A Fast Azd Robust Baed on Stero Matching Algorithm

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Abstract: The are-based stereo matching algorithm is the commonly used method in stereo matching. Due to the traditional are-based stereo matching algorithm have high matching error rate, sensitive for noise and matching speed low, a fast and robust are-based stereo matching algorithm is proposed. In this paper a new similarity function is employed to improve the robust of matching. At the same time, the disparity gradient is used to reduce matching search space and improve matching speed largely. The result of experimental prove that the algorithm in this paper have lower matching error rate than SSD algorithm and doubled the matching speed of the SSD algorithm.

Keywords: stereo matching, disparity gradient, robust

1. Introduction

Stereo vision is an important way to obtain the information of a three-dimensional objects which use the computer vision technology，it has large application in intelligent Robot, Route Planning, Navigation, Reverse engineering and so on. Stereo matching is critical step and most difficult step[1]. According to the different elements of matching, matching algorithm can be divided into are-based stereo matching algorithm, feature matching algorithm, phase-based matching algorithm[2]. Are-based matching algorithm is based mainly around images corresponding points neighborhood of the relevance of gray, its characteristics are easy to implement and can obtain dense disparity map, but its accuracy vulnerable to the surface structure and light reflection effects[3]. Feature matching through the extraction point, line or edge, and other features to match, characterized by the extraction of these features is not too sensitive to noise, robustness, matching high precision, but can only get the sparse disparity map. Phase matching is to use a band-pass under conditions similar to the corresponding point of the phase of the terms of disparity, characterized by anti-noise and has a good performance and resisted the geometric distortion and radiation distortion, but there is the singular point and phase-phase winding problems.

Through the above analysis, we use the information of regional gray of image for the matching groups. Construction of the new measure similar function improved matching algorithms anti-noise and robustness.

Reduce matching the search space and increasing the matching rate by the introduction of the disparity gradient. At same time use the small matching window to reduce the matching error rate at the edge of image.

2. Similar Measure Function

The traditional similar measure functions which are commonly used by the are-based matching are SSD, SAD, NCC, etc. These similar measure functions are sensitivity of the noise. Such as SSD, its function of the mathematical expression as formula (1) as shown below.

$$\text{SSD(x,y,d)}=\sum_{xy}[(I_L(x,y)-I_R(x-d,y)]^2 \quad (1)$$

Among the formula (1), $I_L(x,y)$ is the gray value of point (x,y) of the left image. $I_R(x-d,y)$ is the gray value of the point $(x-d,y)$ of the right image. d is the disparity. We can see that the function is actually a quadratic function $\rho(x)=X^2$. It's the derivative function is $\varphi(x)=2X$, the two function curve as shown in Figure 1.

From the figure 1 (a) we can seen that $\rho(x)$ change largely with the X changed. Figure 1 (b) reflects the SSD function for the noise in stereo matching is a linear increasing. Therefore noise reduces the performance of the SSD function. In order to solve the noise problem, we employ a new similar measure function which based on $\rho_\sigma(n)$ function[4]. $\rho_\sigma(n)$ and its derivative functions of the mathematical expression:

$$\rho_\sigma(n)=\log[1+\frac{1}{2}(\frac{n^2}{\sigma})] \quad (2)$$

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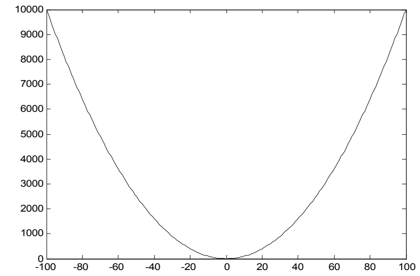
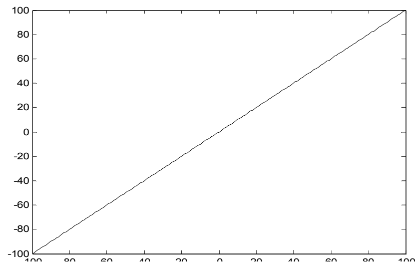
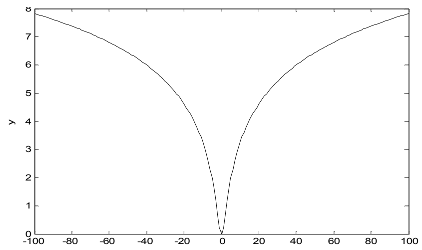


