May 28, 2019

Identifying and Correcting an Edge-Fattened Area Generated by Stereo-Matching Techniques

Onur Guleryuz

Ambrus Csaszar

Identifying and Correcting an Edge-Fattened Area Generated by Stereo-Matching Techniques

Abstract:

This publication describes an image-boundary manager used in an image-capture device. The image-boundary manager uses a low-complexity algorithm to compute an edge-fattened area of a foreground object included in an image of a scene generated by the image-capture device. After computing the edge-fattened area of the foreground object, the image-capture manager assigns correct depth values to the edge-fattened area such that the image-capture device renders the foreground object, in a modified image of the scene, accurately and without the edge-fattened area.

Keywords:

image stereo-matching, image edge-depth, image boundary-depth, dual-imager smartphone, dual-pixel sensor, portrait mode image, augmented-reality image

Background:

An image-capture device, such as a digital camera or a smartphone with image-capturing capabilities, may capture and generate an image of a scene in a variety of modes. In some instances, the device may use stereo-matching techniques to generate the image of the scene and represent a depth between a foreground object and a background included in the scene. Examples of such modes include an augmented-reality mode, wherein the image-capture device places a virtual asset into the foreground of a scene while generating the augmented-reality image of the scene, and a portrait mode.

Today, and while operating in such modes, the image-capture device may use stereo-matching techniques to perform one or more calculations that triangulate points that are common to different perspectives of the scene to compute a depth map. The calculations, which are window-based calculations, match the points by calculating summed differences of pixel luminance within one or more windows of a different perspective of the scene.

For points that are in boundary areas of a foreground object that has a close background, such window-based calculations are adversely affected; foreground objects appear to have an edge-fattened area (*e.g.*, a distorted edge) using techniques of today to compute depth maps and render the image of the scene. An example contrasting a correct reference image versus a reference image incorporating such a calculated depth map is illustrated in Figure 1 below:

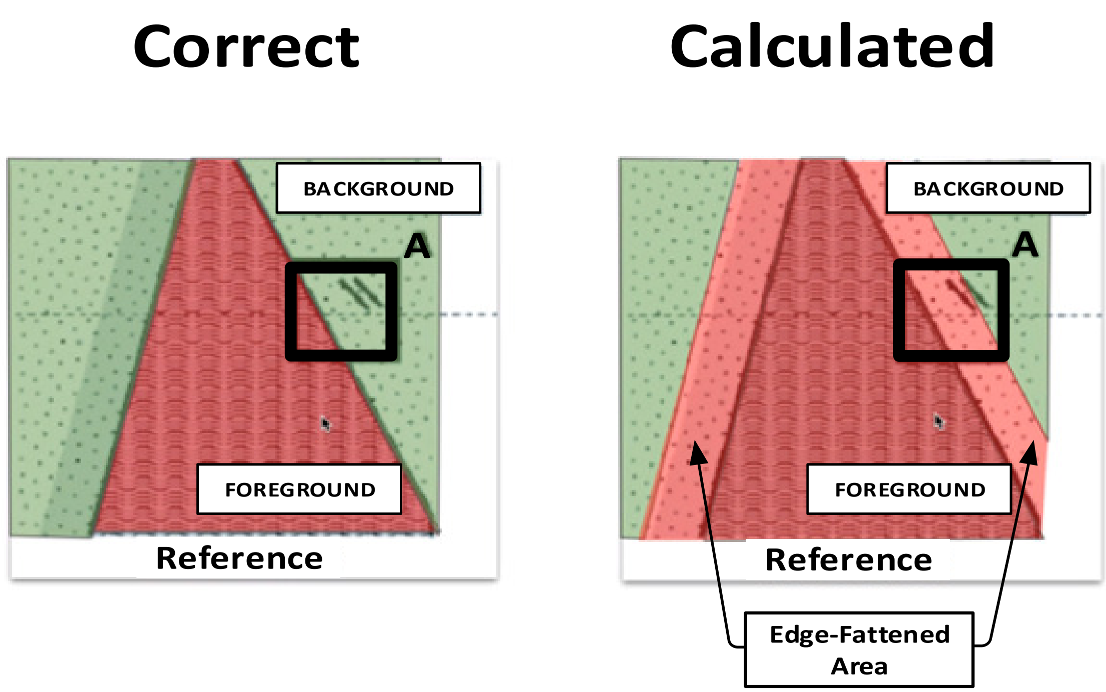

Figure 1

As illustrated by Figure 1, the stereo-matching techniques perform the window-based calculations (*e.g.*, using windows such as window “A”) to calculate the depth map that, when applied to the reference image for rendering, fattens the edges of the foreground object. This fattening has several detrimental effects, including a distortion of the edges of the foreground object and an enlargement of a size of the foreground object disproportionately.

