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March 2020

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Vicky Wen

Austin Chen

Yichi Chen

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Recommended Citation
Wen, Vicky; Chen, Austin; and Chen, Yichi, "SMOOTH BRIGHTNESS TRANSITION FOR COMPUTING DEVICES", Technical Disclosure Commons, (March 16, 2020)
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SMOOTH BRIGHTNESS TRANSITION FOR COMPUTING DEVICES

ABSTRACT

A brightness transition module is described that enables a computing device (e.g., a mobile phone, a camera, a tablet computer, etc.) to smoothly adjust an amount of light output by a display of the computing device when the computing device transitions between a high brightness mode and a normal mode (e.g., transitioning based on ambient lighting conditions). By smoothly adjusting the amount of light emitted by the display when transitioning between modes, the brightness transition module may prevent a sudden or abrupt change in the brightness (e.g., prevent a sudden flash when transitioning from the normal mode to the high brightness mode), thereby improving the user experience.

DESCRIPTION

Displays (e.g., of a computing device) may be able to operate in different modes, including a normal mode and a high brightness mode. The peak brightness of a display may vary based on the operating mode. For instance, the peak brightness of a display operating in the normal mode may be 450 nits while the peak brightness of the same display operating in the high brightness mode may be 700 nits. Some computing devices may adjust the operating mode of their displays based on ambient lighting conditions. For instance, a computing device may cause a display of the computing device to transition from the normal mode to the high brightness mode where a level of ambient light exceeds an ambient light threshold (e.g., where the device has been moved out into sunlight). However, when the computing device activates or disables the high brightness mode, the user will see a sudden brightness change due to the change in the display's peak brightness. Techniques described in this disclosure enable smooth brightness

transitions for a computing device in which the computing device automatically adjusts gray levels of pixels of a display when the computing device activates or disables the high brightness mode.

Figure 1 below is a conceptual diagram illustrating an example computing device configured to provide smooth brightness transitions. In the example of FIG. 1, computing device 100 may represent a mobile phone (including a so-called smartphone), a tablet computer, a laptop computer, a desktop computer, a server, a mainframe, a set-top box, a television (including a so-called “smart television”), a wearable device (e.g., a computerized watch, a computerized eyewear, a computerized glove, etc.), a home automation device or system (e.g., an intelligent thermostat or home assistant device), a personal digital assistant (PDA), a gaming system, a media player, an e-book reader, a mobile television platform, an automobile navigation or infotainment system, a smartwatch, a virtual reality device, an augmented reality device, a mixed reality device, a head mounted display device, or any other type of mobile, non-mobile, wearable, and non-wearable computing device that contains display capable of operating in a normal mode and a high brightness mode.

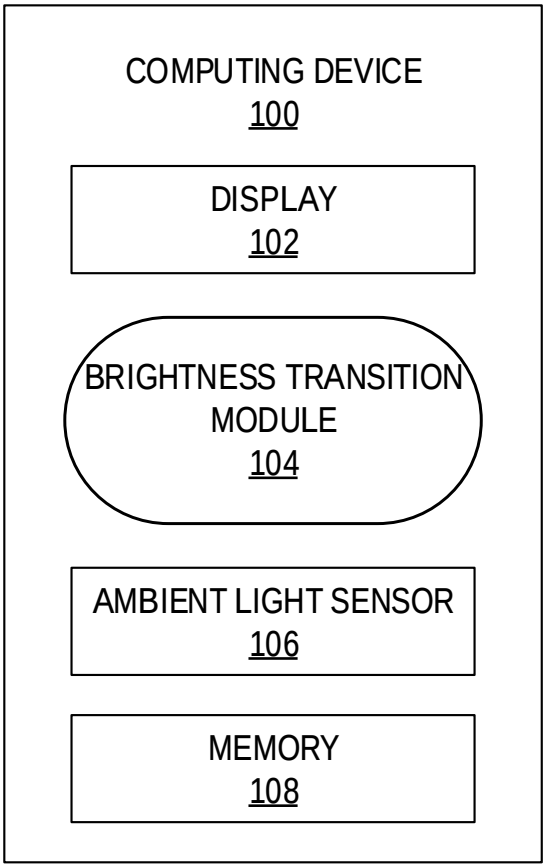

FIG. 1

In the example illustrated in FIG. 1, computing device 100 includes a display 102, a brightness transition module 104, an ambient light sensor 106, and a memory 108. Display 102 may be a liquid crystal display (LCD), a thin-film transistor display (TFT), an organic light emitting diode display (OLED), or any suitable display. In some examples, display 102 may be a projector. Display 102 may be capable of operating in a plurality of modes that each have a different peak brightness. As one example, in a normal mode of the plurality of modes, display 102 may have a relatively low peak brightness (e.g., approximately 500 nits or less). As another example, in a high brightness mode of the plurality of modes, display 102 may have a relatively high peak brightness (e.g., approximately 700 nits or more). Display 102 may consume more

power when operating in the high brightness mode than when operating in the normal mode. When a higher brightness is needed, such as because the ambient light level is higher, display 102 may transition from the normal mode to the high brightness mode. For example, it is generally accepted that in an environment with relatively bright sunlight, contrast is important for display readability. Thus, when display 102 transitions from the normal mode to the high brightness mode due to a higher ambient light level, the brightness of colors in the region of maximum sensitivity of the human eye may be increased to provide increased contrast. In some examples, the transition between the normal mode and the high brightness mode may be performed by a display device integrated circuit (DDIC), such as an application specific integrated circuit (ASIC). In some examples, such DDIC executes instructions that are stored on memory 108 or on the circuit itself.

