

NANYANG TECHNOLOGICAL UNIVERSITY

COMPUTER VISION ASSIGNMENT02

Stereo Vision

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1 Describe the procedure of disparity computing

1.1 Polar rectifying

The purpose of rectifying is to make polar of two images in a horizontal line. In this assignment, we ignore this procedure because we have gotten rectified images before.

1.2 Feature matching

In this step, we use NCC to achieve feature matching. After rectifying a pair of images, the depth is calculated by horizontal bias because the depth is proportionate to the bias. After calculating the depth Z , we can get the disparity map which is the same size as original images.

$$Z = \frac{fb}{x_l - x_r}$$

f is the focus

b is the distance between centers of two different viewpoints

1.3 Depth recovering

From the disparity map, we also get the depth map basing on the formula of resembled rectangular.

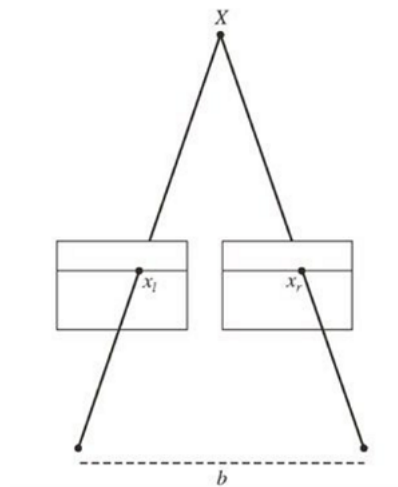


Figure 1: disparity map

2 Write a computer algorithm that computes the disparity

2.1 Code

The Python function mainly achieves the mathematic formula NCC (Normalization cross-correlation) and return best disparity for every pixel.

$$ncc(I_1, I_2) = \frac{\sum_x (I_1(x) - \mu_1)(I_2(x) - \mu_2)}{\sqrt{\sum_x (I_1(x) - \mu_1)^2 \sum_x (I_2(x) - \mu_2)^2}}$$

```
from PIL import Image
import numpy as np
from scipy.ndimage import filters
import scipy.misc
import warnings
warnings.filterwarnings("ignore")

def plane_sweep_ncc(im_l, im_r, start, steps, wid):
    """ Use NCC to compute disparity map """
    m, n = im_l.shape
    # Save different sums
    mean_l = np.zeros((m, n))
    mean_r = np.zeros((m, n))

    s = np.zeros((m, n))
    s_l = np.zeros((m, n))
    s_r = np.zeros((m, n))
    # Save the disparity maps
    dmaps = np.zeros((m, n, steps))
    # Computer the average of images' trunks
    filters.uniform_filter(im_l, wid, mean_l)
    filters.uniform_filter(im_r, wid, mean_r)
    # Normalize the picture
    norm_l = im_l - mean_l
    norm_r = im_r - mean_r
    # Try different disparities
    for displ in range(steps):
        # make left image move to the right and summarize them
        filters.uniform_filter(np.roll(norm_l, -displ - start) *
                               norm_r, wid, s)
        filters.uniform_filter(np.roll(norm_l, -displ - start) * np
                               .roll(norm_l, -displ -
                                     start), wid, s_l)
        filters.uniform_filter(norm_r * norm_r, wid, s_r)
        # Save the grade of NCC
        dmaps[:, :, displ] = s / np.sqrt(s_l * s_r)
    # Choose best pixel for every sub-pictures
    return np.argmax(dmaps, axis=2)
```

2.2 Result

In order to get the comparison, we use the Python function to get the disparity map and then compare it with original images. Use the code below to generate the result of comparison.

```
im_l = np.array(Image.open('../pictures/corridorl.jpg').convert('L', 'f'))
im_r = np.array(Image.open('../pictures/corridorr.jpg').convert('L', 'f'))

# Set steps and starts
steps = 12
start = 4
# Set the length of ncc
wid = 9
res = plane_sweep_ncc(im_l, im_r, start, steps, wid)
scipy.misc.imsave('../pictures/depth_corridor.jpg', res)

# Generate the comparison
plt.rcParams['figure.figsize'] = (16.0, 16.0)
plt.subplot(2, 2, 1)
plt.title("corridorl.jpg")
plt.imshow(Image.open("../pictures/corridorl.jpg"), cmap="gray")

plt.subplot(2, 2, 2)
plt.title("corridorr.jpg")
plt.imshow(Image.open("../pictures/corridorr.jpg"), cmap="gray")

plt.subplot(2, 2, 3)
plt.title("depth_corridor.jpg")
plt.imshow(Image.open("../pictures/depth_corridor.jpg"), cmap="gray")
```

