인포커스 및 디포커스 영상으로부터 깊이맵 생성

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A Depth Estimation Method Using Infocused and Defocused Images

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요약
The blur amount of an image changes proportional to scene depth. Depth from Defocus (DFD) is an approach in which a depth map can be obtained using blur amount calculation. In this paper, a novel DFD method is proposed in which depth is measured using an infocused and a defocused image. Subbaro's algorithm is used as a preliminary depth estimation method and edge blur estimation is provided to overcome drawbacks in edge.

1. Introduction

Development of three dimensional (3D) video and image is growing rapidly in devices including 3DTV and mobile phones. In this intermediate period where the creation of 3D content is limited, the development of 2D-to-3D conversion algorithms is needed. A stereoscopic image can be constructed using an infocused 2D image and a scene depth map. Depth information shows relative distance of objects from camera [1]. Depth from Defocus (DFD) is one of 2D-to-3D conversion methods in which depth can be obtained based on blur amount of 2D images using a single camera. In conventional DFD methods, blur value is calculated using two defocused images [2][3]. However, it is well known that the quality of a reconstructed infocused image from defocused images is not satisfactory. Therefore, a novel DFD method is proposed in this paper that uses a pair of infocused and defocused images.

In the proposed method, Subbaro's approach is used to achieve a basic depth map and an additional procedure is considered to improve the depth map quality of the basic method. Using both infocused and defocused images helps to provide useful depth cues to obtain an improved depth map. Furthermore, a proper stereoscopic image can be generated by an infocused image and a depth map.

2. Proposed Method

A. Subbaro Algorithm

Subbaro [4] modeled an image as a two-variable cubic polynomial in a small (3 x 3 pixels) image neighborhood using spatial domain transform and proved that the relationship between two images g_1 and g_2 with blur values σ_1 and σ_2 can be represented as (1)

$$\sigma_1^2 - \sigma_2^2 = 4 \cdot \frac{g_1 - g_2}{\Delta^2 g} = G \tag{1}$$

where Δ^2 is a Laplacian operator and $\Delta^2 g$ is defined by (2):

$$\Delta^2 g = \frac{\Delta^2 g_1 + \Delta^2 g_2}{2} \tag{2}$$

Referring to (1), the blur amount for infocused image g_2 is zero ($\sigma_2=0$) and the blur value can be estimated in defocused image by

$$\sigma_1 = \beta = \sqrt{G} \tag{3}$$

For two edge and non-edge pixels with identical depth, Laplacian value is much larger for edge pixel due to Laplacian edge sensitivity. Then according to (3), the blur calculated for edge pixel is much lower than non-edge pixel blur. Thus, the correct edge depth can not be measured accurately from Subbaro's method. To solve this, a new method is proposed in this paper to obtain a correct depth for edge regions.

B. Edge Blur Estimation

The methodology for the estimation of defocus blur in edge regions is described for 1-D signal first and then extended for 2D image. In Fig. 1, for co-located edge pixels in infocused and defocused images, the difference between gradient magnitudes of step edges is computed. The difference value varies proportional to blur changes.

The edge blur *e(x)* can be modeled as the convolution of an ideal edge *Au(x)+B* with point spread function (PSF) where *u(x)* is a step function, *A* is an amplitude and *B* is an offset. The PSF for 1-D signal is expressed as a Gaussian kernel *g(x,σ)* (4) and a Gradient for an edge with blur value σ can be represented as (4):

$$g(x,\sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}} \tag{4}$$

$$\nabla e_i(x) = \nabla((Au(x)+B) \otimes g(x,\sigma_i)) = \frac{A}{\sqrt{2\pi\tau_i^2}} e^{-\frac{x^2}{2\sigma_i^2}}$$

where $\nabla e_i(x)$ denotes the edge gradient at location *x*.

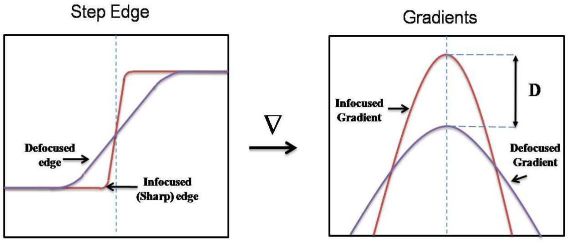

Fig. 1. Infocused and defocused step edges and their gradient difference. Vertical dash line indicates edge location