Ambient light sensor 106 may sense an amount of ambient light present near computing device 100 and output light data that represents a light intensity of ambient light to brightness transition module 104. Examples of ambient light sensor 106 include, but are not limited to, photoresistors, photodiodes, and the like.

Brightness transition module 104 may represent an application, service, or component executing at or accessible to computing device 100 that enables the computing device to adjust the gray levels of the pixels of display 102. In some examples, brightness transition module 104 may be a native application provided by a first-party developer or by a third-party developer and may be pre-installed or downloaded from an application market. As an alternative, brightness transition module 104 may be integrated into an operating system that provides an execution environment in which applications execute.

Brightness transition module 104 may receive the light data that represents a light intensity of ambient light from ambient light sensor 106. Based on the received light data, brightness transition module 104 may automatically activate or disable the high brightness mode. For example, if computing device 100 is moved (e.g., carried by a user) from a dim environment to a bright environment (e.g., from indoor to outdoor), light data provided by ambient light sensor 106 may indicate a change in ambient light level. Brightness transition module 104 may analyze the provided light data and determine, based on the light data, whether to activate or disable the high brightness mode. As one example, where display 102 is operating in the normal mode and a value of the light data upwardly crosses a light threshold (e.g., goes from below to above the light threshold, which may be 5k lux), brightness transition module 104 may activate the high brightness mode (e.g., determine to transition to the high brightness mode from the normal mode). As another example, where display 102 is operating in the high brightness mode and a value of the light data downwardly crosses the light threshold (e.g., goes from above to below the light threshold), brightness transition module 104 may activate the normal mode (e.g., determine to transition to the normal mode from the high brightness mode).

As discussed above, the peak brightness of display 102 may vary greatly depending on whether display 102 is operating in the normal mode versus the high brightness mode. As such, the high brightness mode allows a change in peak luminance for display 102 from a relatively low peak brightness (e.g., 450 nits) to a relatively high peak brightness (e.g., 700 nits). When the operating mode of display 102 is changed from the normal mode to the high brightness mode, the resulting sudden increase in peak luminance may be undesirable. In accordance with one or more techniques of this disclosure, brightness transition module 104 may gradually adjust the brightness of display 102 from the normal mode to the high brightness mode. For instance,

brightness transition module 104 may alter the gray levels of pixels of display 102 in order to create intermediate peak brightness levels between the peak brightness of the normal mode and the peak brightness of the high brightness mode. Brightness transition module 104 may determine a quantity of intermediate peak brightness levels based on a target setting. The target setting may be set by a user or may be provided by a first-party developer. For example, the user may set a target setting to increase the brightness of display 102 by a certain brightness per step (e.g., 50 nits per step) and/or may set a duration of each step (e.g., 5 seconds per step). Where the peak brightness of the normal mode is 450 nits, the peak brightness of the high brightness mode is 700 nits, and the step size is 50 nits, brightness transition module 104 may step through intermediate peak brightness levels of 500, 550, 600, and 650 nits before arriving at the final peak brightness level of 700 nits. In this way, brightness transition module 104 may help to avoid a sudden change in the brightness of display 102.

In some examples, brightness transition module 104 may use a lookup table to determine the corresponding gray levels of intermediate peak brightness levels. Figure 2 below illustrates an example lookup table. The lookup table may be stored in memory 108 of computing device 100. Memory 108 may represent a magnetic hard disc, an optical disc, a floppy disc, a flash memory, or any suitable storage unit.

	700nits	650 nits	600nits	550nits	500nits	450nits
Gray Levels	255	248	238	228	220	209
	254	248	238	228	220	209
	253	247	237	227	219	208
	252	246	236	226	218	207
	251	245	235	225	217	206
	250	244	234	224	216	205
	249	243	233	223	215	205
	248	242	232	222	214	204
	247	241	231	221	214	203
	246	240	230	220	213	202
	245	239	229	220	212	201
	244	238	228	219	211	200
	243	237	227	218	210	200
	242	236	226	217	209	199
	241	235	225	216	208	198
	240	234	224	215	208	197
	239	233	224	214	207	196
	238	232	223	213	206	196
	237	231	222	212	205	195
	236	230	221	212	204	194
	⋮	⋮	⋮	⋮	⋮	⋮
	⋮	⋮	⋮	⋮	⋮	⋮
	1	1	1	1	1	1
	0	0	0	0	0	0

FIG. 2

When computing device 100 sets display 102 from the normal mode to the high brightness mode (e.g., peak brightness changes from 450 nits to 700 nits), instead of directly set the gray levels of the pixels of display 102 to original gray levels (i.e., gray level 250), brightness transition module 104 may use the lookup table to transform the original gray levels of the pixels of display 102 to corresponding gray levels of a brightness in the normal mode (e.g., gray level

205 of 450 nits). Brightness transition module 104 may gradually increase the brightness of display 102 by transforming the original gray level of the pixel to corresponding gray levels for intermediate peak brightness levels. For example, to achieve a smooth transition from the normal mode to the high brightness mode (e.g., peak brightness changes from 450 nits to 700 nits), brightness transition module 104 may gradually adjust the gray level of the pixel to 209, 220, 228, 238, 248, and 255 to increase the brightness of display 102 by 50 nits per step. In this way, brightness transition module 104 may smoothly adjust the brightness of display 102 from a relatively low peak brightness to a relatively high peak brightness by adjusting gray levels of the pixels of display 102 according to the lookup table.

It is noted that the techniques of this disclosure may be combined with any other suitable technique or combination of techniques. As one example, the techniques of this disclosure may be combined with the techniques described in U.S. Patent Publication 2017/0110092 A1. As another example, the techniques of this disclosure may be combined with the techniques described in U.S. Patent Publication 2015/0070337 A1.