2.3 Compare disparity maps

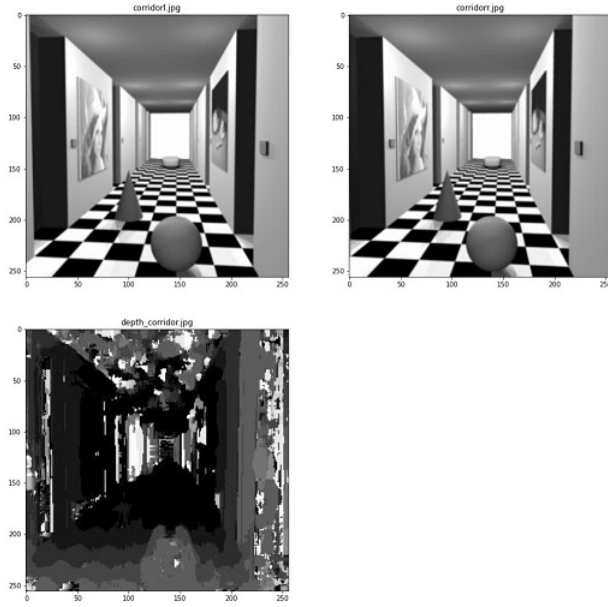


Figure 2: Corridors' comparisons between disparity map and original images

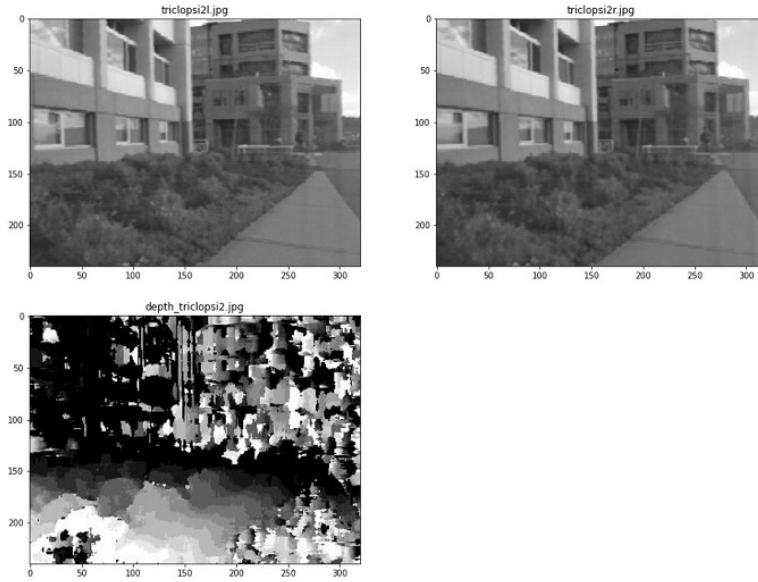


Figure 3: Triclipsi2's comparisons between disparity map and original images

3 Apply developed algorithm and discuss observation of the disparity maps

3.1 Gaussian Filter

After reading some papers, I try to use NCC with gaussian filter to improve the disparity map.

```
def plane_sweep_gauss(im_l, im_r, start, steps, wid):  
    """ Use cross-correlation with Gaussian filter to compute  
        disparity map """  
  
    m, n = im_l.shape  
    # Save different sums  
    mean_l = np.zeros((m, n))  
    mean_r = np.zeros((m, n))  
  
    s = np.zeros((m, n))  
    s_l = np.zeros((m, n))  
    s_r = np.zeros((m, n))  
  
    # Save the disparity maps  
    dmaps = np.zeros((m, n, steps))  
    # Computer the average  
    filters.gaussian_filter(im_l, wid, 0, mean_l)  
    filters.gaussian_filter(im_r, wid, 0, mean_r)  
    # Normalize the picture  
    norm_l = im_l - mean_l  
    norm_r = im_r - mean_r  
    # Try different disparities  
    for displ in range(steps):  
        # make left image move to the right and summarize them  
        filters.gaussian_filter(np.roll(norm_l, -displ - start) *  
                                norm_r, wid, 0, s)  
        filters.gaussian_filter(np.roll(norm_l, -displ - start) *  
                                np.roll(norm_l, -displ -  
                                start), wid, 0, s_l)  
        filters.gaussian_filter(norm_r * norm_r, wid, 0, s_r)  
        # Save the grade of NCC  
        dmaps[:, :, displ] = s / np.sqrt(s_l * s_r)  
    # Choose best pixel for every sub-pictures  
    return np.argmax(dmaps, axis=2)
