GCP acquisition using simulated SAR derived from DTM.

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Abstract:

A method for the GCP acquisition using simulated SAR image, derived from Digital Terrain Model, DTM, is proposed.

The Japanese Earth Resource Satellite-1, JERS-1, will be launch in 1992. Before that, it will be better preparing GCPs for the precise geometric correction of SAR image data.

In order to acquire GCPs without real SAR image data, SAR image has been simulated by using DTM. In this study, simulated image is derived from elevation data only so that suppose the simple scattering model without consideration of complex conductivity.

Performance of the acquired GCPs has been evaluated by using some measurs for considering automatic GCP acquisition. Some effect by window size of GCP chip, include GCP in center of it, has been investigated.

This paper described the detail of the proposed mdthod and results of investigations, to determine whether control points can be automatically acquired in the simulation image study.

[key word]
GCP, DTM, DEM, Texture feature, SAR, JER-1, AUtomatic matching, GCP aquisition, geometric disdtortion, GLCM

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1. Introduction

For many years, methodology for GCP acquisition of optical imaging sensor data have been proposed and studied. Such techniques are applicable for SAR images effectively according to the recent investigations (B.guindon, et, al 1983,1985,1987). Ref. 1 showed the method for automatic matching of topographically distorted real SAR image and simulated image.

Real SAR images have geometric distortions caused by satellites attitude and position changes and their estimation accuracies result in skew, rotation, offset, magnification errors.

Japanese ERS-1 will be launched with the mission instruments SAR and OPS, in 1992. Before the launching of J-ERS1, GCPs for geometric accuracy assessment of SAR should be created. Therefore by using simulated images generated from DTM prepared by Geographic Survey Institute of Japan, acquisition of GCPs were attempted. In this process, some measures were tried to represent goodness of the candidate GCPs in terms of cross correlation between raw and geometrically distorted GCP chip images. This paper describes the method for simulation of SAR image at first. Second texture features will be introduced for representation of goodness of GCPs. Then some results from the experiments on matching accuracy between simulated and artificially distorted SAR image chips. Finally, comparative study of texture features in terms of cross correlation will also be described.

2. Simulation of SAR image.

2.1 Mesh data and interpolation

Numerical Geographic data of Japan including DTM and/or DEM are available on the standard magnetic tape file. The file (file code KS-110-1) has terrain height data with one meter step, according to the format called "Standard Area Mesh System" Ref. 8.

The area (80km*80km wide, corresponding to 1/200,000 topographic map) has been extracted from intensive study area, because no data loss(KS-110-1 has no data for the sea area), and contain rugged mountain area. This area includes Mt. Fuji as shown in Fig. 1. Although the Original mesh grid distance is 250m, data are interpolated with the interval of 50m by 3-dimensional spline function.

2.2 Expression of backscattering

Assuming that backscattering coefficients are almost same in the area because it almost covered by Lambertian surface of forest. Geometric relationship between the satellite and the targets is shown in Fig.3. Also assuming that satellite is located west side of the area, altitude is 570 km, side looking angle is 35 deg , satellite course is along to longitude line during observation.

Image was simulated according to the following algorithm.

1) Elevation between the neighboring grids is derived from the DTM data.
2) Calculate the incidence angle of radar beam to target, and

obtains the distribution of backscattering coefficient according to the following equation,

$$In = Ir \cos \theta \qquad (1)$$

where In:vertically incident beam; Ir:reflected beam to the direction of θ.

3) Resampling the data along with the range direction according to the following equation.
The aim of this resampling is to adjust the pixel interval deformed by topographic artifacts illustrated in Fig.4.

$$P(i) = e_i \{ x - | \frac{1}{2} x - \delta x_i | \} / x \qquad (2)$$

P(i) : Pixel value of resampled data
ei : Pixel value of before resample
Xi : Standard pixel distance
δXi : magnitude of distortion by topographic related artifacts.

4) Divide the image into 10*10 chips. These chips consist of 32 lines by 32 pixels. The gray level variance of these chips are indicated in Table 1. 14 chips which were selected for the study is illustrated in Table 1-2, and also shown in Fig.5.

3. Automatic matching of GCP chip to the artificially distorted image.

The original image was distorted by skew and rotation to represent the geometric distortion, then area correlation was calculated between the original chip image and the distorted chip. The chip what has max correlation coefficient to be decided the matching target.

