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Declarations under Rule 4.17:
— *as to the identity of the inventor (Rule 4.17(i))*
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) **Title**: CONTENT ADAPTIVE BACKLIGHT POWER SAVING TECHNOLOGY

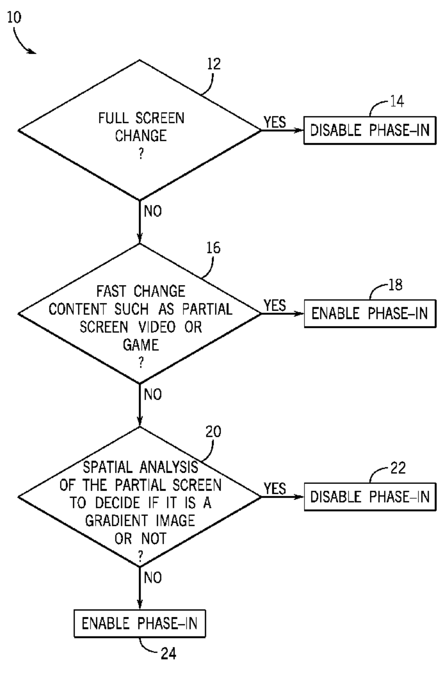

FIG. 2

(57) **Abstract**: A hybrid phase-in method mitigates the flicker and rolling artifact based on screen change detection or the combination of screen change detection and image spatial analysis. It applies, for example, to solutions that involve backlight and pixel modulation including global dimming and local dimming. If it is full screen change, then no phase-in is needed and the backlight and pixel change can be applied instantly. If it is partial screen change, then content type and spatial image analysis may be used to decide whether to use phase-in or not. The spatial image analysis concept provides additional useful information besides the image brightness analysis for display backlight power saving solutions to make better tradeoffs between power saving and visual quality.

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

CONTENT ADAPTIVE BACKLIGHT POWER SAVING TECHNOLOGY

Background

[0001] The display is a major power consumer on mobile platforms. Content adaptive backlight power saving technology saves display backlight power by dynamically dimming display backlighting and enhancing pixel brightness at the same time to achieve the same perceived brightness and image fidelity. The backlight dimming level depends on a pixel brightness analysis, which can be done through various methods, such as histogram analysis based on the V value in HSV color space. Image brightness changes cause backlight and pixel adjustment.

[0002] If the transition of backlight and pixel brightness is not properly implemented, then temporal artifacts such as flicker or rolling artifact will be observed. For example, if backlight and pixel brightness changes are not synchronized, then flicker will be observed.

[0003] However, even if the backlight and pixel change are well synchronized, if the change is applied instantly, then flicker will be observed in the unchanged area during partial screen update. An example of such a case is playing video in a big window (but not full screen) and the unchanged area is bright. If the backlight and pixel change are applied instantly, there will be flicker in the unchanged area.

[0004] Applying a small relative percentage change every frame for both backlight and pixel change can help mitigate the flicker issue. That is why gradual or progressive change over time, called phase-in, has been implemented in the display power saving technology.

Brief Description Of The Drawings

[0005] Some embodiments are described with respect to the following figures:

Figure 1 is a depiction of a partial screen change according to one embodiment;

Figure 2 is a flow chart for one embodiment;

Figure 3 is a flow chart for a 24-bit (and above) panel according to one embodiment;

Figure 4 is a screen shot showing a pixel and its two neighbors;

Figure 5 is an example of gradient image;

Figure 6 is a histogram build based on the maximum difference for the gradient image of Figure 5, according to one embodiment;

Figure 7 is another example of a non-gradient image;

Figure 8 is a histogram built for Figure 7; and

Figure 9 is a system schematic for one embodiment.

Detailed Description

[0006] However, for images with a fine change gradient, phase-in could cause rolling artifacts during the phase-in period, due to the quantization error. The rolling artifact can be mitigated through dithering for a native 24-bit panel since dithering makes the panel behave like a 30-bit panel, mitigating quantization. However, for low bit depth panel such as 18-bit panel (6 bits per color), the rolling artifact cannot be well mitigated with dithering due to the limited bit depth. To avoid the rolling artifact, it is better to disable phase-in. However, today there is no mechanism available on the platform to differentiate gradient images from non-gradient images. In summary, the temporal artifact such as flicker and rolling happens in different scenarios when display backlight power saving type of technology is enabled.

[0007] A hybrid phase-in method mitigates the flicker and rolling artifact based on screen change detection or the combination of screen change detection and image spatial analysis. It applies, for example, to solutions that involve backlight and pixel modulation including global dimming and local dimming. If it is full screen change, then no phase-in is needed and the backlight and pixel change can be applied instantly. If it is partial screen change, then content type and spatial image analysis may be used to decide whether to use phase-in or not. The spatial image analysis concept provides additional useful information besides the image brightness analysis for display backlight power saving solutions to make better tradeoffs between power saving and visual quality.

[0008] The detection of full screen and partial screen change can be done by graphics hardware or may be provided by an operating system (OS). The partial region change can be defined by the pixel positions of the four corners a, b, c, d of partial region 2 of screen 1, as shown in the Figure 1.

[0009] If there is partial screen change, then whether to apply phase-in is further analyzed depending on the scene change rate in the partial screen window. If the scene change rate is fast, such as playing video in the partial screen, then phase-in mitigates the potential flicker issue in the unchanged area. If the scene change rate is slow such as viewing a static image in partial screen, then further spatial analysis is performed on the static image to decide whether to use phase-in or not in order to mitigate the potential rolling artifact on gradient images.

