International Journal of Hybrid Information Technology
Vol.3, No.1, January, 2010

A New Stereo Matching Algorithm for Binocular Vision

[1]Tao Hu and [2]May Huang

[1]School of Information Engineering, Hubei University for Nationalities
Enshi, Hubei, P.R. China
[2]School of Software and Microelectronics, Peking University
Beijing, P.R. China
[1]hutao_505@hotmail.com, [2]may_y_huang@yahoo.com

Abstract

The stereo matching algorithms for binocular vision are very popular and widely applied. However, the algorithms may have lower matching quality or higher time complexity. To improve that, a new stereo matching algorithm based on square and gradient for binocular vision is proposed in the paper. It divides an image line into a serious of ranges with comparing the gradients of the points in left and right image lines. The best matching in each range is found based on the summery of squared differences. The algorithm inherits the high quality of gradient algorithm and high performance of SSD algorithm and meanwhile avoids the additive noise.

Keywords: *Stereo Matching, Binocular Vision, Gradient, Confident*

1. Introduction

Computer vision is an important research area which has a broad range of applications. The research on computer binocular vision is a critical and challenge issue in the field of computer vision.

The binocular vision is a method to capture the information of an object in three-dimensional (3D) vision based on disparity among numbers of images. It can reconstruct a profile of the object and define its location in 3D space. David Marr, worked at Artificial Intelligence Laboratory of MIT, proposed a computational vision theory in 80's and used it in binocular matching. Marr's theory was that image processing in the human visual system has a complicated hierarchical structure that involves several layers of processing [4].

The classical stereo matching for binocular vision can be described briefly as: Using two cameras to screen a scene, use two data in two-dimensional (2D) visions to implement a point in 3D vision [2]. Using an appropriate method to process these two images, compute the location of a point in 3D and the distance from the point to the central of two cameras. There are a lot of researches in the field such as Grosso et al (1989), Grosso and Tistarelli (1995) did stereo matching for binocular vision [3].

Three type's stereo matching algorithms are commonly used: Local Matching, Feature Matching and Phase Matching [4].

In this paper, a new stereo matching algorithm which is introduced below: There are images taken by two cameras. Set the left image as the original and the right as the matching image. Compute the gradients on both left and right images in order to determine the matching range. Find out confident points in left and right images based on the gradients. Compute the matching range and obtain the disparity range based on the confident points. Find out the best matching points in the matching range using the disparity range. Generate a disparity map for the matching.

2. Key Technique

2.1 Gradient Vector

The gradient in scalar field is similar to a vector in vector field in calculus. The gradient of a point in scalar field identifies the direction in which the scalar field increased fastest [5]. The length of gradient is the largest change rate. In general, people use the gradient to estimate the changes of edges of an image.

The new algorithm proposed in the paper uses the difference of gradients between left and right images to determine if the corresponding points are confidence points. We use Sobel operator to calculate the gradients in the images. The Sobel operator in X axis is shown in Figure 2.1 (a), and The Sobel operator in Y axis is shown in Figure 2.1 (b).

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

(a) (b)

Figure 2.1 Sobel operator

Assuming the coordinate of a point in an image is (x, y), apply template operation on this point and it's neighborhood with the Sobel operator. The results of this operation are $\frac{\partial I}{\partial x}(x,y)$ and $\frac{\partial I}{\partial y}(x,y)$. Formula 2-1 gives the calculation to the gradient of this point.

$$g(x,y) = \sqrt{(\frac{\partial I}{\partial x}(x,y))^2 + (\frac{\partial I}{\partial y}(x,y))^2} \tag{2-1}$$

2.2 Confidence Point

Using gradient-based stereo matching, we can know if a successful matching is achieved. Defining the difference of gradients in left and right images as a threshold to determine if the corresponding points are confident points.