1) Extracted the reference image chip (64 pixel by 64 line around the GCP) and distorted this chip by skew and/or rotation.
2) Set the searching window (48 pixel by 48 line).
3) Move the GCP chip, pixel by pixel, in the searching window.

Skew and rotation range 0 to 4 deg. To refine the coarsely estimated location, a 3*3 area, centered on the peak correlation is extracted and using 2-dimensional polynomial for interpolation refined peak is found. On the other hand, 0 to 10 degree distortions are considered for GCP NO.1-3 to investigate the case of which miss identification is more than one pixel. These 3 chips are also used for investigation of chip size effect. Chip size of (32*32, 28*28, 24*24, 20*20, 16*16, 12*12) are considered.

4. Texture features of the GCP chips.

4.1 Method

To assess goodness of GCP, texture features are taken into account due to the fact that gray level variance indicated in Table 1, do not always represent busyness of the terrain surface. In this study, GLCM (Gray Level Co-occurrence Matrix) proposed by Haralick et al (1973) was used 256 levels were suppressed into 125 levels for computational convenience. GLCM was normarized by the following equation.

$$P(i,j,d,\theta) = \frac{P(i,j,d,\theta)}{R} \qquad (3)$$

$$R = \quad (P(i,j,d,\theta))$$

Ng :number of gray levels

P(i,j) :element of GLCM

d :pixel distance (1 or 2)

θ :0,45,90,135 deg.

Texture features were computed by the following equations.

i) Contrast

$$CON = \sum_i \sum_j (i-j)^2 P_{ij} \qquad (4)$$

ii) Chi-Square

$$CHI = \sum_i \sum_j \frac{P_{ij}^2}{P_x(i) P_y(j)} \qquad (5)$$

iii) Entropy

$$ENT = \sum_i \sum_j P_{ij} \log P_{ij} \qquad (6)$$

iv) Angular Second Moment

$$ASM = \sum_i \sum_j P_{ij}^2 \qquad (7)$$

v) Homogeneity

$$HOM = \sum_i \sum_j \frac{P_{ij}}{1+(i-j)^2} \qquad (8)$$

vi) Dissimilarity

$$DIS = \sum_i \sum_j |i-j| P_{ij} \qquad (9)$$

vii) Correlation

$$COR = \{\sum_i \sum_j (i\,j) P_{ij} - \mu_x \mu_y\} / \sigma_x \sigma_y \qquad (10)$$

Pij : element of GLCM
i,j : row and column
Px(i);Py(j) : marginal probability matrix obtained by summing the rows (columns) of P(i,j)
ux, uy, ox, and oy are the means and standard deviations of Px(i), Py(j)

4.2 Results

The computed texture features are indicated in Table 2.

Table 3 indicates miss-identification of GCPs between true GCP position and functional peak of correlation.

Variance-covariance and correlation coefficient matrices between estimation error and each texture feature are illustrated in Table 4. Fig. 6 shows that optimum size depends on the characteristic of chip.

5. Concluding Remarkes.

1) Variance do not always represents the busyness of topography while contrast and dissimilality have relatively strong negative correlation. Meanwhile entropy, angular second moment, and homogeneity have positive correlation. These values are sufficient to define the criteria for goodness of GCPs.

2) It was found that variance plays not so significient role compared to the wave number of space frequency effect.

3) It is also obvious that small size chips have been affected relatively little effect with distortions. Since the chip have little information, some hidden risks of miss-identification will be increased.