[0010] Existing technologies, such as Panel Self Refresh, detect screen change. If there is no screen change, then there will be no new data sent to panel. The display interface will be shut down, and panel goes to self refresh. There are mechanisms that can detect either full screen change or partial screen change. In the case of only a partial screen change, only the changed data are fetched from memory and sent over display interface to panel.

[0011] One implementation is shown in Figure 2. If the panel has high bit depth, 24-bit or above, then further spatial analysis might not be needed if dithering is enabled for the purpose of mitigating the rolling artifact and the implementation can be as shown in Figure 2. However, the implementation in Figure 2 does not exclude high bit depth panels.

[0012] The sequence 10 shown in Figure 2 can be implemented in software, firmware, and/or hardware. In software and firmware embodiments it may be implemented by computer executed instructions stored in one or more non-transitory computer readable media such as magnetic, optical or semiconductor storage.

[0013] The sequence 10 begins by detecting whether there is a full screen change at diamond 12. This may be done in hardware or using the operating system. If it is a full screen change then phase-in is disabled as shown in block 14.

[0014] If there is a partial screen change, as determined in diamond 12, then a check at diamond 16 determines if there is fast change content such as partial screen video or video game. If so, phase-in may be enabled as indicated in block 18.

[0015] Otherwise, a check at diamond 20 determines whether spatial analysis of the partial screen indicates that it is a gradient image or not. If so, the phase-in is disabled as indicated in block 22 and otherwise phase-in is enabled as indicated in block 24.

[0016] Figure 3 is a flow-chart on phase-in decision 24-bit panel and above with dithering enabled. If at diamond 26 there is a full screen change, phase-in is disabled at block 28.

[0017] If there is a partial screen change, then phase-in is enabled at block 30.

[0018] Image spatial information has been lacking in content adaptive backlight power saving solutions. Spatial information may be used in content adaptive backlight power saving solutions. Combined with brightness information that content adaptive backlight power saving solutions already have, a better tradeoff between power and visual quality can be made.

[0019] A spatial analysis method may be used to differentiate gradient images. A gradient image has smaller color value differences between adjacent pixels. The analysis is based on calculating the maximum difference of a pixel with its two neighboring pixels in both horizontal (left) (P(i-1, j)) and vertical direction (top) (P(i, j-1)) as shown in Figure 4. The calculation can be based on Value in HSV color space or Luma Y in YUV color space or on sub-pixel values.

[0020] One example of pseudo code based on V is set forth below to explain how the maximum difference for each pixel besides the boundary pixels are calculated.

V(i,j) = max(P(i,j)(R,G,B))

Diff_L(i,j) = abs(V(i,j)-V(i-1,j))

Diff_T(i,j) = abs(V(I,j)-V(i,j-1))

[0021] P_diff (i,j) = max(Diff_L, Diff_T)

[0022] Then a histogram based on the maximum difference of pixels with respect to their neighbors is built. If it is a gradient image then the majority of maximum differences is small and fall into low histogram bins. Therefore, whether it is a gradient image or not can be decided based on the percentage of low histogram bins. For example, a first threshold may be used to define low histogram bins and a second threshold can be used to assign a percentage above which it is decided that a high percentage of the pixels are in low histogram bins.

[0023] For example, for the gradient image in Figure 5, the histogram based on maximum of pixel difference at a step of 2 is built and the result is shown in Figure 6. It shows that most of the maximum difference falls into the lowest bin which holds value from 0 to 2. So this would be a gradient image.

[0024] An example of a non-gradient image is shown in Figure 7 and histogram based on maximum of pixel difference is shown in Figure 8, which shows the percentage of pixels falling into the lowest bin is much lower than the gradient image example of Figures 5 and 6.

[0025] These are just examples. In real implementation, 128-bins might not be needed and how such a histogram is built is an implementation choice.

[0026] Combined with the histogram build based on image brightness, a gradient image can be differentiated from a uniform image. As stated previously, the spatial analysis serves as providing additional information for better power and image fidelity decisions. The backlight and pixel adjustment amount is mainly determined based on image brightness analysis, however, the spatial analysis can help fine tune that decision. Furthermore, the spatial analysis in not limited to full screen or partial screen. This concept can be applied to multi-region analysis to achieve better visual quality at the minimum cost of power saving loss.

[0027] Figure 9 is a diagram illustrating an example of a computing device 100 to implement the techniques discussed herein. The computing device 100 may be, for example, a laptop computer, desktop computer, ultrabook, tablet computer, mobile device, or server, among others. The computing device 100 may include a central processing unit (CPU) 102 that is configured to execute stored instructions, as well as a memory device 104 that stores instructions that are executable by the CPU 102. For example, processor 102 may execute instructions to implement the sequences of Figures 2 and 3. The CPU may be coupled to the memory device 104 by a bus 106. Additionally, the CPU 102 can be a single core processor, a multi-core processor, a computing cluster, or any number of other configurations. Furthermore, the computing device 100 may include more than one CPU 102.

[0028] The computing device 100 may also include a graphics processing unit (GPU) 108. As shown, the CPU 102 may be coupled through the bus 106 to the GPU 108. The GPU 108 may be configured to perform any number of graphics functions and actions within the computing device 100. For example, the GPU 108 may be configured to render or manipulate graphics images, graphics frames, videos, or the like, to be displayed to a user of the computing device 100.