```

3.2 Observation

From the result based on NCC or Gaussian filter, we can know that:

1. There is more information among the disparity maps based on NCC, but also more noise in these pictures. However, for gaussian filter to calculate the disparity, the image is smooth but too noisy.
2. For a series of the pictures about corridors, the disparity map filtered by NCC is better than another, because it includes more details and will be easier to observe.

3. For a series of the pictures about triclopsi2, the disparity map filtered by Gaussian filter is better than another, because it ignores more useless details and can show a more smooth disparity map to us.

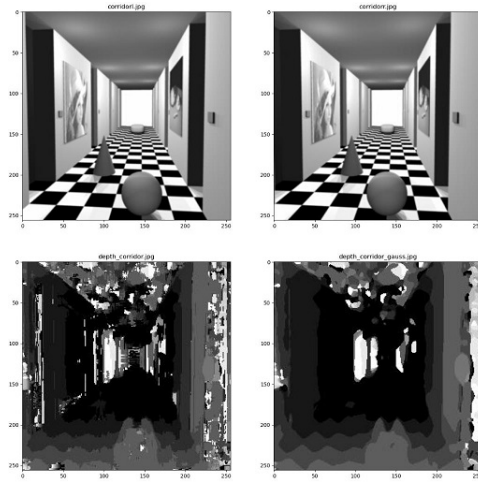


Figure 4: 4 comparisons between disparity map and corridors' images

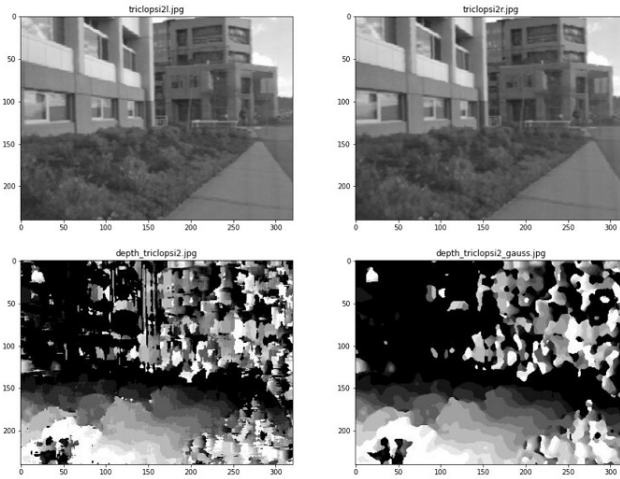


Figure 5: 4 comparisons between disparity map and triclopsi2' images

4 Discuss affects for the disparity map and improvements, Implement and verify ideas

4.1 Affects

1. The algorithm: From the 2 algorithms we chose above, the results of disparity map mainly depend on filters. The weights of the NCC filter are same, but the weights of gaussian filter are decreasing from the centre to borders. So that's why we can see more smooth images by the way of gaussian filter.
2. The size of windows: The size of filters influences on the result of filtering and finally influences on disparity map. Seeing the disparity map below, we know that for the way of NCC, the larger the size of filters, the less details are, but the smoother the images are. On the contrast, for the way of gaussian filter, the increase of the size of windows will show much less information to us and it is not suitable to expand the size of windows by this way.

