

Updated Paired Regions for Shadow Detection from Single Image

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1 Introduction

In this Supplemental Material, we provide more experimental results that are organised as below:

- Section 2, we explore the effect of dilate size τ when locating candidate paired regions.
- Section 3, we explore the effect of penumbra detection.
- Section 4, we explore the effect of δ in the confidence coefficient term of Equation 2.

2 The effect of τ

Because there exists penumbra region between the shadowed region and its paired unshadowed region, sometimes the paired regions may be not adjacent to each other after image segmentation. The dilate operation is used to build the connection between regions that are not adjacent when locating candidate paired regions. In this section we propose a series of experiments to explore the effect of τ .

We design four experiments to explore the effect of τ . The dilate size of the first experiment is one pixel, which refers to using the adjacent regions as the candidate paired regions. The second experiment uses a small number (10 pixels) as τ , while the third experiment uses a big dilate size (100 pixels). The fourth experiment's τ is calculated according to the size of input image, indicated by $\tau=0.1*\max(X,Y)$ where X and Y refer to the size of input image.

	SBU	UCF	ISTD
$\tau=1$	12.96	11.32	3.08
$\tau=10$	8.52	10.47	2.21
$\tau=100$	4.65	7.56	2.21
$\$ \tau=0.1 * \max(X, Y)$	4.65	7.56	2.21

Table 1: Quantitative comparison results on the effect of τ with BER metric. Smaller is better.

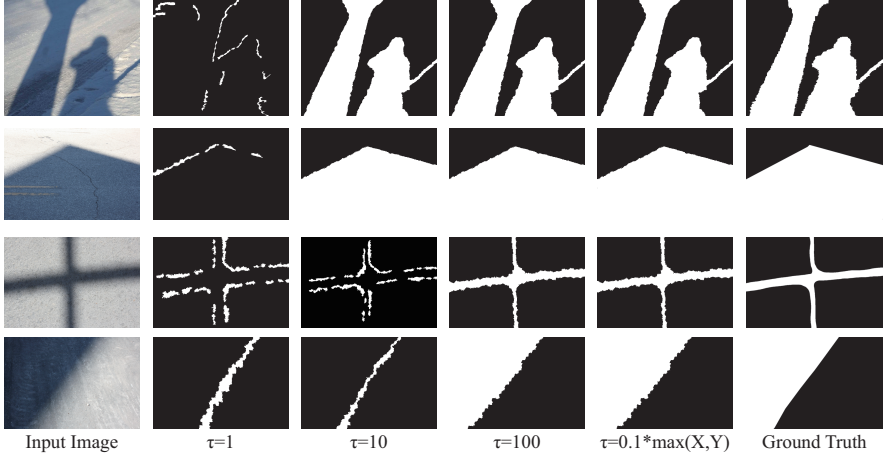


Figure 1: Visual comparison of shadow detection results on the effect of τ .

The quantitative comparison results are shown in Table 1. The visual comparison results are shown in Figure 1. From the results, we can see that for shadowed regions that have obvious penumbra regions, larger τ lead to better result since the real paired regions are defined as candidate paired regions. If the dilate size τ is too small, the connection between shadowed region and its paired region may not be able to be built. If the dilate size τ is too big, the candidate paired strategies will be very complex. So the proposed approach adopts the τ calculated by the fourth way. For the ISTD dataset, the dilate size τ has little effect on final results. This is because the penumbra regions in most pictures of this dataset are not obvious due to the low shield object and can not be segmented by the proposed approach.

3 The effect of penumbra detection

When the proposed approach building candidate paired strategies, the penumbra regions are used as a decisive cue. If penumbra region exists between two regions according to the detection result, these two regions are determined as shadowed region and its paired unshadowed region directly. Other regions that have relation with these two regions are eliminated from candidate paired regions. To explore the effect of penumbra detection, here we design an experiment to see the shadow detection results of the proposed approach if penumbra detection is not used.

The quantitative comparison results are shown in Table 2. The visual comparison results are shown in Figure 2. The results show that the penumbra detection is very useful when the

	SBU	UCF	ISTD
Without Penumbra	7.24	8.49	2.21
With Penumbra	4.65	7.56	2.21

Table 2: Quantitative comparison results on the effect of penumbra detection with BER metric. Smaller is better.

