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Display Brightness Based Camera Parameter Control for Selfie Capture in Darkness

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ABSTRACT

When a user in a dark room captures a selfie image or video using a front camera of a device, the display brightness can impact the captured image or video. Oscillations can occur due to a feedback loop between the image captured by the camera which when displayed on the device screen causes changes in display brightness. This disclosure describes techniques to automatically estimate the impact of display illumination on the face of a subject and slow down convergence. Per the techniques, exposure and/or white balance parameters for the camera are estimated using display illumination (brightness), depth (distance of the subject), and reflectance. Machine learning techniques or a lookup table or regression on historical data can be used for estimation. Oscillations in the captured image or video due to a feedback loop are reduced or eliminated.

KEYWORDS

- Display illumination
- Subject depth
- Subject luminance
- Selfie video
- Front camera
- Automatic exposure (AE)
- Automatic white balance (AWB)
- Image oscillation
- Ambient light
- Dark room

BACKGROUND

When the front camera on a smartphone or other device is used during video capture (e.g., during a video conference), light from the screen falls on the face of the subject if the subject is close to the front camera. When there is insufficient illumination (e.g., no other source of illumination if the subject is in a dark room), the brightness of the display can have a major impact upon the illumination of the face of the subject.

When the subject is closer to the display, the change in exposure and white balance of the front camera (which influences the captured image) can impact the display brightness and/or display white balance. This happens because of the different latencies between the auto-exposure (AE), automatic white balance (AWB), sensor, and display. In this situation, a feedback loop may arise between the display illumination and AE/AWB.

For example, the feedback loop can include the following steps:

1. Camera AE estimates that the scene is dark.
2. Exposure is increased to reach a target.
3. Display gets brighter due to the brighter captured frame (due to higher exposure). As a result, there is greater illumination on the face.
4. Camera AE estimates that the scene is bright.
5. Exposure is reduced to reach a target.
6. Display gets darker due to the lower brightness of the captured frame. As a result, the face receives lower illumination.
7. Go back to step 1.

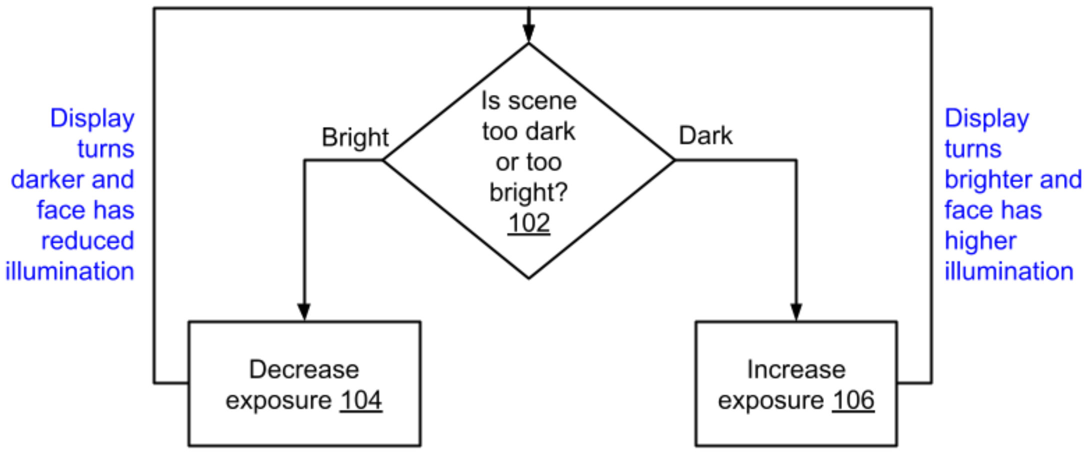

Fig 1: Feedback loop between the display illumination and auto exposure/white balance

Fig. 1 illustrates an example of how a feedback loop occurs while capturing video from a device front camera in situations where the subject is close to the camera in a dark zone such that the screen brightness of the device is the main source of illumination. The device's sensors will attempt to judge if the scene is too dark or too bright (102). If it is too bright, exposure is automatically decreased (104). The display turns darker as a consequence, and the face that is being captured will now show reduced illumination. If the scene is too dark instead, the exposure is automatically increased (106). This turns the display brighter, and the face that is being captured will not show higher illumination.

Implementation of auto exposure and auto white balance without considering such a feedback loop can cause oscillations or inconsistencies in the brightness and color of the captured video or image. For example, during a video call, the user's face in the video may oscillate between bright and dark (inconsistency in brightness) when there is no other source of illumination other than the display screen is in the user's vicinity. In this situation, the captured face region can also have inconsistency in color.

Some approaches include detecting that such oscillation is taking place (from calculated exposure and white balance values) and slowing down the convergence. This results in oscillations for a few frames before damping. It also affects the responsiveness of the AE/AWB.

