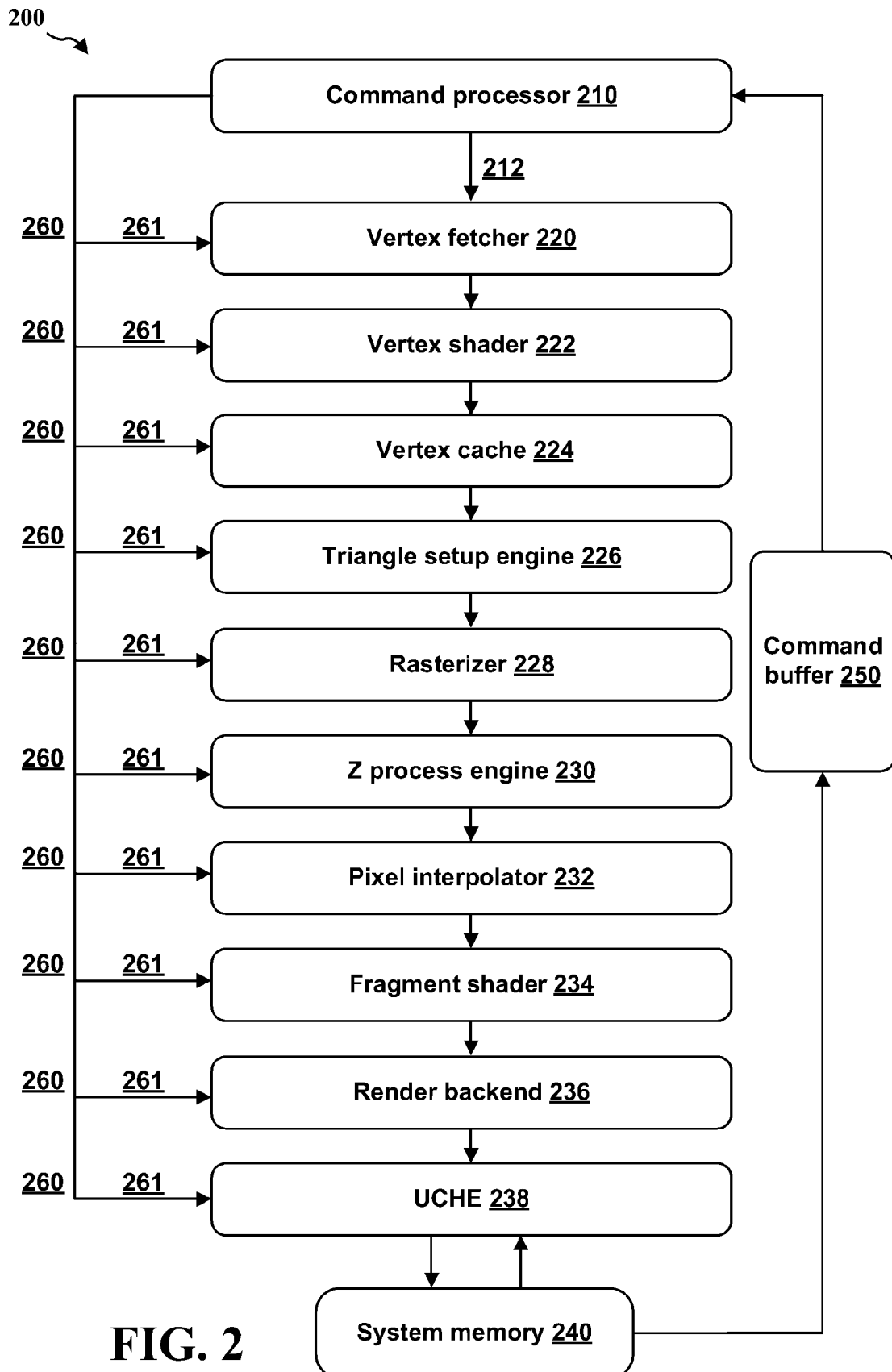