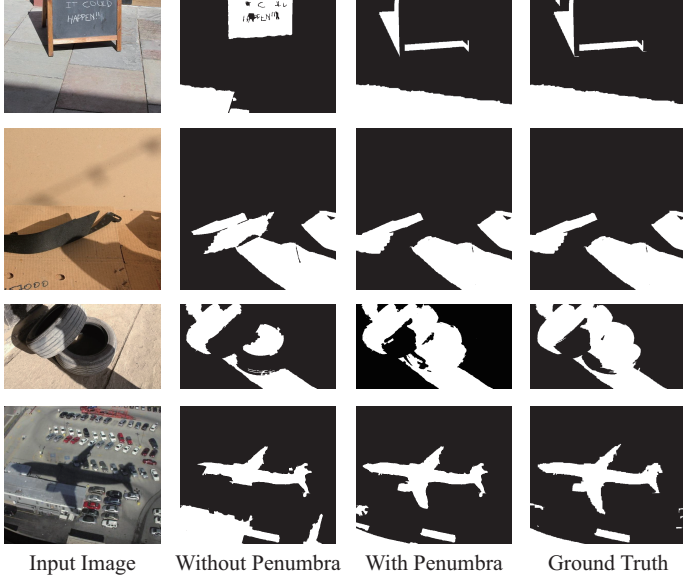


Figure 2: Visual comparison of shadow detection results on the effect of penumbra detection.

structure of the scene is very complex. Some dark unshadowed regions can be recognised through this since they have been eliminated from the candidate shadowed regions. If the structure of input image is very simple, like the input images shown in Figure 1, penumbra detection will not have too much effect. For the ISTD dataset, the structure of pictures in this dataset are simple, and they don't have obvious penumbra regions as mentioned before. So penumbra detection doesn't have much effect on this dataset.

4 The effect of δ

δ in the confidence coefficient term of objective function is used to relieve the error caused by different factors. For example, the electronic noise may be very large to real response value when the response value of a channel is small. And the simplification when calculating the ratio of two colors using Equation 2 also affects the final result. These reasons will hamper the ability of confidence coefficients when modeling the relationship between two regions. So a reasonable δ is very important. We explore the effect of δ through two experiments. The δ value in first experiment is fixed to 0.2. The δ of the other experiment is calculated according to the minimum channel of the darker region's RGB color, indicated by $\delta = f(C_{min})$. The reason why we choose the minimum channel of the darker region as input are that (i) the electronic noise. (ii) the simplification of Equation 2 will affect the confidence

	SBU	UCF	ISTD
$\delta=0.2$	9.61	10.26	2.88
$\delta=f(C_{min})$	4.65	7.56	2.21

Table 3: Quantitative comparison results on the effect of δ with BER metric. Smaller is better.

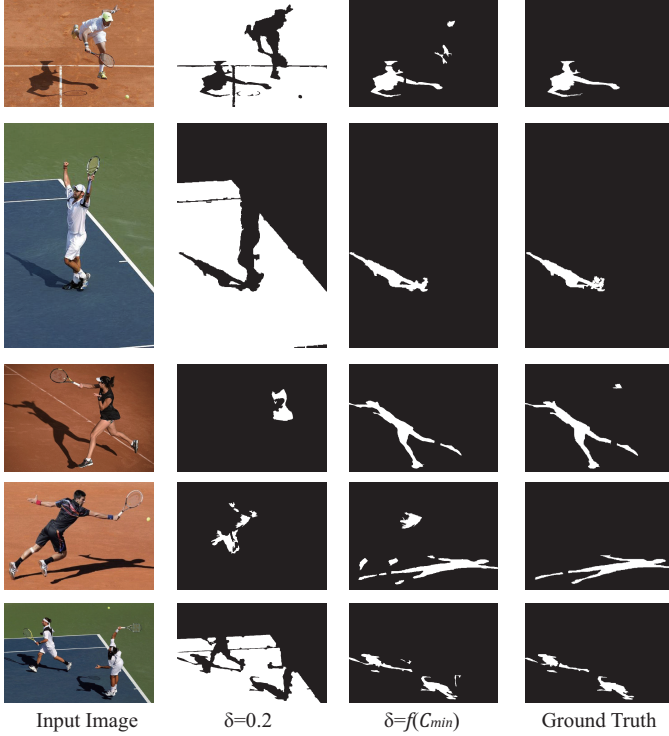


Figure 3: Visual comparison of shadow detection results on the effect of δ .

coefficient more if the value of color is small.

The quantitative comparison results are shown in Table 3. The visual comparison results are shown in Figure 3. It can be seen that a reasonable δ is very important for the proposed approach. If δ is too small, some candidate paired regions will be punished too much by the confidence coefficient term and lead to wrong shadow detection results. If δ is too big, the confidence coefficient term will not be able to constrain the relation between regions when calculating the value of objective function, which leads to the result that all regions are involved during shadow detection. The proposed approach will collapse, so we don't explore this situation.