

# A Feature Based Method of Image Matching for computing stereo models

Chi-Kou Shu

**Abstract**—The purpose of this paper is to propose a image matching method based on regions and features of images for the purpose of Computing 3D Models of Stereo Image Pairs. The method includes a sequence of image processing and algorithms to do the matching between two images of a stereo image pair. A stereo image pair also is named as stereopair. The image matching is one of important primal researches in machine vision for automatic objects recognition and objects identification with stereopairs. We integrate primary image processing methods, feature detection, interesting point computing, neural network of self-organizing map, and related computing for image matching. Some practical tests are discussed for showing the efficiency of the image matching. By experiments, the propose method can achieve the precision to subpixel that is a considerable accuracy to meet the image matching requirement for computing 3D models of stereopairs . The developed method in fact is precise and fast for 3D computing practically.

**Index Terms**—conjugate points, homologous points, stereopair, Interesting operator, subpixel, parallax.

## I. INTRODUCTION

**A**N image is a two-dimensional (2D) record of the the radiation intensity of light come from the three dimensional (3D) spatial scene at some time. Therefore, an image, or image frame, can refer to a two-dimensional light intensity function  $f(x, y)$ , where  $x, y$  denote 2D coordinates. Briefly, an image is a style of 2D record of a 3D scenery in a space at some time.

A man's two eyes take two 2D images respectively as two 2D signals for him to percept the spacial scenes. Both his eyes take 2D images simultaneously and separately in time to form a sequence of stereo image pairs for him to percept stereo scenes in 3D space. A stereo image pair also be named stereopair that are two images of the same spatial scene taken from two respective viewpoints that have a slightly different in position. If the distance between the viewpoints is known, the relative depth of imaged objects can be computed, or to say perceived, based on the observed object parallax. Stereo vision obviously plays an important role in human vision. We can simulate the human vision to take separately two images of the same spatial scene to form a stereopair. By means of the same principle and

similar way of the human vision, a stereopair can be used to compute the relative depth of distant objects and scenery in machine vision. Remote sensing applications that measure terrain elevation on Earth and on extraterrestrial bodies use stereo image pairs as source data and an effective means for gathering a great deal of digital terrain data. And then, the digital terrain model be computed and established. In remote sensing, we commonly get the useful image pairs by a video camera installed in an aircraft or an unmanned aerial vehicle that is flying high enough above the ground, or a satellite in its particular orbit around the Earth.

All the above applications should implement a computation of image matching to get all conjugate pairs of points. The conjugate points also named as homologous points between the image pair. Thus, we can consider a image pair as a pair to be composed of the left and right images that is taken separately at slightly different viewpoints. They also are often taken at different time. Thus, the image pair may not be a perfect stereopair, but only have some overlap of image contents of the image pair. That is, only the overlap of the image pair can be of the same 3D scene, and all corresponding Homologous points belong to the overlap are the light intensity of the same points in the spatial scene. All these correspondent pair of matched points in the overlap are called conjugate points of the stereopair. The computing to obtain all conjugate points of a stereopair is image matching. We would like to develop a method with great precision to accomplish image matching, so that we can build the 3D model of objects and scenes of the stereopair for machine vision applications. An important application is the automatic identification or recognition objects that appeared in the stereopairs. In this paper, the image matching problems and solutions of the image matching is discussed.

The proposed method we have developed includes four steps for computing the image matching. The first is the particular designed feature based image matching to evaluate accurately the respective regions belong to the overlap of the stereopair.

--The first is the particular designed feature based image matching to evaluate accurately the respective regions belong to the overlap of the stereopair.

--The second step is the execution of the interesting operator to obtain all possible and useful interesting points.

--The third step is the Normalized Cross Correlation image matching method to computing all conjugate points of the stereo image pair.

--The the fourth step is to computing the subpixels for precision image matching.

