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Improving Under-Display Fingerprint Authentication Latency by Normalizing Frame Luminance

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Abstract:

This publication describes systems and techniques directed to improving under-display fingerprint authentication latency by normalizing frame luminance. In aspects, a computing device having an organic light-emitting diode (OLED) display and an under-display fingerprint sensor (UDFPS) includes a local high brightness mode manager configured to selectively adjust luminance and digital gray settings in a high-luminance region of the display for predetermined intervals. In so doing, user input may be stably illuminated during UDFPS image capturing, facilitating UDFPS sensing, and improving under-display fingerprint authentication latency.

Keywords:

Display panel, display driver integrated circuit (DDIC), frame rate, active-matrix organic light-emitting diode (AMOLED), organic light-emitting diode (OLED), localized brightness compensation, local high brightness mode (LHBM), first frame dimming (FFD), under-display fingerprint sensor (UDFPS), latency, biometric authentication

Background:

Biometric authentication systems (e.g., fingerprint authentication, face authentication) provide personalized and convenient methods of user authentication to computing device users. Fingerprint scanning, for example, is a method that enables quick and reliable user authentication, denying or permitting user access to computing devices based on authorized fingerprints. Computing devices offering fingerprint scanning may often possess an optical under-display

fingerprint sensor (UDFPS). Using a UDFPS, a user may attempt authentication by providing user input (e.g., a fingerprint) to the computing device. For example, a user may place one or more fingers on a display of the computing device directly above the UDFPS. The display may illuminate the user input such that the UDFPS can capture reflected light and generate frames ("image capturing") at a predetermined frequency (e.g., frame rate). The frames may then undergo processing before being evaluated by a fingerprint-matching algorithm ("matcher"). For example, the matcher may authenticate the user input based on whether information (e.g., minutia of a fingerprint, minutia of a face) inferred from the frames matches an enrolled frame of a previously authenticated user input.

However, if the user input is illuminated sub-optimally (e.g., dimly, inconsistently) during UDFPS sensing, user authentication may be delayed. For example, in some instances, an output of organic light-emitting diodes (OLEDs) in a display may gradually increase to a target luminance, providing inadequate illumination of the user input during an initial stage of UDFPS image capturing. This delay in luminance is an inherent property of OLED technology, known as first frame dimming (FFD), and may be caused by a hysteresis effect inherent to the components (e.g., transistors, capacitors) of the display driver integrated circuit (DDIC). As a result, matcher evaluation of the user input may be delayed until receipt of later frames, slowing user authentication. Biometric authentication systems with slower user authentication speeds are often undesirable to users.

Description:

This publication describes systems and techniques, implemented on a computing device (e.g., smartphone), directed to improving under-display fingerprint authentication latency by

normalizing frame intensity. In aspects, the computing device may have an active-matrix OLED (AMOLED) display, a UDFPS, and a local high brightness mode (LHBM) manager configured to selectively adjust luminance and digital signal settings in a high-luminance region of the display for predetermined intervals. An example computing device referred to herein is a smartphone. In other implementations, the computing device may be a variety of other consumer computing devices (e.g., tablets, laptops, smartwatches). The smartphone may include one or more processors, an input/output device (e.g., a display), sensor(s), and a computer-readable medium (CRM) for storing device data (e.g., user data, applications, an operating system). The processor(s) may be configured to execute instructions or commands stored on the CRM to implement an operating system, application(s), and the LHBM manager. For example, the processor(s) may execute instructions of the operating system to implement a biometric authentication system (e.g., fingerprint authentication, face authentication). Implementing fingerprint authentication may involve the processor(s) further executing instructions of the LHBM manager to activate the sensor(s), control a display, process signals, and trigger a biometric matching algorithm ("matcher").

