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BOKEH RENDERING USING INTELLIGENT BLURRING

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Abstract-
In photography, the bokeh effect is a prevalent technique where one part of the image is strategically blurred. Bokeh serves as a backdrop to the focus region, drawing attention to specific background light sources. This research aims to create an intelligent blurring system to achieve a dynamic blurring while rendering Bokeh effects in smartphones. Our solution segments the image to separate and identify the foreground and applies color spectrum expansion and amplification. This processed foreground is blurred based on certain criteria and generates an enhanced blur effect for the Bokeh image.

Index Terms-
Image Segmentation, Color enhancement, Gaussian Blur, Median Blur, Bilateral Blur, Bokeh

I. INTRODUCTION

Most mid-range smartphones come with a Bokeh rendering solution termed as "Portrait Mode" which is commonly linked to the artificial blurring of the background, mimicking the bokeh effect we typically see in dedicated DSLR or mirrorless cameras with specialized lenses, larger sensors, and high focal lengths, all of which help reduce the depth of field and blur backgrounds. Basic bokeh rendering algorithms generally involve uniform blurring of the background and enhancement of edges of the foreground. However, as the complexity of the algorithms increase i.e., usage of neural networks, image processing techniques, pyramid fusion techniques, etc. the computation also increases significantly [1]. Our solution aims to provide a depth-aware, realistic bokeh effect while also keeping in mind the constraints that generally come with a smartphone. The flow of the proposed algorithm is as follows-

1. **Image Segmentation:** Input Image is segmented using a deep lab segmentation algorithm to generate separate image segments.
2. **Foreground Identification & Separation:** The input image segments are then passed through a Depth Map Analyzer to separate the foreground and background segments called ROIs.
3. **Color Spectrum Expansion & Amplification:** Each ROI and foreground are passed through this step to enhance the visibility of the segments. The effects are:
    a. Better visibility and distinction of foreground
    b. Optimized background regions for Blur processing in next step
4. **Smart Blur Category Identification for Motion:** This step provides fine grain segmentation detects motion/static segments and separate them accordingly.
5. **Apply Blur intelligently:** All the segments generated are passed through the intelligent blur Algorithm.
6. **Final Image Generation:** Final Image is generated by combining all the segments together

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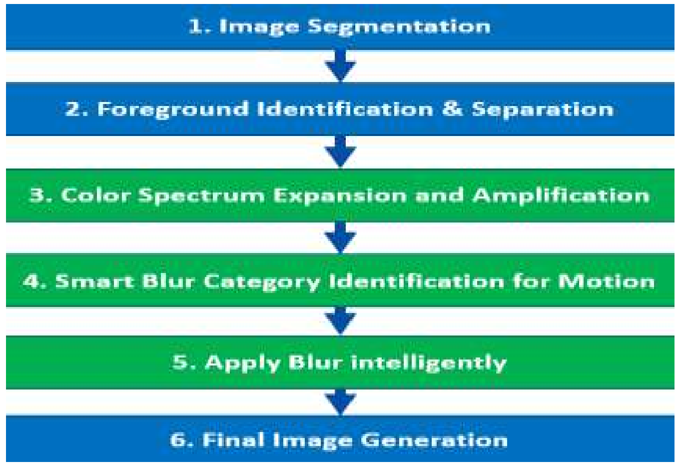

Figure 1: Proposed Algorithm

The following diagram provides a detailed process- flow of the algorithm working with the hardware:

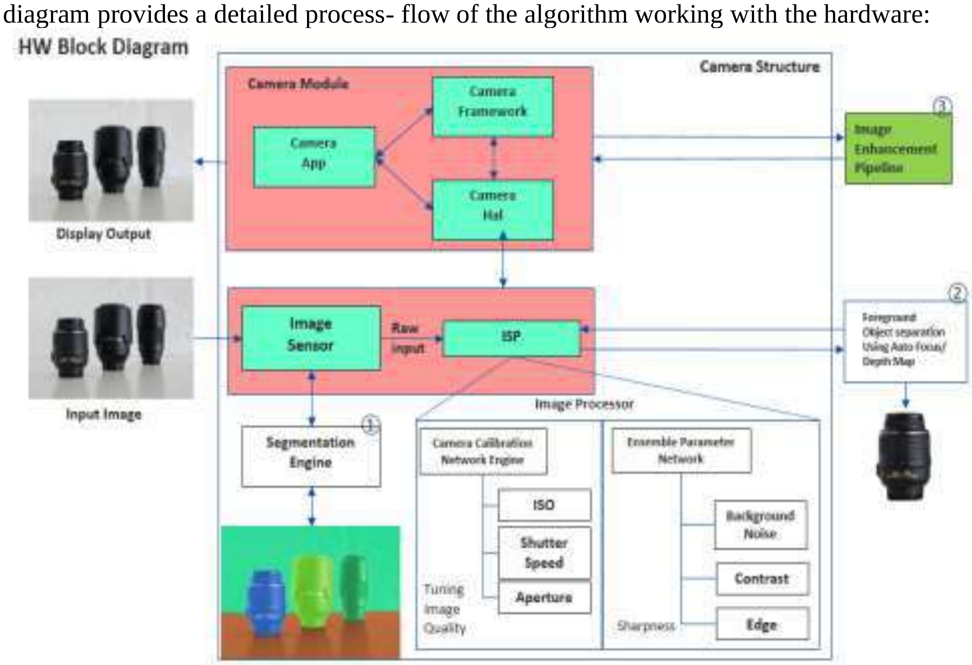

Figure 2: Process Flow in the backend of a smartphone

II. PROPOSED ALGORITHM

A. IMAGE SEGMENTATION

Image segmentation is the division of a digital image into multiple subgroups of pixels known as Image Objects. This procedure can minimize the complexity of the image, making image analysis easier [2]. Our solution uses a deep learning based image segmentation algorithm to achieve dynamic and accurate segments. Deep Lab is used to perform image segmentation. It helps achieve the following:

- Control signal decimation
- Reduction in number of samples
- Reduction in the amount of information that the network must process.

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Using DeepLab segmentation enables us to learn multi-scale contextual features while also aggregating them. This leads to improved accuracy in segmentation of objects that may not me distinguishable from one another while using other segmentation algorithms. DeepLab uses a pre-trained residual network for feature extraction, thus, avoiding problems such as vanishing gradient [3].
The output of the segmentation network is an image which highlights different segments.

Figure 3: Segmented Image

The primary segmentation criteria applied here is depth analysis. Each segment represents a different depth in the image. In the above image, we have segments s1, s2, s3, etc. This representation of depth enables us to blur the image dynamically [4] [9].

B. FOREGROUND IDENTIFICATION AND SEPARATION

This step primarily focuses on selecting a suitable foreground from the segments obtained in the previous step. We provide two options in this step-

- **Manual Mode:** The user selected object is considered as the foreground.
- **Auto Mode:** Depth Map Analysis is used to determine the foreground object.
-

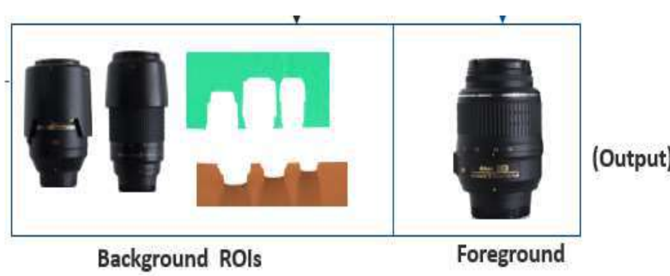

Figure 4: Depth Map analysis identifies a foreground and background

C. COLOUR SPECTRUM EXPANSION/AMPLIFICATION

This step enhances the vibrancy and prominence of the foreground as compared to the background. This is done by generating a color spectrum for each object by calculating the wavelength for each color and taking the minimum and the maximum as the wavelength range [5].

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Figure 5: Conversion from RGB to wavelength

The range of the visible spectrum is expanded to the typical values of the particular color in spectrum and calculations are done to determine the change in ratio. Finally, the gray levels are intensified by making blacks darker and the whites brighter. The Wavelength Range obtained for the given color is ignored and set to 0 if the range change is below a particular value or is not observed in the given ROI.

W_{ol} = W(old, lowest) (lowest value of W for given color in spectrum)

W_{ou} = W(old, highest) (highest value of W for given color in the spectrum)

Wavelength Range = (W_{ol} to W_{ou}) (calculated separately for each color in spectrum)

$$Range = W_{ou} - W_{ol}$$

For the given foreground, the calculations would be as follows-

Color	Typical Spectrum range (W_{nl}, W_{nu})	$Range_o$	$Range_n$	Change in range ($Range_n$ - $Range_o$)
Red	0	0	0	0
Orange	0	0	0	0
Yellow	551-580	9	29	20
Green	0	0	0	0

Table 1: Example of color spectrum expansion

As observed above, color amplification will we done for yellow. The range change ratio will be 2.2.