4.2 Changing the size of windows

Based on the analysis and assumptions of affects and improvements above, we can test different the size of windows to influence the rectified images.

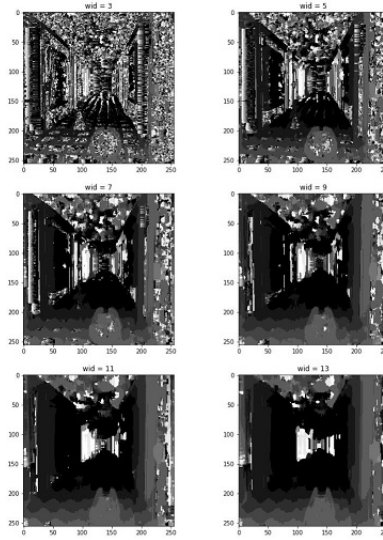


Figure 6: Corridors' ncc of different wids

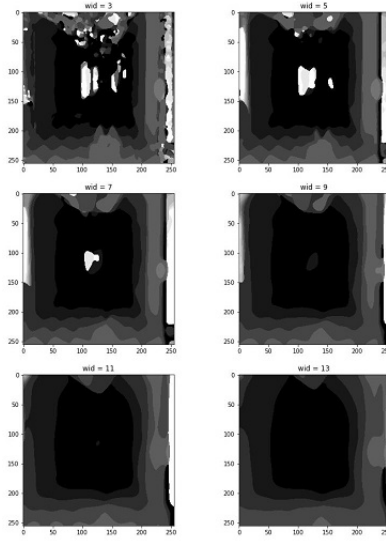


Figure 7: Corridors' ncc of different wids with gaussian filter

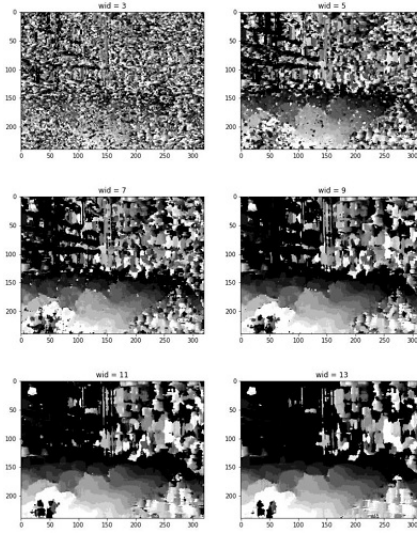


Figure 8: Triclops2's ncc of different wids

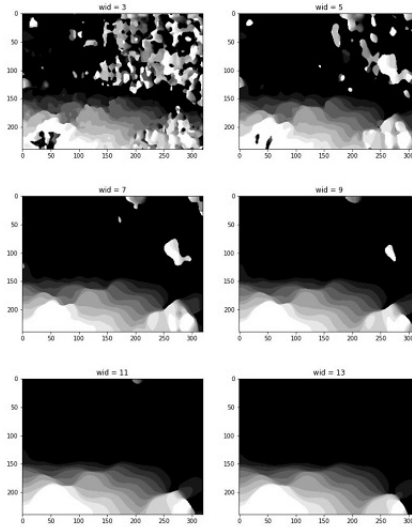


Figure 9: Triclops2’s ncc of different wids with gaussian filter

4.3 Summary

Finally, we find that if we choose the size of windows for basic NCC is 9 or 11, not too big or too small, the result is better than others. And if we choose the size of windows for Gaussian filter is 3 or 5, it’s enough because too large size will ignore too many details.

References

- [1] Daniel Scharstein. A taxonomy and evaluation of dense two-frame stereo correspondence. In *Proceedings of the IEEE Workshop on Stereo and Multi-Baseline Vision, Kauai, HI, Dec, 2001*, 2001.
- [2] Daniel Scharstein and Richard Szeliski. High-accuracy stereo depth maps using structured light. In *2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2003. Proceedings.*, volume 1, pages I–I. IEEE, 2003.
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- [4] Wikipedia contributors. Computer stereo vision — Wikipedia, the free encyclopedia, 2020. [Online; accessed 14-October-2020].