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IMPLEMENTATION OF DISPARITY ESTIMATION ALGORITHM FOR DIGITAL IMAGES

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Abstract - Obtaining the reliable disparity maps, indicating distance of surface from the stereo camera pair. Stereo vision is one of the methods. It uses stereo image pairs from two cameras to produce disparity maps that can be easily turn into depth maps. Reliability of depth maps and computational cost of algorithm is key issue for implementing real time robust applications.

Algorithm for visual correspondence search has been implemented to generated disparity. Quality metrics used for evaluating the performance of stereo correspondence algorithms and the techniques used for acquiring image data sets and ground truth estimates and got comparisons of the algorithm.

Keywords - Image Processing, Stereo matching, Window based method, horizontally line based method.

I. INTRODUCTION

In recent years, it is important research direction applying visual image technology for underwater target and environment detection.

Binocular vision, which is inspired by human visual process, computes the disparity between correspondence points in images captured by two cameras for distance measurement, and then recovers the depth information of the object. The image matching is one of the key technologies to realize underwater binocular vision. And the result of the matching would affect directly the precision of object recognition and 3D reconstruction.

Image matching is process of seeking the corresponding feature points in two different images which are in the same scene.

Binocular vision is the process of recovering depth from two images with the same height, the same direction and a certain distance, similar to human vision principle. During the process, stereo matching is the key point, which means to find the correspondence pixels of the same physical spatial point on both images. Binocular stereo matching algorithm research into two categories. One is based on sparse points, and the other is based on dense points. Many binocular dense-point matching methods in which the representatives are Birch Field and Yoon algorithm.

Obtaining reliable depth maps, indicating distance of surface from the stereo camera pair, have importance in robotic applications and autonomous systems.

II. BRIEF REVIEW

Stereo matching is technique that is well known for measure and it is very easy to understand. With stereo matching we can get the exact position of a target by two stereo pictures.

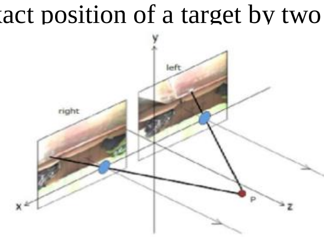

Figure:1Left and Right images with projection point P

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The position of a point P in 3D space can be measured by traditional stereo matching that computes the coordinate of *P*, *(x, y, z)*, from two pictures called left image and right image taken by two cameras separately.

In Figure 1 and 2 the point *P* is our target we want to know *P(x, y, z)* exactly. For convenience we only show the *x-z* plane in Figure 2. Assume that the two cameras have the same focus distance *f*, the distance between the two cameras is d, pl(*xl*,*yl*) denotes the coordinates of P in the left image and pr(*xr*,*yr*) denotes the coordinate of P in right image, we can get P(*x*,*y*,*z*) by,

$$x = \frac{d}{2} \cdot \frac{x_l + x_r}{x_l - x_r} \quad (1)$$

$$y = \frac{y_l . d}{x_l - x_r} \quad (2)$$

$$z = \frac{f.d}{m(x_l - x_r)} \quad (3)$$

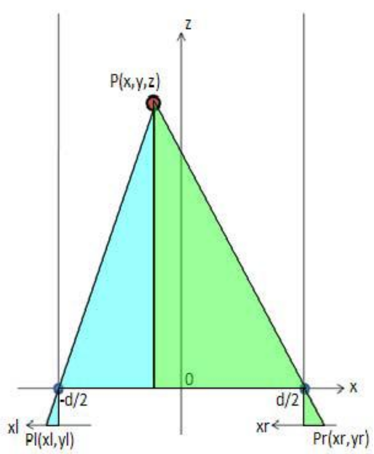


Figure:2Coordinates in xy-plane with point

III. PROPOSED METHODS

a) Window based Stereo Matching method:

In this method, we used a block-matching technique in order to construct an Error Energy matrix for every disparity. Lets denote left image in RGB format by *L*(*i*, *j*,*c*) , denote right image in RGB format by *R*(*i*, *j*, *c*) and error energy by *e*(*i*, *j*, *d*) . For *n* ×*m* window size of block matching, error energy *e*(*i*, *j*, *d*) can be expressed by,

$$e(i,j,d) = \frac{1}{3*n*m} \sum_{x=i}^{i+n} \sum_{y=j}^{j+m} \sum_{k=1}^{3} \left(L(x,y+d,k) - R(x,y,k)\right)^2 \quad (4)$$

where, c represents RGB components of images and takes value of {1,2,3} □ corresponding to red, blue and green. *d* is the disparity. For a predetermined disparity search range (*w*), every *e*(*i*, *j*, *d*) matrix respect to disparity is smoothed by applying averaging filter many times. For *n*×*m* window size, averaging filtering of *e*(*i*, *j*, *d*) can be expressed by following equation,

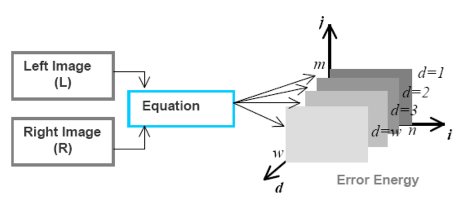
$$\tilde{e}(i,j,d) = \frac{1}{n*m} \sum_{x=i}^{i+n} \sum_{y=j}^{j+m} e(x,y,d) \quad (5)$$

After iterative application of averaging filtering to error energy for each disparity, we selected the disparity (*d*), which has minimum error energy *e*~(*i*, *j*,*d*) as the most reliable disparity estimation for pixel (*i*, *j*) of disparity map. Let's write basic steps of algorithm more properly,

Step 1: For every disparity , calculate error energy matrix.

Step 2: Apply average filtering iteratively to every error matrix.

Step 3: For every (*i*, *j*) pixel, find the minimum error energy *e*~(*i*, *j*,*d*) , assign its disparity index (*d*) to *d*(*i*, *j*) which is called disparity map.



(a) Construction error energy matrix

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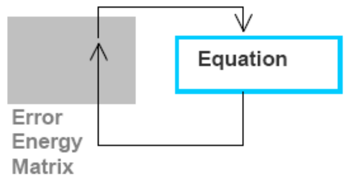
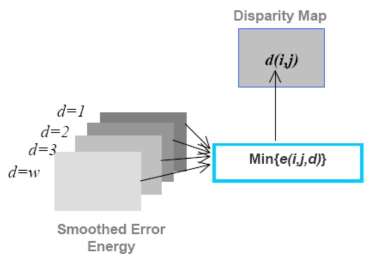


(b) Smoothing energy matrix for every disparity values



(c) Disparity map generation by minimum energy points

Figure 3. Method using global error energy minimization by smoothing functions

b) Line Based Stereo Matching method:

In this manner, we consider region-growing mechanism in two phases operation. First phase, finding root point to grow region and the second phase, growing region for a root point corresponding to predefined rule. Let's generally express steps of the algorithm in a list,

Step 1: (*Root Selection process*) Select a point, which isn't belonging to any grown region and find its disparity using energy function equation (1). Set it root point and set its disparity to region disparity then go to step 2. If you didn't find any disparity with lower enough error energy, repeat this step for the next point.

Step 2: (*Region Growing process*) Calculates error energy of neighbor points just for root point disparity, which was called region disparity. If it is lower than the predetermined error energy threshold, associate this point to region.

Step 3: Proceed the Step 2 until region growing any more. In the case that region growing is completed, turn back to step 1 to find out new root point to repeat these steps. When all points in image processed, stop the algorithm. Grown disparity regions composes disparity map $d(i, j)$

In order to reduce complexity of the algorithm, we allow the region growing in the direction of rows since disparity of stereo image is only in row directions. So, only one neighbor, which is the point after searched point, is inspected for region growing.

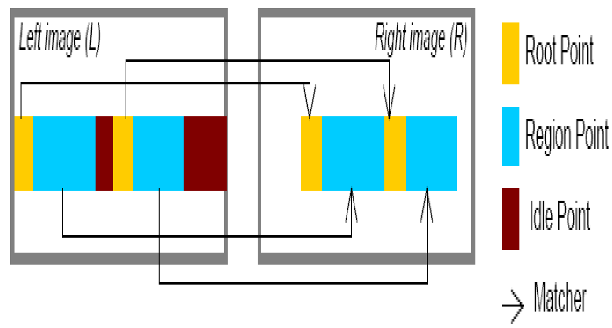


Figure: 4 Method using line growing

IV. PROBLEM STATEMENT

In our work a number of cameras are located around of target and the two pictures taken by each pair are used for stereo matching calculation. It is impossible to compute the coordinate of target because the axes of camera lens are probably not paralleled each other. Assume these cameras having the same height we proposed a stereo axes correction algorithm and new equations to solve the unparalleled lens axes problem.

