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Using Image-Processing Settings to Determine an Optimal Operating Point for Object Detection on Imaging Devices

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Abstract:

This publication describes techniques and processes for using image-processing settings (*e.g.*, Auto-Exposure (AE), Auto-Focus (AF), and/or Auto-White Balance (AWB)) to determine an optimal operating point for object detection by an object detector on an imaging device. An operating point is provided to the object detector by a manufacturer to enable the object detector to execute object detection. Through object detection, the object detector determines if an object is identified in the scene based on a confidence score. The optimal operating point has a computed image-processing setting that is closest to an ideal value of the image-processing setting. In an example, a fixed penalty function allows an optimal operating point to be determined using computed AE results for the image at different operating points compared to an ideal AE for the image. The smallest difference between the computed AEs and ideal AE corresponds to the optimal operating point for the image. The process can be repeated for many images to determine an optimal operating point across many types of images. Additionally, the process can be conducted with other image-processing settings, such as AF and AWB, to guide the selection of an optimal operating point across many settings. The determined optimal operating point can be provided to an object detector on an imaging device to provide a positive user experience with the imaging device.

Keywords:

Object detector, image detection, face recognition, object detection, Auto-Focus (AF), Auto-White Balance (AWB), Auto-Exposure (AE), imaging device, camera, ideal value, golden value, precision, recall, operating point, optimization, fixed penalty function, gain, threshold

Background:

In order to improve the quality of an image taken by an imaging device, such as a digital camera or a smartphone with image-capturing capabilities, the imaging device may utilize an object detector and image-processing settings. The object detector performs object detection to identify areas of interest within an image for image-processing settings to be optimized. In an example, the object detector may identify a face in an image and adjust image-processing settings, such as the 3A's (*e.g.*, Auto-Focus (AF), Auto-Exposure (AE), Auto-White Balance (AWB)) to produce a high-quality image of the identified face within a scene.

However, the object detector may not operate as intended. Using the face example, if the object detector has an operating point (*i.e.*, detection threshold) set too high, a face within an image may not be identified, and if the operating point is set too low, objects may be mistakenly identified as faces. The process to calculate the operating point of the object detector may rely on continuous tuning that attempts to optimize precision (*e.g.*, identifying all objects/faces) and recall (*e.g.*, identifying only objects/faces) by working through a large database of images and adjusting the operating point based on errors. However, continuous tuning may not produce the optimized operating point for image quality.

Therefore, it is desirable to determine an operating point of an object detector using a process that provides a single, optimal value for an operating point that corresponds to a high-quality image.

Description:

This publication describes techniques and processes for determining an optimal operating point for face/object detection by an object detector using image-processing settings (*e.g.*, Auto-Exposure (AE), Auto-Focus (AF), and/or Auto-White Balance (AWB)) as inputs to a fixed penalty function. The optimal operating point for face/object detection by an object detector has a computed image-processing setting that is closest to an ideal value of the image-processing setting. In an example, the fixed penalty function allows an optimal operating point to converge using AE computed for different operating points compared to an optimal AE, as will be discussed below in detail. Figure 1 illustrates examples of imaging devices that may utilize object detection technology.

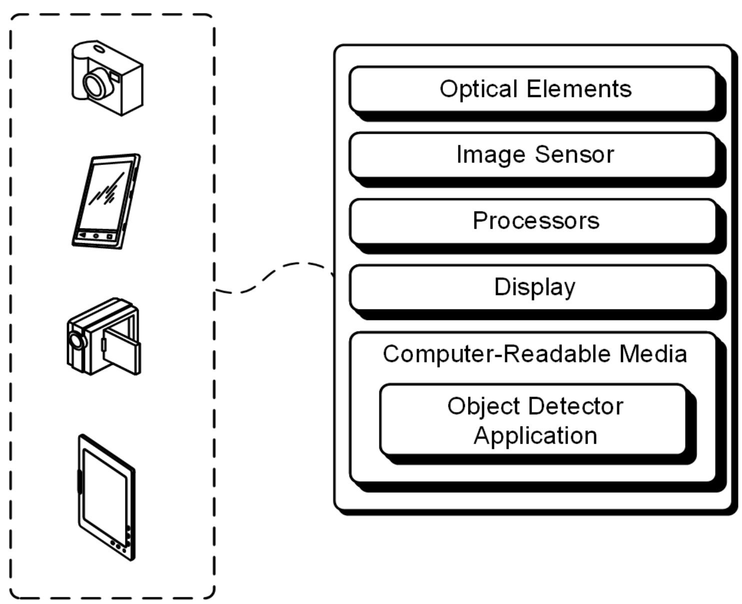

Figure 1

An imaging device can capture an image of a scene. In the example of Figure 1, the imaging device is illustrated as being a camera, a smartphone, a video recorder, or a tablet computer. The imaging device includes an image sensor (*e.g.*, a complementary metal-oxide-semiconductor (CMOS) image sensor, a charged-couple device (CCD) image sensor) for detecting information used to make an image. The imaging device may include one or more optical elements (*e.g.*, a lens, a mechanical shutter, an electrical shutter, an aperture). The imaging device may also include a display for displaying a user interface. The user interface may be configured to receive input from a user of the imaging device. The user interface may include one or more of a touchscreen, a button, a dial, or a keypad. Inputs may include, for example, parameters that are associated with one or more imaging device settings, a selection or deletion of a captured image, or activities associated with post-processing the captured image.

