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Logical Camera Module for a Heterogeneous Camera System

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Logical Camera Module for a Heterogeneous Camera System

Abstract:

This publication describes techniques and apparatuses that enable a smartphone, with a heterogeneous camera system (*e.g.*, cameras having different physical specifications) to combine image information from multiple cameras utilizing a logical camera module. Cameras having different physical specifications include color cameras (*e.g.*, RGB cameras) and near-infrared (NIR) cameras. In one aspect, the logical camera module is implemented in an operating system of the smartphone and the logical camera module is accessible to applications on the device through an application programming interface (API). Applications may access the API to obtain color, depth, or color and depth image information.

Keywords:

Logical camera, heterogeneous camera system, multi-camera system, RGB camera, infrared camera, IR camera, near-infrared camera, NIR camera, camera sensor, image sensor, vertical synchronization, VSYNC, dot projector, flood illuminator, application programming interface, API.

Background:

An original design manufacturer may embed multiple cameras and sensors in or on a user equipment (UE), such as a smartphone, as is illustrated in Figure 1.

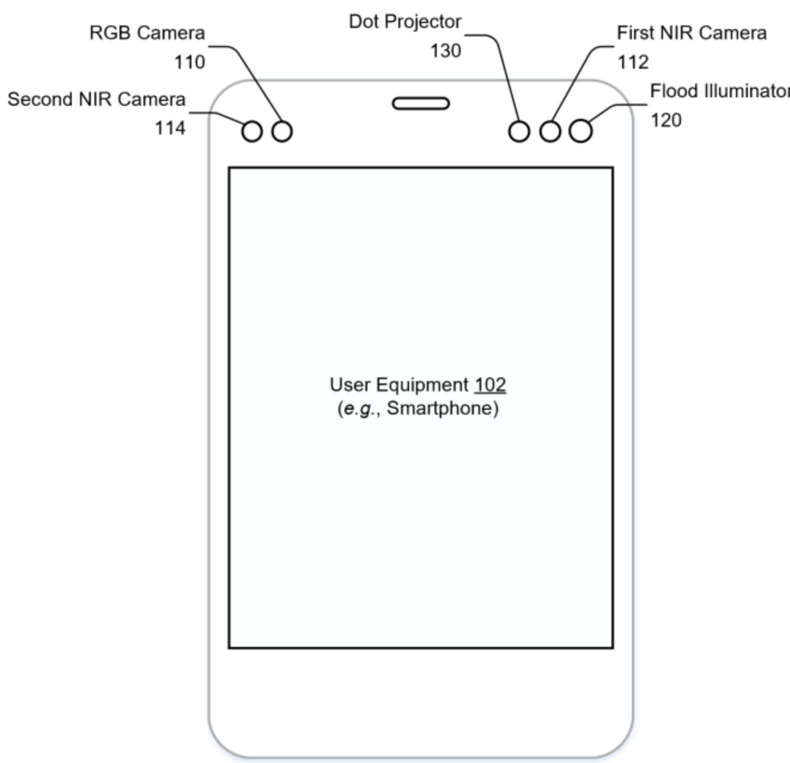

Figure 1

Figure 1 illustrates an example smartphone that contains front-facing components, including a color camera 110 (*e.g.*, RGB camera), a first near-infrared (NIR) camera 112 (first NIR camera), a second NIR camera 114 (second NIR camera), a flood illuminator 120 (flood illuminator), and a dot projector 130 (dot projector). Depending on the type of the activity, a user may use only the RGB camera, one of the NIR cameras, both NIR cameras, and/or all cameras. Utilizing a logical camera module, a user may utilize multiple cameras to generate an image.

A logical camera module that supports two or more image sensors of RGB cameras, however, does not properly support a heterogenous camera system that contains RGB *and* NIR image sensors. For a heterogeneous camera system that has at least one RGB image sensor and multiple NIR image sensors, the camera module needs to support both color (RGB) image capturing and depth (NIR) streaming, separately and/or concurrently. Therefore, it is desirable to have a technological solution that can support color, depth, or color and depth image capturing.

Description:

This publication describes techniques and apparatuses that enable a UE, such as a smartphone, with a heterogeneous camera system (*e.g.*, cameras having different physical specification) to combine image information from multiple cameras (*e.g.*, one RGB camera and two NIR cameras) by utilizing a logical camera module. In one aspect, the logical camera module is part of an operating system (OS) of the smartphone and the logical camera module is accessible to applications on the device using an application programming interface (API). Although this publication describes a heterogeneous camera system with one RGB camera and two NIR cameras, the same techniques and apparatuses can be used in a heterogeneous camera system with one RGB camera and three NIR cameras, with two RGB cameras and two NIR cameras, with two RGB cameras and three NIR cameras, and with any combination of cameras that have different physical specifications.

Figure 2 helps illustrate how the logical camera module uses one RGB image sensor and two NIR image sensors to generate an image that has both color and depth information.