[0029] The memory device 104 can include random access memory (RAM), read only memory (ROM), flash memory, or any other suitable memory systems. For example, the memory device 104 may include dynamic random access memory (DRAM). The computing device 100 includes an image capture mechanism 110. In some examples, the image capture mechanism 110 is a camera, stereoscopic camera, scanner, infrared sensor, or the like.

[0030] The CPU 102 may be linked through the bus 106 to a display interface 112 configured to connect the computing device 100 to one or more display devices 114. The display device(s) 114 may include a display screen that is a built-in component of the computing device 100. Examples of such a computing device include mobile computing devices, such as cell phones, tablets, 2-in-1 computers, notebook computers or the like. The display devices 114 may also include a computer monitor, television, or projector, among others, that is externally connected to the computing device 100. In some cases, the display devices 114 may be headmounted display devices having a display capacity via projection, digital display, filtering incoming light, and the like.

[0031] The CPU 102 may also be connected through the bus 106 to an input/output (I/O) device interface 116 configured to connect the computing device 100 to one or more I/O devices 118. The I/O devices 118 may include, for example, a keyboard and a pointing device, wherein the pointing device may include a touchpad or a touchscreen, among others. The I/O devices 118 may be built-in components of the computing device 100, or may be devices that are externally connected to the computing device 100. In some cases, the I/O devices 118 are touchscreen devices integrated within a display device, such as one or more of the display devices 114.

[0032] The computing device 100 may also include a storage device 120. The storage device 120 is a physical memory such as a hard drive, an optical drive, a thumbdrive, an array of drives, or any combinations thereof. The storage device 120 may also include remote storage drives. The computing device 100 may also include a network interface controller (NIC) 122 may be configured to connect the computing device 100 through the bus 106 to a network 124. The network 124 may be a wide area network (WAN), local area network (LAN), or the Internet, among others.

[0033] The computing device 100 and each of its components may be powered by a power supply unit (PSU) 126. The CPU 102 may be coupled to the PSU through the bus 106 which may communicate control signals or status signals between then CPU 102 and the PSU 126. The PSU 126 is further coupled through a power source connector 128 to a power source 130. The power source 130 provides electrical current to the PSU 126 through the power source connector 128. A power source connector can include conducting wires, plates or any other means of transmitting power from a power source to the PSU.

[0034] The computing device 100 may also include a distributed memory panel 132 located on the display devices 114 to distribute memory on a panel. In some examples, the distributed memory panel 132 may store image data to be displayed so that the computing device 100 does store them in a storage 120 or a memory device 104.

[0035] The block diagram of Figure 9 is not intended to indicate that the computing device 100 is to include all of the components shown in Figure 9. Further, the computing device 100 may include any number of additional components not shown in Figure 9, depending on the details of the specific implementation.

[0036] The following clauses and/or examples pertain to further embodiments:

One example embodiment may be a method comprising determining whether there is a partial change of screen that affects less than all of a display screen, performing a spatial analysis of the partial screen change to decide if the partial screen is a gradient image and if so, disabling phase-in of the screen change and if not enabling phase-in of the screen change. The method may also include detecting fast changing content and enabling phase-in only if the content is changing quickly. The method may also include wherein performing spatial analysis includes calculating the maximum difference of a pixel with neighboring pixels. The method may also include wherein determining maximum difference includes determining the maximum difference in two directions. The method may also include determining the maximum difference based on the V component in an HSV color space. The method may also include determining the maximum difference based on the Y component in YUV color space. The method may also include building a histogram based on maximum difference of pixels versus their neighbors. The method may also include determining if a screen change is a gradient image depending on whether the majority of maximum differences fall into lower histogram bins.

[0037] Another example embodiment may be one or more non-transitory computer readable media storing instructions executed by a processor to perform a sequence comprising determining whether there is a partial change of screen that affects less than all of a display screen, performing a spatial analysis of the partial screen change to decide if the partial screen is a gradient image, and if so, disabling phase-in of the screen change and if not enabling phase-in of the screen change. The media may also include said sequence including detecting fast changing content and enabling phase-in only if the content is changing quickly. The media may also include said sequence wherein performing spatial analysis includes calculating the maximum difference of a pixel with neighboring pixels. The media may also include wherein determining maximum difference includes determining the maximum difference in two directions. The media may also include said sequence including determining the maximum difference based on the V component in an HSV color space. The media may also include said sequence including determining the maximum difference based on the Y component in YUV color space. The media may also include said sequence including building a histogram based on maximum difference of pixels versus their neighbors. The media may also include said sequence including determining if a screen change is a gradient image depending on whether the majority of maximum differences fall into lower histogram bins.

[0038] In another example embodiment an apparatus comprising a processor to determine whether there is a partial change of screen that affects less than all of a display screen, perform a spatial analysis of the partial screen change to decide if the partial screen is a gradient image, and if so, disable phase-in of the screen change and if not enabling phase-in of the screen change; and a storage coupled to said processor. The apparatus may include said processor to detect fast changing content and enabling phase-in only if the content is changing quickly. The apparatus may include said processor calculate the maximum difference of a pixel with neighboring pixels. The apparatus may include said processor to determine the maximum difference in two directions. The apparatus may include said processor to determine the maximum difference based on the V component in an HSV color space. The apparatus may include said processor to determine the maximum difference based on the Y component in YUV color space. The apparatus may include said processor to build a histogram based on maximum difference of pixels versus their neighbors. The apparatus may include said processor to determine if a screen change is a gradient image depending on whether the majority of maximum differences fall into lower histogram bins.