FIG. 1



300 ↗

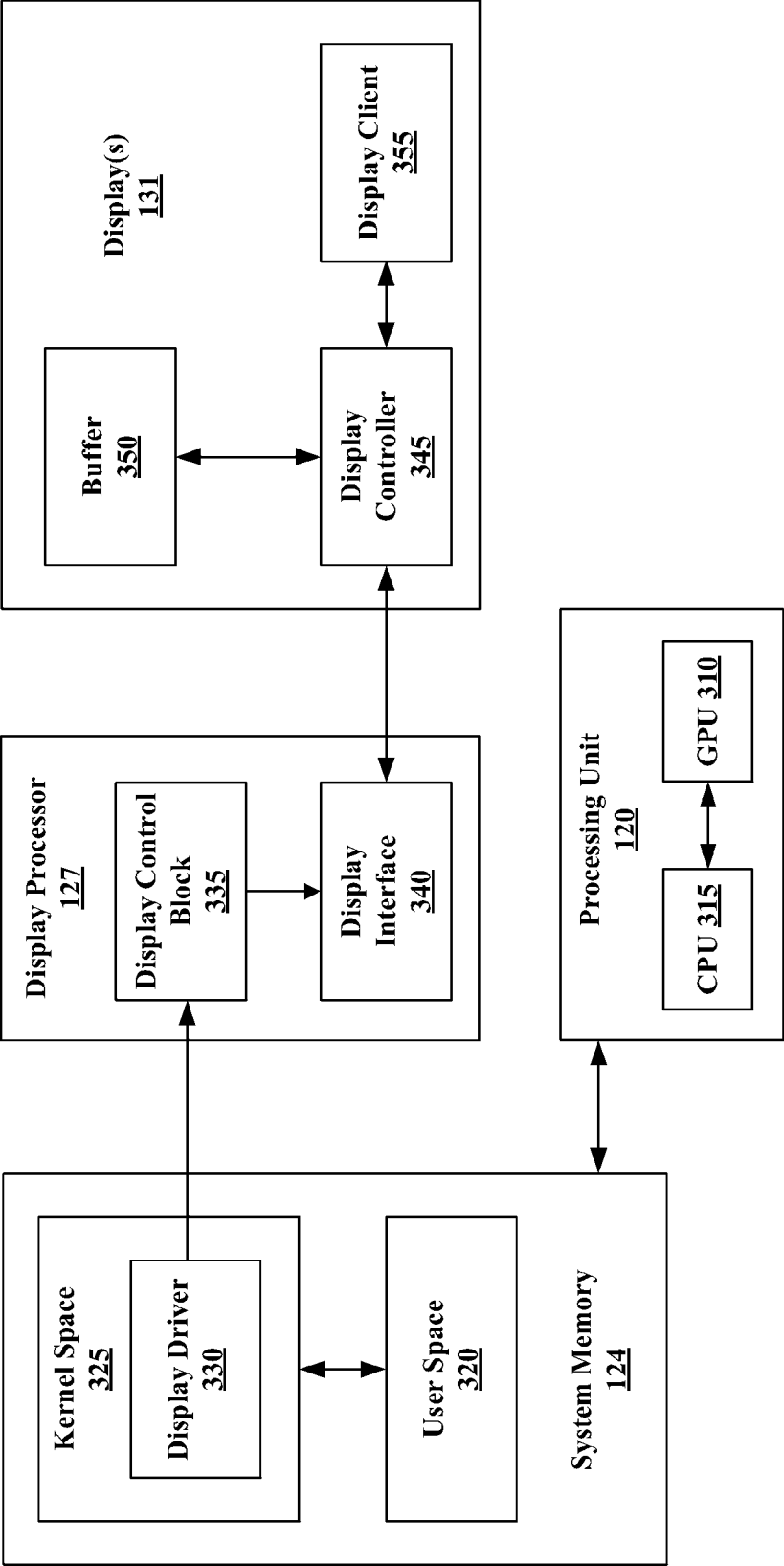
