ABSTRACT

This paper presents the new algorithm technique for searching and identifying a pair of points from two 2D aerial images, recorded by stereo technique. This matching point algorithm technique is modified from the relation of parallax and cross ratio. The window of 7x7 points with 3x3 mask inside is proposed to examine disparity points on two images and consequently to select the corresponding points. The points obtained from this algorithm have high accuracy and high precision in a position and height data. This algorithm is appropriate to the photograph at any level of the height, especially in survey and remote sensing area.

Keywords: Parallax, Cross Ratio, Stereo, Matching Window, Gray scale Image, 2-D Terrain Map, CCD, TM, TM+

1. INTRODUCTION

The methods for searching and identifying a pair of two points that corresponding to each other on stereo pair images are useful. These methods of stereo matching relate to area-based, feature-based, and relation-based methods. The latest is used to find the relation of the corresponding points on images using a epipolar geometry, maximum and minimum disparity gap, local attribute, uniqueness, disparity continuity, correlation-based, CBPR (contour based pyramidal resolution method), and CBDL (contour based disparity limits method) [1]-[4]. The disadvantage of the mentioned method is that it cannot be used with photographs at any level of height. In addition, it is difficult and quite complex when these methods are applied for immediate work, which at the same time requires high accuracy. In this paper, we modify a technique that can be applied to all levels of height by proposing 7x7 window with 3x3 mask running inside based on parallax and cross ratio in stereo technique. The results show that the corresponding points with high accuracy can be identified by processing in an ordinary PC.

2. CONCEPT THEORY

The concept to obtain the same position from stereo images is to manipulate a 7x7 window along the pixels at the same coordinate of the images. The size of window is defined from the concept of cross ratio [5]. Let consider if A, B, C, and D are the points in the line being viewed from the first position and A’, B’, C’, and D’ are from the second position. This gives the distance \( l_1,l_2,l_3,l_4 \) as defined from the distance AD, BD, AC, and BC. In similarly, \( l_1’,l_2’,l_3’,l_4’ \) are also defined. Since these four points refer to the same points but with different coordinator in the stereo image, if we consider only one point of interest there will be 3 points left which is possibly around the point of interest. Then, there are 7 points possible in any considerable line when this vicinity is analyzed. This leads to the construction of 7x7 window which will be described in the next section.

![Fig. 1: Interesting points in two stereo images](image-url)
stereo images, and X,Y are the coordinates of real object on earth. The accuracy of data and errors of data can be as follows. Consider equation (3)

\[ H' = H - h' \]  
and compare with eq. (2), the derivative can be found as

\[ dH' = dh' = \frac{H^2}{B \times f'} dp. \]  

Then, the errors of data from height of object, or height error, \( \sigma_h \), can be found as

\[ \sigma_h = \frac{H^2 \times \sigma_p}{B \times f'} = \frac{B}{H'} \sigma_p \]  

where \( \sigma_p \) is the parallax error expressed as

\[ \sigma_p = \left[ \sigma_x^2 + \sigma_y^2 + \sigma_z^2 \right]^{\frac{1}{2}} = \sqrt{2} \times \sigma \]  

with \( \sigma_x \) and \( \sigma_y \) the errors at coordinates (x, y). After manipulating eq. 5, the estimation of height errors becomes

\[ \frac{\sigma_h}{H'} = \frac{\sqrt{2} \times \sigma}{B \times \frac{H'}{f'}} \]  

Similarly, the horizontal error \( \sigma_R \) can be found such that

\[ \frac{\sigma_h}{H'} = \frac{\sigma_R}{f'}. \]  

3. PROPOSE TECHNIQUE

From the concept theory of cross section, we can form the relation of variable values and then design window 7x7 point as shown in Fig. 3, which brings about 4 points originating from the center point in 8 directions.

![Fig. 3: Window of 7x7 points formed by cross ratio.](image)

(a) first set  (b) 3x3 window  (c) second set

![Fig. 4: The 3x3 window with two separated sets](image)

A window of 3x3 point shown in Fig. 4 is also formed additionally for the process. This window is divided into two sets of points surrounding the center point. The first set has 4 points on each corner and the second set has 4 points on the middle of each side of square area. The first set is used as a reference window working on the first image and the second set is a searching-point window working on the second image.