[0039] The graphics processing techniques described herein may be implemented in various hardware architectures. For example, graphics functionality may be integrated within a chipset. Alternatively, a discrete graphics processor may be used. As still another embodiment, the graphics functions may be implemented by a general purpose processor, including a multicore processor.

[0040] References throughout this specification to “one embodiment” or “an embodiment” mean that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one implementation encompassed within the present disclosure. Thus, appearances of the phrase “one embodiment” or “in an embodiment” are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be instituted in other suitable forms other than the particular embodiment illustrated and all such forms may be encompassed within the claims of the present application.

[0041] While a limited number of embodiments have been described, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this disclosure.

What is claimed is:

1. A method comprising:

determining whether there is a partial change of screen that affects less than all of a display screen;

performing a spatial analysis of the partial screen change to decide if the partial screen is a gradient image; and

if so, disabling phase-in of the screen change and if not enabling phase-in of the screen change.

2. The method of claim 1 including detecting fast changing content and enabling phase-in only if the content is changing quickly.

3. The method of claim 1 wherein performing spatial analysis includes calculating the maximum difference of a pixel with neighboring pixels.

4. The method of claim 3 wherein determining maximum difference includes determining the maximum difference in two directions.

5. The method of claim 4 including determining the maximum difference based on the V component in an HSV color space.

6. The method of claim 4 including determining the maximum difference based on the Y component in YUV color space.

7. The method of claim 3 including building a histogram based on maximum difference of pixels versus their neighbors.

8. The method of claim 7 including determining if a screen change is a gradient image depending on whether the majority of maximum differences fall into lower histogram bins.

9. One or more non-transitory computer readable media storing instructions executed by a processor to perform a sequence comprising:

determining whether there is a partial change of screen that affects less than all of a display screen;

performing a spatial analysis of the partial screen change to decide if the partial screen is a gradient image; and

if so, disabling phase-in of the screen change and if not enabling phase-in of the screen change.

10. The media of claim 9, said sequence including detecting fast changing content and enabling phase-in only if the content is changing quickly.

11. The media of claim 9, said sequence wherein performing spatial analysis includes calculating the maximum difference of a pixel with neighboring pixels.

12. The media of claim 11 wherein determining maximum difference includes determining the maximum difference in two directions.

13. The media of claim 12, said sequence including determining the maximum difference based on the V component in an HSV color space.

14. The media of claim 12, said sequence including determining the maximum difference based on the Y component in YUV color space.

15. The media of claim 11, said sequence including building a histogram based on maximum difference of pixels versus their neighbors.

16. The media of claim 15, said sequence including determining if a screen change is a gradient image depending on whether the majority of maximum differences fall into lower histogram bins.

17. An apparatus comprising:

a processor to determine whether there is a partial change of screen that affects less than all of a display screen, perform a spatial analysis of the partial screen change to decide if the partial screen is a gradient image, and if so, disable phase-in of the screen change and if not enabling phase-in of the screen change; and

a storage coupled to said processor.

18. The apparatus of claim 17, said processor to detect fast changing content and enabling phase-in only if the content is changing quickly.

19. The apparatus of claim 17, said processor calculate the maximum difference of a pixel with neighboring pixels.

20. The apparatus of claim 19, said processor to determine the maximum difference in two directions.

21. The apparatus of claim 20, said processor to determine the maximum difference based on the V component in an HSV color space.

22. The apparatus of claim 20, said processor to determine the maximum difference based on the Y component in YUV color space.

23. The apparatus of claim 19, said processor to build a histogram based on maximum difference of pixels versus their neighbors.

24. The apparatus of claim 23, said processor to determine if a screen change is a gradient image depending on whether the majority of maximum differences fall into lower histogram bins.

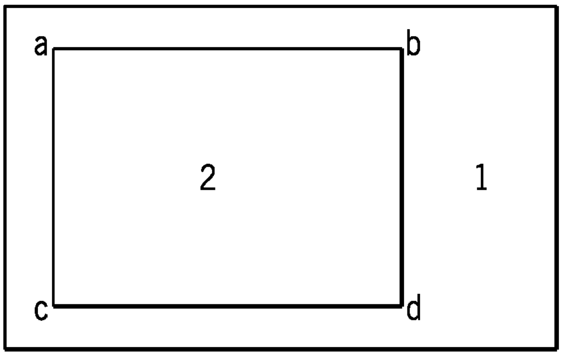
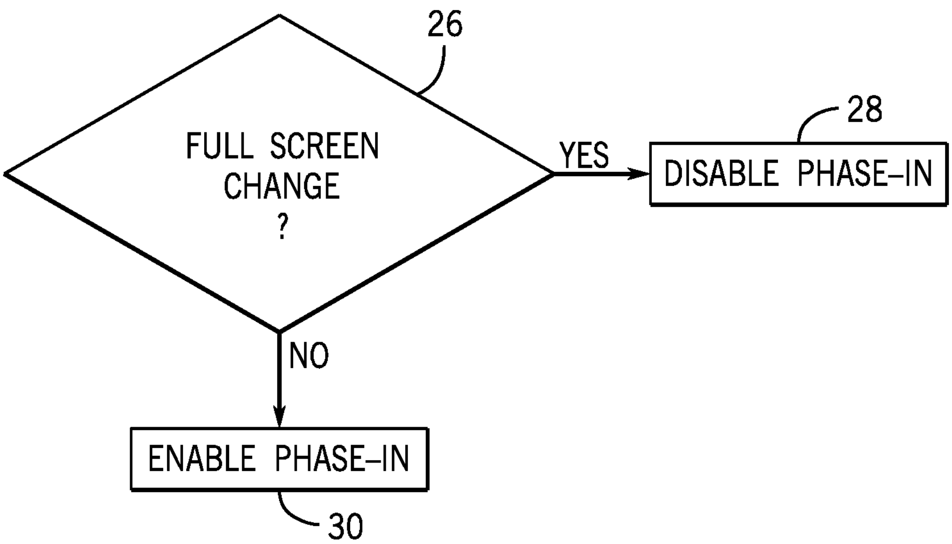