In the new algorithm, we find the confident value of a point with calculating its gradient. And then compare the calculated value with the threshold to determine if the point is a confident point. Assuming a test line defined on the left image and a point on the test line is (x, y). The disparity value tested is (dx, dy). The point in right image would be (x+dx, y+dy). We use Formula 2-1 to calculate the gradients of the points: GL(x, y) and GR(x+dx, y+dy). The confident value of a point on the left image can be calculated using Formula 2-2.

$$Gt(x,dx,y,dy)=\frac{\left|GL(x,y)-GR(x+dx,y+dy)\right|^2}{\left|GL(x,y)\right|^2} \tag{2-2}$$

After the confident values of all points on testing line being calculated, use Formula 2-3 to determine if point (x, y) is a confident point.

$$d\_con = Gt(x,dx,y,dy) - confidence\_threshold \tag{2-3}$$

If the d_con >0, this means that the point (x, y) in left image and the point (x+dx, y+dy) in right image are the pair of confident points.Using the confident points and their disparity values, we can divide the test line on an image into pieces ranges. Formula 2-4 can be used for selecting the range which is closest to the camera.

$$Confidence\,Point(x,dx,y,dy) = \max(Gt(x,dx,y,dy)) \tag{2-4}$$

Recursive calculation is then applied in the range.

In order to reduce the confident threshold and disparity range, a linear interpolation method can be used to confirm a new disparity range. For a linear equation f(x), the linear interpolation is shown in Formula 2-5. The proportion of current confident threshold is then used to compute a new threshold. With continuing reduce of the threshold, the confidence value of a point keep increasing. When the value of threshold is close to zero, we call the state of the point as base case. In the base case, the disparity range is small, and the accuracy of matching is high.

$$f(c) = f(a) + \frac{c-a}{b-a}(f(b) - f(a)) \tag{2-5}$$

The recursive operation is applied to obtain the base case.

2.3. Stereo Matching

After we found the nearest matching range, fill the range with grey values using linear interpolation method. Use the SSD (Sum of Squared Differences) [6] method to do stereo matching for this paragraph. For a disparity range which we have estimated in part 2.2 and a variable range [-n, n], we can use Formula 2-6 [5] to calculate point's SSD value on left the image.

$$SSD(x,y) = \sum_{v=-n}^{n}\sum_{u=-n}^{n}(L(x,y) - R(x+v+t, y+u))^2 \tag{2-6}$$

Set a threshold d; calculate the SSD(x, y) in different t in the disparity range. If SSD(x, y) <d, set d equal SSD(x, y) and record t. When computed the whole disparity range, we can obtain best disparity value T. The point (x+T, y) on right image which can provide the best match with the point (x, y) on left image.

3. Stereo Matching Algorithm

Base on the confident points and the SSD, the Figure 3.1 shows the whole matching procession for binocular vision.

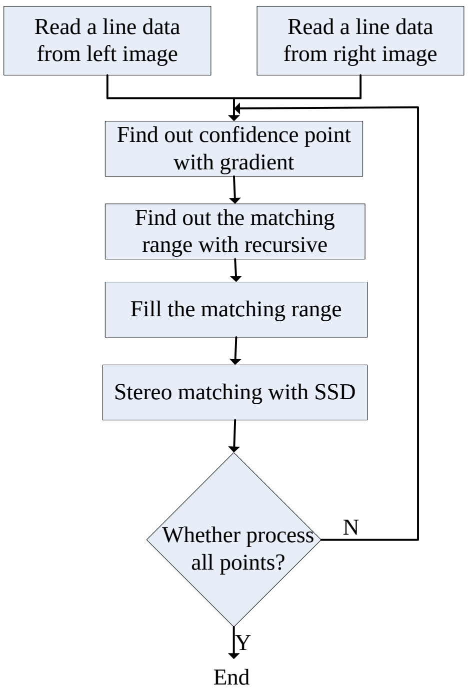

Figure 3.1 The algorithm flow chart

4. Experimental Results

Two Logitech® QucikCamTM cameras were used for capturing images from two angles, and the algorithm introduced above was applied to process the images toward stereo matching.

Two pairs of images taken by two cameras are shown in Figure 4.1 and 4.2 individually. With applying the algorithm, the matching results of the two test cases are shown in Figure 4.3.