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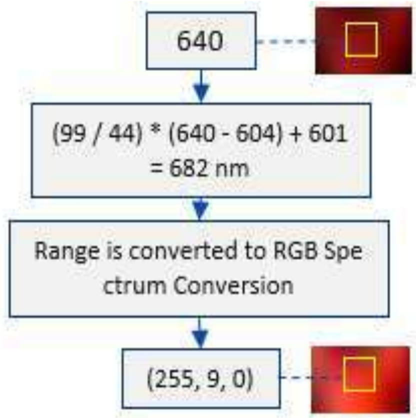


Figure 6: Obtaining the new wavelength and pixel values

Similarly, values are generated for all the segments and this Color Expansion and Amplification is applied for all the ROIs.

D. MOTION/STATIC BLUR ROI SEPARATION

Motion blur refers to the visual streaking or smearing that is recorded on camera due to movement of the camera, the subject, or a combination of the two [6]. The goal of this step is to identify linear and rotational motion so as to apply a motion blur if detected thus enhancing the bokeh effect. We use a fine trained deep lab segmentation model to divide the segments into finer detail segments. These segments are analyzed for motion. For example-

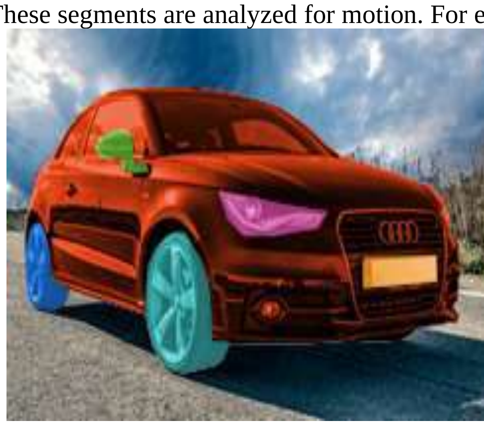
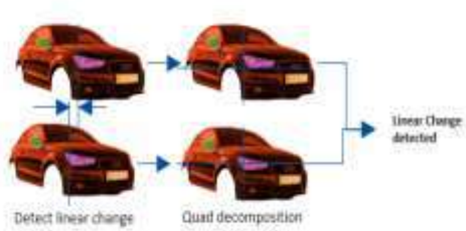


Figure 7: Image of a car in motion

Post fine-image segmentation we detect linear motion in the body of the car and rotational motion in the wheels. Therefore, the output is as follows:



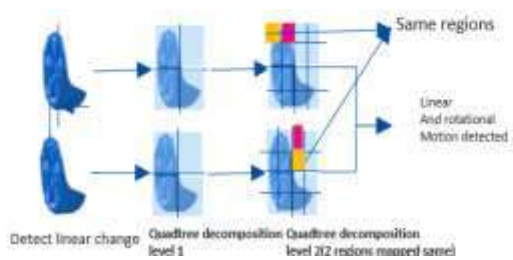


Figure 8: Linear motion in the body of the car *Figure 9: Linear and Rotational Motion Detected in tires*

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Figure 10: Static Segments

The initial input, intermediate input, and final output after applying motion blur to the corresponding segments is as follows:

Figure 11: Normal image with sharp foreground and background

Figure 12: Motion blur applied to background and side of car to depict the motion of object

Figure 13: Radial blur applied to wheel rims to depict the motion of object.

In the final generated image wo have bonnet as a sharp object, side of car and background with motion blur and rims of car with radial blur to depict motion.

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In images where no motion is detected, we apply static blur to all ROIs. The flowchart is as follows-

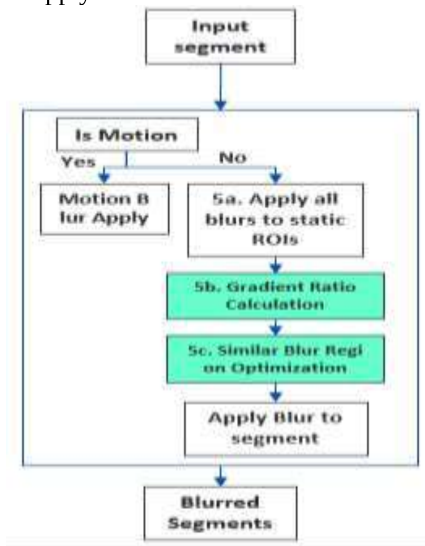

Figure 14: Algorithm to apply motion or static blur

E. APPLICATION OF BLUR INTELLIGENTLY

This algorithm is responsible for choosing the type of blur that will be applied on a segment. The different types of static blur include-

