Abstract—This paper presents a low-light image enhancement method using a convolutional neural network (CNN). Given a low-light input image, the proposed method converts RGB color space to CIELAB color space. The luminance and chrominance components are separately enhanced. The luminance channel is enhanced using a CNN to increase the brightness. On the other hand, the chrominance channels are enhanced using a dilated CNN to reduce the color distortion. Experimental results demonstrate that the proposed method can successfully enhance low-light images of a vehicular imaging system without color distortion.

I. INTRODUCTION

Consumer imaging devices have been widely used in many applications such as smart-phones, dash-board camera, and surveillance systems. However, the dynamic range of the acquired image in the low-light condition is narrowed due to the insufficient amount of light and it results in low signal-to-noise ratio. This problem degrades the performance in the computer vision-based post-processing such as object detection, tracking, and recognition. To solve this problem, many low-light image enhancement methods have been proposed in the literature.

The retinex-based methods assume that the observed image is obtained by the multiplication of the illumination and reflectance components and the enhanced results is obtained by eliminating the illumination component [1]. Rahman’s et al. proposed multi-scale retinex using Gaussian low-pass filter of different standard deviations to estimate accurate illumination component [2]. However, since retinex-based methods estimate illumination component using low-pass filtering, the resulting image is degraded by halo-artifact near strong edge.

Recently, low-light enhancement methods using deep learning have been proposed. Shen et al. proposed low-light image enhancement method using the convolutional neural network (CNN) based on multi-scale retinex method [3]. However, this method cannot overcome the color distortion and undesired artifact.

To solve this problem, this paper presents a low-light enhancement method using a CNN and CIELAB color space. Experimental results show that the proposed method can provide the enhanced result without undesired artifact and brightness saturation.

II. LOW-LIGHT IMAGE ENHANCEMENT NETWORK

This section presents the proposed low-light image enhancement network. The proposed method can be written as

\[ \hat{f} = f_3(f_1(g_L), f_2(g_{ab})) \]  

where \( g_L \) and \( g_{ab} \) respectively represent L and AB channels of CIELAB color space and \( \hat{f} \) the enhanced result image. \( f_1 \) is the CNN for the brightness enhancement of L channel, \( f_2 \) the dilated CNN for color component enhancement of AB channels, \( f_3 \) the reconstruction layer using the estimated features of \( f_1 \) and \( f_2 \).

Fig. 1 shows the network architecture of the proposed method. As shown in Fig. 1, the proposed method incorporates with the CNN and dilated CNN for the enhancement of the luminance and chrominance components, respectively.

Generally, the pooling layer is used to extract the global features with large receptive field at multiply scaled spaces, but it results in the loss of the details in the enhanced result. In the proposed method, the dilated CNNs are used to increase the receptive field instead of using the pooling layer. The dilated convolution has the advantage that the number of parameters increases linearly receptive fields increases exponentially [4]. Although increasing dilation factors extend the receptive field, it shows the limitations in extracting the local features of small objects [5]. To solve this problem, \( f_2 \) consists of dilated CNN.

In the proposed enhancement network, leaky rectified linear unit is used as the activation function [6]. The size of filter in the convolution layers of \( f_1 \) was set to \( 3 \times 3 \). The loss function is defined using mean squared error (MSE) as

\[ l = \frac{1}{N} \sum_{i=1}^{N} \| \hat{f}(y_i) - x_i \|^2 \]  

where \( N \) is the number of training dataset, \( y_i \) a low-light input image, \( \hat{f}(\cdot) \) the proposed low-light image enhancement network, and \( x_i \) the ground-truth image.

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Fig. 1. The architecture of the proposed low-light image enhancement network.

Fig. 2. Comparative results of low-light image enhancement: (a) an input image (NIQE:5.0139), (b) Rahman’s method (NIQE:4.7215) [2], (c) Shen’s method (NIQE:4.0999) [3], and (d) the proposed method (NIQE:4.0305).

Fig. 3. Comparative results of backlit image enhancement: (a) an input image (AE:7.0878), (b) Rahman’s method (AE:6.8970) [2], (c) Shen’s method (AE:7.4497) [3], and (d) the proposed method (AE:7.5176).

III. EXPERIMENTAL RESULTS

The performance of the proposed low-light image enhancement method was evaluated using average entropy (AE) and the natural image quality evaluator (NIQE) [7], [8]. The NIQE is a non-reference image quality measure, and a smaller score indicates a better image quality. The training dataset was generated using DIV2K dataset and a low-light image was synthesized using the gamma correction [9]. The adjusting parameter was randomly selected in $\gamma \in [3, 4]$. The batch size was set to 128 and Adam optimizer was used with learning rate of 0.00005 [10].

Figs. 2 and 3 show comparative results of low-light and backlit image enhancement. As shown in Fig. 2(b) and 3(b), Rahman’s method enhances averaged brightness, but it cannot avoid the color distortion. In Figs. 2(c) and 3(c), the enhanced results also show the imbalanced amplification of color components. On the other hand, the proposed method can provide high-quality enhanced result image without color distortion and undesired artifact.

IV. CONCLUSION

This paper presents a low-light enhancement method using a CNN and CIELAB color space. The proposed method separates the low-light input image into luminance and chrominance components, and performs image enhancement for each component, respectively. As shown in the experimental results, the proposed method can provide better enhanced results without undesired artifact and color distortion. For that reason, proposed method can be applied to the consumer imaging systems to enhance the low-light and backlit images.

REFERENCES