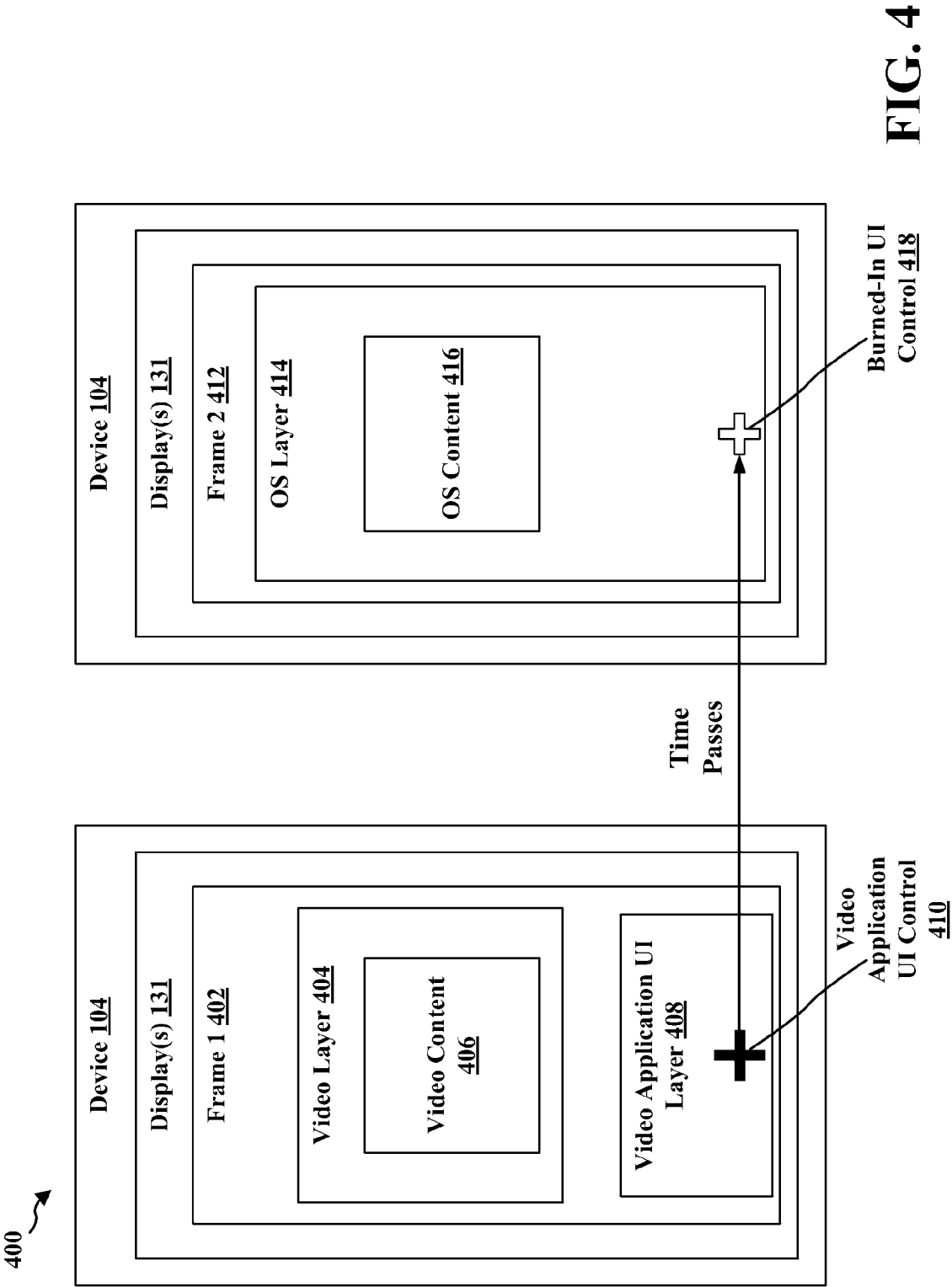