(a) $\rho(x) = X^2$ function curves

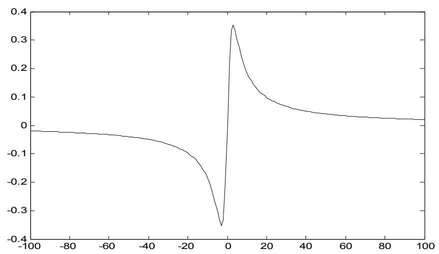


(b) $\varphi(x) = 2X$ Function curves

Figure 1. $\rho(x) = X^2$ **Function curves and** $\varphi(x) = 2X$ **function curves**



(a) $\rho_\sigma(n)$ Function curves



(b) $\psi_\sigma(n)$ function curves

Figure 2. $\rho_\sigma(n)$ **Function curves and** $\psi_\sigma(n)$ **function curves**

$$\psi_\sigma(n) = \frac{2n}{2\sigma^2 + n^2} \tag{3}$$

Among them, d is disparity and the n express $n(x,y) = I_L(x,y) - I_R(x-d,y)$. σ is variable parameter. The two function curve shown in Figure 2.

From the figure 2(b) we can seen that $\rho_\sigma(n)$ smoothly suppress noise and make the noise effect to zero. Replacing the traditional SSD function with the $\rho_\sigma(n)$ function, a new similar measure function is created as formula (4) as show below.

$$E(d) = \sum_{xy} \rho_\sigma(I_L(x,y) - I_R(x-d,y)) \tag{4}$$

Disparity is:

$$d = \arg\min E(d) \tag{5}$$

3. Disparity Gradient Bound and Window Choose

3.1 Disparity Gradient Definition and Binding

Though studying the human visual system, Burt P and Julesz B find that a point in the left image which can find corresponding point in right image the disparity gradient between them must be less than K[5]. As shown in figure 3 of the binocular stereo vision system for any point $P(x,y,z)$ in the scene, its projection points respectively in left image and right image are $P_L(x_L, y_L)$ and $P_R(x_R, y_R)$ .Regarding the system is binocular stereo vision system ,so the $y_L = y_R$ and the disparity can express as: $d = x_L - x_R$. Any two points $P^1(x^1, y^1, z^1)$ and $P^2(x^2, y^2, z^2)$ in the scene, their projection points on left and right image respectively for $P_L^1(x_L^1, y_L^1)$, $P_L^2(x_L^2, y_L^2)$, $P_R^1(x_R^1, y_R^1)$, $P_R^2(x_R^2, y_R^2)$ .The disparity gradient can be defined as[6]:

$$\nabla d = \frac{|d_2 - d_1|}{\|P_C^2 - P_C^1\|} = \frac{2\left|(x_L^2 - x_R^2) - (x_L^1 - x_R^1)\right|}{\|(P_L^2 + P_R^2) - (P_L^1 + P_R^1)\|} \tag{6}$$

Among the formula (6): $d_1 = x_L^1 - x_R^1$, $d_2 = x_L^2 - x_R^2$,

$$P_C^1 = \frac{P_L^1 + P_R^1}{2}, \quad P_C^2 = \frac{P_L^2 + P_R^2}{2}.$$

Set $\Delta x_L = x_L^2 - x_L^1$, $\Delta x_R = x_R^2 - x_R^1$. In this paper we consider that all images make the external epipolar correction and corresponding scanning lines and epipolar line at the same location and direction. So we match point by point before and after along scanning lines by order restraint which based on left image, then we can deduce $\Delta y_L = \Delta y_R = \Delta y = y^2 - y^1 = 0$. $\Delta x_L = 1$ [7]. Thus disparity gradient simplify:

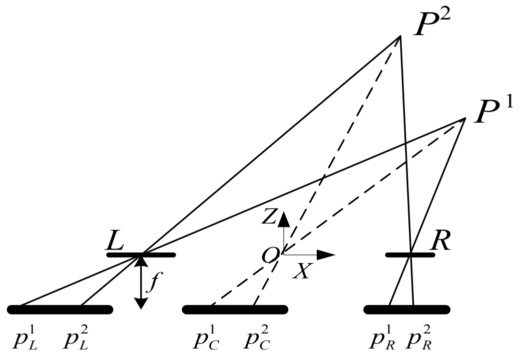


Figure 3. Parallel binocular vision system disparity gradient definition

Table 1 ∇d of the scope and the range between Δx_R

Δx_R of the range	∇d of the range
0	2
1,2,3,4	(0,+1.2)
4,5,6… d_{max}	(+1.2,2)

$$\nabla d = \frac{2\left|\Delta x_L - \Delta x_R\right|}{\sqrt{(\Delta x_L + \Delta x_R)^2}} = \frac{2\left|\Delta x_R - 1\right|}{\sqrt{(1+\Delta x_R)^2}} = \frac{2\left|\Delta x_R - 1\right|}{1+\Delta x_R} \qquad (7)$$

