

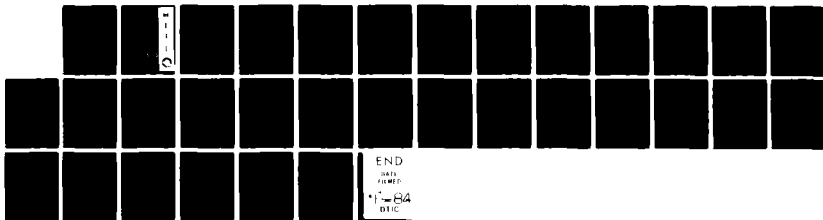
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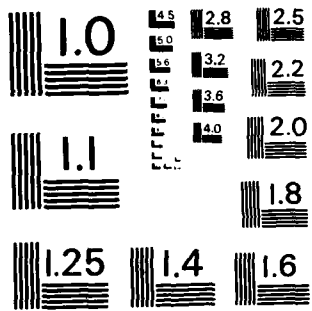
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Application of a feature selection technique to samples of high resolution synthetic aperture radar imagery

Richard A. Hevenor

July 1983

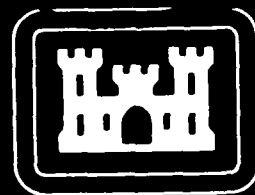
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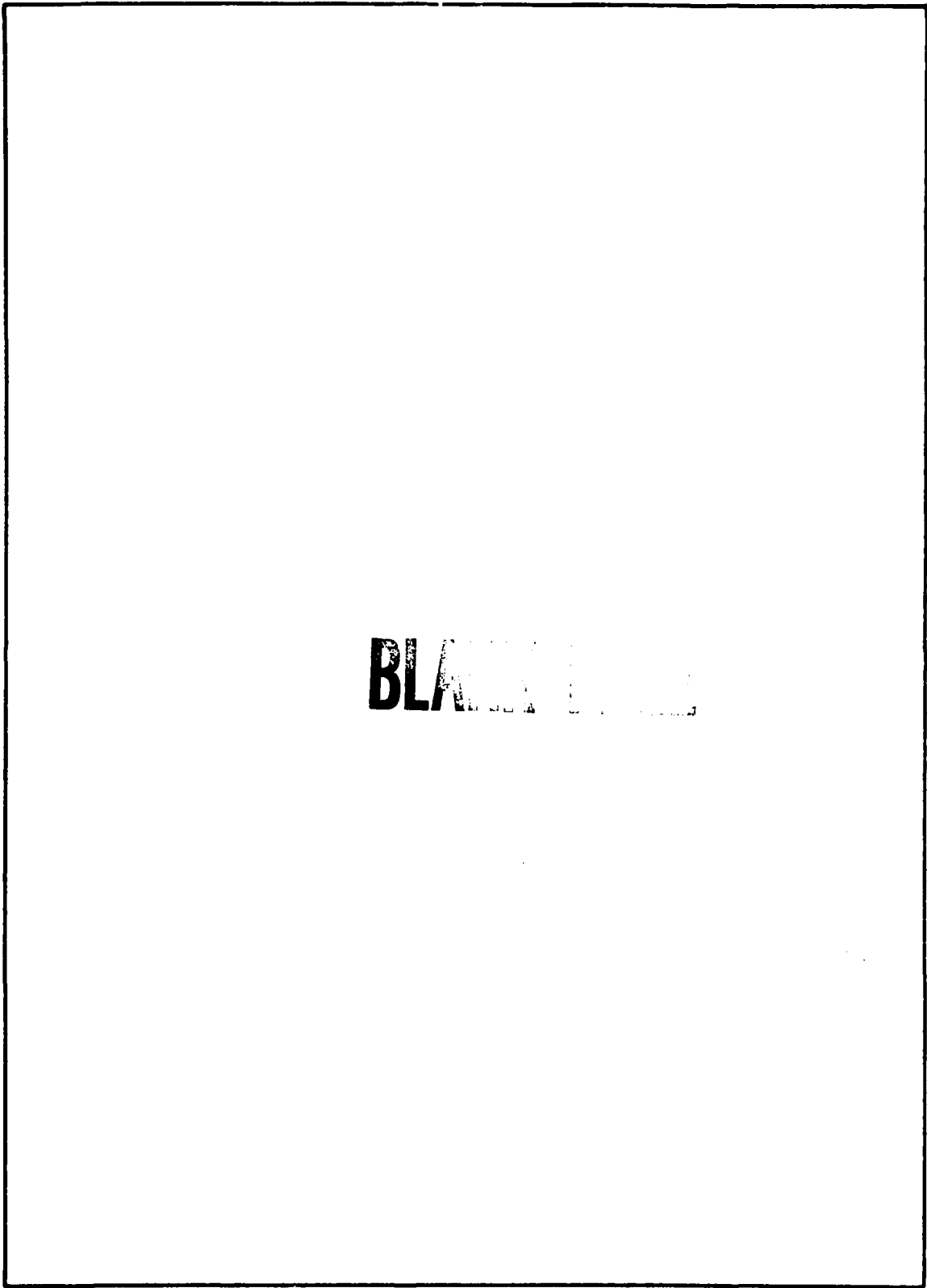
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A feature selection technique was applied to samples of synthetic aperture radar imagery. This technique was applied to four classes of terrain features on selected samples of radar imagery. The four classes considered were forests, cities, agricultural fields, and water. A feature vector was computed from samples of each class. A linear transformation was utilized to develop a new feature vector of reduced dimensionality. This transformation chooses those features that are most effective for performing class separability.		