a
b
2
1
c
d

FIG. 1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ENABLE PHASE-IN
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FIG. 3

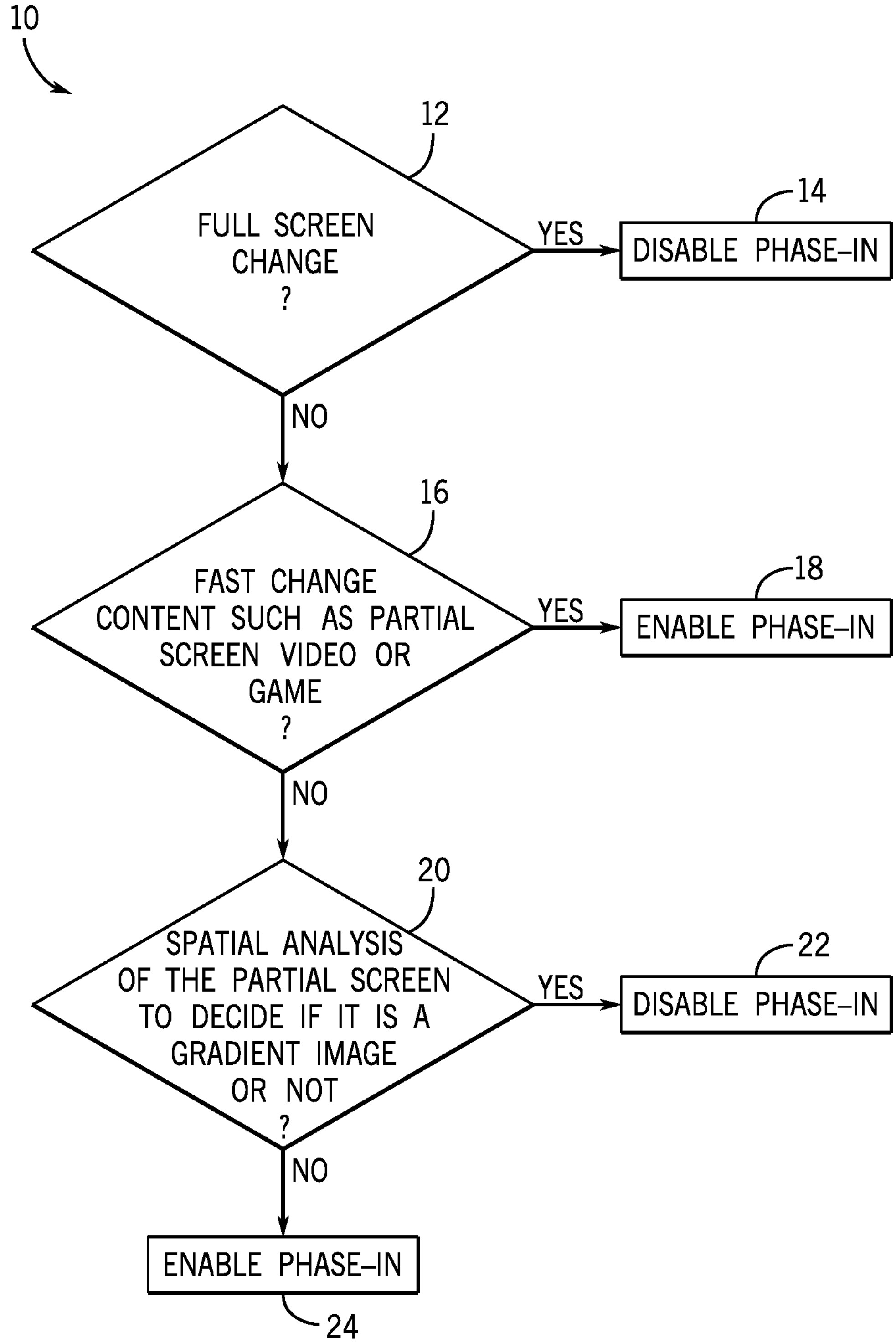

10
12
FULL SCREEN CHANGE ?
YES
14
DISABLE PHASE–IN
NO
16
FAST CHANGE CONTENT SUCH AS PARTIAL SCREEN VIDEO OR GAME ?
YES
18
ENABLE PHASE–IN
NO
20
SPATIAL ANALYSIS OF THE PARTIAL SCREEN TO DECIDE IF IT IS A GRADIENT IMAGE OR NOT ?
YES
22
DISABLE PHASE–IN
NO
ENABLE PHASE–IN
24