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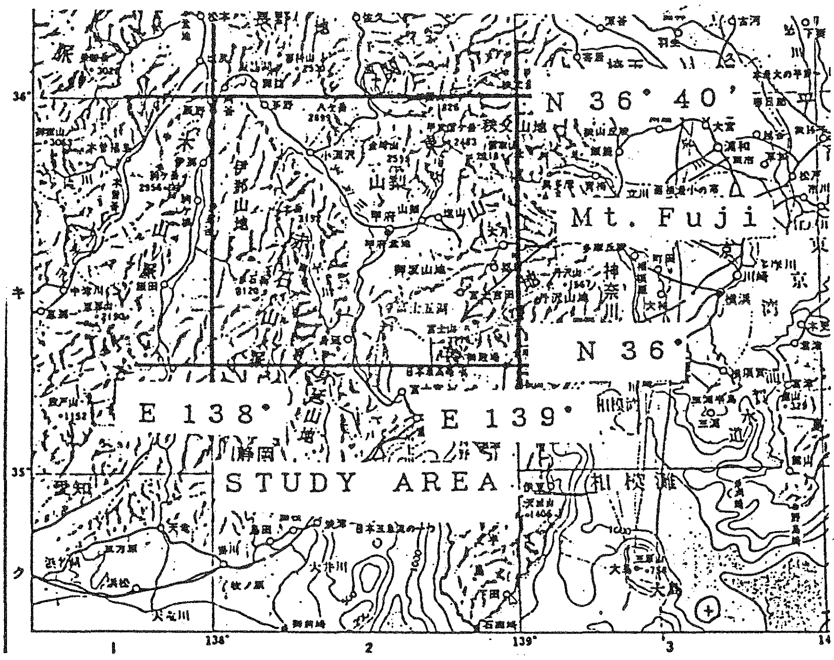

FIG. 1 TOPOGRAPHIC MAP OF INTENSIVE STUDY AREA.

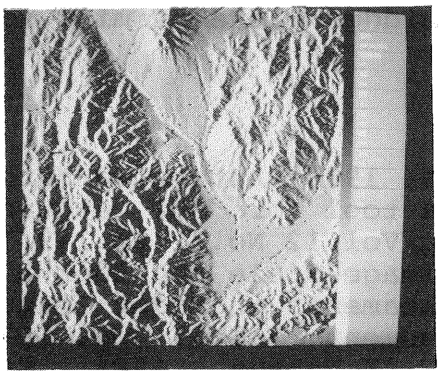

FIG. 2 AN EXAMPLE OF THE SIMULATED SAR IMAGE.

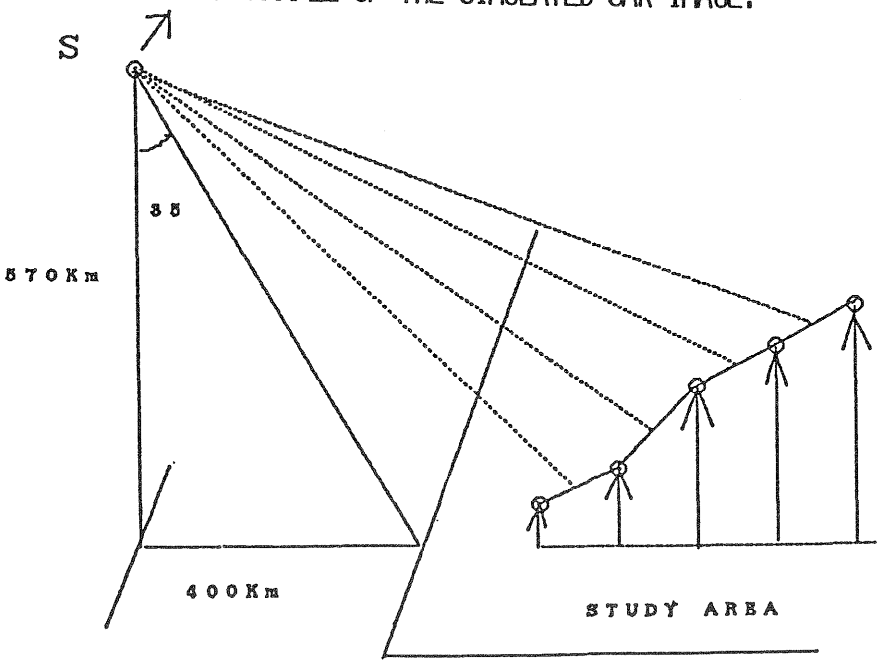

FIG. 3 GEOMETRIC RELATIONSHIP BETWEEN SATELLITE AND TARGET.

