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Quarterly Status and Technical Progress Report

Landsat-D Thematic Mapper Image Dimensionality Reduction and Geometric Correction Accuracy

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G3/43 Unclas 00011

1. Problems

No problems were encountered during this reporting period which have impeded the progress of the investigation.

2. Accomplishments

In the area of dimensionality reduction, a literature survey was completed, the analytical development of dimensionality reduction algorithms was continued, and software development was also continued. The development of a distributed stochastic image model based on physical models of spectral reflectivity is nearing completion, and algorithms based on this model are under development.

Preliminary results of principal component analysis of a 512 by 512 TM subscene of a section of the Sacramento River have been obtained. They show that, as expected, there is lower correlation among the TM spectral components than has been observed for the MSS spectral components. For comparison purposes, we have applied principal component analysis to a Landsat 2 MSS subscene of the same area. The MSS scene was acquired in a different season and year, but it still allows some comparisons to be made. The results are summarized in Tables 1 and 2. The matrix elements are in band sequence for each sensor system.

The correlation coefficient matrices (normalized covariance matrices) indicate the pairwise linear similarity and correlation of the data for the spectral components. The TM correlation coefficient matrix shows that bands 1, 2, and 3 are highly correlated; bands 4, 5, and 7 have positive correlation; and band 6 (thermal) has a highly negative correlation with the three visible bands (1, 2, and 3). The correlations between any of the visible bands and the reflective infrared bands (4, 5, and 7) is very low.

The MSS correlation coefficient matrix shows that the visible bands (4 and 5) are highly correlated, as are the infrared bands (6 and 7). However, the correlations between the visible and infrared bands are still fairly high.

The principal components transformation matrix, which is composed of the normalized eigenvectors of the covariance matrix ordered by eigenvalues, indicates the weights applied to the original components to generate the transformed components. The first transformed component of the TM data is seen to be roughly an average of the infrared components. The second component is roughly an average of the visible components minus the negatively correlated thermal component. The third transformed component is roughly band 4 minus the average of bands 3, 5, and 7. Thus, the first two TM components can be described as visible and near infrared. For the MSS data, however, the first transformed component is roughly the average of the four original components, and has been referred to as the brightness component. The second transformed component is roughly the difference between the visible and infrared components, and has been referred to as the greeness component.

It has been shown that if the data is represented by L transformed components of the N original components, where L<N, then mean-square error of the approximation is given by:

$$\varepsilon_L = \sum_{K=1}^{L} \lambda_k$$

where λ_k's are the eigenvalues of the covariance matrix. The percent variance in transformed component k is given by:

$$var_k(\%) = 100 \frac{\lambda_k}{\varepsilon_N}$$

and the cumulative percent variance of the first L transformed components is given by:

$$cvar_k = 100 \frac{\varepsilon_L}{\varepsilon_N}$$

Refering again to Tables 1 and 2, we see that 97.0% of the variance in a TM image is contained in the first three components, while 99.0% of the variance in an MSS image is contained in only two transformed components.

Further efforts on dimensionality reduction by principal components analysis and canonical analysis will be made in the next quarter.

In the area of geometric correction, the software for automated control point acquisition by scene-to-map feature matching was developed and is currently under test. In this algorithm, linear scene features are digitized from a map, a synthetic image is created, a rough geometric transformation is applied, and the spatial correlation between the transformed synthetic image and the TM image is computed for a sequence of vertical and horizontal shifts of the synthetic images. The shift values of the peak correlation are used to compute a very accurate control point pair. The algorithm is used to acquire over 100 control point pairs in the TM scene, which in turn are used to evaluate the accuracy of the TM geometric correction. Preliminary results indicate that the geometry is very good. More quantitative results will be reported in the next quarter.

3. Significant Results

The significant results obtained this quarter are those involving principal components analysis, as reported in section 2.

4. Publications

No publications were released during this period.

5. Recommendations

No recommendations were made concerning changes relating to maximum utilization of the Landsat-D system.

[redacted]

[redacted]

6. Data Utility

A habitat analysis of a portion of the Sacramento River has been performed for the U.S. Army Corps of Engineers using TM data. A report on this project is in preparation. Initial results indicate that the TM data will provide much better vegetative classification results.

Table 1. TM Principal Components Transformation

Correlation Coefficient Matrix:

1.00	0.93	0.87	0.05	-0.05	-0.80	0.05
0.93	1.00	0.92	0.08	-0.12	-0.72	-0.03
0.87	0.92	1.00	-0.13	-0.15	-0.59	-0.02
0.05	0.08	-0.13	1.00	0.59	-0.13	0.44
-0.05	-0.12	-0.15	0.59	1.00	0.10	0.94
-0.80	-0.72	-0.59	-0.13	0.10	1.00	0.04
0.05	-0.03	-0.02	0.44	0.94	0.04	1.00

Covariances

37.4	13.9	24.8	92.0	157.9	14.8	43.0

Principal Components Transformation Matrix (Eigenvectors):

-0.02	-0.02	-0.05	0.46	0.80	0.01	0.38
0.66	0.40	0.49	0.20	-0.06	-0.35	0.02
-0.13	-0.03	-0.20	0.84	-0.34	-0.03	-0.35
-0.15	0.21	0.54	0.11	-0.02	0.78	-0.05
-0.08	0.01	-0.03	0.13	-0.49	0.03	0.85
-0.70	0.14	0.48	0.00	0.04	-0.50	-0.02
-0.15	0.88	-0.44	-0.08	0.03	0.05	-0.01

Eigenvalues:

238.0	81.4	52.9	6.8	2.2	1.9	0.7

Percent Variance in Transformed Components:

62.0	21.2	13.8	1.8	0.6	0.5	0.2

Cumulative Percent Variance in Transformed Components:

62.0	83.2	97.0	98.7	99.3	99.8	100.0

Table 2. MSS Principal Components Transformation

Correlation Coefficient Matrix:

1.00	0.93	0.63	0.48
0.93	1.00	0.62	0.51
0.63	0.62	1.00	0.97
0.48	0.51	0.97	1.00

Covariances:

31.1	135.0	229.7	417.1

Principal Components Transformation Matrix (Eigenvectors):

0.13	0.29	0.57	0.76
0.39	0.84	-0.03	-0.36
0.46	-0.37	0.67	-0.44
0.79	-0.25	-0.47	0.31

Eigenvalues:

697.2	107.1	7.1	1.5

Percent Variance in Transformed Components:

85.8	13.2	0.9	0.2

Cumulative Percent Variance in Transformed Components:

85.8	59.0	99.8	100.0