FIG. 2

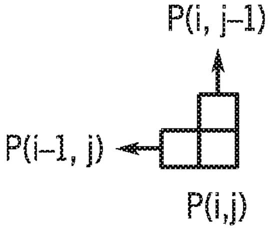


FIG. 4

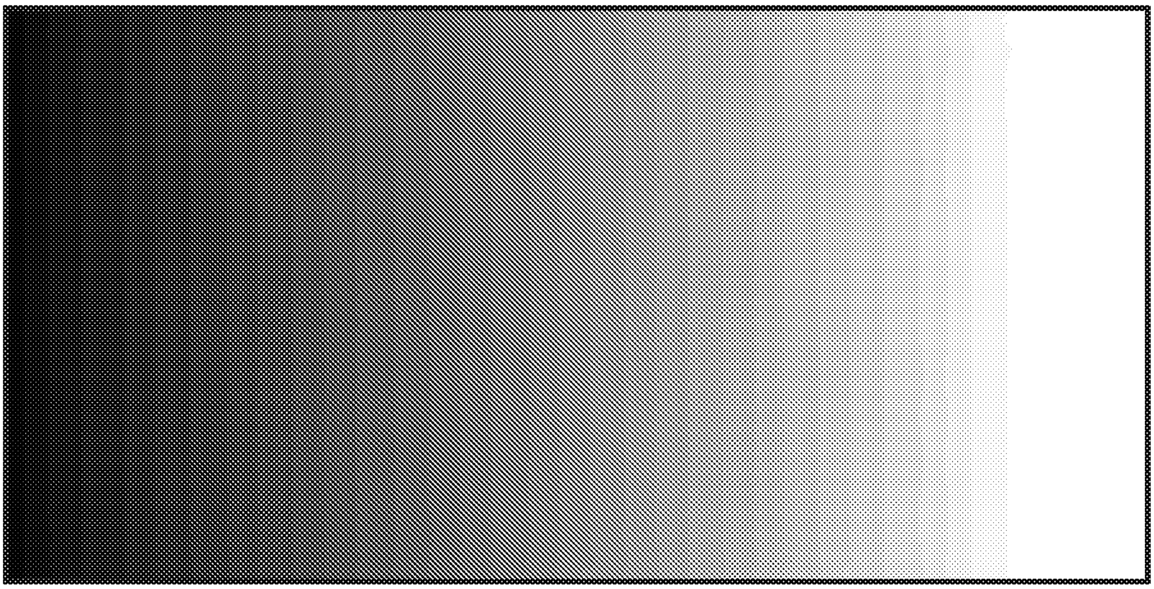
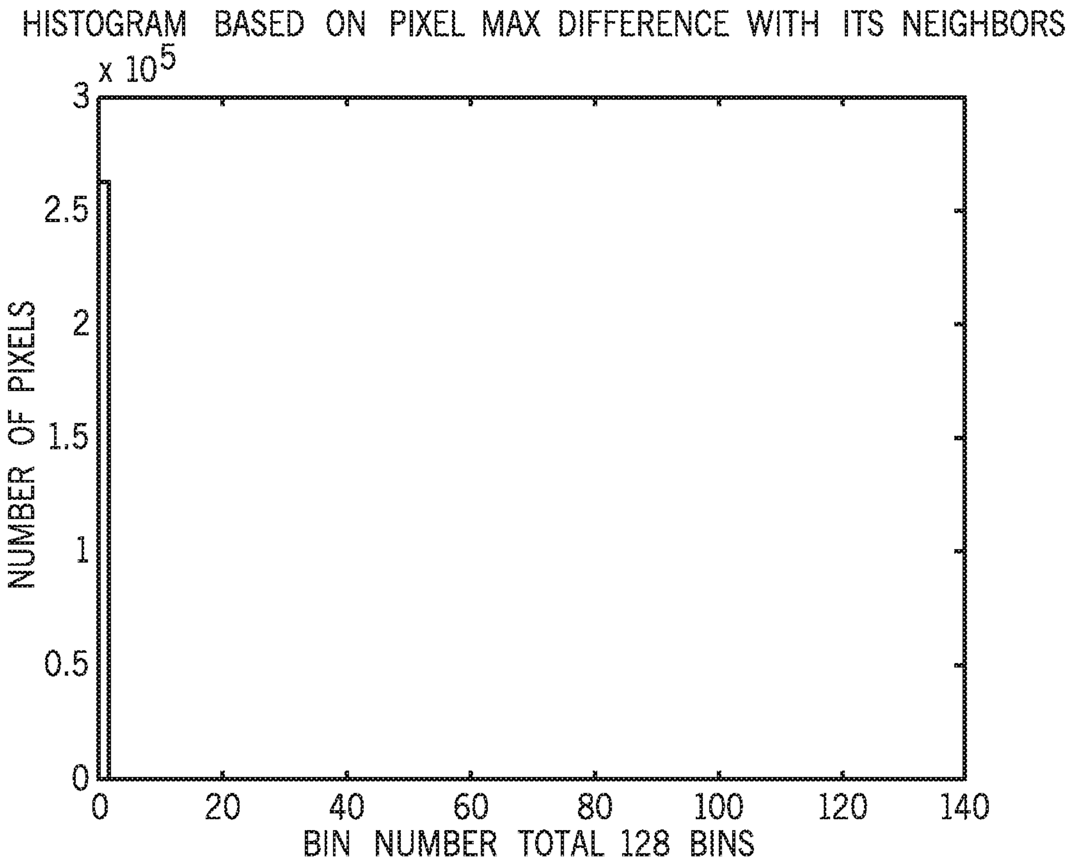