Description:

This publication describes an image-boundary manager used in an image-capture device. The image-boundary manager uses a low-complexity algorithm to compute an edge-fattened area of a foreground object included in an image of a scene generated by the image-capture device. After computing the edge-fattened area of the foreground object, the image-capture manager assigns correct depth values to the edge-fattened area such that the image-capture device renders the foreground object in the scene accurately and without the edge-fattened area.

Figure 2 illustrates example image-capture devices having the image-boundary manager:

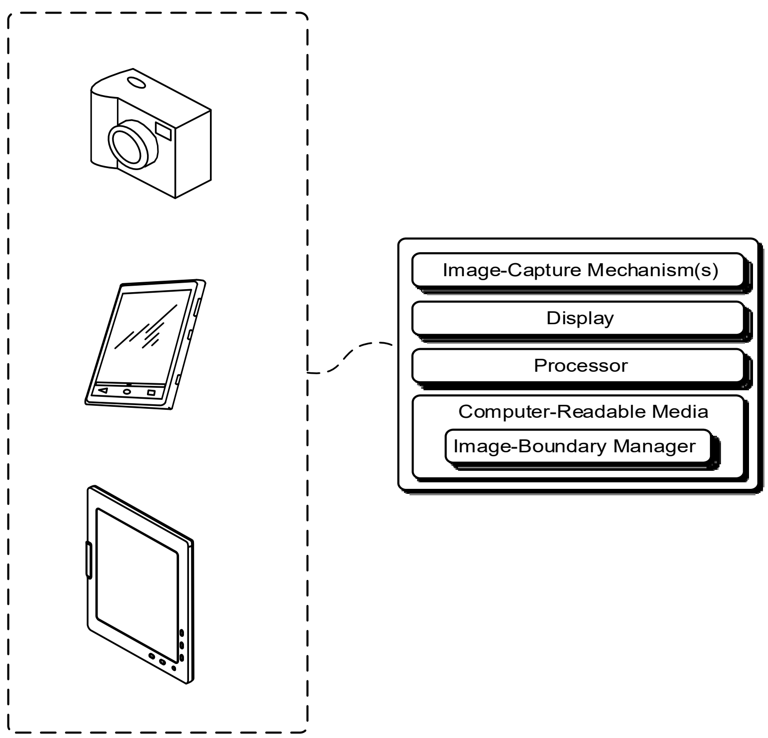

Figure 2

As illustrated, and as non-limiting examples, the image-capture device having the image-capture manager may be a camera, a smartphone, or a tablet. The image-capture device may include one or more image-capture mechanisms that may be complementary metal-oxide semiconductor (CMOS) image sensors or charge-coupled device (CCD) image sensors. In an instance where the image-capture device includes one image-capture mechanism, the image-capture mechanism may use dual-pixel sensing technology (*e.g.*, photodiodes located on complementary sides of a pixel) for depth calculations (*e.g.*, stereo matching). In an instance where the image-capture device includes multiple image-capture mechanisms, the multiple-image capture mechanisms may capture an image of a scene from different perspectives for the depth calculations.

The image-capture device includes a display, such as a liquid crystal display (LCD) or a light emitting diode (LED) display, for rendering the image of the scene. The image-capture device also includes a processor and a computer-readable medium (CRM). The processor may be a single core processor or a multiple core processor composed of a variety of materials, such as silicon, polysilicon, high-K dielectric, copper, and so on. The CRM may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory.