The imaging device further includes at least one processor (*e.g.*, an image processor for processing images, an image detector for detecting objects). The image processor (*e.g.*, an Image Signal Processor (ISP)) of the imaging device is utilized to improve the quality of images generated by the imaging device through image-processing settings such as black level correction, noise reduction, AWB, AE, and/or AF. In some cases, an image processor may also operate as an image detector, performing object detection (*i.e.*, an object detector).

The imaging device also includes executable instructions of an object detector application. The object detector application may be implemented on the computer-readable media (CRM) of the imaging device. The CRM may include any suitable memory or storage device such as random-access memory (RAM), read-only (ROM), or flash memory. The imaging device performs operations under the direction of the object detector application to 1) identify areas of interest in an image and 2) use the detection results so that the appropriate image-processing settings can be optimized for those areas.

For the object detector application to operate, a provider (*e.g.*, a manufacturer) provides an operating point to the object detector to execute object detection (*e.g.*, face detection), for example, to determine if an object is identified in the scene based on a confidence score. In aspects, if the object detector performing face detection executes with an operating point that is too high, a face within an image may not be identified, and if the operating point is too low, objects may be mistakenly identified as faces. Mistakes in facial identification can cause the overall image quality to be compromised. The optimal operating point of the object detector is the value for the operating point that can provide the overall best image quality.

The process for determining the optimal operating point of the object detector utilizes a fixed penalty function (*e.g.*, an algorithm for solving an optimization problem that allows a solution to converge) with image-processing settings as inputs to the function. Figure 2 illustrates a process 200 for determining the optimal operating point, using AE as an example input.

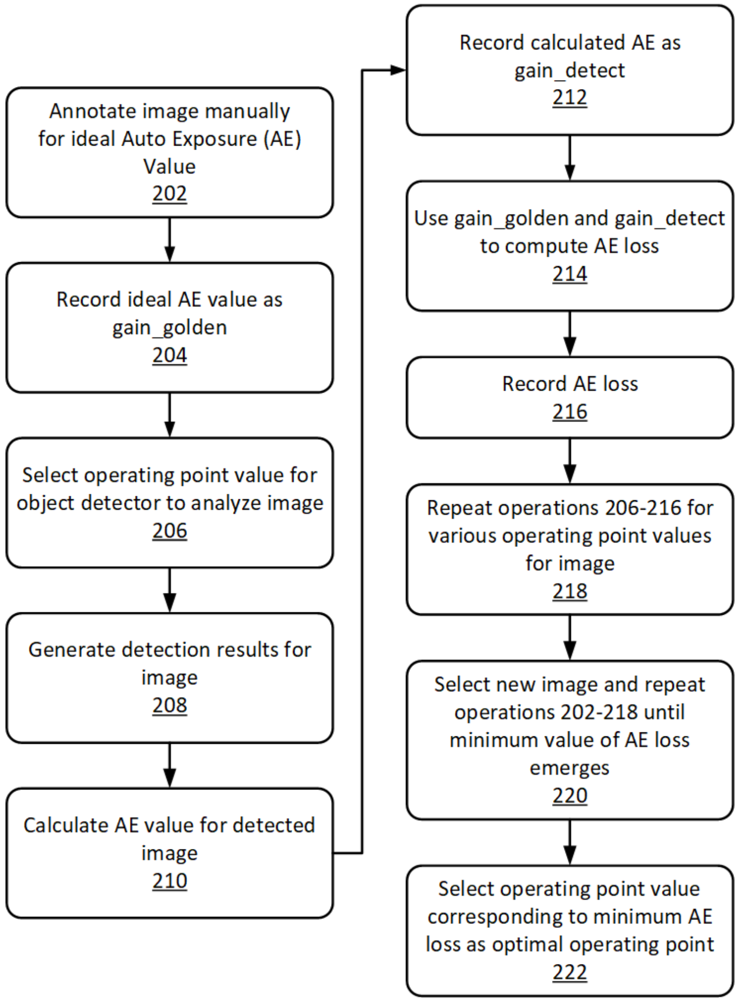

Figure 2

In a first operation 202, the ideal or "golden" AE value for an image (hereinafter "image1") is annotated by someone who is knowledgeable at photography and is able to identify objects (*e.g.*, faces) without error. Alternatively, the ideal AE value can be computed by using an ideal or "golden" object detection result and an AE algorithm. The AE algorithm can generate the ideal AE value based on the ideal object detection result. The ideal AE value for an image with a face would not overexpose the face, so the face appears white, nor would it underexpose the face, so that the face appears dark. For example, if a face is poorly illuminated in an otherwise well-lit scene, the ideal AE value balances how to best expose the face while maintaining the scene. This ideal AE value can be recorded as gain_golden at 204.