FIG. 5


HISTOGRAM BASED ON PIXEL MAX DIFFERENCE WITH ITS NEIGHBORS
x 10^5
3
2.5
2
1.5
1
0.5
0
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20
40
60
80
100
120
140
BIN NUMBER TOTAL 128 BINS

FIG. 6

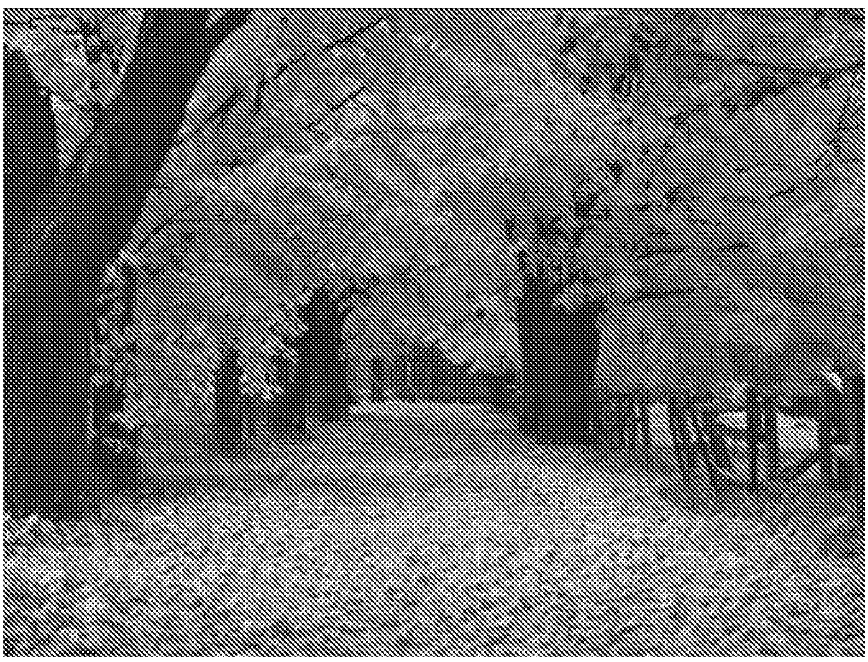
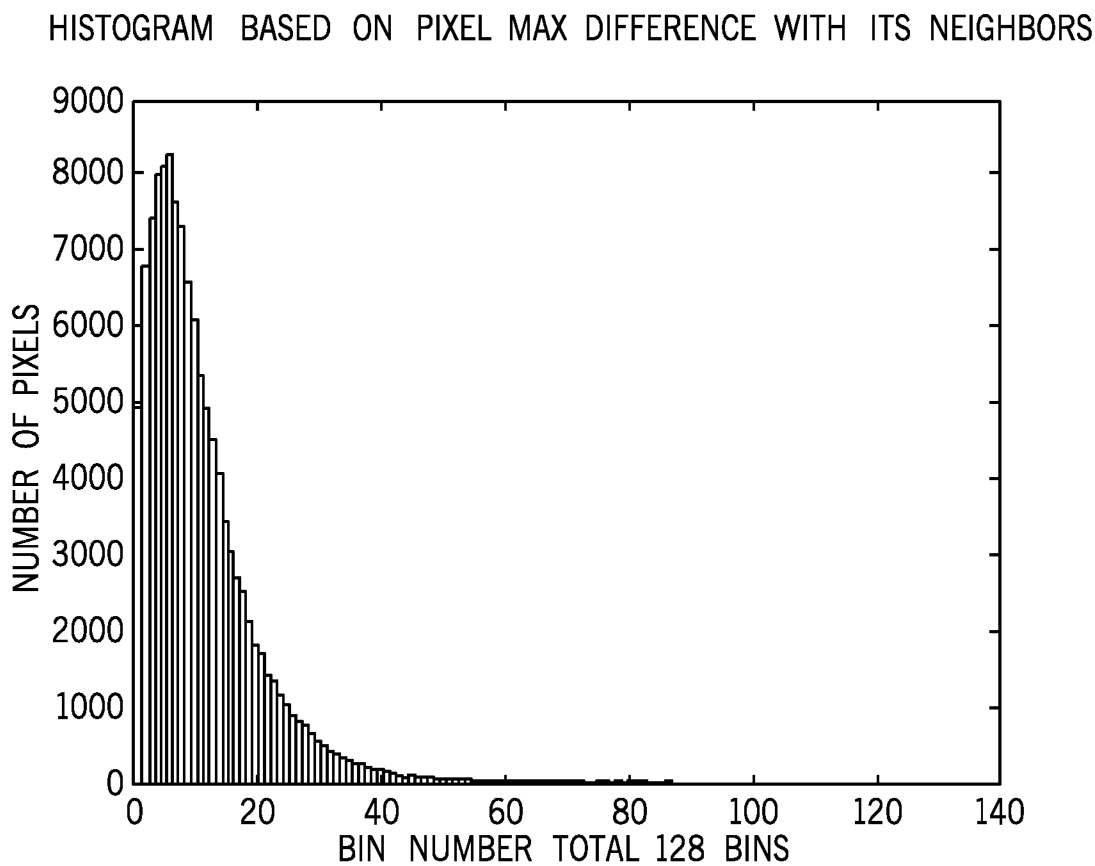