The above four steps make up the proposed method for computing the image matching accurately. In the first step, the

particular feature based image matching method is designed for

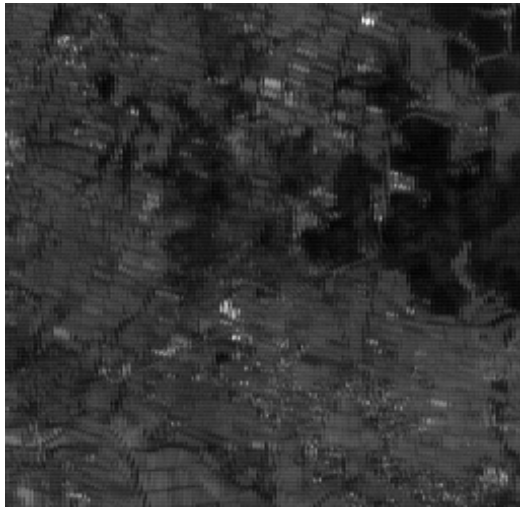


Fig. 1. An aerial photograph of ground taken at left viewpoint

evaluating the square region correspondences between the two images of the stereopair. All these square pairs constitute the total overlap of the image pair. Then, within the square region we can evaluate the quite approximation to the real conjugate points and the parallax. The next step is to computing to obtain suitable interesting points for matching. Then, the Normalized Cross Correlation (NCC) image matching is used to do the optimal conjugate points matching. The subpixel matching processing for quite precision is executed as the final step for image matching.

## II. THE PROPOSED IMAGE MATCHING METHOD

### A. Preview

No matter whether it is human's eyes watching the scene, photogrammetric operations computing DTM, or machine vision recognizing the scene and objects, the essential and basic work is to compute all conjugate points within the overlap region of the stereopair in order to calculate the 3D data and stereo model of the scene. Therefore, it is essential to develop the image matching methods and software to compute the conjugate points precisely and quickly.

In order to attain the highly automatic image matching results in the situation that we do not know the relative viewpoint and exact directions of view of the stereopair, we can develop and design a feature based image matching method as the initial matching to estimate the overlap of the left and right images of the image pair. Then, we can evaluate the very good approximate conjugate points and parallax with great precision..

### B. Image Processing and Feature Extraction

The image processing such as the image enhancement is not necessary. These basic image processings are optional and only depend on the quality of the image. It is usual to processing the image for noise reduction. There are feature-based image matching methods include processing steps to detect and extract features such as edges, small blocks, and regions with the original images. Then, the next step of the feature-based

methods is for estimating the overlap and the conjugate points



Fig. 2. The equalization strength of Fig. 1.



Fig. 3. The histogram of Fig. 1.

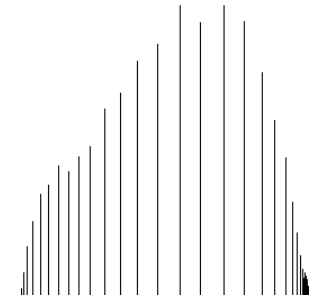


Fig. 4. The histogram of Fig. 2.

of the stereopair. Anyway, the detected features is not enough

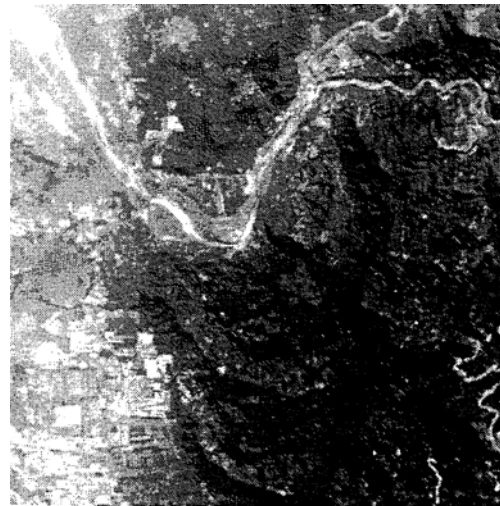


Fig. 5. An aerial photograph of ground

to evaluate the overlap region of the stereopair precisely.

