

Digital Mosaic of Color Aerial Photographs

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ABSTRACT

Color ortho-photo map with scale of 1:50,000 or 1:25,000 is produced by mosaic of several pieces of color ortho-photographs. While black and white mosaics of aerial photographs involve less distinctive seams at around their boundaries, color mosaics of color aerial photographs or color ortho-photographs involve more discontinuities of color tones.

The objectives of this study are to remove the discontinuous seams of color mosaics by means of digital techniques for digital image processing of digitized color ortho-photographs, and to establish the methodology to produce good looking mosaics of color ortho-photo map with use of digital image output equipment.

As the results of this study, digital mosaics of color ortho-photographs with the continuously varied tones, that is, seamless mosaics can be produced by the methodology which has been developed by the authors.

INTRODUCTION

Discontinuities of color mosaics are resulted from the following reasons.

- 1) Difference of look angle between lense and object.
- 2) Difference of incident angle of sun, including sun glitter.
- 3) Vignetting effect of $\cos^4\theta$.
- 4) Difference of photographic processing for models or courses.
- 5) Geometric distortion resulted from misregistration.
- 6) Difference of the data of photographs taken.

In digital mosaic, there needs a lot of computing time for geometric registration in the region of overlap or sidelap between models or courses. When ortho-photos are utilized to produce a mosaic, geometric registration for rotation distortion is not necessary only if ortho-photos could be set up in parallel to the axis of digitizing drum scanner.

PROCEDURES OF DIGITAL MOSAIC

Procedures of digital mosaic involve the following six steps.

Step 1: Digitization of Color photographs

Color photographs are digitized into three primal colors, red, green and blue with the pixel size of 0.1 or 0.2 millimeters. Adjacent photographs should have 20 or 30 percentages at least. Color charts and gray tone steps should be also digitized together with photographs for calibration of color and tone.

Step 2: Extraction of overlapped area and geometric registration

Overlapped area of digitized files should be extracted for geometric registration. Affine transform will be determined for geometric registration by selecting several pass-points in the overlapped area.

Rearrangement of pixels into geometrically registered direction should be carried out by computer.

Step 3: Radiometric correction

Preprocessing of radiometric correction will be executed for vignetting in each photograph and difference of histograms between two adjacent photographs in the overlapped area.

The density averaging technique which has been developed by the authors, are utilized to correct those radiometric distortions as the function of position variant.

Step 4: Detection of seam point, line by line

The point with minimum difference of density for the width of several pixels in a line could be searched as seam point, that is, boundary point of mosaic.

Detection of seam point differs from each other for the case of overlap in the direction of left and right, and for the case of sidelap in the direction of upper and lower.

Step 5: Smoothing discontinuity around boundaries

Discontinuity around boundaries will be smoothed by linear interpolation.

Step 6: Image output of digital mosaic

Digitally corrected files are converted into color film by image output device such as drum scanner.

DENSITY AVERAGING TECHNIQUE

This technique has been developed to correct the difference of density which is given as a function of position.

Firstly overlapped area is divided into the subareas with M by N pixels, of which average difference of density is $D(i,j)$ as shown in the following equation, and in the Fig. 1.

$$D(i,j) = \frac{1}{M \times N} \sum_{u=u_0+1}^{u_0+M} \sum_{v=v_0+1}^{v_0+N} \{P_1(u,v) - P_2(u,v)\} \quad (1)$$

where

$$u_0 = (i - \frac{1}{2}) M$$

$$v_0 = (j - \frac{1}{2}) N$$

Correction for the difference of density at arbitrary point (m,n) can be interpolated as shown in Fig. 2.

$$D(m,n) = (1-u)(1-v)D(i,j) + u(1-v)D(i+1,j) + (1-u)vD(i,j+1) + uvD(i+1,j+1) \quad (2)$$

where

$$u = (m-i)/M, \quad v = (n-j)/N$$

Finally, density data at point (m,n) can be corrected as follows.