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PREFACE The authority for performing the work described in this research note is contained in Project 4A161102B52C, "Research in Geodetic, Cartographic, and Geographic Sciences."

The work described in this research note represents an application of a standard feature selection technique to samples of high resolution synthetic aperture radar imagery. The task was performed under the supervision of Dr. Frederick W. Rohde, Team Leader, Center for Physical Sciences and Mr. Melvin Crowell, Jr., Director, Research Institute.

COL Edward K. Wintz, CE, was the Commander and Director and Mr. Robert P. Macchia was the Technical Director of the Engineer Topographic Laboratories during the study period.

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APPLICATION OF A FEATURE SELECTION TECHNIQUE TO SAMPLES OF HIGH RESOLUTION SYNTHETIC APERTURE RADAR IMAGERY

INTRODUCTION The purpose of this research note is to show the application of a feature selection technique to samples of synthetic aperture radar imagery and to present some preliminary results. In the past, feature selection techniques have been applied to data computed from digitized aerial photography. However, it appears that no one has as yet applied feature selection techniques to high resolution radar imagery. In order to perform classification of terrain features using radar imagery, feature selection is an important initial step. Feature selection consists of choosing those features that are most effective for showing class separability and for performing a reduction in the dimensionality of the feature vector. The following sections will present a discussion of the feature selection technique, along with its application to selected samples of radar imagery.

METHODOLOGY The application of pattern recognition techniques is accomplished usually in two steps, namely, feature selection and classifier design. The feature selection process that precedes the classification process consists of techniques applicable to one class or to multiple classes. The feature selection technique to be discussed here is applicable to multiple classes. It provides the capability of reducing the number of components of the original feature vector in such a way that the resulting components are optimized to show class separability. The feature selection technique comes from the field of discriminant analysis of statistics and is independent of the probability density functions of the feature vector data. The feature selection operation can be expressed as a linear transformation of the following form:

$$Y = AX \quad (1)$$

where X is the original feature vector with dimensionality $n \times 1$; A is the transformation matrix of dimensionality $m \times n$, where m is less than n ; and Y is the transformed feature vector with dimensionality $m \times 1$. The feature selection problem is now reduced to determining the matrix A . In order to calculate A , use is made of the within-class and between-class scatter matrices. A within-class scatter matrix shows the scatter of samples around their class expected vector and can be expressed by

$$S_w = \sum_{i=1}^N P(\omega_i) C_i \quad (2)$$

where S_w is the within-class scatter matrix, $P(\omega_i)$ is the a priori probability of the i^{th} class, C_i is the covariance matrix of the i^{th} class, and N is the total number of classes. A between-class scatter matrix can be defined in many ways; however, the following definition was the one utilized here:

$$S_b = C_1 + C_2 + (M_1 - M_2) (M_1 - M_2)^T \quad (3)$$

where S_b is the between-class scatter matrix, C_1 is the covariance matrix for class 1, C_2 is the covariance matrix for class 2, M_1 is the mean vector for class 1, M_2 is the mean vector for class 2, and T means transpose. This definition of the between-class scatter matrix is valid only for the case where N (the number of classes) is equal to two. In order to have criteria for class separability, a number must be derived from the scatter matrices. This number should increase when the distances between points belonging to different classes are increasing or when the distances between points belonging to the same class are decreasing. One criterion is the use of J_1 , which can be defined as follows:

$$J_1 = \text{trace} (S_{2m}^{-1} S_{1m}) \quad (4)$$

where

$$S_{2m} = AS_w A^T \text{ and } S_{1m} = AS_b A^T$$

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The feature selection problem now requires that we select the particular transformation matrix A , which maximizes the value of J_1 . Fukunaga¹ shows that A is made up of the normalized eigenvectors of the matrix $S_w^{-1} S_b$.