### C. The Feature Based Image Matching

The method is designed for evaluating accurately the square region correspondences between the two images of the stereo-

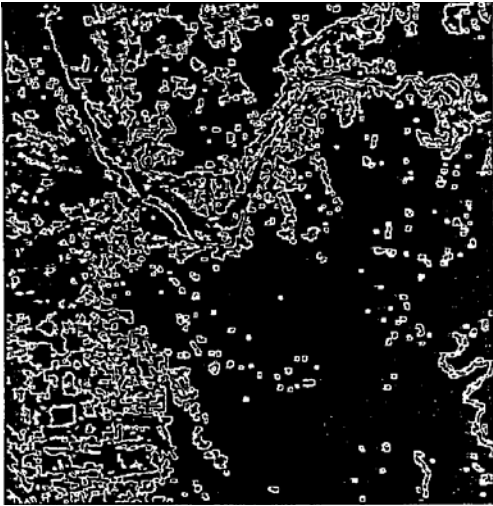


Fig. 6. An optimal Linear operator to detect edges of Fig. 5.

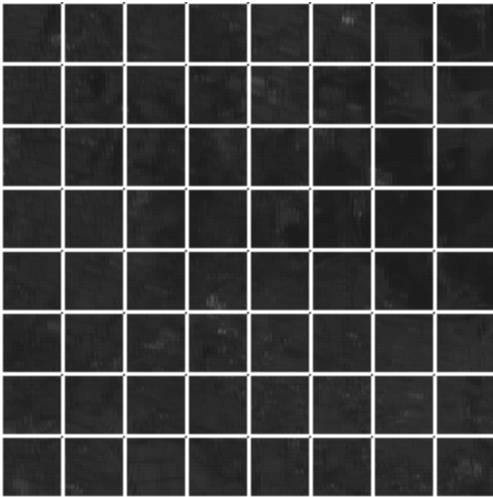


Fig.7. The left image with a lattice of squares to cover all of the image

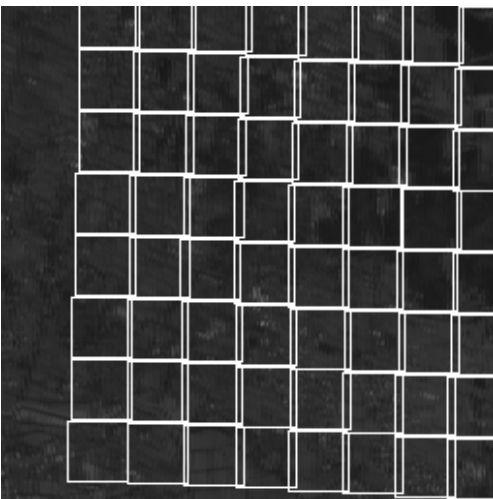


Fig. 8. The right image with correspondence squares to form the overlap region of the stereopair pair. All these square pairs constitute the overlap of the image pair. Due to the square regions are considerable dimensions, the total overlap is accurate enough for the next step.

It is treated as the initial matching of the image pair. The separated square correspondency by way of feature matching is considered as a kind of conjugate relationship similar to the conjugate points of the stereopair, but each square of their respective images is a square region of  $32 \times 32$  pixels for images size of  $400 \times 400$  pixels or bigger. Then, within the square region we can evaluate the quite approximations to the real conjugate points and the parallax.

In this paper, the proposed image matching method include a particular feature based image matching as the initial matching to obtain accurately the overlap of the stereo image pair and all small conjugate square regions that form the overlap. It is easier to correctly compute the conjugate square regions than to compute precisely all conjugate points directly. Thus, we can think the image matching computation to small square regions for the first step. Then, we can evaluate both the directions and relative positions of both viewpoints of the stereopair. We also can evaluate all approximate X and Y parallax. The next step is to compute the interesting points and obtain all possible interesting points of both overlap regions of their respective images. Then, the next step for image matching is to execute the normalized cross correlation method to obtain precise conjugate points. The execution of the subpixels method for precision image matching is the final step.

The processing steps for the square matching description are listed as follows.

- 1) The left image is segmented with squares setting to cover all image as a lattice. All squares are of the same size,  $32 \times 32$  pixels.
- 2) Choose the middle square of the lattice as the start square to matching a square of the same size in right image.
- 3) All squares of the left image are a  $32 \times 32$  self organization feature map neural network are used to obtain the optimal square matching of the right image one by one until all squares are processed to get the overlap of the stereopair.