The AMOLED display of the smartphone may include display circuitry having a display driver integrated circuit (DDIC), drivers, and an array of pixel circuits. The DDIC may include a timing controller and a data-line driver. The timing controller may provide interfacing functionality between the processor(s) and the drivers (e.g., data-line driver). For example, the timing controller may accept commands and data from the processor(s) and generate signals having appropriate voltage, current, and timing. The timing controller may then pass the signals to the drivers. The drivers may be operably coupled to pixel circuits via driver lines.

The sensor(s) of the smartphone may be located anywhere in or on the smartphone, such as within a housing of the smartphone, laminated underneath the AMOLED display of the smartphone, and so forth. The sensor(s) may include one or more of a touch input sensor (e.g., a touchscreen), a UDFPS, an image capture device (e.g., a camera), a fingerprint sensor (e.g., an ultrasonic fingerprint sensor, an optical fingerprint sensor), a proximity sensor (e.g., a capacitive sensor), or an ambient light sensor (e.g., a photodetector).

In an implementation, the sensor is a UDFPS laminated beneath the AMOLED display. Figure 1 illustrates a partial top plan view and a partial cross-sectional view of the smartphone having the UDFPS and the AMOLED display having a display panel stack including a cover layer and a display module.

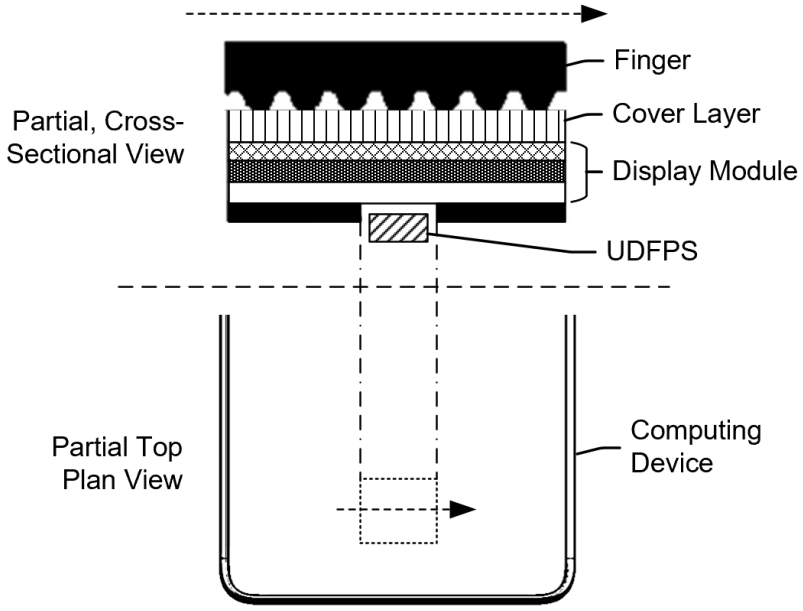

Figure 1. Top plan and cross-sectional views of a computing device having a UDFPS.

The UDFPS of the smartphone may be attached (e.g., bonded, laminated) to the underside of the AMOLED display. The UDFPS may be configured to capture reflected light of a user input (e.g., a fingerprint) transmitted through the AMOLED display. Upon capturing the reflected light

of the user input, the UDFPS may generate a frame containing a visual representation of the user input. The UDFPS may generate multiple frames at a predetermined frequency ("frame rate").

In aspects, during fingerprint authentication, the LHBM manager may instruct the processor(s) to implement a high luminance in a localized region of the AMOLED display ("high-luminance region"). The DDIC, implementing operations of the LHBM manager, may increase the luminance of the individual OLEDs of each pixel within the high-luminance region. Also implementing operations of the LHBM manager, the DDIC may direct the pixels in the high-luminance region to emit a specific color of light (e.g., red, green, blue) or a specific shade of gray to increase the luminance of the high-luminance region. For example, the DDIC may direct the pixels to emit gray 255 (G255) over G100 to increase luminance of the high-luminance region. Using the eight-bit color code, Figure 2 illustrates the difference in luminance for various shades of gray.