DESCRIPTION

This disclosure describes techniques to estimate the impact of display illumination on the face of a subject and slow down convergence from the initial frame of captured video. Oscillation is thus controlled. If the subject is far, no restriction is placed on convergence, providing faster response. Per the techniques, exposure and/or white balance parameters for the camera are estimated based on display illumination (brightness), depth (distance of the subject), and reflectance. Machine learning techniques or a lookup table or regression on historical data can be used for such estimation. Oscillations in the captured image or video due to a feedback loop are reduced or eliminated.

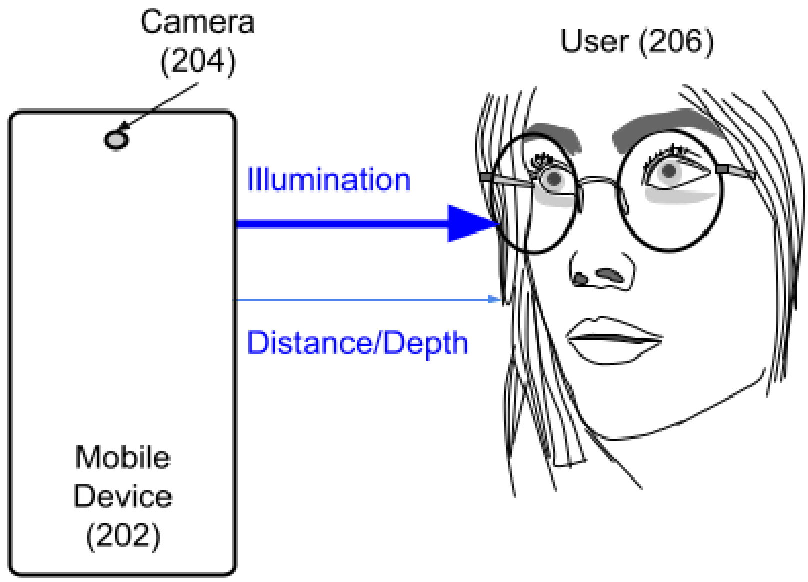

Fig 2: Automatic camera control during low light video capture

Fig. 2 illustrates automatic brightness control during low light video capture, per techniques of this disclosure. As shown in Fig. 2, a user (206) of a mobile device (202) is capturing video while in a location where the main source of illumination is the brightness of the device screen.

Per the techniques, the impact of display illumination on the user's face is estimated based on the display brightness and depth. The depth of the user's face may be estimated using a depth sensor and/or by using the face size as a proxy for monocular depth estimation. The display illumination is estimated based on the brightness value sent to the display hardware and the frame that is being displayed. For example, the display values sent to the display driver are obtained and are converted to nits (unit of brightness), e.g., by using a display calibration table.

The illumination at depth *d* can be estimated as:

```
Display_illumination (on subject) =
    kScalingConstant*DisplayIllumination/(depth*depth)
```

The display impact factor can then be calculated as:

```
Display impact factor =
    (Total subject luminance-ReflectanceFactor*Display_Illumination)/
    Total subject luminance
```

Based on the display impact factor, convergence can be adjusted without having to wait for oscillation to happen. The exposure target can be set as a function of display illumination, depth, and subject reflectance.

```
    Exposure Target=F(DisplayIllumination, Depth, SubjectReflectance)
```

The function *F()* can be a lookup table or a machine learning model.

In this manner, the described techniques enable automatic estimation of the impact of display illumination on the face of the subject and adjust camera parameters accordingly. This enables a device such as a smartphone, tablet, laptop computer, or any other device with a front facing camera, to capture high quality images with consistent color and without oscillations even under low light conditions.

The depth and the display illumination combined are used to estimate the impact of display illumination on the scene. Camera parameters for exposure and white balance are adjusted starting from the initial frames captured. Depending on the depth and the display illumination:

1. The exposure and white balance calculated can be limited to pretuned or dynamically calculated minimum and maximum values.
2. The convergence rate can be limited based on the calculated display illumination impact.
3. The history of estimated scene brightness, depth, display illumination and the exposure and white balance values, can be used to calculate the new exposure and white balance values.

The exposure and white balance limitation (1) and the slowing down of convergence (2) based on the likely impact of display illumination on the captured frames reduces the likelihood of oscillation for scenes affected by display illumination, while still maintaining faster responsiveness for other scenes. Exposure and white balance calculation based on the history of estimated scene brightness, depth, display illumination, can be factors to determine optimal exposure and white balance without overestimation or underestimation.

The described techniques can be implemented on any device that includes a camera and a display on the same side of the device, e.g., a smartphone (including foldable smartphones), tablet, laptop, etc. The techniques can also be used to adjust external camera parameters when the camera is on the same side as a display. No additional sensor is required to implement the techniques.

CONCLUSION

This disclosure describes techniques to automatically estimate the impact of display illumination on the face of a subject and slow down convergence. Per the techniques, exposure and/or white balance parameters for the camera are estimated using display illumination (brightness), depth (distance of the subject), and reflectance. Machine learning techniques or a lookup table or regression on historical data can be used for estimation. Oscillations in the captured image or video due to a feedback loop are reduced or eliminated.

REFERENCES

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