$$A^T = [\phi_1 \ \phi_2 \ \dots \ \phi_m] \quad (5)$$

where ϕ_1 is the eigenvector associated with the largest eigenvalue, ϕ_2 is the eigenvector associated with the second largest eigenvalue, etc. Once the matrix A is computed from (5), the new feature vector Y can be computed for each point in each class.

INVESTIGATION

The feature selection technique was applied to samples of high resolution synthetic aperture radar imagery taken over the Huntsville, Alabama, area with the APD-10 radar system. Sections of the radar imagery were digitized and stored on a digital disk unit. A Lexidata system 3400 display processor was used to display the images on a cathode ray tube and to take 100 samples for each of four terrain classes from the imagery. Each sample consisted of a 32 by 32 pixel element window located within a section of one particular terrain class. The four classes considered were cities (combination of commercial and residential structures, DLMS category #504 FIC 301 and #505 FIC 401), fields (agriculture used primarily for crop and pasture land, DLMS category #510 FIC 950), water (rivers with smooth fresh water, DLMS category #510 FIC 940) and fresh water subject to ice (lakes and reservoirs, DLMS category #510 FIC 943), and forests (mixed trees, deciduous and evergreens, DLMS category #510 FIC 954). A feature vector consisting of 13 components was computed for each sample. These 13 components were made up of the first- and second-order gray level histogram statistics computed from each sample window. The explicit equations used for the 13 components of the original feature vector are shown in appendix A. A computer program was written for the Hewlett-Packard 1000 computer to calculate J_1 as a function of displacement in x and y . This computer program was also used to calculate the transformation matrix A . A listing of this program is provided in appendix B. A second computer program was written to calculate the new feature vector Y for the four hundred samples taken from the radar imagery. A listing for this second computer program is given in appendix C.

¹Keinosuke Fukunaga, *Introduction to Statistical Pattern Recognition*, Academic Press, 1972.

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RESULTS In this section some results of numerical calculations are presented. Table 1 shows the results of calculating the value of J_1 for various values of displacement DX and DY for the two classes of forests and cities. The a priori probabilities for the two classes were assumed equal to 0.5.² In table 1 the largest value of J_1 is 29.8525, which is associated with a DX of -3 and a DY of 4. The significance of a maximum value of J_1 occurring at these particular values of displacement is not understood at this time. The values of the displacement DX and DY associated with the largest value of J_1 were utilized to compute a new feature vector Y with two dimensions.

Figure 1 shows a plot of two second-order statistical components for the forest and city samples. The triangles are the results from city calculations; and the x's are the results from forest calculations. This figure clearly shows the need for feature selection because the original data for forests and cities is not separated. Figure 2 presents the results after the transformation $Y = AX$ is applied to the original feature vector X . In this figure the x's again represent calculations from forests. We now see that the data from forests is clustered and almost totally separated from the data for cities, represented by the triangles. Even though a few points still overlap, the improvement is very dramatic. The transformation has succeeded in reducing the dimensionality of the original feature vector from 13 to 2 and also in separating the clusters of data for the two classes.

Figure 3 shows the results of the transformation for the two classes of cities and fields. The x's represent the data from cities. Good separation is obtained for the two classes as only a few points are overlapping. Figure 4 shows the results of calculations for the two classes of cities and water. The x's represent the data from cities. In this particular case the two classes are totally separated as well as being clustered fairly well. Figure 5 presents the results for forests and water. The x's represent the data for forests. Again the two classes have clearly been separated by the transformation. Figure 6 shows the results for fields and water, with the data for fields represented by the x's. These two classes have also been totally separated. Figure 7 shows the results for forests and fields with the data for forests represented by the x's. The two classes are not well separated and other features may have to be investigated to obtain better separation. Another possibility would be to try using nonlinear feature selection techniques for these two classes.

²This assumption of equal probability for cities and forests appeared to be appropriate for the area where the samples were taken.