When a 7x7 window is put onto the stereo images, a 3x3 window is moving inside to manipulate data corresponding to the same coordinate point in the 7x7 window. The intensity value of each scan point is obtained by following the constraints.

\[ c_p = \left( \frac{I_1 + I_2 + I_3 + I_4}{4} \right), \]  

\[ c_s = \left( \frac{I_5 + I_6 + I_7 + I_8}{4} \right) \]  

where \( c_p \) and \( c_s \) are the average values of light intensity (I) obtained from the first set and second set, respectively, of 3x3 window.

Let \( L \) be the dispersion values of light of the Environment. It can be defined as

\[ L = \left( \frac{I_{\text{max}} - I_{\text{min}}}{N} \right), \]  

where \( N \) is the total number of light intensity values.
where, in considering of 3x3 or 7x7 window, $I_{\text{max}}$ is the maximum light intensity, $I_{\text{min}}$ minimum light intensity, and $N$ is the number of image points. Let $k$ be the different average value of light intensity between two data sets which is $k = c_r - c_s$. The decision criterion $M$ to consider the matching point is obtained as $M = k \times L$. The condition of matching point of two image points is allowed only with in $\pm M$.

To use this algorithm, the reference window is moving along the row and column starting from the top left to bottom right as illustrated in Fig. 3. Then let the searching window searches around a reference point not more than 4 points away as shown in Fig. 4.

4. PROCESSING AND RESULT ANALYSIS

The stereo images used were originally taken from airplane (case (b) in Fig. 5) and from the satellite (TM, cases (a), (c)-(e) in Fig. 5). The image size is 500x500 points with 2D gray scale. The known variables include, for instances, $H$ (distance from reference plane to photography line) = 6,500 m (aerial), 705 km (TM), $f'$ (the focal length of camera) = 0.153 m (aerial), 0.76 m (TM), $B$ (the distance of image recording first and second) = 850 m (aerial), 93 km (TM), and the coordinate measurement errors = 0.0000030 m (aerial), 0.0000012 m (TM).
Fig. 5 shows the output terrain images reconstructing from five different ((a)-(e)) 2D aerial stereo images (L-left, R-right) on the left hand side. As can be noticed in terms of clear pictures, the matching technique proposed here gives better results compared to the Robust Technique [3]. This means that the proposed technique performs more number of data points. In addition, this can be verified from Figs. 6 and 7. These terrain images reconstructed here can be viewed to see the height of the geometry at any angle since many data detail has been obtained.

Table 1: The points and times involved in the processes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Input Size (Points)</th>
<th>Robust Algorithm [3] (Points)</th>
<th>Matching (Points)</th>
<th>Times Process (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>500x500</td>
<td>207,643</td>
<td>240,045</td>
<td>≈ 5.30</td>
</tr>
<tr>
<td>(b)</td>
<td>500x500</td>
<td>245,754</td>
<td>249,000</td>
<td>≈ 5.40</td>
</tr>
<tr>
<td>(c)</td>
<td>500x500</td>
<td>231,982</td>
<td>241,785</td>
<td>≈ 5.00</td>
</tr>
<tr>
<td>(d)</td>
<td>500x500</td>
<td>210,619</td>
<td>244,912</td>
<td>≈ 5.20</td>
</tr>
<tr>
<td>(e)</td>
<td>500x500</td>
<td>221,160</td>
<td>241,000</td>
<td>≈ 5.10</td>
</tr>
</tbody>
</table>

5. CONCLUSION

The new algorithm to search and identify a pair of points from 2D gray-scale stereo aerial images is proposed by using a 7x7 window with a 3x3 point mask inside. The window technique demonstrated here is based on the concept of parallax, cross ratio, and stereo, to render a number of points. This processing makes 3x3 point window function within the whole area of 7x7 point window. These two windows are divided into two sets, which function as a reference window working on the first image and as a searching window working on the second image. The range of searching point is not more than 4 points away from the reference point. In searching and identifying for a corresponding point, the windows work together on two images. The results in comparison with the Robust technique approves the improvement of terrain map quality. This algorithm provides the search and identification of the corresponding point with high precision since the errors are reduced. Furthermore, this algorithm can be applied for photographing at all levels of height, especially for photographing in survey and remote sensing.

REFERENCES