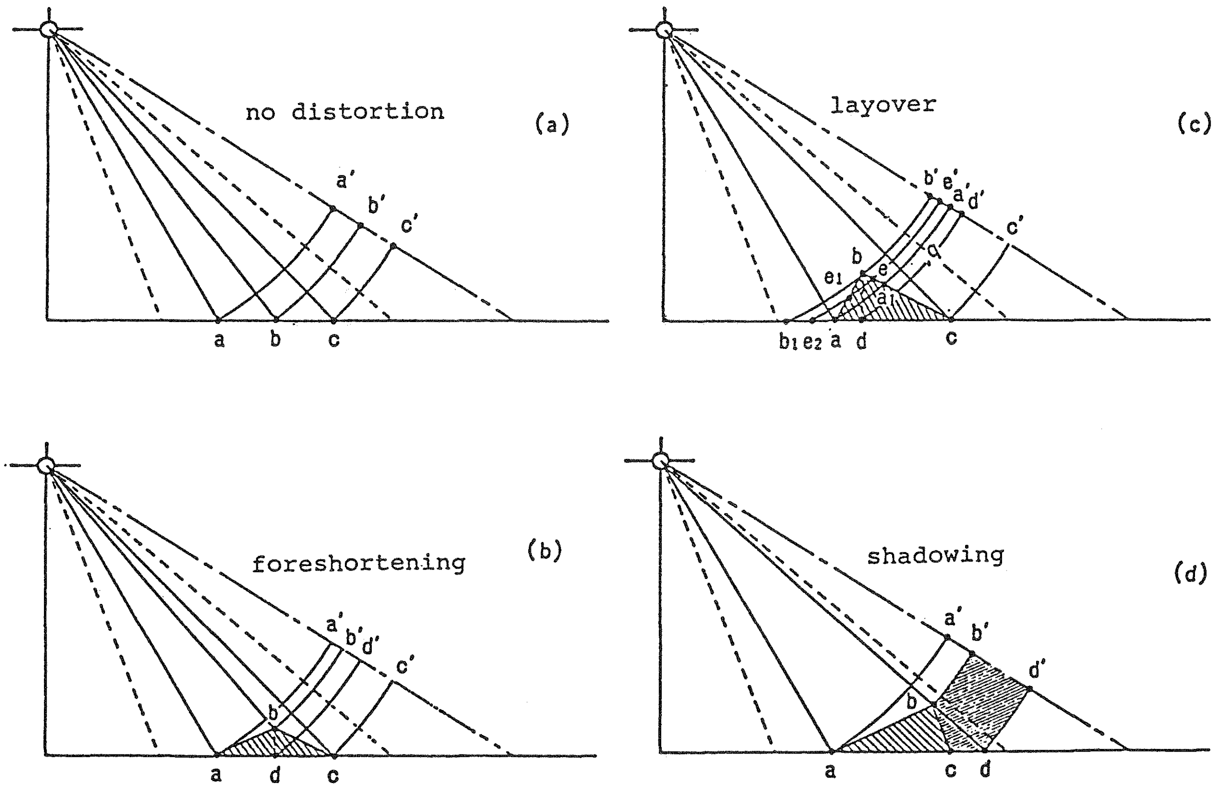

FIG. 4 TOPOGRAPHIC_RELATED ARTIFACTS

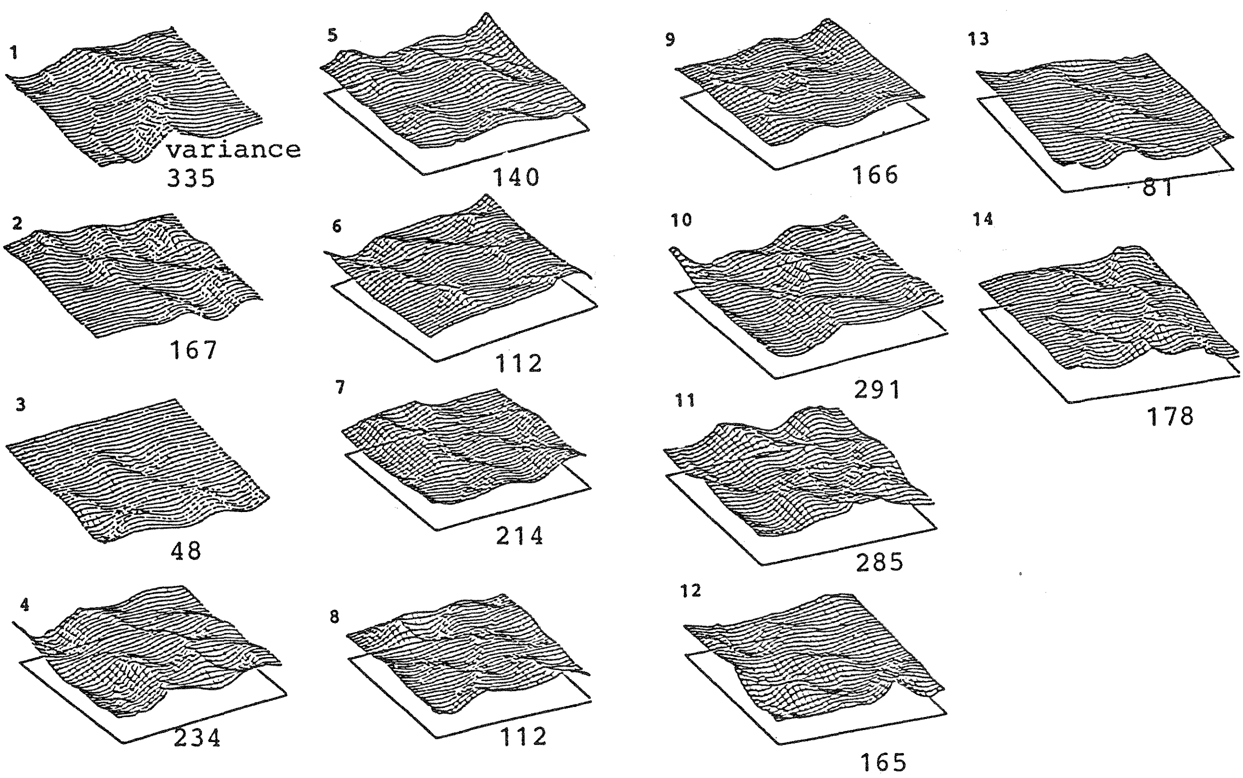

FIG. 5 GRAY LEVEL 3D IMAGE AND IT'S VARIANCE OF GCP CHIP

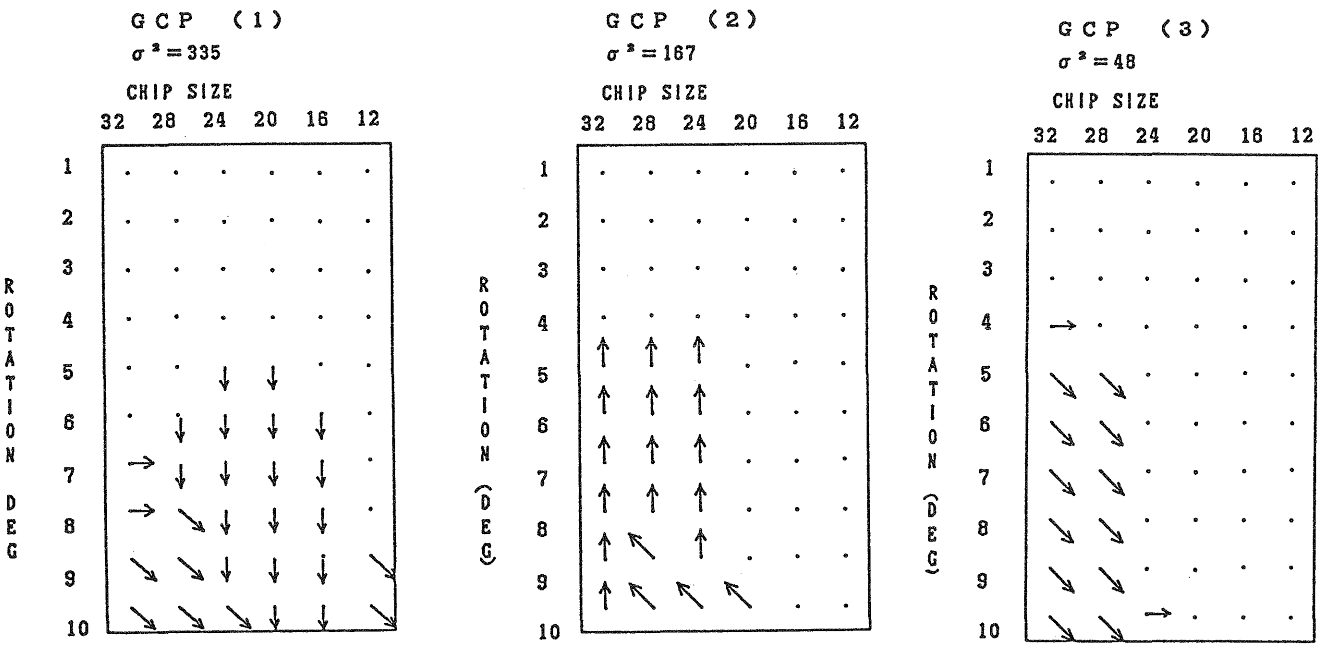

FIG. 6 DISTORTION VECTOR OF GCP

SKEW	CONT(0°)
0.8410	7.0900
0.6700	9.2200
1.1260	2.7400
0.3080	11.2300
0.6620	6.8300
0.6030	7.2700
0.4070	8.1700
0.5480	7.2600
0.2920	4.9400
0.3890	9.3100
0.2300	11.7400
0.6210	7.0000
0.7650	3.3000
0.4820	10.0500

data name	mean	variance	standard deviation
SKEW	0.5674	0.0594	0.2437
CONT(0°)	7.5821	7.1393	2.6719

