Graduation Project

Optimization of the Adaptive Matching Method for Indoor Environment Based on Binocular Vision

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Content

1.1 Introduction of Stereo Matching

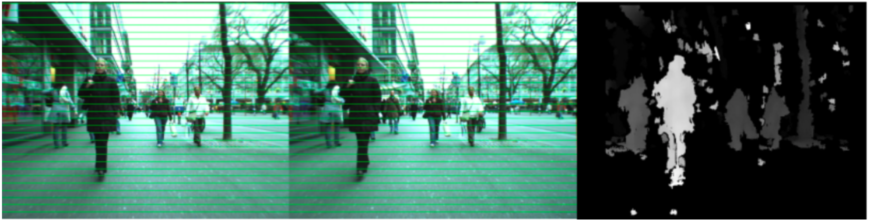


Figure 1: Stereo Matching

As an important branch of computer vision, stereo matching aims to extract three-dimensional information from two-dimensional images and restore the three-dimensional scene.

1.2 Application of Stereo Matching

(a) Machine inspection (b) Fingerprint recognition (c) Face detection

Figure 2: Application of stereo matching

Industrial application : Machine inspection, Fingerprint recognition, Face detection, 3D reconstruction and etc.

1.3 Classification of stereo matching

According to the optimization theory used, stereo matching algorithm can be divided to global matching algorithm and local matching algorithm.

Table 1: Classification of stereo matching

Type	Time	Accuracy	Example
Global	long	high	graph cuts, belief propagation
Local	short	low	SAD, SSD, NCC, ASW

ASW(Adaptive Support-weight) algorithm is one of the most accurate local matching algorithms, while it consumes much time to calculate weights because of its high computational complexity and needs to be improved.

2. Research work

1. Using the 4 standard image test pair supported by stereo matching standard test platform, study and experimentally analyze current local matching algorithms, including SAD, SSD, NCC and ASW.
2. Optimize the ASW algorithm by simplifying its color support-weight function
3. Add subsequently processes to the original disparity map, including left-right continuity test, occluded filling and median filtering.

3.1 Stereo matching principle

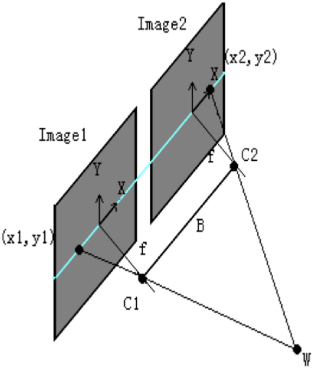


Figure 3: Binocular imaging

- Disparity : B is the optical center distance of two cameras, f is the focal distance, $(x1, y1)$, $(x2, y2)$ are the position of point w respectively on the left image and the right image. Then $d = |x1 - x2|$ is the disparity of two 2D points.
- Based on the pixel disparity, we can restore its 3D information according to the principle of projection geometry.

3.2 Principle of SAD, SSD and NCC

Suppose that p_i and p_j are the gray values of the matching points and candidate matching points, the matching cost of each algorithm is as follows :

- SAD(Sum of Absolute Difference) :

$$C_{SAD} = \sum (p_i - p_j) \tag{1}$$

- SSD(Sum of Square Difference) :

$$C_{SSD} = \sum (p_i - p_j)^2 \tag{2}$$

- NCC(Normalized Cross Correlation) :

$$C_{NCC} = \frac{\sum p_i p_j}{\sqrt{\sum p_i^2 p_j^2}} \tag{3}$$

3.3 Principle of ASW

Suppose that p is the pixel to be matched in the left view, q is a pixel in the support window of the left view, the support weight of the pixel point p for pixel point q is :

$$w(p,q) = f(\Delta c_{pq}) \cdot f(\Delta g_{pq}) \tag{4}$$

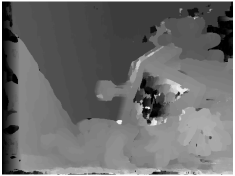
where $f(\Delta c_{pq})$ represent the color similarity of p and q, $f(\Delta g_{pq})$ represent the spatial similarity of p and q.
Then the matching cost of p and $\overline{p_d}$ is given as follow :

$$E(p,\overline{p_d}) = \frac{\sum_{q\in N_p,\overline{q}\in N_{\overline{p_d}}} w(p,q)w(\overline{p_d},\overline{q_d})e_0(q,\overline{q_d})}{\sum_{q\in N_p,\overline{q}\in N_{\overline{p_d}}} w(p,q)w(\overline{p_d},\overline{q_d})} \tag{5}$$