From the formula (7) we can obtain the relationship between of the availability range of ∇d and the availability range of Δx_R which shown in table 1

When $\nabla d > 21$, violation of the restraint order. When $\nabla d = 2$, violation of the only restraint. When $0 < \nabla d < 1.2$,the smooth disparity region. When $1.2 < \nabla d < 2$,the edge region of image[8]. From $\Delta x_R = x_R^2 - x_R^1$ and the formula (7), the formula (8) can be deduced:

$$x_R^2 = \Delta x_R + x_R^1 = \frac{2+\nabla d}{2-\nabla d} - d_1 + x_L^1 \qquad (8)$$

Through the formula (8) we can predict the next point search range in the right image by the location , disparity and disparity gradient of previous point.

3.2 Windows Choose

In the are-based matching algorithm, the window size is a difficult choice. On the one hand, in the smooth region the window size must choose as large as possible to include more information to reduce the matching error rate. On the other hand, in the edge region the window size must choose as small as possible to reduce unnecessary information which leaded the wrong matching. So under the previous derived, when $0 < \nabla d < 1.2$, choose the 15×15 window size to match, when $1.2 < \nabla d < 2$, choose the 3×3 window size to match.

3.3 Algorithm Flow

1) Input left image I_L and right I_R , use 15×15 size of the window, obtain the corresponding first and second point of disparity d_1 and d_2 by the formula $\arg\min E(d)$ from the upper left corner of image which based on the left image.

2) According the formula (7) to calculate the disparity gradient ∇d , when $0 < \nabla d < 1.2$ the size of matching window choose 15×15 ,when $1.2 < \nabla d < 2$ the size of matching window choose 3×3 , and use the formula (8) to predict the search range along the external epipolar line.

3) According to $\arg\min E(d)$ determine the corresponding match point and obtain the disparity d' .

4) Go to 5) if the search has attain the bottom right corner of the image, else go to 2)

5) Use median filter to disparity map.

4. The Experimental Results

We used two groups of international standard pictures to test our algorithm and obtain satisfactory results. Experimental use of the 128 M memory of the Pentium III 550 MHZ PC, with matlab programming. The stereo images use the Tree and Tsukuba which the largest disparity is 19 pixels. Table 2 shows the relation of our algorithm and SSD in calculation time and matching error rates. From the table 2,we can seen that our algorithm not only matching error rate lower than the SSD algorithm, but also with more speed than SSD algorithm.

Table 2 is as follow:

5 Conclusions

Through analysis existing stereo matching algorithm and their constraints, the anti-noise and robust similar measure function was proposed in this paper. By introducing disparity gradient to restrain search interval to reduce redundant search and improve the matching rate. At the same time, according the scope of disparity gradient determine the edge of image and use the small