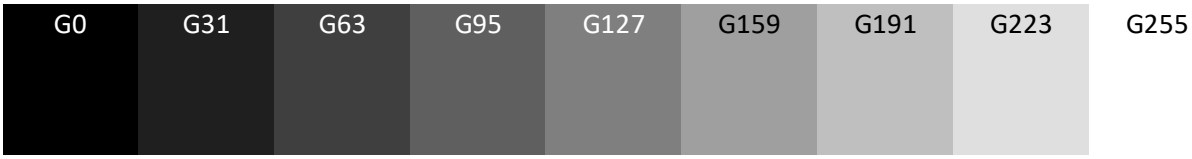

Figure 2. Eight-bit color code shades of gray.

The high-luminance region, implemented by the LHBM manager, may be localized anywhere on a portion of the AMOLED display, situated above the UDFPS, and defined by a two-dimensional shape (e.g., circle, square). The luminance of the high-luminance region, expressed in candela per square meter (nit), may be hundreds to thousands of nits greater in luminance than other portions of the AMOLED display during fingerprint authentication. As a result, during fingerprint authentication, the surface of the user input may be optimally illuminated, facilitating transmission of the reflected light through the display module and onto the UDFPS. The UDFPS may then generate vivid frames of the user input.

As described in the background, in some situations, during fingerprint authentication, the OLEDs in the high-luminance region of the AMOLED display may experience a response time delay ("latency") when driven by one or more drivers to increase in luminance, for example, known as first frame dimming (FFD). As a result of FFD, the luminance of the pixels in the high-luminance region may be lower than a target luminance, gradually increasing to the target luminance. The gradual increase in luminance may coincide with an initial stage of UDFPS image capturing (e.g., generating a first frame, generating a first couple of frames). Figure 3 illustrates a graphical representation of FFD in the high-luminance region during fingerprint authentication.