- Median Blur
- Bilateral Blur
- Gaussian Blur
- Box Blur
- Channel Blur

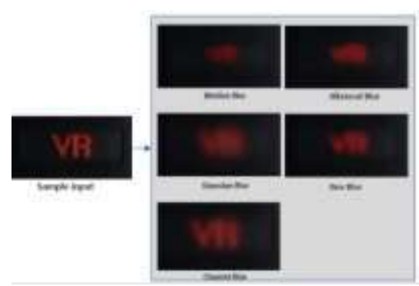

Figure 15: Different blurs applied on a subject

After the static and motion blurs are applied, the gradient ratios are calculated for all the blurs applied. The gradient ratios are calculated as follows-

1. Pixels from the original image as well as the blurred image are considered.
2. The absolute difference between RGB pixel values are calculated.
3. The RMS of the generated absolute difference is calculated and is divided by the RMS of the blurred region.
4. The ratio obtained ($\frac{D_{orig}}{D_{bi}}$) is used to determine the blur type.

The calculation of D(x, y) Is as follows:

$$D(x,y) = \left(\sum_{\substack{C_y=\{-s,s\} \\ C_{x=\{-s,s\}}}} p(x,y) - p(x+cx, y+cy) \right)^{\frac{1}{2}}$$

Let G_{ip} be the gradient ratio for the i[th] blur type for pixel p. For a given pixel, the maximum G_{ip} value is used to determine the blur type applied.

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The region of blurring is decided by selecting RGB pixel values within the range of the original target pixel. The area is constructed by considering all the pixels within the range of the target pixel which have a threshold less than a pre-decided value for a single channel.

The algorithm designed for similar blur region optimization is as follows:

1. The Distance between two pixel values are calculated as follows:

$$Difference = mod\big(Target(R,G,B) - Nearby(R,G,B)\big)$$
$$= \big[mod\big(Target(R) - Nearby(R)\big), \quad mod\big(Target(G) - Nearby(G)\big), \quad mod\big(Target(B) - Nearby(B)\big)\big] = Difference(R), Difference(G), Difference(B)$$

2. Distance = Max(Difference(R), Difference(G), Difference(B))

3. If(distance < 17) consider in same segment
Else ignore

Figure 16: Different Blurs Applied on different regions identified

F. FINAL IMAGE GENERATION

Each of segments identified in the preceding steps are merged together to generate the final image. The segments have the appropriate blurring applied to them thus resulting in a final image with different blurs applied.

III. RESULTS AND DISCUSSIONS

In a typical bokeh rendering algorithm, a single type of blur is used, generally – Gaussian blur. Although this enhances the depth information in the image, it is not sufficient if there are multiple objects at different depths.

In our algorithm, we make use of depth information to enhance the blurring at each depth. We also make use of multiple blurring techniques to make each segment look more realistic.

The results obtained from our algorithm are visibly more realistic and contain more depth information than a typical bokeh rendering algorithm.

Figure 18: Final Result after Blurring

In order to do a formal comparison of the algorithms the following criteria were identified:

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Effect	Normal Bokeh Effect[7][8]	Our Bokeh Enhancement
Degree of Blur/background Details	For a single blur contour details are sometimes not completely removed retaining the shape of t he background objects resulting in lower foregr ound background contrast.	Higher degree of blurring is achieved by our me thod for same sigma value. Because maximum gradient ratio reduces the sudden change in pix el values from one pixel to another So blur beco mes more uniform by losing shape details result ing in greater degree of blurring.
Better Foreground	The foreground separation is not completely se parable from the background and does not have a clear separation	The Color Spectrum Expansion and Amplificati on helps to enhance the details of the foregroun d object resulting in better and separated foregr ound as compared to the background.
Patch/Detail removal from Non ROI regions	Diminishing the details in background requires increasing the sigma value which will mix and r emove the general object shape in the backgrou nd.	Due to segmentation and ROI separation our al gorithm helps to diminish the unwanted details in the Non ROI regions
Real-time Blur identification for videos	No such method exists for automated blur type estimation for videos in the knowledge of our in terest	Using our method helps to determine the blur ef fect to be applied for videos based on the Gradi ent and Motion Estimation resulting in real-tim e blur type determination for videos.

Table 2: Formal Comparison of Bokeh Rendering Algorithms

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