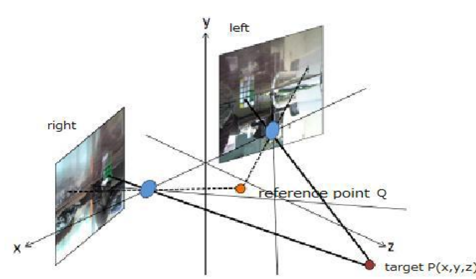


Figure 5. Stereo axes correction

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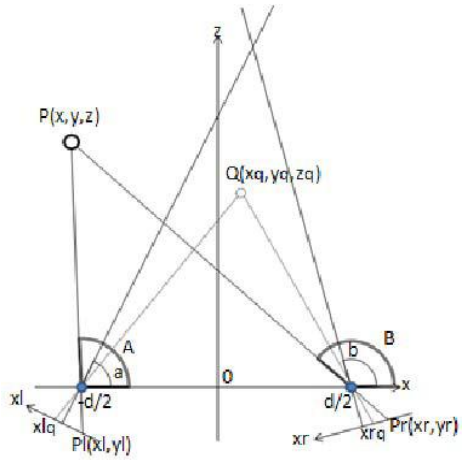

Figure 6. The principle of stereo axes correction

In order to find out the lens axes inclined angle *a* and *b* of Figure 6 we pick up a known point $Q(x_q,y_q,z_q)$ as the reference point whose depth value z_q and the distance between camera and *Q* can be measured by any measure tool. Figure 7 and (9) gives the method to measure the point *Q*.

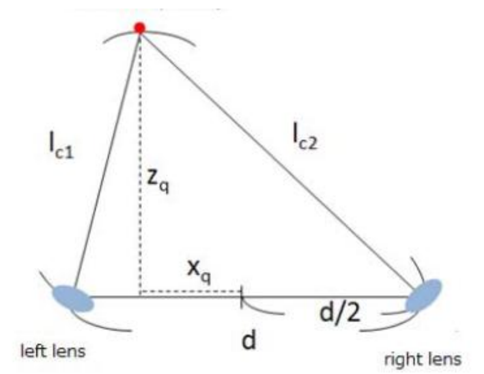

Figure 7. The Measure of the reference point

$$x_q = \frac{l^2.c_1 - l^2.c_2}{2.d}$$

(6)

$$z_q = \sqrt{l^2.c_1 -}\,(x_q + \frac{d}{2})^2$$

(7)

Now the known $Q(x_q,\ y_q,\ z_q)$ into equations, where x_{lq} is coordinate *x* of *Q* in the left image and x_{rq} is coordinate *x* of *Q* in the right image,

$$a = \tan^{-1}\left(\frac{z_q}{x_q + \frac{d}{2}}\right) + \tan^{-1}\left(\frac{x_{lq}.\,m}{f}\right) \quad (8)$$

$$b = \tan^{-1}\left(\frac{z_q}{x_q - \frac{d}{2}}\right) + \tan^{-1}\left(\frac{x_{rq}.\,m}{f}\right)$$

(9)

A and *B* that are inclined angles of target *P* in the left image and the right image can be expressed by

$$A = a - \tan^{-1}\left(\frac{x_l.m}{f}\right)$$

(10)

$$B = a - \tan^{-1}\left(\frac{x_r.m}{f}\right)$$

(11)

Therefore the coordinate of target *P* can be obtained by

$$X = -\frac{d}{2} * \frac{\tan(A) + \tan(B)}{\tan(A) - \tan(B)}$$

(12)

$$y = \frac{y_l.m.\sqrt{\left(x + \frac{d}{2}\right)^2 + z^2}}{\sqrt{f^2 + (m.x_l)^2}}$$

(13)

$$z = \tan(A).\left(x + \frac{d}{2}\right)$$

(14)