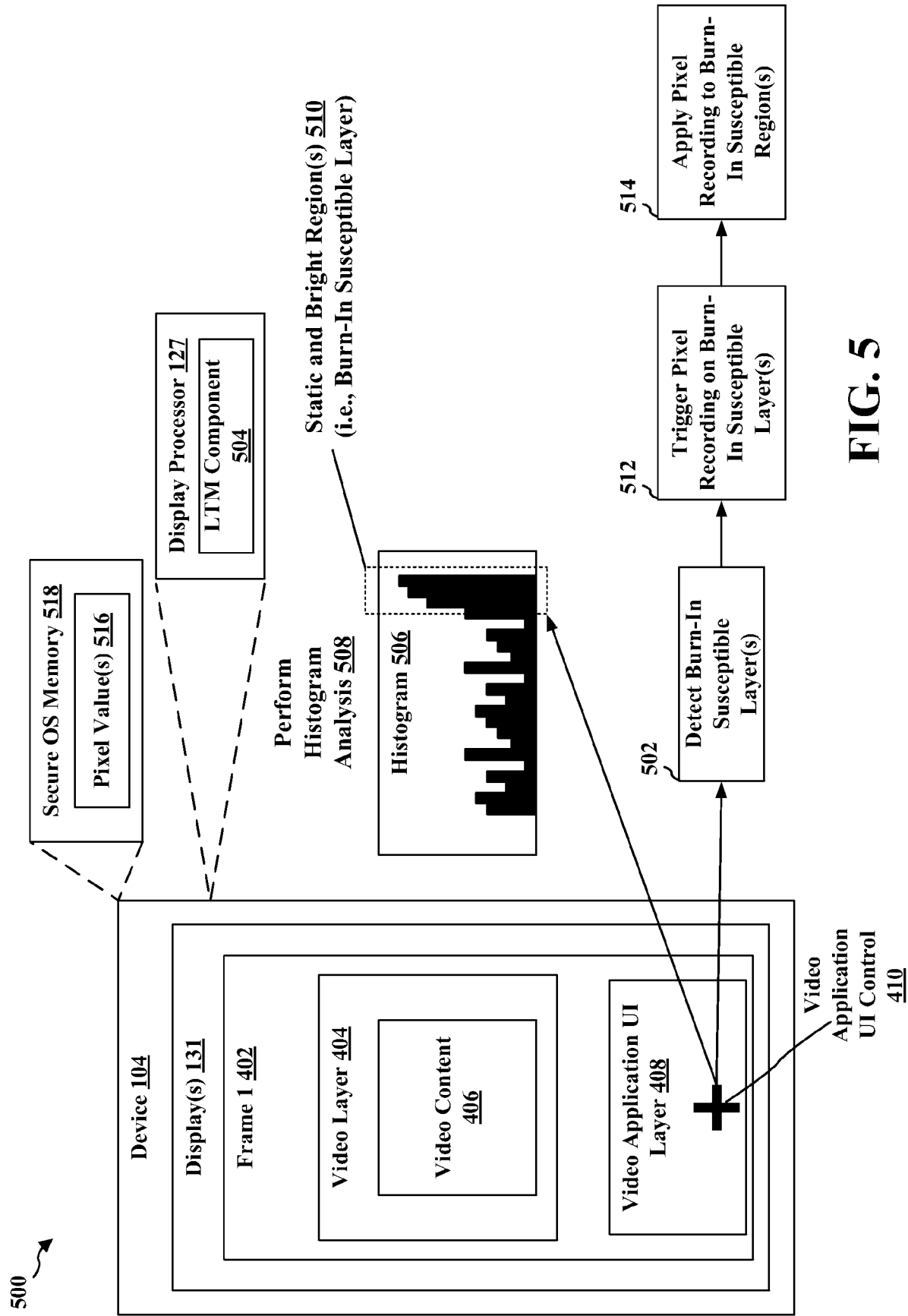