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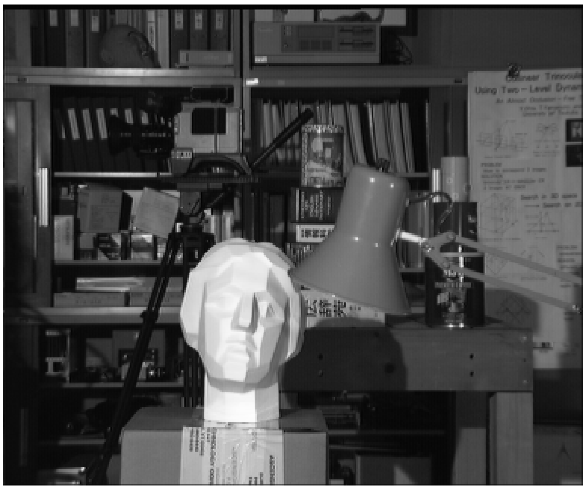
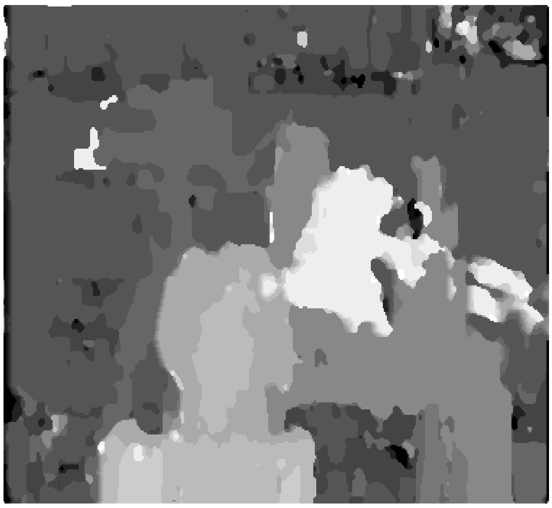
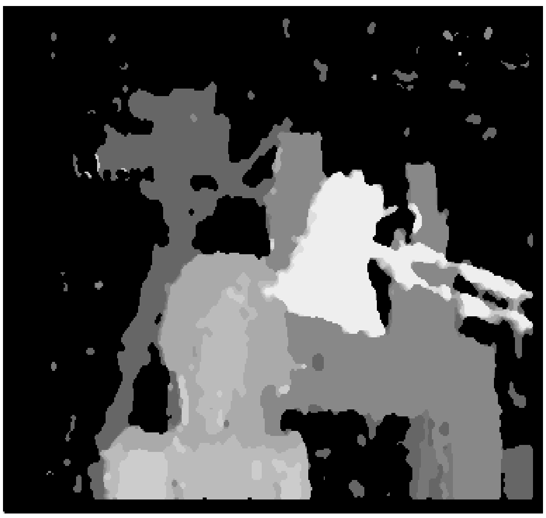


(a) Tsukuba left image

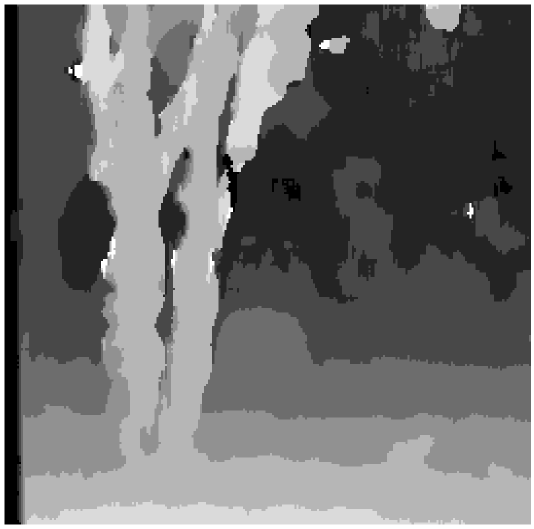


(b) SSD's disparity

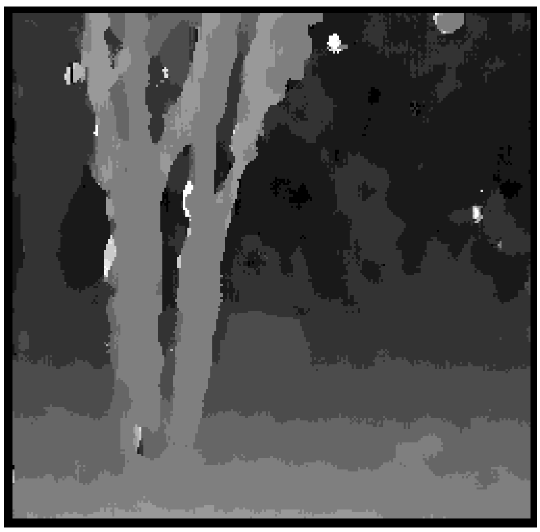


(c) Paper's disparity

(d) Tree left image



(e) SSD's disparity



(f) Paper's disparity

Figure 4. Experimental results of tes

Table 2 This algorithm and SSD computing time, the match error rate compared

Image pairs	Large/ Pixels	Computing time/s		Error rate of matching%	
		Paper's algorithm	SSD	Paper's algorithm	SSD
Tree	256x233	148	336	6.2%	8.6%
Tsukuba	384x288	206	435	7.1%	9.7%

size of window to match, so this solve the traditional fixed window matching algorithm have poor match at edge of image. From the results of the experiment, this method is simple, robust, low error rate of matching, matching high-speed, adapted to the requirements of real-time system.

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