$$\begin{aligned} x_1 &= x_1 - (1-\lambda) D(m,n) \\ x_2 &= x_2 + \lambda D(m,n) \end{aligned} \quad (3)$$

where

$$\lambda = n / \text{total number of pixels in a line.}$$

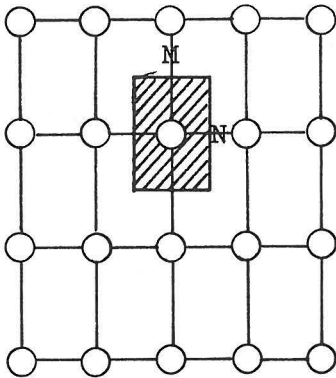


Fig. 1 Subarea

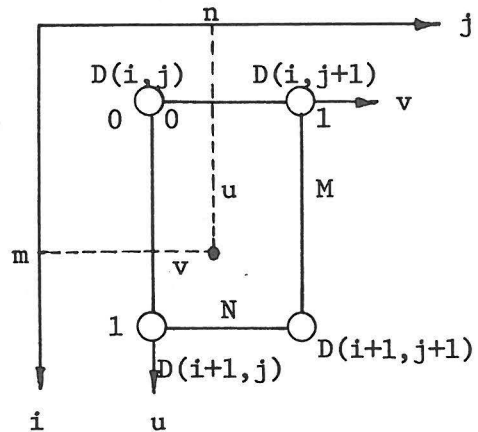


Fig. 2 Interpolation

DETECTION OF SEAM POINT

a. Left and right model

In the case of left and right model as shown in Fig. 3, a seam point j in a line can be detected by minimizing the difference of density in the range of width w , as follows.

$$j = \{j : D_j = \min_i \sum_{i-w}^w (x_{j+i} - y_{j+i})\} \quad (4)$$

b. Upper and lower model

In the case of upper and lower model as shown in Fig. 4, a seam point should be located in each column. However, since all of pixels in the overlap area can not be stored in core memory generally, a special procedure for searching seam point in the direction of lines should be developed.

In this study, every five or seven lines are stored to search such seam points.

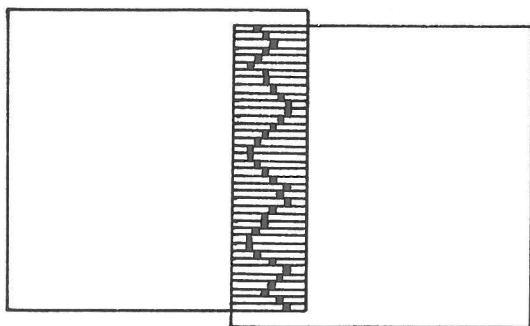


Fig. 3 Left and Right Model

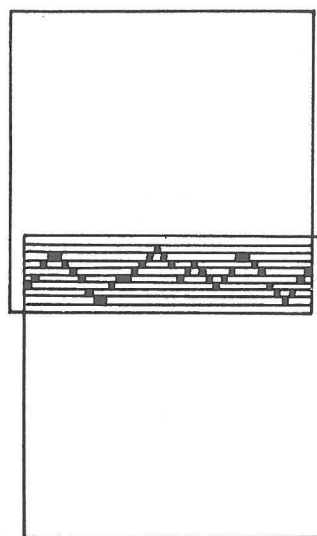


Fig. 4 Upper and Lower Model

SMOOTHING DISCONTINUITY AROUND BOUNDARIES

a. Left and right model

In the case of left and right model, the following linear smoothing is executed, line by line.

$$Z_i = x_i \frac{W-i}{2W} + y_i \frac{W+i}{2W} \quad (5)$$

$$-W \leq i \leq W$$

where

Z : smoothed density
x,y : density in overlapped aera

b. Upper and lower model

In the case of upper and lower model, a special program has been developed for smoothing descontinuity around boundaries in the direction of column, keeping the order of search in the array of line scanning.

APPLICATIONS

a. A mosaic of two color aerial photographs -Left and right model-

Two color aerial photographs as shown in Fig. 5, were digitized to produce a seamless mosaic. Fig. 6 shows the passpoints for geomtric registration. Fig. 7 shows a comparison of effects between radiometrically uncorrected mosaic and radiometrically smoothed mosaic. Smoothing effect can be seen especially in water area. Fig. 8 shows a full scene of digital mosaic which were produced from the above two color aerial photographs.

b. A mosaic of eight patches of orthophotos -Left-right and upper-lower model-

Eigth patches of orthophotos as shown in Fig.9 were digitized into the geometrically registered format as shown in Fig. 10. Fig. 11 shows a seamless digital mosaic which were produced from eight patches of orthophotos, and Fig. 12 shows a mosaic which were made manually. Digitally smoothed mosaic looks much better than manually made mosaic.