The CRM includes executable instructions of an image-boundary manager which includes a low-complexity algorithm. The instructions of the image-boundary manager, when executed by the processor, cause the image-capture device to compute an edge-fattened area of a foreground object in a scene captured by the one or more image-capture mechanisms. The instructions of the image-boundary manager also, when executed by the processor, assign correct depth values to the edge-fattened area such that the image-capture device can render the foreground object in the scene on its display, in a modified image, accurately and without the edge-fattened area.

Figure 3, below, illustrates an example method performed by the image-capture device:

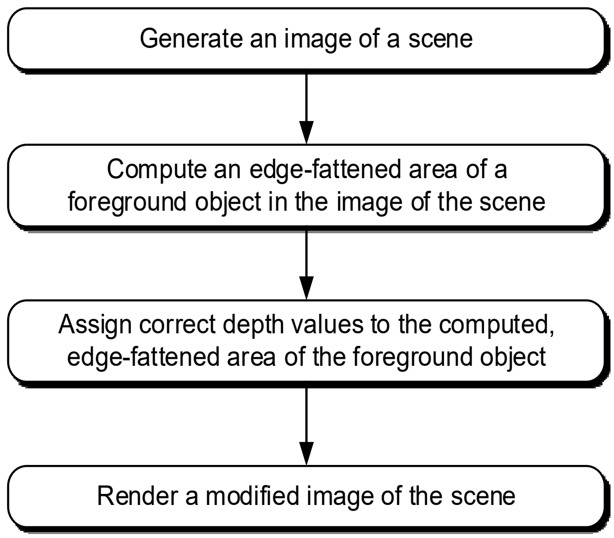

Figure 3

As illustrated by Figure 3, the image-capture device generates an image of a scene. Generating the image of the scene may include the image-capture device applying stereo-matching techniques to a temporary image of the scene captured through the image-capture mechanisms of the image-capture device. The generated image of the scene includes content that is a foreground object and content that is a background, where the foreground object and the background have features with different, associated depths.

The image-capture device (*e.g.*, the processor executing the instructions of the image-boundary manager) then computes an edge-fattened area of the foreground object in the generated image of the scene. Using the low-complexity algorithm of the image-boundary manager, the image-capture device identifies luminance edges for the generated image of the scene, where a luminance edge corresponds to an intensity of a color wavelength (*e.g.*, a red wavelength of λ = 700-635 nm or a blue wavelength of λ = 490-450 nm) reflected from the features of the foreground object and the background. The image-capture device (using the low-complexity algorithm) then assesses alignment amongst the identified luminance edges. In general, a set of aligned, identified luminance edges indicates the presence of an edge of an object (*e.g.*, an edge of the foreground object), whereas an individual, identified luminance edge that is proximate to the set of aligned, identified luminance edges, but misaligned with the set, indicates a disparity or a depth. The image-capture device (using the low-complexity algorithm) then computes an edge-fattened area, where the edge-fattened area corresponds to an area between the set of aligned, identified luminance edges and the individual, identified luminance edge that is misaligned.

The image-capture device (*e.g.*, the processor executing the instructions of the image-boundary manager) then assigns correct depth values to the computed, edge-fattened area of the foreground object. In some instances, this may include the image-capture device "trimming" the individual, identified luminance edge that is misaligned such that it matches the set of aligned, identified luminance edges.

The image-capture device then renders, on the display, a modified image of the scene, in which the foreground object is rendered accurately and without the edge-fattened area.

Techniques and systems, applicable to the image-boundary manager as described herein, are non-limiting and by way of example only. Variations are diverse and include, for example, an image-boundary manager that is included or provided as part of a cloud-computing service. In this example variation, the image-capture device captures the temporary image of the scene and provides the temporary image of the scene to the cloud-computing service. The cloud-computing service may apply stereo-matching techniques to the temporary image of the scene and, in turn, execute the code of the image-boundary manager to generate the modified image of the scene (*e.g.*, where the edge-fattened area is removed from the foreground object). The cloud-computing service may then provide the modified image of the scene to another device for rendering.

In conclusion, the low-complexity algorithm of the image-boundary manager is combinable with today's stereo-matching techniques to render images with improved edge and depth characteristics. This combination is applicable to a variety of image-capture modes implemented in image-capture devices today, including the aforementioned augmented-reality mode and portrait mode.