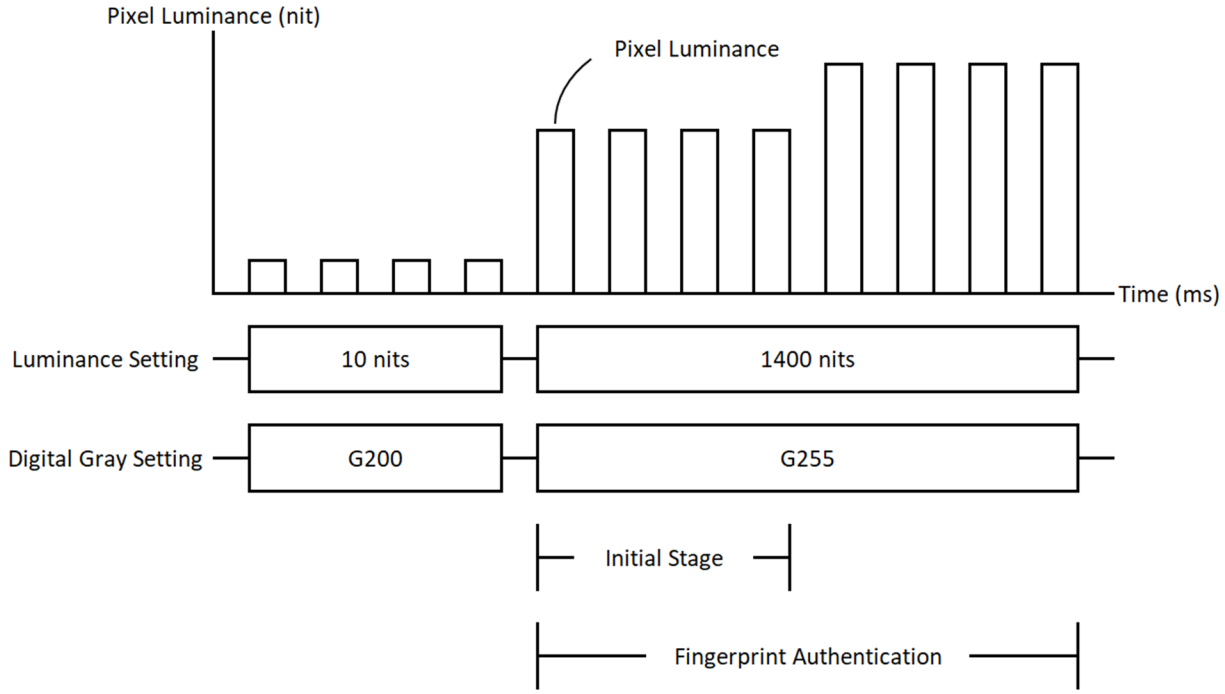

Figure 3. Graphical representation of FFD.

The pixel luminance versus time graph illustrates the pixel luminance of the high-luminance region gradually increasing in luminance during fingerprint authentication. Figure 3 further illustrates the timing of luminance and digital gray settings, implemented by the LHBM manager. As an example, prior to fingerprint authentication, the entire AMOLED display may emit light at a luminance of 10 nits and a color of G200. Upon initiation of fingerprint

authentication, pixel circuits of the pixel circuit array may receive data-line signals (e.g., voltages) from the data-line driver operably coupled to the DDIC to implement a luminance of 1400 nits and a color of G255. During an initial stage of fingerprint authentication, the pixels of the pixel circuits within the high-luminance region may emit light at a luminance of approximately 1000 nits, despite receiving data-line signals targeting a luminance of approximately 1400 nits. After the initial stage of fingerprint authentication, lasting tens of milliseconds (ms) (e.g., 25 ms), the pixels within the high-luminance region may then emit light at a luminance of approximately 1400 nits. FFD within the high-luminance region of the display may delay fingerprint authentication since the user input may be inconsistently illuminated from the first frame to the second and third frames, driving the UDFPS to generate additional frames.

Figure 4 illustrates a graphical representation of the LHBM manager compensating for display luminance latency in the high-luminance region during fingerprint authentication.