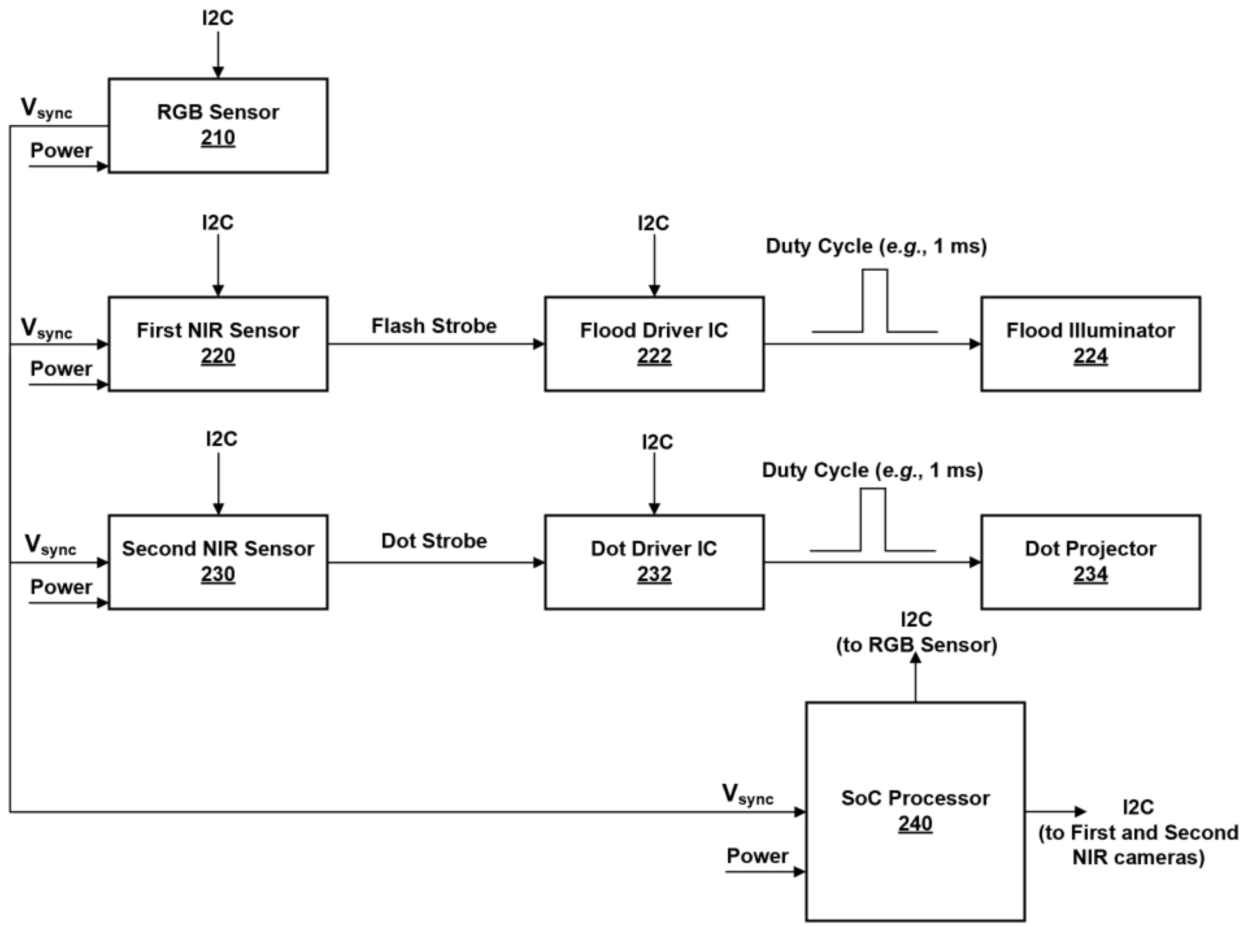

Figure 2

Figure 2 illustrates a heterogeneous camera system that includes an RGB image sensor 210 (RGB sensor) that operates as a leader (primary), a first NIR image sensor 220 (first NIR sensor) that operates as a follower (secondary), and a second NIR image sensor 230 (second NIR sensor) that also operates as a follower (secondary). The RGB sensor can be any sensor, such as a complementary metal-oxide-semiconductor sensor or a charge-coupled device sensor. The RGB sensor enables a user to capture color image information, and the NIR sensors enable the user to capture depth image information. The user, however, may want to capture color image information, depth image information, and/or color and depth image information depending on how they want to use the heterogeneous camera system (*e.g.*, low-light conditions, face authentication, daylight conditions). To do so, the logical camera module needs to synchronize the timing of the RGB sensor, the first NIR sensor, a flood driver integrated circuit (IC) 222 (flood driver IC), a flood illuminator 224 (flood illuminator), the second NIR sensor, a dot driver IC 232 (dot driver IC), a flood illuminator 234 (flood illuminator), and a system on chip (SoC) processor 240 (SoC processor). Note that the SoC processor may include any processor, such as a central processor unit or a multi-core processor.