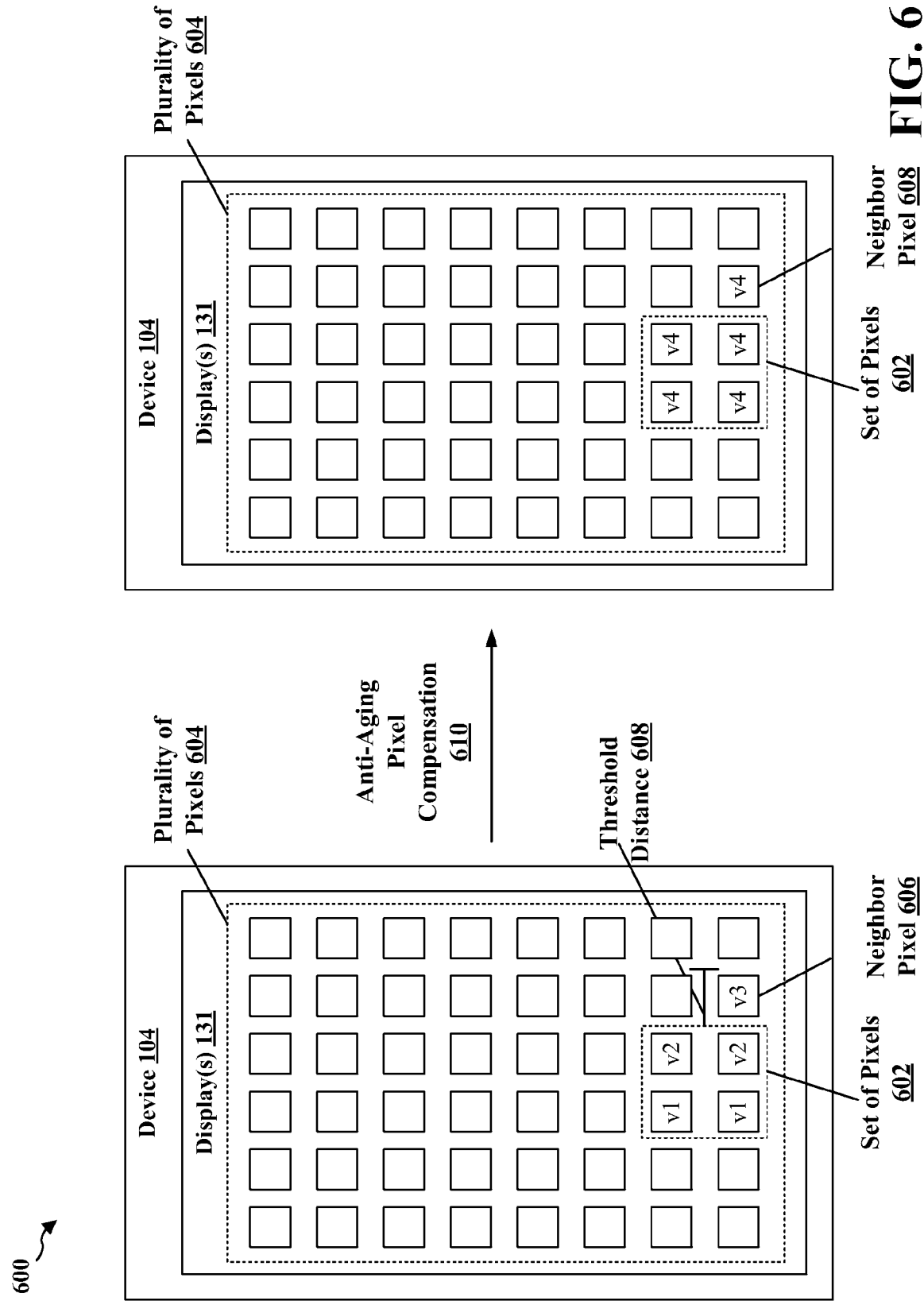