correlation between SKEW and CONT(0°)
covariance=-.450735
correlation=-.692354

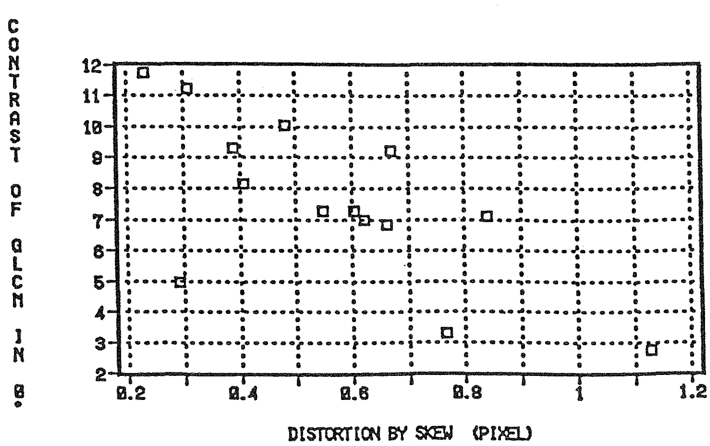

FIG. 7 CORRELATION BETWEEN SKEW DISTORTION AND CONTRAST (0 DEG)

TABLE 1.1 GRAY LEVEL VARIANCE OF EACH GCP CHIP OF FULL SCENE DEVIDE BY 10*10 AREAS.

171	93	25	382	25	145	188	273	260	211
224	320	79	74	100	223	296	284	387	528
198	623	343	31	142	215	225	309	275	346
346	848	336	126	94	246	139	280	254	225
406	844	752	281	81	103	131	124	276	238
709	1082	272	540	69	15	32	162	224	153
675	954	415	634	61	104	236	260	121	133
740	1032	529	585	127	269	263	167	177	204
1092	474	873	408	212	671	50	8	59	134
858	766	920	791	421	346	439	150	45	42

(shaded) This area is selected for subscene

TABLE 1.2 GRAY LEVEL VARIANCE OF EACH GCP CHIP OF SUB SCENE DEVIDE BY 10*10 AREAS.

165	32	25	80	191	165	64	3	5	95
58	61	141	189	119	198	81	48	13	235
106	150	214	112	166	130	163	28	42	251
131	162	265	185	206	252	82	65	41	265
124	227	292	253	301	122	169	98	41	249
183	179	340	305	139	85	179	118	137	406
79	254	174	137	242	131	218	201	190	535
58	208	234	83	140	112	291	104	155	508
58	167	285	165	81	178	335	140	130	1037
57	66	167	122	188	285	287	294	139	718