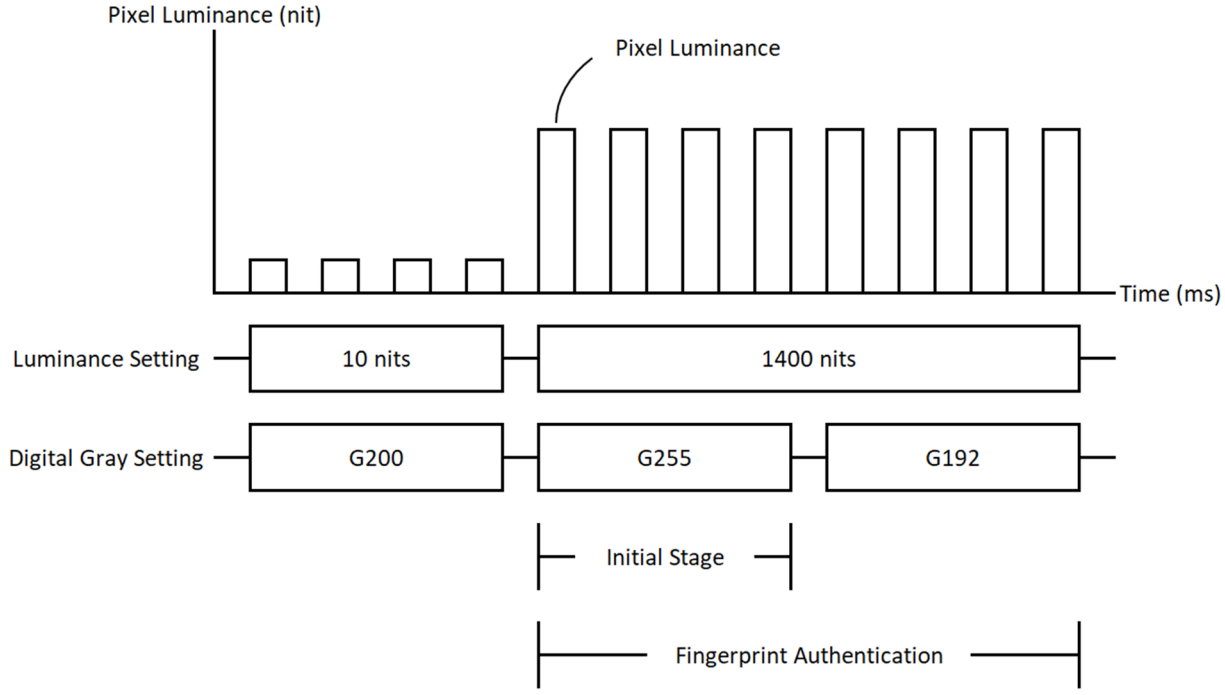

Figure 4. Graphical representation of compensating for luminance latency.

In aspects, during fingerprint authentication, the LHBM manager may compensate for FFD by normalizing the luminance after the initial stage of fingerprint authentication to the luminance during the initial stage of authentication. For example, during the initial stage of fingerprint authentication, it may be known that the pixel luminance is 80% that of the pixel luminance after the initial stage. It may also be known that the luminance of G192 is 80% of the luminance of G255. To normalize the luminance in the high-luminance region during fingerprint authentication, the LHBM manager may direct the pixels to emit G255 during the initial stage of fingerprint authentication and G192 after the initial stage. By so doing, the luminance of the high-luminance region during fingerprint authentication may be stable, eliminating the need for the UDFPS to generate additional frames after the initial stage of fingerprint authentication and improving user experience.

The LHBM manager may base the shade of gray after the initial stage of fingerprint authentication, during which the pixel circuits may be affected by, for example, FFD, on a golden calibration profile generated by a manufacturer of the display. The golden profile may be generated by the manufacturer, for example, by measuring the luminance of many AMOLED displays emitting various shades of gray. The empirical data from these measurements may be used to generate a luminance versus digital gray setting lookup table, graph, or the like.

Figure 5 illustrates a process flow for normalizing frame luminance in the high-luminance region of an AMOLED display of a smartphone during fingerprint authentication.