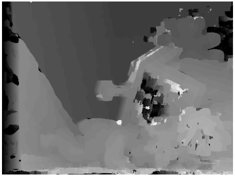
4.1.1 Disparity maps of SAD, SSD, NCC and ASW

Take Teddy test pair for example, matching window 11×11

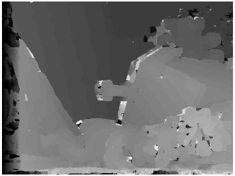
(a) Left image



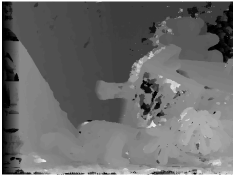
(b) SAD diaparity



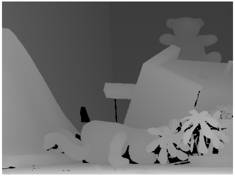
(c) SSD disparity



(d) NCC disparity



(e) ASW diaparity



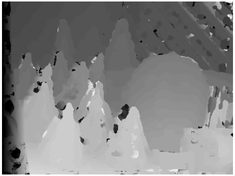
(f) Standard disparity

Figure 4: Result of Teddy test pair

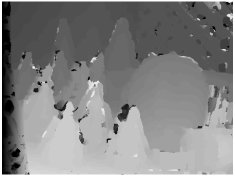
4.1.1 Disparity maps of SAD, SSD, NCC and ASW

Take Cones test pair for example, matching window 11×11

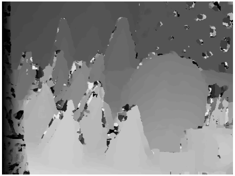
(a) Left image



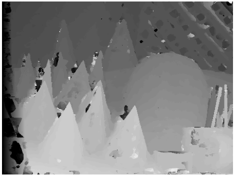
(b) SAD diaparity



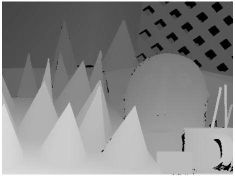
(c) SSD disparity



(d) NCC disparity



(e) ASW diaparity



(f) Standard disparity

Figure 5: Result of Cones test pair

4.1.2 Contrast between four algorithms

Here are the false matching rate contrast of disparity maps generated by four algorithms

Table 2: False matching rate contrast (unit : percent)

	Avg.	Cones			Teddy			Tsukuba			Venus		
		nonocc	all	disc	nonocc	all	disc	nonocc	all	disc	nonocc	all	disc
SAD	18.30	21.02	23.20	20.57	27.81	28.84	32.65	14.45	14.74	29.52	6.77	6.69	39.48
SSD	18.67	20.21	23.03	20.82	27.77	29.11	33.13	15.45	15.76	36.93	6.84	6.77	42.74
NCC	17.10	19.50	22.66	16.48	21.42	24.20	26.10	15.51	15.79	15.41	5.80	5.73	28.82
ASW	17.89	17.52	19.69	16.48	23.29	25.08	26.10	13.70	13.94	15.41	12.72	12.85	28.82

where nonocc stands for non-occluded region, all stands for all region and disc stands for discontinuity region.

4.1.2 Contrast between four algorithms

Here are the running time contrast of disparity maps generated by four algorithms

Table 3: Running time contrast (unit : second)

	Cones	Teddy	Tsukuba	Venus
SAD	20	19	4	7
SSD	65	64	11	20
NCC	129	129	23	45
ASW	606	597	104	202

We can easily find that the running time of ASW $>$ NCC $>$ SSD $> SAD$.

4.2 Design of optimization

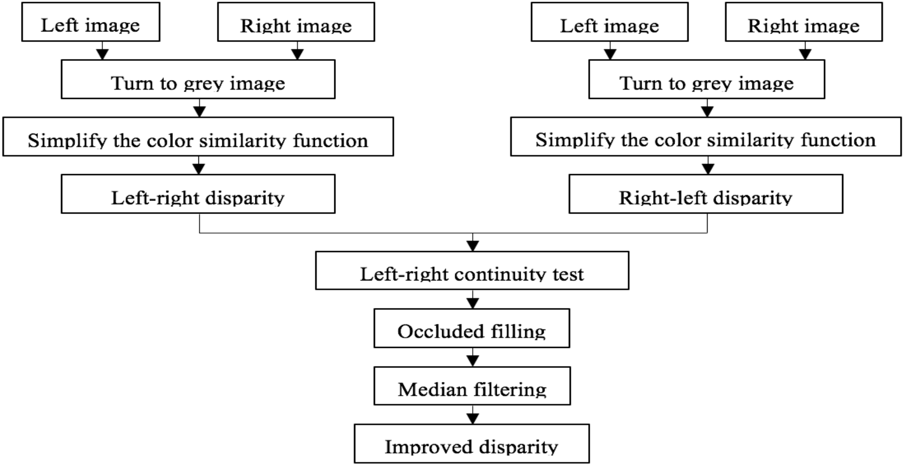
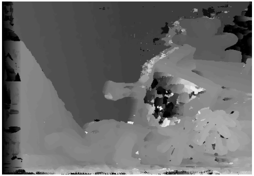


