

Shadow Elimination for Constructing Virtual Environments

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Abstract: Immersive virtual reality is collecting attention thanks to the advancement of head mounted displays and omnidirectional cameras. When we capture photos for constructing virtual environments, the shadow of the capturing device, such as a tripod remains in the photo. We propose a method to eliminate the shadow. Unlike conventional methods for eliminating a shadow in a single photo, we propose to use multiple omnidirectional photos taken at different locations. We show a preliminary result (figure.1).

Keywords: inpainting, virtual reality



(a) input image (b) output image
Fig. 1 input and output images

1. Introduction

In order to construct virtual environments, omnidirectional cameras are useful to record all of the viewing directions. However, when we capture a photo, the shadow of a capturing device, such as a tripod, remains on the ground in the photo. This causes unnatural appearance as a virtual environment. Although conventional inpainting methods can be applied to eliminate the shadow, they use just a single photo. If we use more than one image, there is a possibility to improve the quality. In this paper, we propose a method that uses multiple omnidirectional images captured at different locations, instead of using just a single image. Besides omnidirectional images, our method can also be applied to eliminate shadow of a regular perspective image in photography.

2. Related work

Image inpainting techniques have been proposed to fill a region in an image [1], [2]. Since these methods use only single image, the performance is limited. When two images capturing the same scene from different viewpoints are available, we can copy the region with no-shadow to that with shadow, while compensating

brightness and color differences by poisson blending method [3]. This method, however, causes blur to eliminate the shadow on the ground because the same region at another image is taken from a distant viewpoint. Our method is able to solve this problem.

3. Our method

As has been stated, in the case of virtual environment construction, we have a series of similar images can be used to eliminate the shadow. The basic idea of our method is to apply more constraints in template searching. Firstly, we input 3 images (figure.3), which are:

- (1) Image A: target image with the shadow we want to eliminate
- (2) Image B: an image similar to A captured from different location
- (3) Image C: perspective transformed image B that road region have the same perspectives with A

Secondly, we do the template searching in A and B. The similarity of the template is defined by the following equations:

$$P'_{most\ similar} = argmin_{P'} E_A + E_C \quad (1)$$

$$E_A = \sum_{i=1}^m (I_i - I_{Ai})^2 \quad (2)$$

$$E_C = \sum_{i=1}^m (I_i - I_{Ci})^2 \quad (3)$$

Where I_i means intensity of pixel P'_i in image A or image B. And I_{Ai} means intensity of pixel P_i in image A. I_{Ci} is the same. Thirdly, we fill the shadow region pixel by pixel with template we found. Details about the procession will be described in next section.

4. Experiment

We implement our method using openCV3.0. To confirm the validity of our method, we simplify the problem to a grey scale procession. The procedure is as follow.

- (1) Do the cube-map transformation to the omnidirectional images (figure.2). The transformation is done by master-theta developed by Rakuten company.

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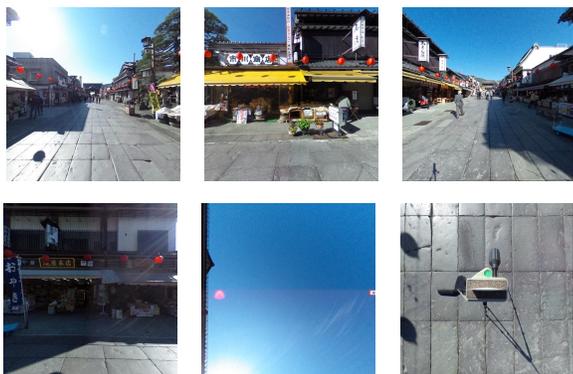
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(a) original omnidirectional image



(b) six faces of cube-map images

Fig. 2 the original omnidirectional image and images of cube-map

(2) input A, B, C, where C is an image transformed from B. To utilize B as another constrain for the template searching, we transform it to an image in which the road has the same perspective with image A (figure.3).



Fig. 3 input images: (left) A; (middle) B; (right) C. region in the red circle means the same part of the road.

(3) split A and B into little patches (figure.4).

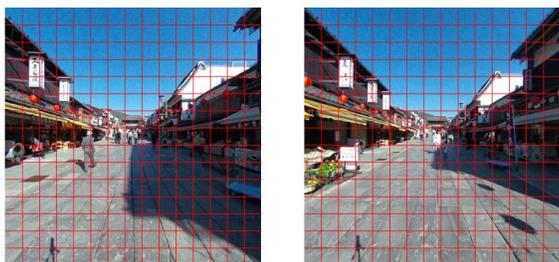
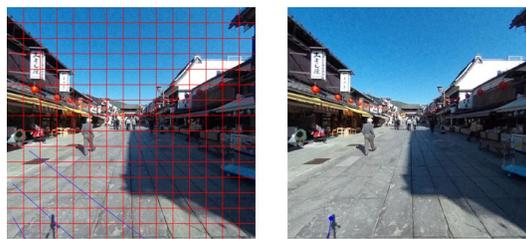


Fig. 4 split A and B into a lot of little patches

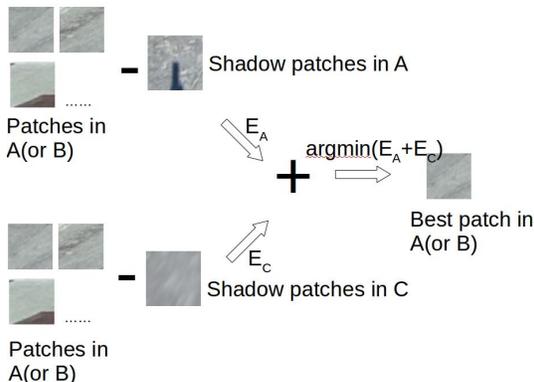
(4) For each pixel of the shadow region in the road region of A, raster scan A and B (figure.5(a)) and find the best patches in A and B respectively according to function (1) (2) (3) (figure.5(b)). Then choose the patch with lower E (error) from the 2 patches again.

(5) Fill the pixel of the shadow region in A with the central pixel of the found patch (figure.6).

Result is as figure.1. In this paper, we did not eliminate the 2016 Information Processing Society of Japan



(a) (left) patches in A (or B); (right) patch of which the center is the chosen pixel. for each pixel in the shadow region, compare patch in the right with all ones in the left to find the most similar patch to fill the shadow.



(b) Estimate the similarity of each pair of patches according to function (1).

Fig. 5 procession of finding the best patches

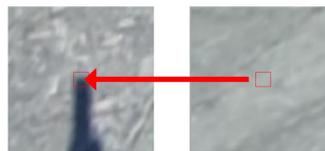


Fig. 6 fill the pixel with the central pixel of the found patch

shadow and tripod in the bottom face of cube. If we do that, people in the environment would feel unnaturally floating on the air. Considering this, we decide to replace the shadow and tripod in the bottom face with a human body or something else instead of eliminate them.

5. Conclusion

In this paper we propose a new method to eliminate the shadow and verify that the result of our method is better than the conventional method. In the progress, we also found that in some case of soft shadow, some texture can be seen by strengthening the intensity of the shadow. Utilization of this cue will be a future work of our research.

References

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