#### D. Interesting Operator and Interesting Points

We can first choose all points that has greater possibility to be correlated. These chosen points have greater gray level than

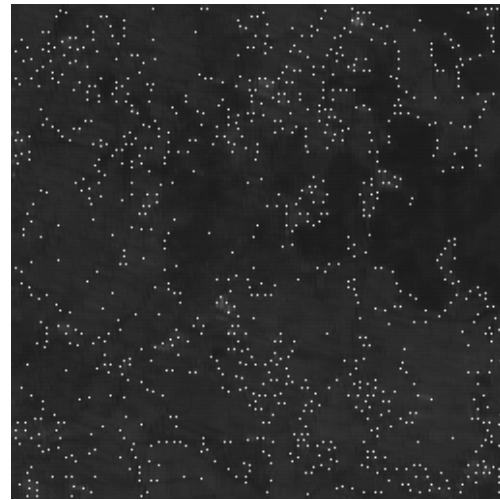


Fig. 9. The interesting points of left image their near neighborhood. We use the Ground interesting

operator that is a  $3 \times 3$  windows to compute all interesting points.

### III. THE NORMALIZED CROSS CORRELATION IMAGE MATCHING

If we have already obtained both very good approximations to relative positions and directions of their respective viewpoints of the stereo image pair by the initial feature based image matching, we can also evaluate the parallax of each conjugate points. Then, we can compute the conjugate points matching between the two images according to the principle of statistic correlation. We adopt the normalized cross correlation (NCC) method to do the accurate digital image matching to get the highly precision matching results. The computing method is expressed in equations as follows.

We denote the left image by the vector  $A = (a_1, a_2, \dots, a_n)^T$  and the right image by the vector  $B = (b_1, b_2, \dots, b_n)^T$ .

$a_i$  denotes the gray level of the left image.

$b_i$  denotes the gray level of the right image.

$\bar{a}$  denotes the average value of all pixel's gray level. That is

$$\bar{a} = \sum_{i=1}^n a_i / n .$$

$\bar{b}$  denotes the average value of all pixel's gray level. That is

$$\bar{b} = \sum_{i=1}^n b_i / n .$$

$n$  denotes the number of pixels to join the similarity measurements. It is the number of elements of the array.

$A_i = a_i - \bar{a}$ , Computing the gray level tidy of left image.

$B_i = b_i - \bar{b}$ , Computing the gray level tidy of right image.

$$\sigma_{AB} = \sum_{i=1}^n A_i B_i = \|A\| \|B\| \cos \theta ,$$

$$\|A\| = (A_1^2 + A_2^2 + \dots + A_n^2)^{\frac{1}{2}}, \quad \sigma_{AA} = \sum_{i=1}^n A_i A_i,$$

$$\|B\| = (B_1^2 + B_2^2 + \dots + B_n^2)^{\frac{1}{2}}, \quad \sigma_{BB} = \sum_{i=1}^n B_i B_i,$$

Where  $\theta$  is the angle of the vector A and vector B.

$$r = \frac{\sigma_{AB}}{\sqrt{\sigma_{AA} \sigma_{BB}}}, \quad \gamma \text{ is the measurement of similarity.}$$

$\gamma$  is called correlation coefficient in statistics.

$$\begin{aligned} \text{Because } \sigma_{AB} &\leq (\sigma_{AA} \cdot \sigma_{BB})^{\frac{1}{2}}, \\ r = \sigma_{AB} / (\sigma_{AA} \cdot \sigma_{BB})^{\frac{1}{2}} &= \frac{\|A\| \|B\| \cos \theta}{\|A\| \|B\|} \\ &= \cos \theta \\ -1 \leq r \leq 1 \text{ and } 0 \leq \theta \leq \pi . \end{aligned}$$

$\gamma$  is also called the normal correlation coefficient

### IV. COMPUTING SUBPIXELS FOR PRECISE IMAGE MATCHING

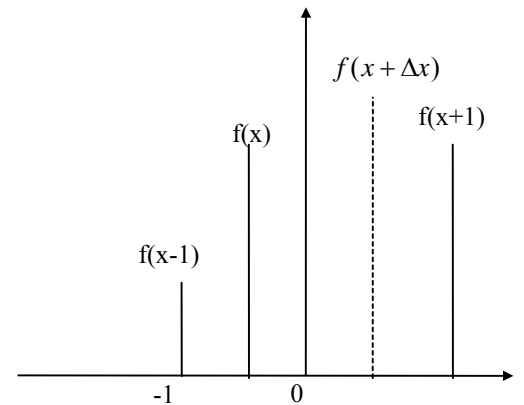
There are in fact two problem must be solved.