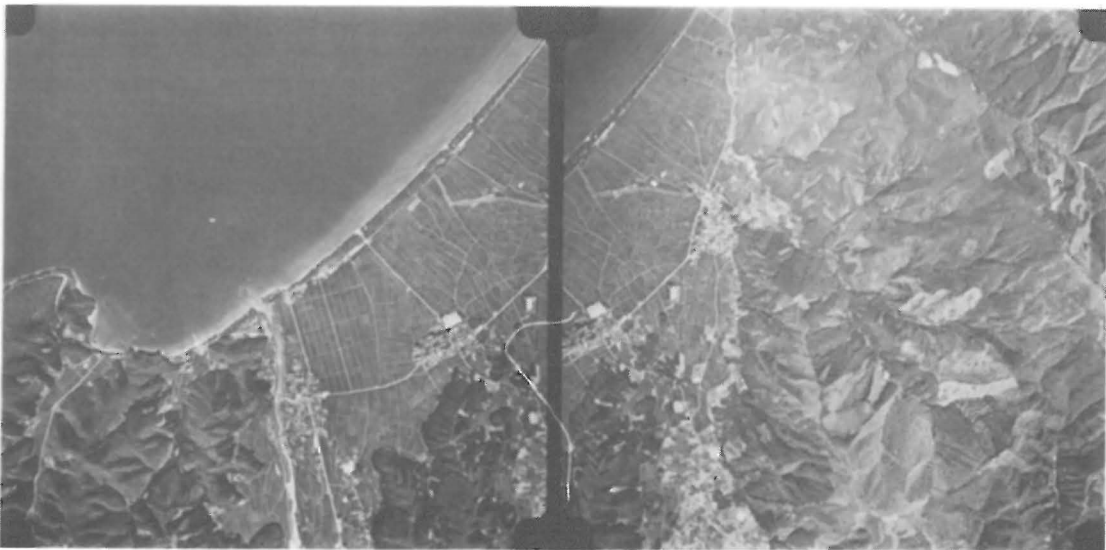
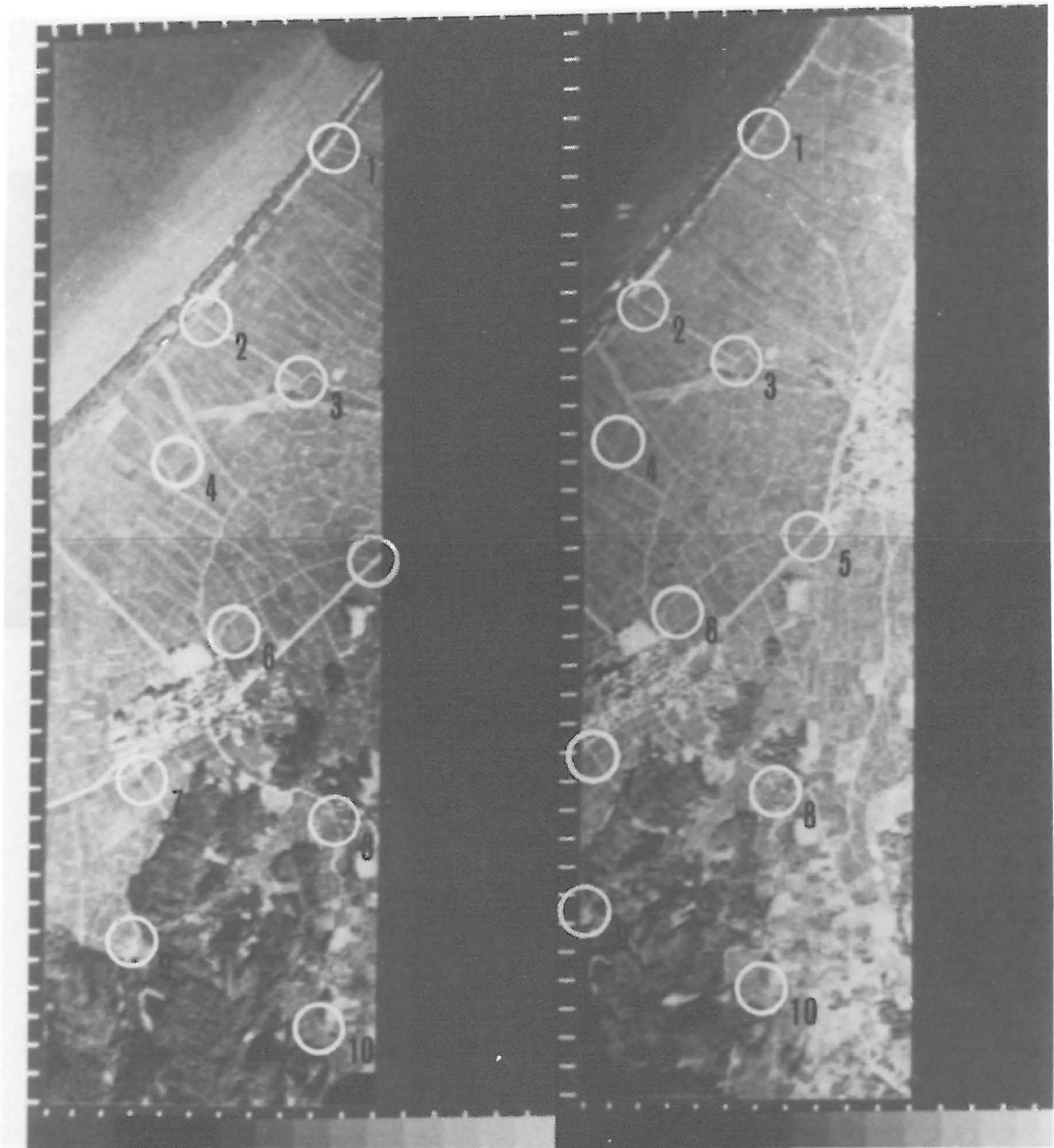
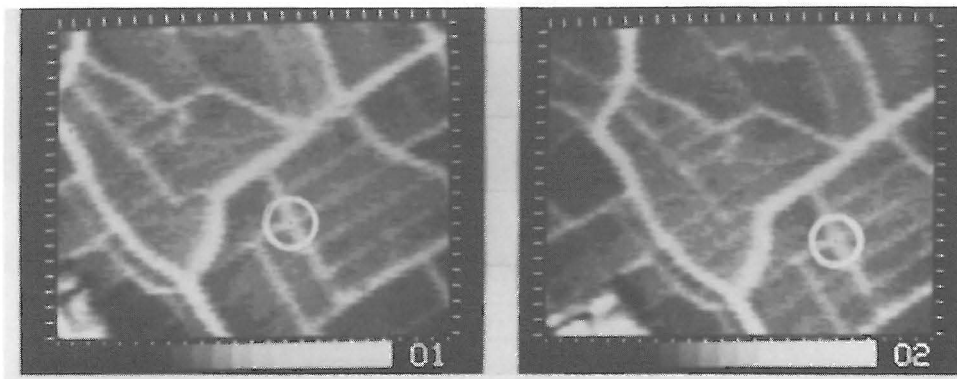


