Enhanced Stereo Matching Technique using Image Gradient for Improved Search Time

Pratibha Vellanki[1], Dr. Madhuri Khambete[2]

[1] ENTC Department, Cummins College of Engineering for Women, Pune University, Pune, India.

[2] Principal, Cummins College of engineering for Women, Pune University. Pune, India.

Abstract:

Stereo matching algorithms developed from local area based correspondence matching involve extensive search. This paper presents a stereo matching technique for computation of a dense disparity map by trimming down the search time for the local area based correspondence matching. We use constraints such as epipolar line, limiting the disparity, uniqueness and continuity to obtain an initial dense disparity map. We attempt to improvise this map by using color information for matching. A new approach has been discussed which is based on the extension of the continuity constraint for reducing the search time. We use correspondence between rows and gradient of image to compute the disparity. Thus we achieve a good trade off between accuracy and search time.

Keywords: *Color stereo matching, Image Gradient, Continuity constraint, Epipolar geometry, Stereo Vision.*

I. Introduction:

Stereo correspondence for dense disparity estimation has been one of the most researched topics in computer vision. Dense surface information is required in 3D reconstruction. The determination of corresponding matches of an object between the left image and the right image is called correspondence. If this correspondence is solved for each pixel then it results in a dense disparity computation. The motivation behind this dense matching is that almost all the image pixels can be matched. Correspondence is an essential problem in dense stereo matching. For the computation of a reliable dense disparity map the stereo algorithm must preserve discontinuities in depth and also avoid gross errors.

Traditional dense matching techniques are divided into two types; local window based matching and global optimization method. Local window based matching compares intensity similarity of neighborhood of the corresponding points to be matched. A cost parameter is used to decide the best match. In this approach the selection of appropriate window size is critical to achieve a smooth and detailed disparity map. The 2nd approach is the global optimization algorithm which optimizes a certain disparity function and the smoothness constraint item to solve the matching problem.

The technique of matching points by correlation uses two windows: a fixed window centered at the pixel of interest in the reference image and a slippery window that browses the search zone [1]. It is important to select two optimal parameters, which are: window size n x n and cost parameter. The window size selection depends on the local variation in texture and disparity. Generally a small window is used for unwanted smoothing, but in areas with low texture it doesn't have enough intensity variation for reliable matching. On the other hand if the disparity varies within the window then intensity values may not correspond due to projective distortions [2].

The design of the cost parameter decides the speed of implementing the stereo algorithm. The cost parameters generally used in area matching are Sum of absolute differences (SAD), Sum of squared differences (SSD), Zero mean normalized cross correlation (ZNCC), Zero mean sum of absolute differences (ZSAD). SAD and SSD are the most popular functions due to their simplicity [3]. We have used SAD as the cost function in a 3 x 3 window.

A. The matching constraints:

Some of the common constraints used for matching in stereo correspondence are as explained below:

- Epipolar constraint: Corresponding points must lie on corresponding epipolar lines.
- Continuity constraint: Disparity tends to vary slowly across a surface
- Uniqueness constraint: A point in one image should have at the most one corresponding match in the other image.
- Ordering constraint: the order of features along epipolar lines is the same.
- Occlusion constraint: discontinuity in one eye corresponds to occlusion in other eye and vice versa.

The motive of this paper is to improve area based correspondence in two aspects: accuracy and search time. To improve accuracy we have proposed to use color information for matching. The color makes matching less sensitive to occlusion considering the fact that occlusion often causes color discontinuities [4]. Thus all the images used in our algorithm are color images.

To make the stereo algorithm fast we have proposed to use inter-row dependency as an assumption. This assumption is based on the fact that, the disparities on the current row will be similar to their neighbors in the previous row unless the top face of a new surface or a new object (i.e. discontinuity) is starting exactly at the pixel of interest. Based on this assumption we have modified the area based matching algorithm to obtain results in less search time.

Even though a general problem of finding correspondences between images involves the search within the whole image, once a pair of stereo images is rectified so that the epipolar lines are horizontal scan lines, a pair of corresponding edges in the right and left images should be searched for only within the same horizontal scanlines. Thus we have used rectified images as inputs to our algorithm.

II. Color Information for matching:

There are many motivations behind using color information in stereo correspondence. Firstly, chromatic information is precisely obtained form CCD sensors of digital cameras. Secondly, recent developments in this area have proved that chromatic information plays an important role in human stereopsis. Thirdly, it is obvious that a red pixel cannot match with a green or blue pixel even if their intensities are same. Thus color information will potentially improve the performance of the matching algorithm.