FIG. 3







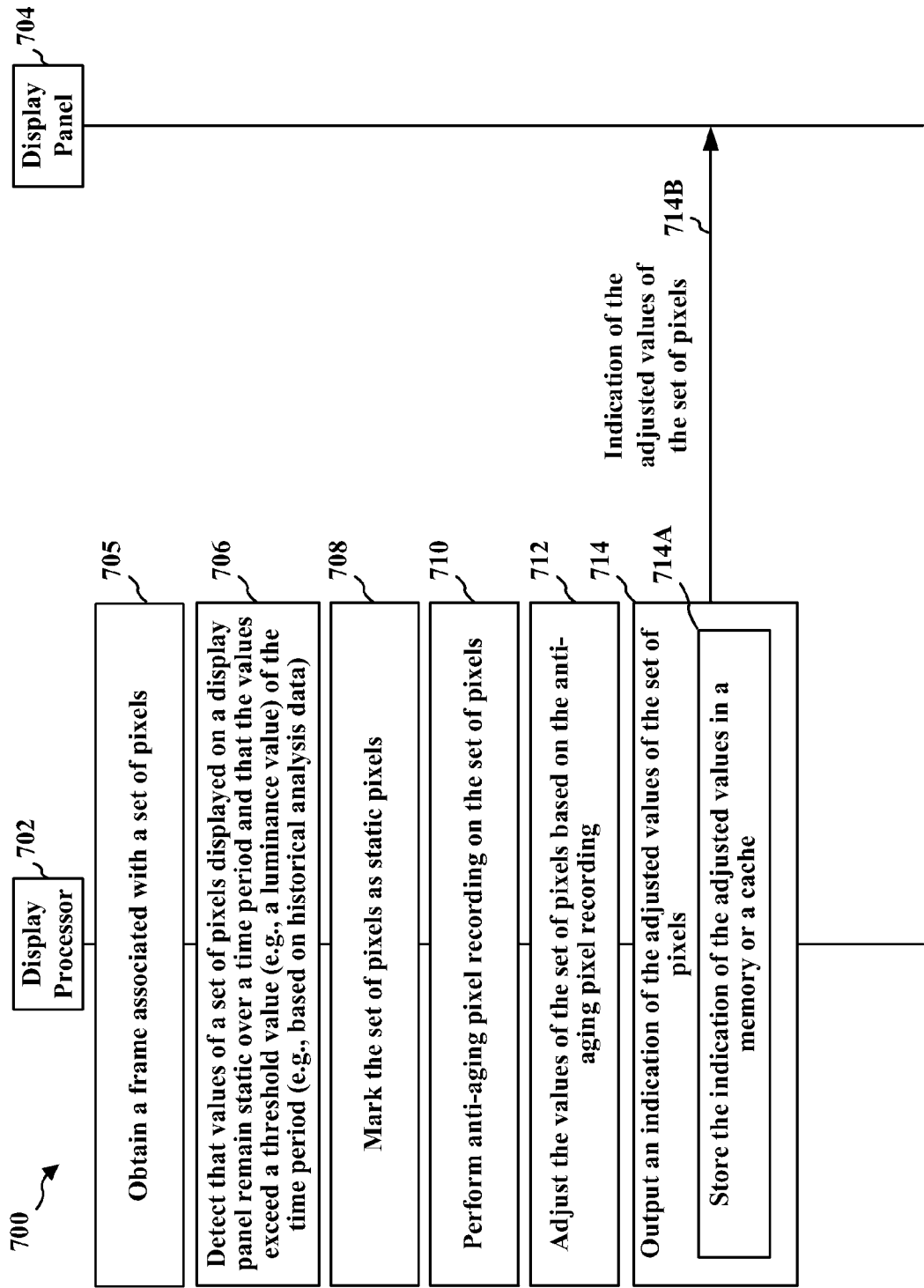


FIG. 7

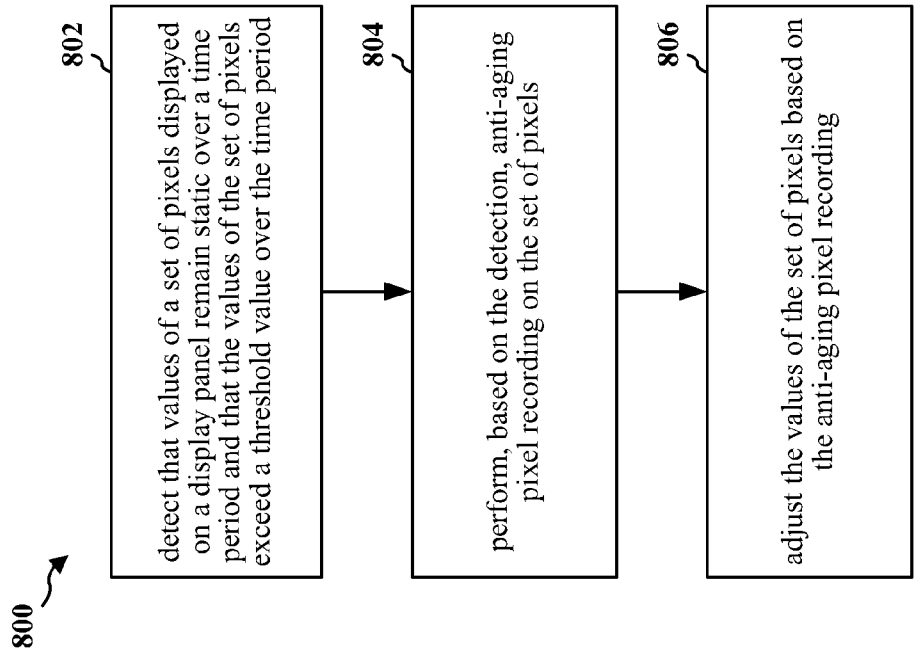


FIG. 8

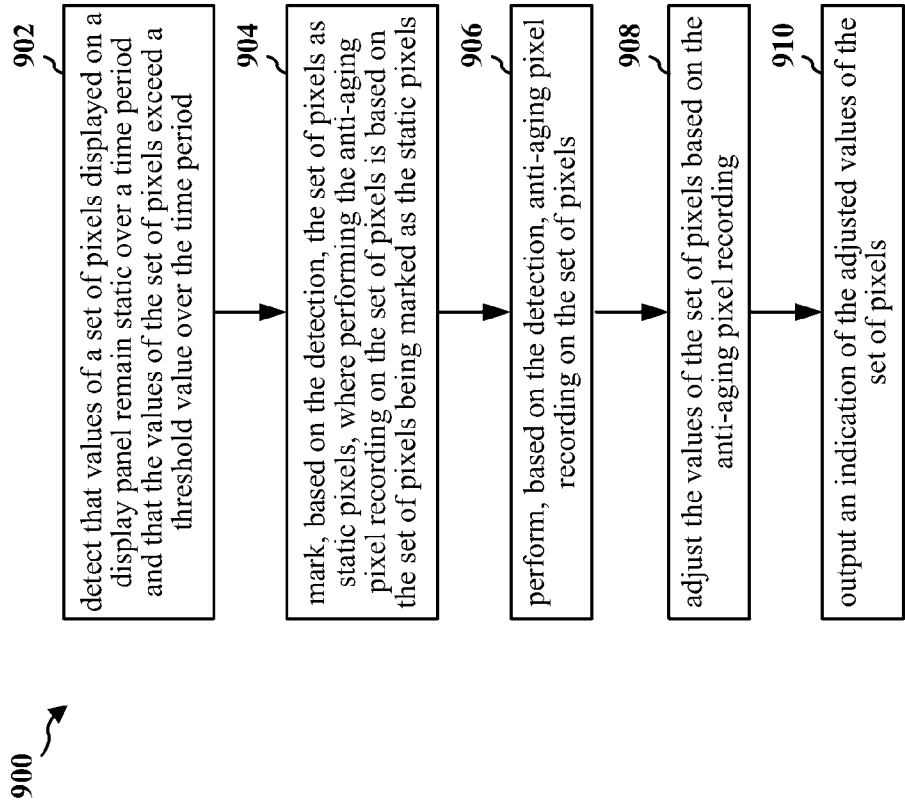


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/096441

A. CLASSIFICATION OF SUBJECT MATTER G09G3/00(2006.01)i 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) IPC:G09G 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) CNABS,DWPI,CNKI,CNTXT,ENTXT: OLED, DISPLAY, PIXEL, ANTI-AGING		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 114341969 A (GOOGLE LLC) 12 April 2022 (2022-04-12) see the whole document	1-30
A	CN 114765017 A (NVIDIA CORP) 19 July 2022 (2022-07-19) see the whole document	1-30
A	WO 2021164004 A1 (QUALCOMM INC) 26 August 2021 (2021-08-26) see the whole document	1-30
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “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 “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 29 January 2024		Date of mailing of the international search report 30 January 2024
Name and mailing address of the ISA/CN CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China		Authorized officer LIN,LiangLiang Telephone No. (+86) 010-62411890

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/096441

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	114341969	A	12 April 2022	WO	2021150249	A1	29 July 2021
				EP	4004903	A1	01 June 2022
				US	2022366846	A1	17 November 2022
CN	114765017	A	19 July 2022	DE	102022100638	A1	14 July 2022
				US	2022223104	A1	14 July 2022
WO	2021164004	A1	26 August 2021	KR	20220143667	A	25 October 2022
				US	2023073736	A1	09 March 2023
				EP	4107719	A1	28 December 2022
				EP	4107719	A4	11 October 2023
				CN	115151969	A	04 October 2022
				IN	202247044662	A	12 August 2022
				WO	2021164004	A1	26 August 2021