Fig. 5 Two Aerial Photographs -Left and Right Model- (Original;Color)

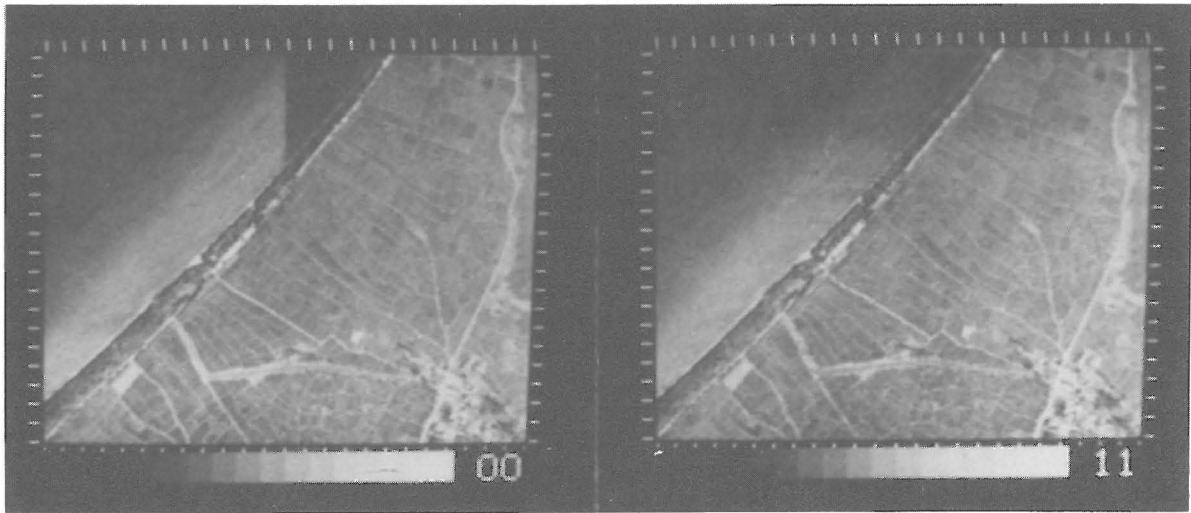


(a) Location of Passpoints



(b) Enlargement(Point No. 6)

Fig. 6 Passpoint for Geometric Registration



(a) Unsmoothed

(b) Digitally Smoothed

Fig. 7 Effects of Smoothing

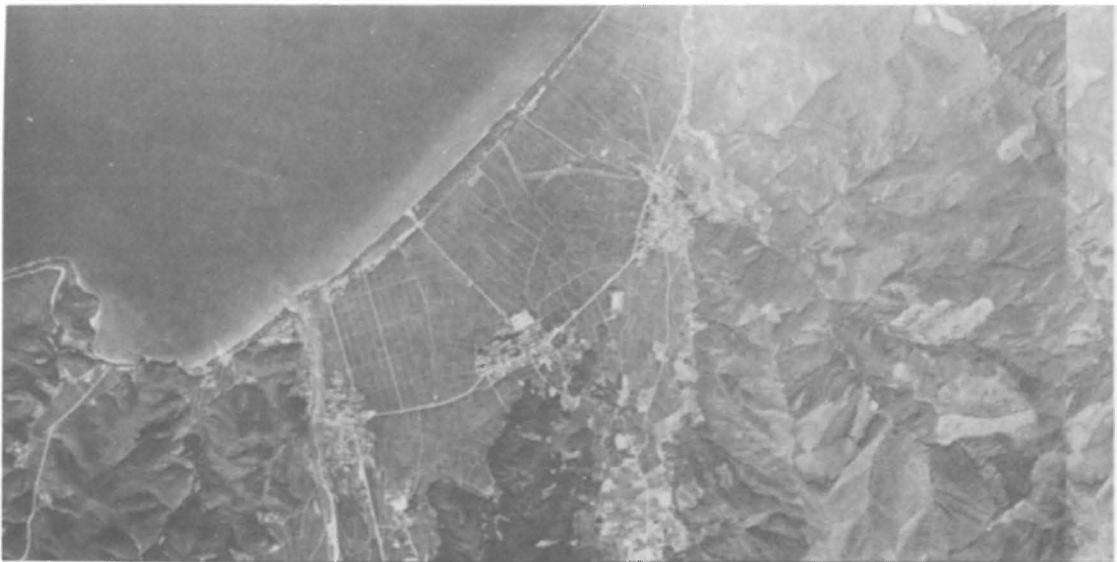


Fig. 8 Digital Mosaic of Two Aerial Photographs (Original;color)