The image sensors and the SoC processor receive power from a power source (not illustrated). As is illustrated in Figure 2, the RGB sensor operates as the primary image sensor by generating a vertical synchronization (V_{sync}) signal to align the three image sensors. From the RGB sensor, the heterogeneous camera system transmits V_{sync} to the first NIR sensor, to the second NIR sensor, and to the SoC processor, concurrently. Thus, V_{sync} helps synchronize all image sensors and enables the SoC processor to assign a timestamp to the images captured by each sensor. That way, each image sensor can support the timestamp feature when they are streaming separately and/or concurrently depending how the user operates the heterogeneous camera system. Also, the heterogeneous camera system utilizes an inter-integrated circuit (I^2C or I2C) communication protocol that controls the image sensors and the SoC processor, where the I2C communication is independent of the timing synchronization. The SoC processor sends a first I2C communication to the RGB sensor and a second I2C communication to the NIR sensors, the flood driver IC, and the dot driver IC. The first NIR camera controls the flood driver IC, and the second NIR camera controls the dot driver IC. The flood driver IC controls the flood illuminator, and the dot driver IC controls the dot projector. The first and the second NIR sensors share the same I2C communication bus, enabling a close time coupling of the NIR sensors. In turn, the close time coupling of the NIR sensors enables a close time coupling of the flood illuminator and the dot projector. Even though the RGB sensor does not share the same I2C communication bus with the NIR sensors, the SoC processor can still send an I2C communication to the RGB sensor that is also closely time coupled to the I2C communication with the NIR sensors, because the SoC processor receives the same V_{sync} signal from the RGB sensor.

Figure 3 illustrates the time synchronization of the RGB sensor, the first NIR sensor, the second NIR sensor, and the dot projector.

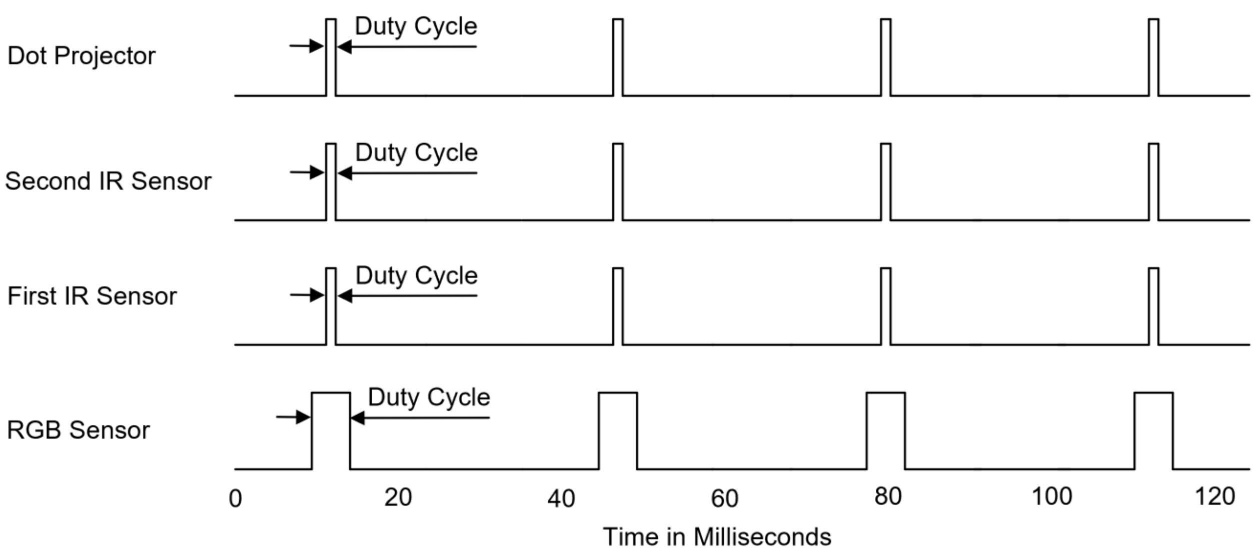

Figure 3

Figure 3 illustrates the RGB sensor with its associated duty cycle, the first NIR sensor with its associated duty cycle, the second NIR sensor with its associated duty cycle, and the dot projector with its associated duty cycle, over time (in milliseconds). As described herein, a duty cycle of an image sensor describes the amount of time the image sensor is exposed to light, and a duty cycle of an illuminator or a projector is the amount of time a light source illuminates or projects light. The signal V_{sync} helps synchronize the operating times of the RGB sensor, the first NIR sensor, and the second NIR sensor, where the operating times of each image sensor define the frames-per-second (FPS) frequency of each image sensor. The illustrated FPS frequencies and duty cycles are an example and do not necessarily represent the exact values that the described heterogeneous camera system uses. Nevertheless, the duty cycle of the NIR cameras is smaller (shorter) than the duty cycle of the RGB sensor, and the time synchronization of the NIR sensors is important to capture depth image information. A short duty cycle of the NIR cameras is one of many reasons why using the same bus for the I2C communication between the SoC processor and the NIR cameras can be helpful. Also, the logical camera module ensures a close synchronization of the dot projector and the NIR cameras, because the NIR cameras can only capture depth image information when the dot projector is operating.

In conclusion, the described logical camera module can properly support a heterogenous camera system that contains RGB *and* NIR sensors and enables various application software to utilize the heterogeneous camera system to successfully capture color, depth, or color and depth image information.

References:

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