- I. Because the position is limited to the point size of the pixel and the method for image matching only computing the pixel positions counted in integer, the obtain conjugate points may not the exact position. Thus the conjugate points may be unavoidable to have a little difference from the real conjugate positions.
- II. If the digital 3D model of the scene or DTM is produced by way of image matching, we first consider the sample interval as the picture is digitized. The sample interval of a digital image need to match up the requirement of the precision of DTM or 3D model of the scene.

Due to the basic problems as described above, the matching results must be refined to get the advanced subpixel precision to approach the exact real conjugate points. If we want to refined the matching position of a pixel, we can take two pixels around the position of the pixel such that one is the preceding pixel and the other is the rear of the pixel. The three point can be fitted by a polynomial function curve of order 2 as follows.

$$f(x) = a_1 + a_1 x + a_2 x^2 \quad (5.1)$$

The ultimate position of the image matching is  $x + \Delta x$ .



The value  $x + \Delta x$  can be computed by the next formula (5.2).

$$x + \Delta x = \frac{f(x+1) - f(x-1)}{4f(x) - 2f(x+1) - 2f(x-1)} \quad (5.2)$$

### V. CONCLUSION

Human stereo vision principle is applied to stereopair to compute the required 3D data for many applications. Anyway, there are still many problems concerning image matching methods together with stereopairs. There is no mathematic formula derived for solving the correspondence problem between the two images of a stereopair. The covers, various hides from view, or noises often make the image matching difficult. The already developed method for image matching can get fairly good results. The programs design and development are very important to practically implement an image matching method as an effective means for machine vision and automatic photogrammetry to gather their data. Therefore, we need to do more practical experiments to test the proposed image matching method for developing the software to be more efficient. In the continuous work, we would like to include the multi-thread programming in C/C++ to implement the computation of image matching more efficiently for computing stereo models of scenes .

#### REFERENCES

- [1] Analysis Levitin, The Design and analysis of Algorithms, second edition, Addison Wesley, 2007.
- [2] Sreeram V.B. Aiyer, Mahesan, and Frank Fallside, A Theoretical Investigation into the performance of the Hopfield Model, IEEE Transactions on neural networks, VOL.1, NO.2, JUNE 1990.
- [3] Debasis Sengupta and Ronald A. Iltis, Neural Solution to the Multitarget Tracking Data Association Problem, IEEE Transactions on Aerospace and Electronic Systems, Vol. AeS-25, No.1 January 1989.
- [4] Robert M. Kuczewski, Neural Network Approaches to Multi-Target Tracking, TRW MEAD, One Rancho Carmel, San Diego, CA. 92128, July 2009.
- [5] J.J. Hopfield and D. W. Tank, "Neural" Computation of Decisions in Optimization Problems, Biological Cybernetics, Vol. 52, 141-152, 1985.
- [6] Johansson, G., and G. Jansson. Perceived Rotary Motion From Changes in a Straight Line., Perception and Psychophysics, 4(3), pp. 165-170, 1968.
- [7] J. P. Gambotto, Segmentation and Interpretation of Infrared Image Sequences, 2003.
- [8] Haralic, R.M./Shapiro, L.G. [1985], "Survey image segmentation techniques", Computer Vision, Graphic, and Image Processing 29 PP. 81-94.
- [9] Schalkoff, R.J. [1989], "Digital image processing and computer vision." , John Wiley & Sons , Inc.
- [10] Robert Hecht-Nielsen [1990], eurocomputing , Addison Wesley.
- [11] Hopfield, J.J. and Tank, D., 1985, Neural Computation of Decisions in Optimization Problems..
- [12] Schenk, T., 1999. Digital Photogrammetry. Volume I, TerraScience, pp. 248-251.
- [13] William B. Langdon, Riccardo Poli, Foundations of Genetic Programming, Springer, 2002.
- [14] Erwin Kreyszig, Advanced Engineering Mathematics, Tenth Edition, John Wiley & Sons Pte Ltd, 2011.