Figure 4.1. Testing image pair one

Figure 4.2. Testing image pair two

Stereo matching for Testing image pair one

Stereo matching for Testing image pair two

Figure 4.3 Stereo matching results

In order to verify the performance of the new algorithm, we tried another two classic stereo matching algorithms for binocular vision: SSD-based matching and Gradient-based matching. We use different sizes of image pairs to test three matching algorithms. The performances of different sized images with different algorithms are shown in Table 4.1, and the corresponding timing curves shown in Figure 4.4.

Table 4.1 Algorithms using time

	Image size: 320*240	Image size: 420*385	Image size: 640*480
SSD Matching	3.25s	5.54s	8.33s
Gradient Matching	68.16s	153.14s	217.47s
New Algorithm	29.76s	48.40s	65.32s

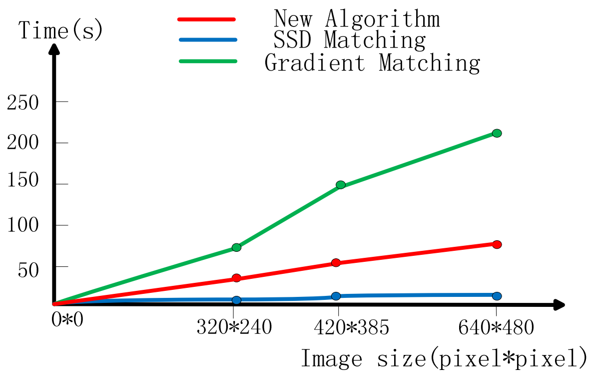

Figure 4.4 Using time curve

The comparison among the three algorithms, the experimental results shown the new algorithm is far efficient than gradient-based matching. Furthermore, the new algorithm is noise-insensitive. SSD-based matching is much faster but the matching results are not comparable to the new algorithm.

We are now improving the new algorithm for generating better disparity map.

5. Conclusion

A new stereo matching algorithm for binocular vision is proposed in the paper. A gradient vector is used to determine confident points and to estimate the disparity range. The new algorithm borrows the principle of SSD matching method and reduces the matching range to the limit with the range of confident points and the range of disparity. The new algorithm is also shown the high performance when finding proper matching and disparity ranges. Further improvement of the new algorithm is our current work to achieve more satisfactory matching results.

Acknowledgements

This work is supported by the Joint Lab between International Technological University and Peking University. During the research, many valuable suggestions provided from Dr. Eric Chen, and a lot of assistance obtained from Hu Xu and Wei Chen.

Reference

[1] David A. Forsyth, Jean Ponce, “Computer Vision: A Modern Approach”, Prentice Hall, 2003.

[2] R. A. Lane, N. A. Thacker. “Stereo vision research: An algorithm survey. Technical Report 94/16, University of Sheffield, 1994.

[3] G. CALIN, V.O. RODA, “Real-TIME DISPARITY MAP EXTRACTION A DUAL HEAD STEREO VISION SYSTEM”, Latin American Applied Research, 2007.

[4] Pan Hua, Guo Ge, “Review of Stereo Vision”, Computer Measurement & Control, 2004.

[5] D. Scharstein, “View Synthesis Using Stereo Vision”, LNCS, 1999.

[6] L. Di Stefano, M. Marchionni, “A Fast Area-Based Stereo Matching Algorithm”, Machine Grapics & Vision, 2004.

Authors

Tao Hu is the Assistant in School of Information Engineering, Hubei University for Nationalities. He received a B.S. degree in Computer Science from Wuhan University of Technology in 2006. And the received a M.S. degree in School of Software and Microelectronics IC Design and Engineering, Peking University. His research interests include artificial intelligence, algorithms, image processing and embedded system.

May Huang, is the Visiting Professor in School of Software and Microelectronics IC Design and Engineering, Peking University. And she is the Professor and Department Head of Electrical Engineering, United States International Technology University. May received M.S. degree in United States Santa Clara University and Ph.D. degree in United States International Technology University. She has studied the artificial intelligence algorithms as a visiting scholar at Santa Clara University. In recent years, she has employed in the Department of Microelectronics, Tsinghua University and Peking University to undertake graduate teaching tasks. Now, she is doing the advanced technology research in integrated circuit design and artificial intelligence. She published many papers in the international academic journals and academic conference and has two U.S. patents and one Chinese patent.