The color space used here is RGB and the metric used is MSE. For color images we use MSE, defined as:

$$MSE_{color}(x, y, d) = \qquad (1)$$

$$(1/n^2)\sum_{i=-k}^{k}\sum_{j=-k}^{k} dist(C_R(x+i, y+j), C_R(x+i, y+j+d))$$

$$dist(c^1, c^2) = (R^1 - R^2)^2 + (G^1 - G^2)^2 + (B^1 - B^2)^2 \qquad (2)$$

In eq(1) and eq(2) d is the disparity and C^1 and C^2 are two points corresponding to the left and right images C_L and C_R, defined as:

$$C^1 = (R^1, G^1, B^1), \qquad C^2 = (R^2, G^2, B^2) \qquad (3)$$

The MSE is calculated using a 3 x 3 window and the left and right color spaces are defined as:

$$C_L(x, y) = (R_L(x, y), G_L(x, y), B_L(x, y)) \qquad (4)$$

$$C_R(x, y) = (R_R(x, y), G_R(x, y), B_R(x, y)) \qquad (5)$$

III. Inter-row dependency with gradient information :

As explained in the introduction the proposed algorithm is based on the assumption that in an image generally there is a background and there are objects placed on the background. Thus it is obvious that the column discontinuities are more than the row discontinuities. Based on this explanation we have modified the program such that the search zone for the pixel match depends on the disparity of its neighbor in the row just above. Except if there exists a column discontinuity then the algorithm will search the complete search zone for the perfect match. This is where the image gradient comes into picture. The column discontinuity is detected by computing the gradient in the column direction.

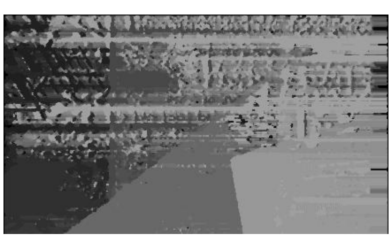
IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 1, May 2011
ISSN (Online): 1694-0814
www.IJCSI.org

The search window used without using inter-row dependency is 20. As the maximum value of true disparity for the test images used is not more than 20, the purpose is solved. With inter-row dependency, we limit the research window to -5 to +5 range of the disparity of the pixel just above the reference pixel. This reduces the research window by 50%. The search zone is further reduced when the gradient in the column direction is used, being -3 to +3 range of the disparity of the pixel just above the reference pixel. The objective to reduce the search time is thus satisfied with this method.

IV. Results and Conclusion:

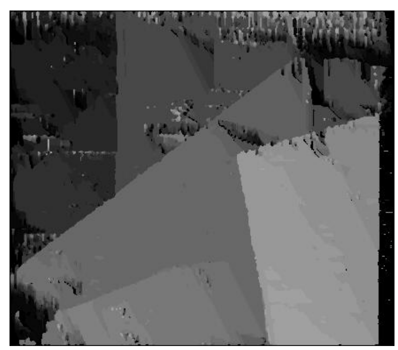
The stereo pair images used as inputs were obtained form middleburry university database. The images are rectified and thus satisfy the epipolar constraint and the intensity assumption. After obtaining the disparity map, median filtering is used to find the disparity of unmatched pixels. Median filter also discards any singular errors and makes the disparity map smooth. The results are as follows:

a) *The right image of the stereo pair*



b) *Output of traditional local area based correspondence algorithm for grayscale images*

c) *Output of traditional local area based correspondence algorithm for color images*



d) *Output of inter-row dependency algorithm*

The following is the table of results which comprises of the percentage of matched pixels for the traditional methods: local area correspondence algorithm for grey and for color images and our proposed algorithm: inter-row dependency algorithm respectively; for a set of 5 images.

Table I

Images	Grey	Color	Inter-row
Barn2	90.68%	97.02%	90.13%
Poster	89.70%	96.37%	88.48%
Venus	88.38%	96.44%	88.47%
Tsukuba	89.79%	93.93%	85.72%
Sawtooth	92.76%	96.98%	91.65%

The average search time for a 383 x 434 image in case of local area based correspondence algorithm is 220 seconds while in case if our inter row dependency algorithm is 30 seconds. From the table I, the percentage of matched pixels of our algorithm is almost the same as the traditional algorithm for grayscale images. From these factors we can conclude that our algorithm achieves good trade off between accuracy and search time.

References:

[1] Mohammed Rziza, Ahmed Tamtaoui, Luce Morin and Driss Aboutajdine, “Estimation and segmentation of a Dense Disparity Map for 3D Reconstruction” IEEE Transaction, 2000.

[2] D. Scharstein and R. Szeliski. “A taxonomy and evaluation of dense two-frame stereo correspondence algorithms" *International Journal of Computer Vision*, 47(1/2/3):7-42, April-June 2002.

[3] Jinhai Cai,”Fast Stereo Matching: Coarser to Finer with Selective Updating “,Proceedings of Image and Vision Computing New Zealand 2007, pp. 266–270, Hamilton, New Zealand, December 2007.

[4] Hajar Sadeghi, Payman Moallem and S. Amirhassn Monadjemi, ”Feature Based Dense Stereo Matching using Dynamic Programming and Color”, International Journal of Information and Mathematical Sciences,2008.

[5] Jiang Ze-tao, Zheng Bi-na, Wu Min and Chen zhong-xiang, “A 3D Reconstruction Method Based on Images Dense Stereo Matching”, IEEE Proceedings of International Conference on Genetic and Evolutionary Computing, 2009.

[6] Lu Yang, Rongben Wang, Pingshu Ge, Fengping Cao, “Research on Area–Matching , Algorithm Based on Feature-Matching Constraints” IEEE Proceedings of 2009 fifth International Conference on Natural Computation.