(shaded) This area is selected for GCP's

TABLE 2. TEXTURE FEATURES OF GCP CHIPS

GCP NO.	σ^2	CON	CHI	ENT	ASM	HOM	DIS
1	335	25.33	30.43	-21.91	.0227	1.79	7.07
2	167	32.82	22.65	-21.50	.0298	1.64	8.25
3	48	10.99	14.66	-17.55	.0784	2.20	4.76
4	234	39.50	20.82	-22.30	.0224	1.52	8.94
5	140	26.75	20.94	-21.13	.0300	1.57	7.87
6	112	25.50	22.11	-20.44	.0342	1.72	7.27
7	214	29.78	19.81	-21.27	.0293	1.55	8.25
8	112	31.15	25.71	-20.54	.0358	1.61	7.98
9	166	19.56	20.83	-20.82	.0306	1.84	6.44
10	291	33.39	32.99	-22.17	.0208	1.16	8.23
11	285	44.13	18.92	-23.09	.0152	1.24	10.39
12	165	30.81	27.09	-21.42	.0248	1.52	8.32
13	81	13.62	18.56	-19.00	.0502	2.00	5.47
14	178	37.17	25.37	-21.57	.0291	1.54	8.76

TABLE 3. MAGNITUDE AND ANGLE OF GCPs' MISS-IDENTIFICATION
OBTAINED BY FUNCTIONAL CORRELTION PEAK.
(UPPER LOW :MAGNITUDE, DENOTE WITH PIXEL;
LOWER LOW :ANGLE, DENOTE WITH DEGREE)

	skew angle (deg)				rotation angle (deg)			
GCP NO	1°	2°	3°	4°	1°	2°	3°	4°
1	.065	.156	.256	.364	.073	.168	.259	.363
	128	123	125	125	-32	-41	-40	-36
2	.078	.139	.204	.250	.083	.165	.287	.441
	-64	-59	-57	-51	109	108	106	104
3	.106	.212	.340	.468	.149	.313	.481	.670
	163	168	169	171	-36	-40	-40	-40
4	.025	.054	.093	.139	.019	.062	.111	.173
	-39	-37	-40	-39	117	117	111	109
5	.070	.125	.195	.272	.026	.080	.139	.200
	38	30	30	27	199	211	217	220
6	.054	.114	.183	.252	.040	.094	.145	.201
	108	98	95	95	220	237	240	239
7	.024	.067	.127	.190	.085	.156	.228	.296
	58	62	68	68	247	248	246	244
8	.057	.106	.159	.226	.014	.054	.095	.154
	-70	-65	-63	-60	75	90	93	99
9	.025	.051	.088	.128	.102	.212	.330	.464
	-9	14	21	22	248	249	248	248
10	.038	.071	.115	.166	.042	.084	.123	.167
	-24	-30	-36	-36	82	93	97	99
11	.026	.041	.070	.095	.029	.058	.092	.127
	80	86	84	82	126	127	130	134
12	.059	.118	.186	.258	.068	.133	.214	.280
	151	149	148	149	-76	-67	-64	-62
13	.077	.115	.226	.306	.048	.087	.131	.179
	247	236	232	228	-15	12	17	24
14	.030	.052	.094	.141	.064	.111	.167	.225
	316	281	267	262	63	75	77	75

TABLE 4. VARIANCE-COVARIANCE-CORRELATION MATRIX OF EACH TEXTURE FEATURE
AND MISS-IDENTIFICATION OF GCPs' BY SKEW OR ROTATION.

	SKEW	ROT	VAR	CON	CHI	ENT	ASM	HOM	DIS
SKEW	.0594	.568	-.488	-.7063	-.1623	.7418	.7566	.7397	-.7278
ROT	.0513	.1372	-.290	-.610	-.3228	.5619	.6259	.6273	-.6281
VAR	-9.891	-8.957	6931.2	.618	.5777	-.8415	-.7794	-.6567	.6028
CON	-1.602	-2.103	478.98	86.687	.3473	-.885	-.8008	-.8778	.9828
CHI	-.1948	-.5888	236.8	15.925	24.255	-.5151	-.5708	-.5145	.3031
ENT	.2532	.2916	-98.14	-11.551	-3.554	1.963	.9689	.8658	-.8952
ASM	.0029	.0036	-1.012	-.1164	-.0439	.0212	.0002	.8317	-.8300
HOM	.0488	.0675	-14.816	-2.215	-.6880	.3288	.0035	.0735	-.8968
DIS	-.2558	-.3357	72.39	13.201	2.1537	-1.809	-.0187	-.3507	2.0814