If the properties of the left camera and the right camera are different, let f_l,m_l and f_r,m_r stand for the focus distance and coefficients *m* of the left camera and the right camera separately, *a*, *b*, *A* and *B* are rewritten as follows,

$$a = \tan^{-1}\left(\frac{z_q}{x_q + \frac{d}{2}}\right) + \tan^{-1}\left(\frac{x_{lq}.m_l}{f_l}\right)$$

(15)

$$b = \tan^{-1}\left(\frac{z_q}{x_q - \frac{d}{2}}\right) + \tan^{-1}\left(\frac{x_{rq}.m_r}{f_r}\right)$$

(16)

$$A = a - \tan^{-1}\left(\frac{x_l.m_l}{f_l}\right)$$

(17)

$$B = b - \tan^{-1}\left(\frac{x_r.m_r}{f_r}\right)$$

(18)

Having the new equations not worry about whether the lens axes of cameras are paralleled or not anymore. And the shadow area of figure become more widely than before, if necessary we can incline leans axes intentionally to get better broad views. Meanwhile in the new method the reference point plays an important role to correct the unparalleled lens axes.

A critical issue in stereo matching is to measure the similarity between correspondences, which is calculated as a *matching cost*. Using the matching cost, many local and global stereo methods have been proposed to improve the matching accuracy, substantially.

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V. WORK

The major innovative point is to combine color aggregation with local disparity estimation and adaptive window matching. It is able to accomplish a better matching accuracy while effectively reducing the time complexity thus improves the performance of the algorithm.

In image based on stereo matching algorithm is already present and here we can see that which output will come if image is based on window-based algorithm or we can use horizontal line based method.

Using window and Horizontal line we use the following steps:

Take the disparity map estimated from the above step as the initial value, now we use window-based correspondence method to optimize the result.

For each pixel p and its neighborhood N_p in reference image, the corresponding pixel p_d and its neighborhood N_p in target image, define the dissimilarity $E\ (p,\ p_4)$ between the two windows:

$$E(p,p_d) = \frac{\sum_{q\in N_p, q_d\in N_{p_d}} w(p,q)w(p_d,q_d)e(q,q_d)}{\sum_{q\in N, q_d\in N_{p_d}} w(p,q)w(p_d,q_d)}$$

(19)

Where $e\ (q\ ,q_d)$ is absolute difference and $w(\ p,\ q)$ is the adaptiveweight:

$$\text{e}(\text{q},q_d) = min\{\sum_{e\in(c,g,b)} |I_c(q) - I_c(q_c)|\ ,T\}$$

(20)

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

Δc_{pq} and Δg_{pq} are color similarity and geometric proximity.

To better understand depth and disparity relation, let see stereo projection representation illustrated in the Figure-8. By considering the figure, one can derive relation between depth (Z) and disparity(d) by using basic geometrical calculations asfollowing.

$$Z(i,j) = f.\frac{T}{d(i,j)}$$

(21)

If real location of object surface projected at pixel (i, j) is willing to calculate, following formulas can be used in calculation of (X ,Y) points after calculation of the Z .

$$X = \frac{(Z-f)}{f}.i \qquad and \qquad Y = \frac{(Z-f)}{f}.j$$

(22)

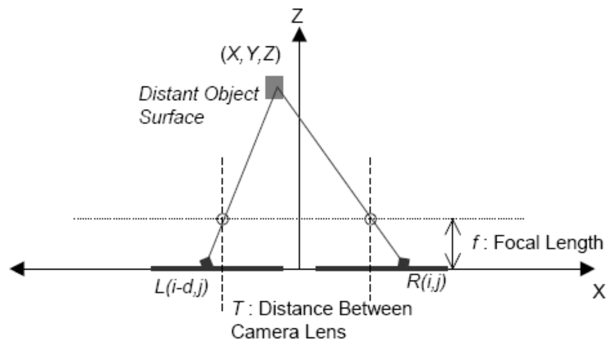

Figure 8. Representation of the stereo projection

In order to obtain smoother depth map to be used in applications such as robot navigation and recent trend for vision in various engineering application.