At 206, an operating point value (*i.e.*, a threshold) for objection detection is selected for an object detector. In aspects, multiple instances of operating point values, corresponding to different other environment variables, may be selected. For example, a first operating point value may be selected for low light indoor scenes, where the operating point value is obtained from a dataset that is from a low light scene; a second operating point value may be selected for a bright outdoor scene; a third operating point value may be selected for a city location scene; a fourth operating point value may be selected for a scene located in a national park; and so on. As discussed previously, a low operating point value will more often incorrectly identify objects, and a high operating point value will more often not detect objects in the image.

At 208, the object detector generates detection results for image1 based on the operating point value. At 210, an AE value for the detected image is calculated using the function: gain_detect=F(detect_result, image). The function uses the detection results along with the raw image in order to compute AE. In some examples, the detection results may have little effect on the overall AE value, but in other examples, such as objects that are backlit, the detection results will require a significant adjustment of the AE. The calculated AE value can be recorded as gain_detect at 212.

At 214, the difference between gain_detect and gain_golden is computed as AE loss and recorded at 216. At 218, operations 206-216 can be repeated with a different operating point value on image1 to calculate AE loss for image1. After completing an analysis of operating point values for image1, at 220, the process can select a different image and repeat operations 202-218 for image2, image3, …, image(i) for a large database. The analysis of operating point values is completed for image1 through image(i) when a minimum value of AE loss emerges. The minimum value of AE loss indicates the operating point where the calculated AE value (*i.e.*, gain_detect) is closest to the ideal AE value (*i.e.*, gain_golden). The minimum value of AE loss may be discovered by plotting AE loss vs. operating points (*i.e.*, thresholds) in a graph. Figure 3 illustrates an example graph using AE loss on a vertical axis plotted against thresholds on a horizontal axis. The combination of optimal operating points can be used to guide the selection of the optimal operating point provided to the object detector on an imaging device.

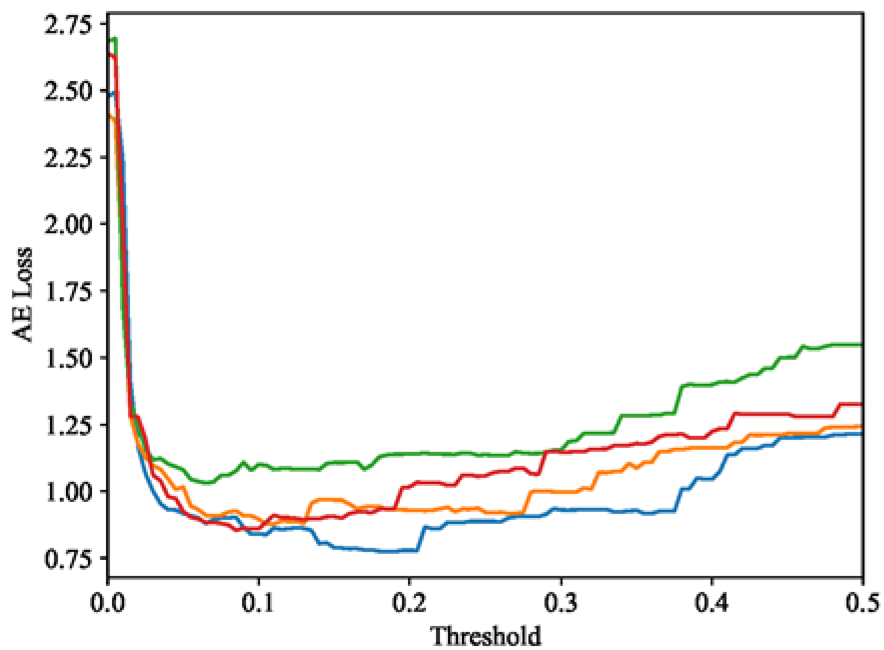

Figure 3

At 222, the operating point corresponding to the minimum AE loss can be selected. This operating point can be considered the optimal operating point for object detection based on image AE. The determined operating point may be for a particular dataset of images that are alike in some way, and accordingly, there may be multiple instances of operating point values corresponding to different environmental variables. For example, one operating point value may be used for low-light indoor scenes with the operating point value obtained from a dataset that is low-light scenes. Similarly, there may be an operating point value that may be used for bright outdoor scenes with the operating point value obtained from a dataset that is bright-light scenes. Additionally, the operating point value may depend on location (*e.g.*, city, national park, etc.).

Although AE is described as a first example, other image-processing settings such as AF and AWB can also be used as inputs to the penalty function. Using AF and/or AWB, the minimum loss can be found by repeating the process for many operating points with a single image and for many images in a large database until a solution for an optimal operating point emerges for each image-processing setting. Each image property setting (*e.g.*, AE, AF, AWB) may generate a different optimal operating point. The combination of optimal operating points across image-processing settings can be used to guide the selection of the optimal operating point provided to the object detector on an imaging device.