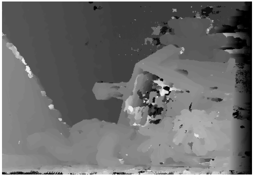
Figure 6: Design of Optimization

4.3.1 Disparity maps of optimized algorithm

Take teddy test pair for example, matching window 11×11

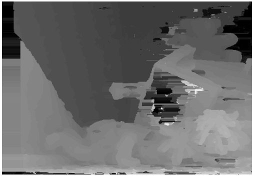


(a) Left-right disparity

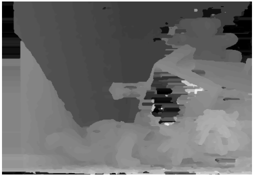


(b) Right-left disparity

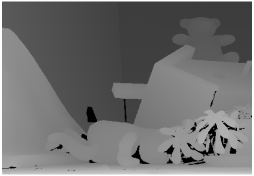
(c) Occluded Region



(d) Occluded Filling



(e) Median Filtering

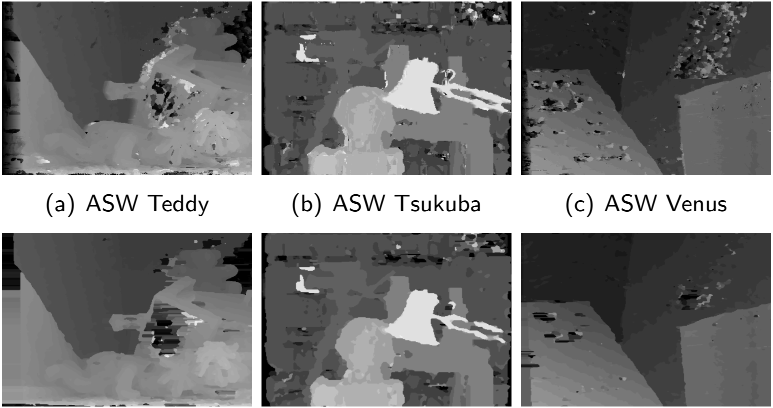


(f) Standard disparity

Figure 7: Result of Teddy test pair

4.3.2 Contrast of optimized algorithm and ASW algorithm

Here are the contrast of optimized algorithm and ASW algorithm for test pair Teddy, Tsukuba and Venus.



(a) ASW Teddy (b) ASW Tsukuba (c) ASW Venus

(d) Optim. Teddy (e) Optim. Tsukuba (f) Optim. Venus

Figure 8: Contrast of two algorithms

4.3.2 Contrast of optimized algorithm and ASW algorithm

Here are the false matching rate contrast of optimized algorithm and ASW algorithm.

Table 4: False matching rate contrast (unit : percent)

	Avg.	Cones			Teddy			Tsukuba			Venus		
		nonocc	all	disc	nonocc	all	disc	nonocc	all	disc	nonocc	all	disc
ASW	17.89	17.89	17.52	19.69	16.48	23.29	25.08	26.10	13.70	15.41	12.72	12.85	28.82
IMP	15.13	19.37	18.91	16.71	23.63	24.74	25.78	11.71	11.88	13.27	5.00	5.00	21.51

Compared with the ASW algorithm, the false matching rate of optimized algorithm has reduced by 2.76 percent on average.

4.3.2 Contrast of optimized algorithm and ASW algorithm

Here are the running time contrast of optimized algorithm and ASW algorithm.

Table 5: Running time contrast (unit : second)

	Cones	Teddy	Tsukuba	Venus
ASW	606	597	104	202
IMP	454	452	82	155

Compared with the ASW algorithm, the running time of optimized algorithm has reduced by 20 percent on average.

4.4 Conclusion

1. By simplifying the color similarity function formula of the original ASW algorithm, the running time of program has reduced by 20 percent.
2. By performing the left and right consistency detection, occlusion filling and median filtering, the accuracy of disparity map has improved by 2.76 percent,
3. The improved algorithm has good stereo matching accuracy on multi-texture region and multi-level region, and its matching accuracy of discontinuous region is better than that of original ASW algorithm.

Thank you !