For that we take a various left and right angle with putting different distance of the camera/webcam and determine the disparity map for image, if time permits then try for real time interface with camera/webcam to computer system and prepare the stereo matching of the images and determine using smoothing with and without consider the reliability of non estimating pixel of images, also determine error, time to be taken for execution in our system.

Our work progress chart show in figure 9.

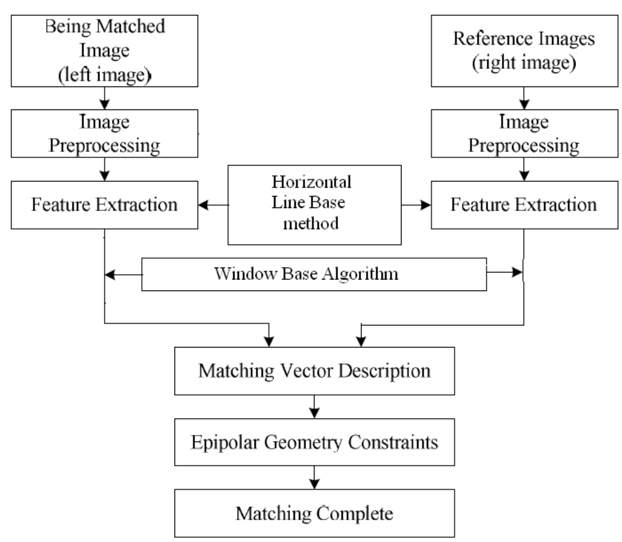

Figure:9 work progress chart

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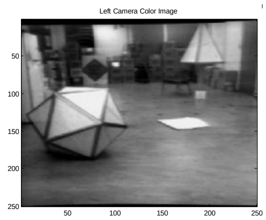
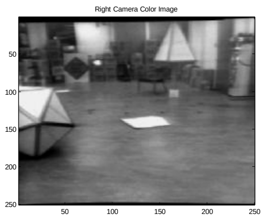
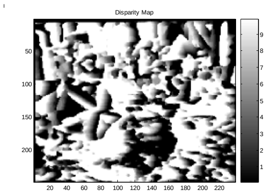
CART IMAGE:



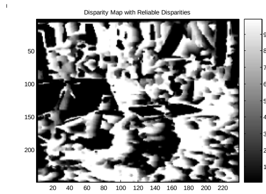
(1) Left camera image



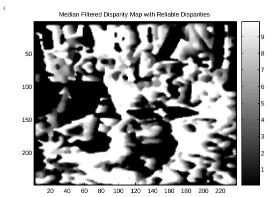
(2) right camera image



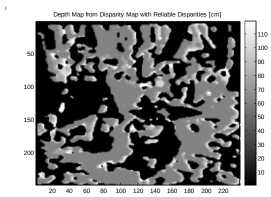
Disparity map



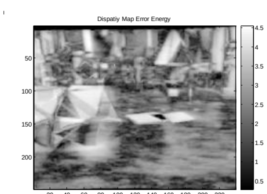
Disparity mapwith reliable disparity



median filtered disparitymap

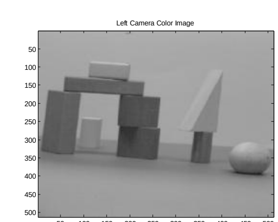


depth map from disparity map

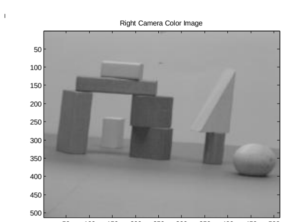


Disparity map error energy

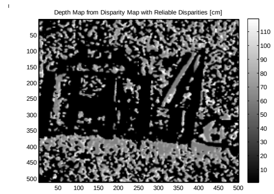
ARCH IMAGE:



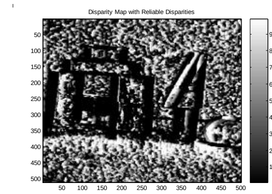
(1) Left Camera Image



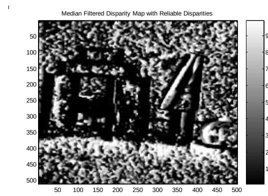
(2) Right Camera Image



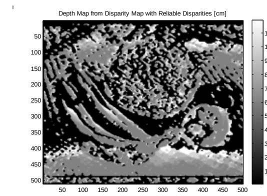
Disparity map



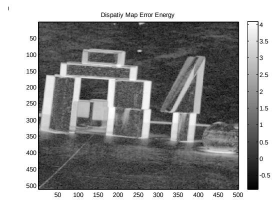
Disparity map with Reliable disparity



Median filtered Disparity map

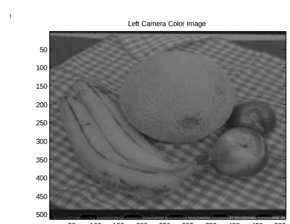


depth map from Disparity map

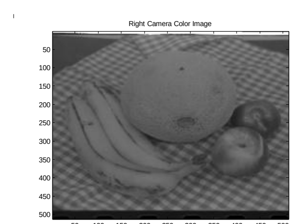


Disparity map error energy

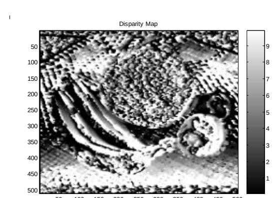
FRUIT IMAGE:



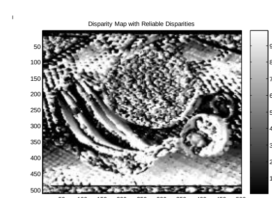
(1) Left camera image



(2) right camera image



Disparity map



Disparity mapwith

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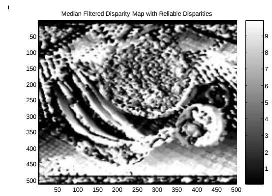
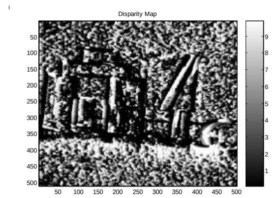
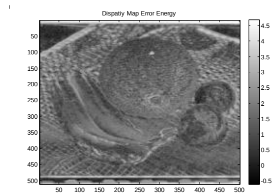
reliable disparity





median filtered disparitymap

depth map from disparity map



Sr. No.	Name Of Image	Dmax	Disparity map	Filtered	Time
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		25	0.001677	0.008737	7.531000
		40	0.004190	0.018804	11.81200
2	Image-2	10	0.003431	0.079736	16.48500
		25	0.003605	0.088353	32.46800
		40	0.003941	0.095381	60.21900
3	Image-3	10	0.001225	0.014783	16.45300
		25	0.001300	0.022803	32.78100
		40	0.001335	0.026656	59.45300

Sr. No.	Name Of Image	Dmax	Disparity map	Filtered	Time
1	Image-1	10	0.000579	0.002933	6.172000
		25	0.001562	0.007842	13.70300
		40	0.003613	0.015883	20.50000
2	Image-2	10	0.003396	0.077350	28.01600
		25	0.003559	0.085219	59.59400
		40	0.003872	0.091078	87.26500
3	Image-3	10	0.001217	0.013957	25.59400
		25	0.001289	0.020552	59.37500
		40	0.001325	0.023584	90.26600

Disparity map error energy

VI. CONCLUSION

Window Based Method: foc=30, T=20

Horizontal Line Based Method: foc=30,T=20

Image-1	Cart
Image-2	Arch
Image-3	Fruit

In this thesis we discusses Results obtained by implementation the algorithms and obtained Quality Matrix of stereo image.

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Matlab has been chosen for implementing different Stereo Matching Algorithms. Approach for visual correspondence search have been implemented to generate disparity Map. Matching (Window-Based) and Matching (Horizontally Line-Based) gives good disparity Map, hence depth Map will also generate from it. Stereo Matching Algorithms are tested on standard images.It is a challenging task to develop and implement Stereo Matching Algorithms with constrains.

- Matching (Window - Based) Algorithm gives good results. Quality of Disparity Map is increased by smoothing.
- In Matching (Horizontally – Line Based) Algorithm, as the value of threshold T is decreased, the matching criteria becomes strict and many pixels remains unmatched.

From this observation table we see that the disparity map value of the both algorithm will be different. And when the value of mismatch point will be decreased, the disparity map value will be decreased.

Here the window based algorithm's disparity map value is less than the horizontal line based algorithm's disparity map value. So it is better for 3D view.

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