TABLE 1. Values of J_1 for first and second order histogram statistics

DX	DY	J_1
1	0	22.1485
2	0	19.8078
3	0	19.4333
4	0	19.3099
5	0	19.7508
6	0	20.3677
7	0	19.8529
0	1	21.0314
0	2	21.7613
0	3	21.3524
0	4	21.7343
0	5	22.3144
0	6	23.1462
0	7	23.5903
1	1	20.6771
1	2	20.4869
2	2	24.3979
3	2	23.9334
4	2	21.5577
3	3	25.7921
- 1	1	20.2745
- 2	2	24.4373
- 3	2	25.0272
- 3	4	29.8525
4	4	22.7131

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CONCLUSIONS

1. The feature selection technique discussed in this report appears to be a powerful tool for the application of pattern recognition to high resolution synthetic aperture radar imagery.
2. In order to separate forests and agricultural fields it appears that the first and second order histogram statistics combined with a linear feature selection technique may not be sufficient as a feature vector.

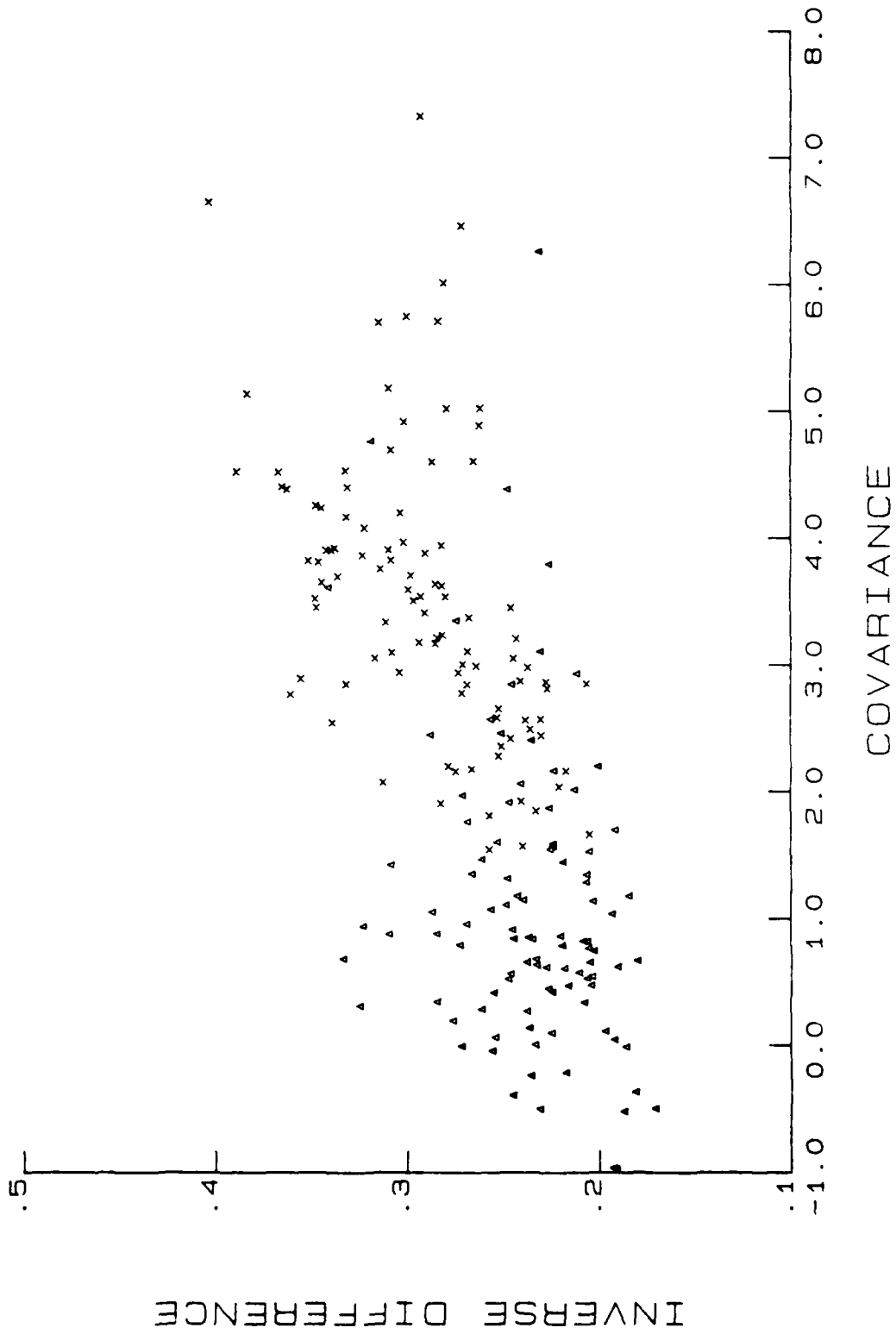


FIGURE 1. Forest and city samples $DX = -3$ $DY = 4$.