FIG. 7


HISTOGRAM BASED ON PIXEL MAX DIFFERENCE WITH ITS NEIGHBORS
NUMBER OF PIXELS
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8000
7000
6000
5000
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2000
1000
0
0
20
40
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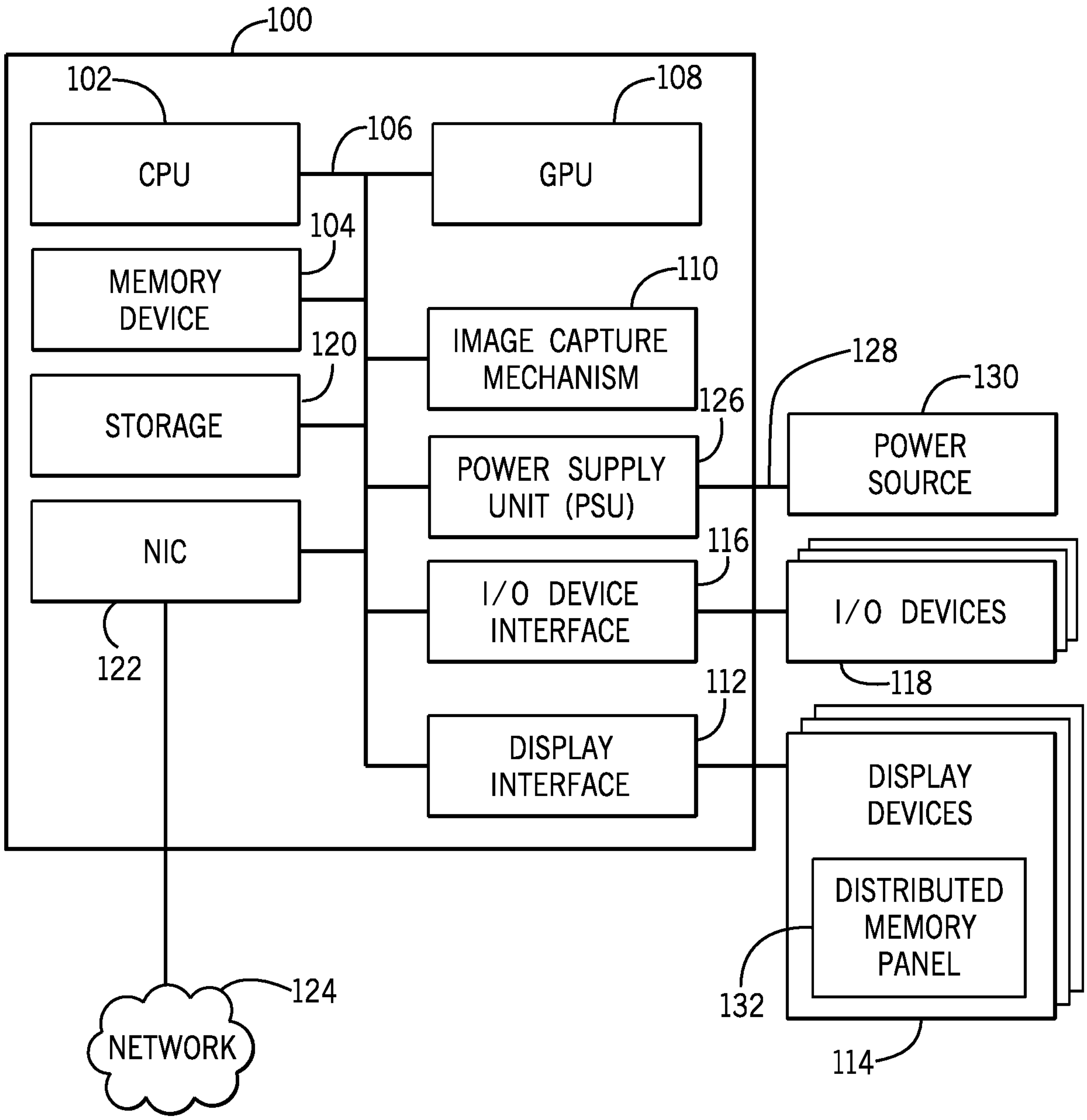
80
100
120
140
BIN NUMBER TOTAL 128 BINS

FIG. 8



100
102
CPU
106
108
GPU
104
MEMORY DEVICE
110
IMAGE CAPTURE MECHANISM
120
STORAGE
126
128
130
POWER SUPPLY UNIT (PSU)
POWER SOURCE
NIC
116
I/O DEVICE INTERFACE
I/O DEVICES
122
118
112
DISPLAY INTERFACE
DISPLAY DEVICES
DISTRIBUTED MEMORY PANEL
132
124
NETWORK
114

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/018880

A. CLASSIFICATION OF SUBJECT MATTER

G09G 3/34(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)
G09G 3/34; G09G 3/36; G09G 3/32; G06T 1/60; G06F 13/14; G09G 5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: partial change, gradient image, phase-in, spatial analysis, histogram

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0187937 A1 (LOUIS JOSEPH KEROFSKY et al.) 25 July 2013 See paragraphs [0024]-[0030]; claims 1-13; and figures 1-12.	1-24
A	US 2012-0162159 A1 (HYOUNG SU KIM et al.) 28 June 2012 See paragraphs [0046]-[0060]; claims 1-11; and figures 1-5.	1-24
A	US 2013-0278614 A1 (ANDREW SULTENFUSS et al.) 24 October 2013 See paragraphs [0016]-[0020]; claims 1-4; and figures 1-3.	1-24
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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