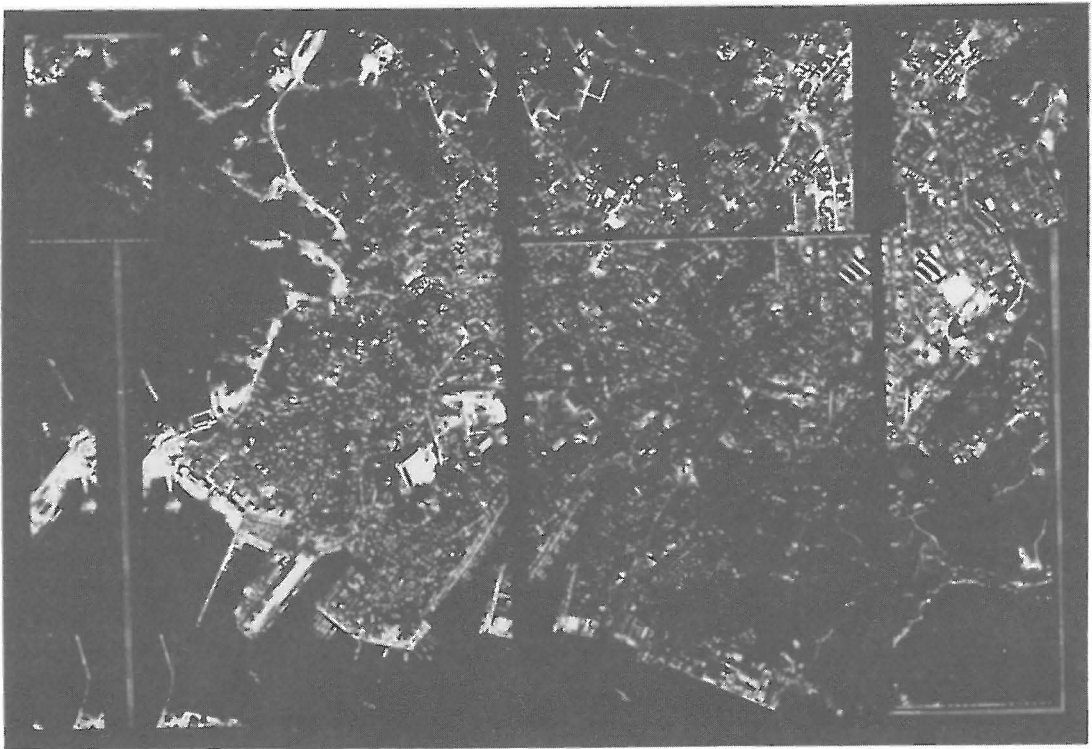


Fig. 9 Eight Patches of Orthophotos (Original; color)

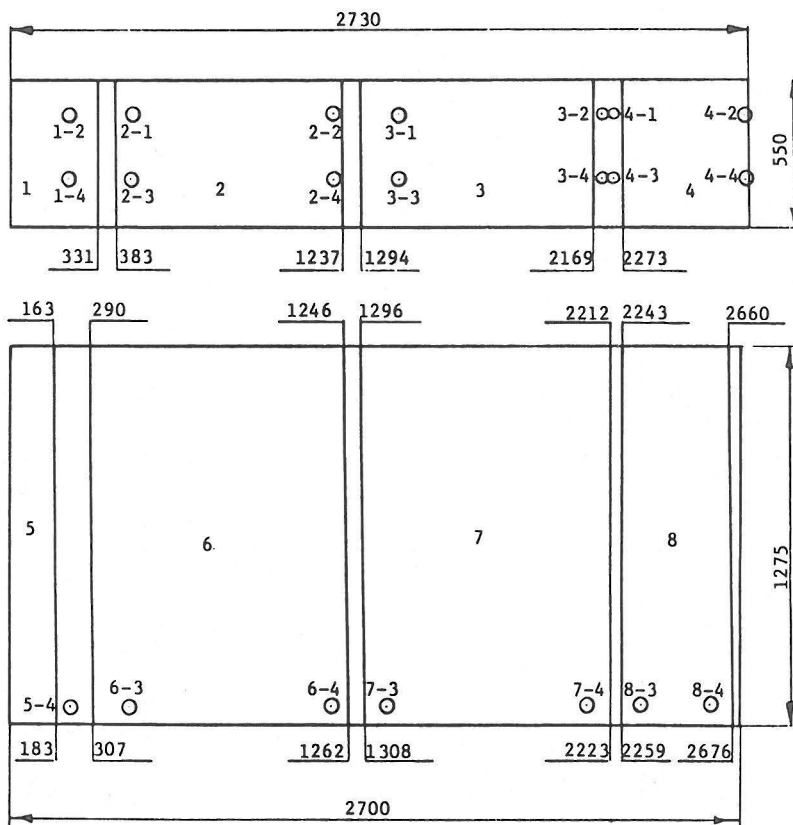


Fig. 10 Geometric Registration for Eight Patches



Fig. 11 Seamless Mosaic Produced from Eight Patches. (Original;color)



Fig. 12 Manually Made Mosaic