Suppose that $\nabla e_i(x)$ and $\nabla e_d(x)$ are gradient magnitudes of infocused and defocused signals respectively. The maximum gradient amplitude occurs at $x=0$. Therefore, $\nabla e_i(0)$ and $\nabla e_d(0)$ are maximum gradient values. In general, $\sigma_d >> \sigma_i$ and σ_i is a small value near zero. Then, the gradient difference D between infocused and defocused signals is computed by (5).

$$\nabla e_i(0) - \nabla e_d(0) = \frac{A}{\sqrt{2\pi\sigma_i^2}} - \frac{A}{\sqrt{2\pi\sigma_d^2}} = \frac{A}{\sqrt{2\pi}}\left(\frac{\sigma_d - \sigma_i}{\sigma_i \sigma_d}\right) \quad (5)$$

Since σ_d is much larger than σ_i and σ_i is a small value near zero, the $\sigma_i\sigma_d$ is small compared to (σ_d - σ_i). Therefore, the gradient difference is proportional to blur changes. Then, we have:

$$\nabla e_i(0) - \nabla e_d(0) \approx \sigma_d - \sigma_i \quad (6)$$

The value σ_i is small and the defocused blur (σ_d) can be estimated from Gradient magnitude difference.

The calculation of blur for 2D image is similar to 1-D signal. In edge regions, a depth map from Subbaro's method is merged with that of the edge blur method by

$$G_{SE} = w_1 g_S + w_2 g_E \quad (7)$$

where G_{SE} is merged depth. g_S and g_E are depth values for Subbaro and edge blur methods respectively. Weighting coefficients are $w_1=0.3, w_2=0.7$.

3. Experimental Results

In the lab, we used a camera with focus control (in Fig. 2) and acquired two images. After capturing an infocused image with autofocus, the defocused image was acquired after changing the focus length. The intrinsic parameter values are unknown. From the two images, we applied our blur estimation method and examined the resulting images.

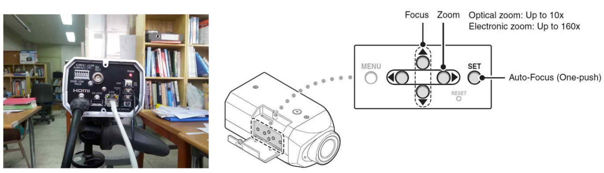

Fig. 2. Camera setup with focus control

Fig. 2 shows input images and resulting images for two scenes. In the first image set, Subbaro's method extracts some acceptable depth information but it is not an ideal result. The final depth map is improved using combination of the edge blur method with basic depth. Subbaro in scene (b) fails to recover proper depth while the complimentary method improves final depth map.

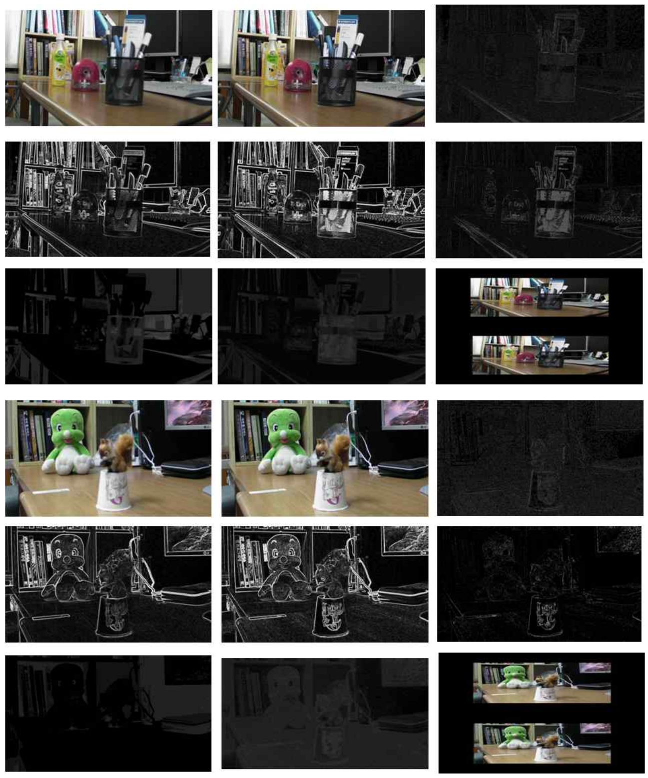

Fig. 2. Resulting DFD images

4. Conclusion

A depth estimation method is proposed using infocused and defocused images. In the proposed method, infocused image helps to simplify calculations for Subbaro's algorithm and edge blur method by assuming infocused blur near zero.

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