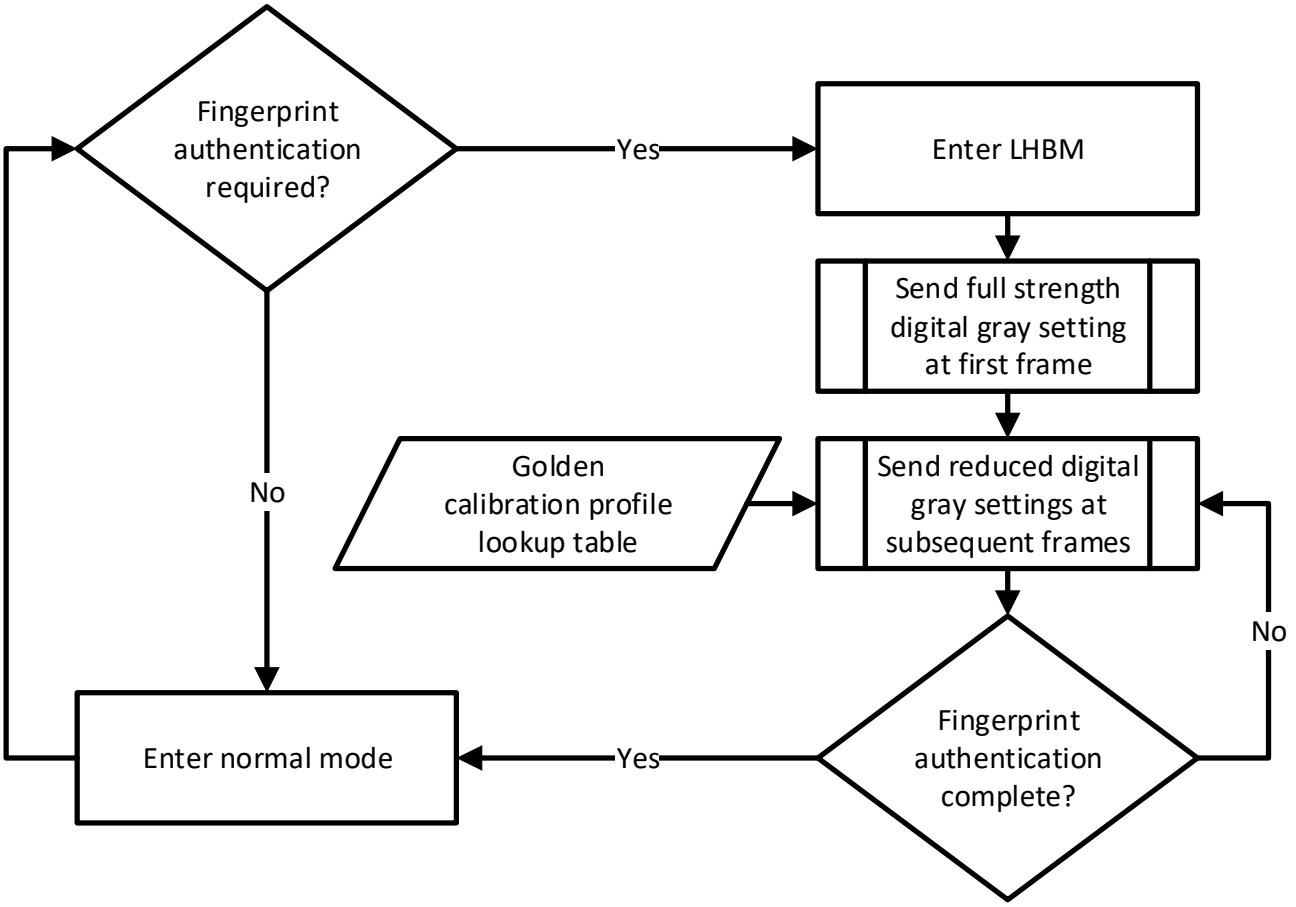

Figure 5. A process flow for normalizing frame luminance.

As illustrated in Figure 5, while fingerprint authentication is not required, the LHBM manager may direct the display to remain in a normal operating mode. When fingerprint authentication is required, the LHBM manager may direct the display to enter LHBM. During LHBM, the LHBM manager may direct the display to emit the full digital gray setting (G255) at the first frame. Then, based on the golden calibration profile lookup table, the LHBM manager may direct the display to emit reduced digital gray settings at subsequent frames. Once fingerprint authentication is complete, the LHBM manager may direct the display to return to the normal operating mode. In addition to compensating for FFD with digital gray setting adjustments, described above, the LHBM manager may combine said adjustments with luminance setting adjustments in a way that achieves the best power efficiency.

In another implementation, rather than compensating for FFD via the software techniques described above (e.g., LHBM manager, digital gray settings, luminance settings), a hardware compensator may compensate for FFD. The hardware compensator may be integrated into a system on a chip of the computing device. Alternatively, the hardware compensator may be integrated into the DDIC of the computing device. The hardware compensator may map an original image file to a tone-mapped image file. The tone-mapped image file may be a version of the original image file with a reduced digital gray setting based on the golden compensation profile lookup table. During fingerprint authentication, if it is the first frame of the LHBM, the hardware compensator may boost the reduced digital gray setting of the tone-mapped image file back to the digital gray setting of the original image file. If it is not the first frame of the LHBM during fingerprint authentication, the hardware compensator may boost the digital gray setting of the tone-mapped image file to a digital gray setting between that of the original image file and the tone-mapped image file. Alternatively, the hardware compensator may not boost the digital gray setting of the tone-mapped image at all, depending on the information provided by the golden calibration profile lookup table.

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