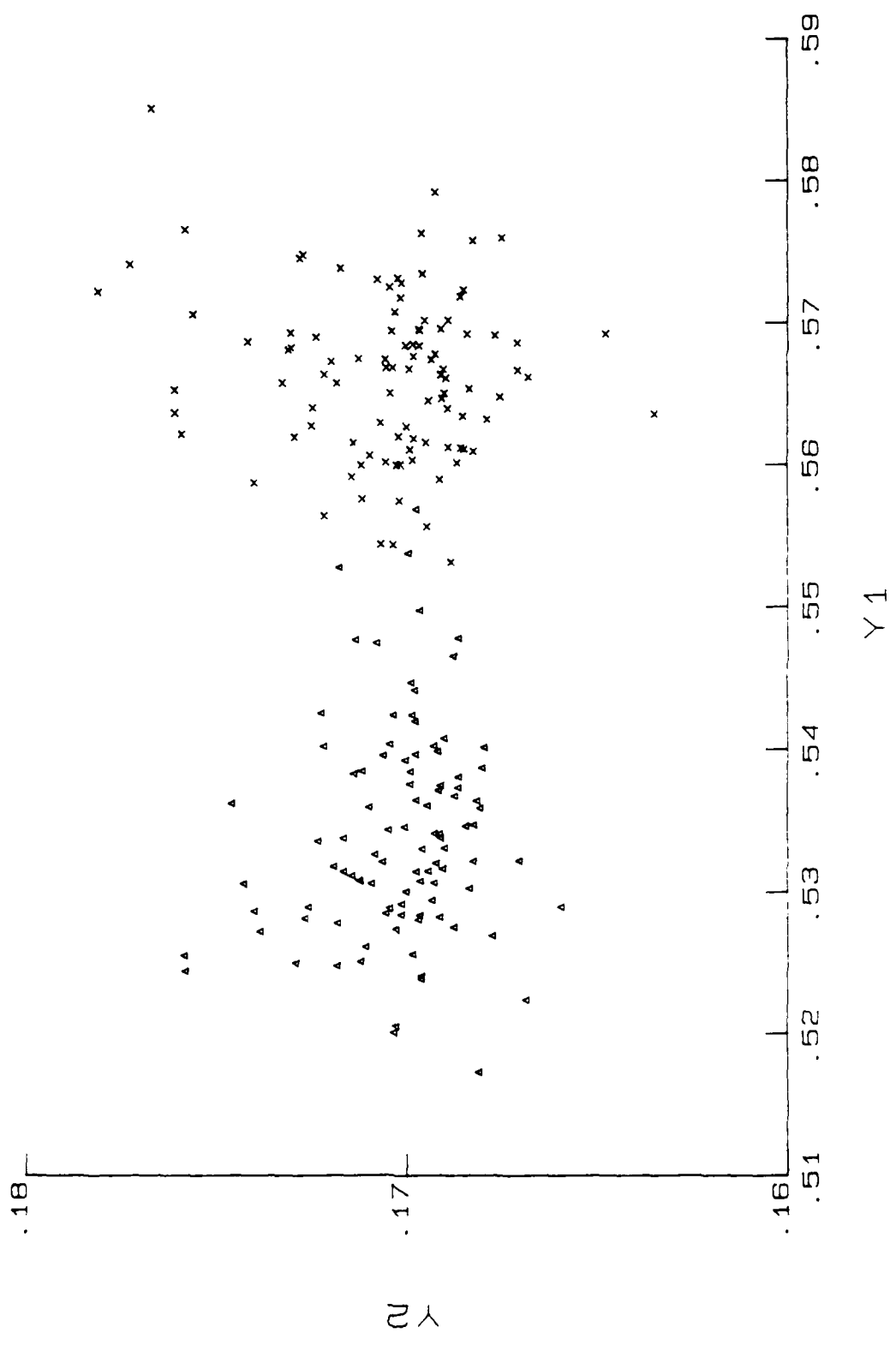


FIGURE 2. Forests and cities DX = -3 DY = 4.

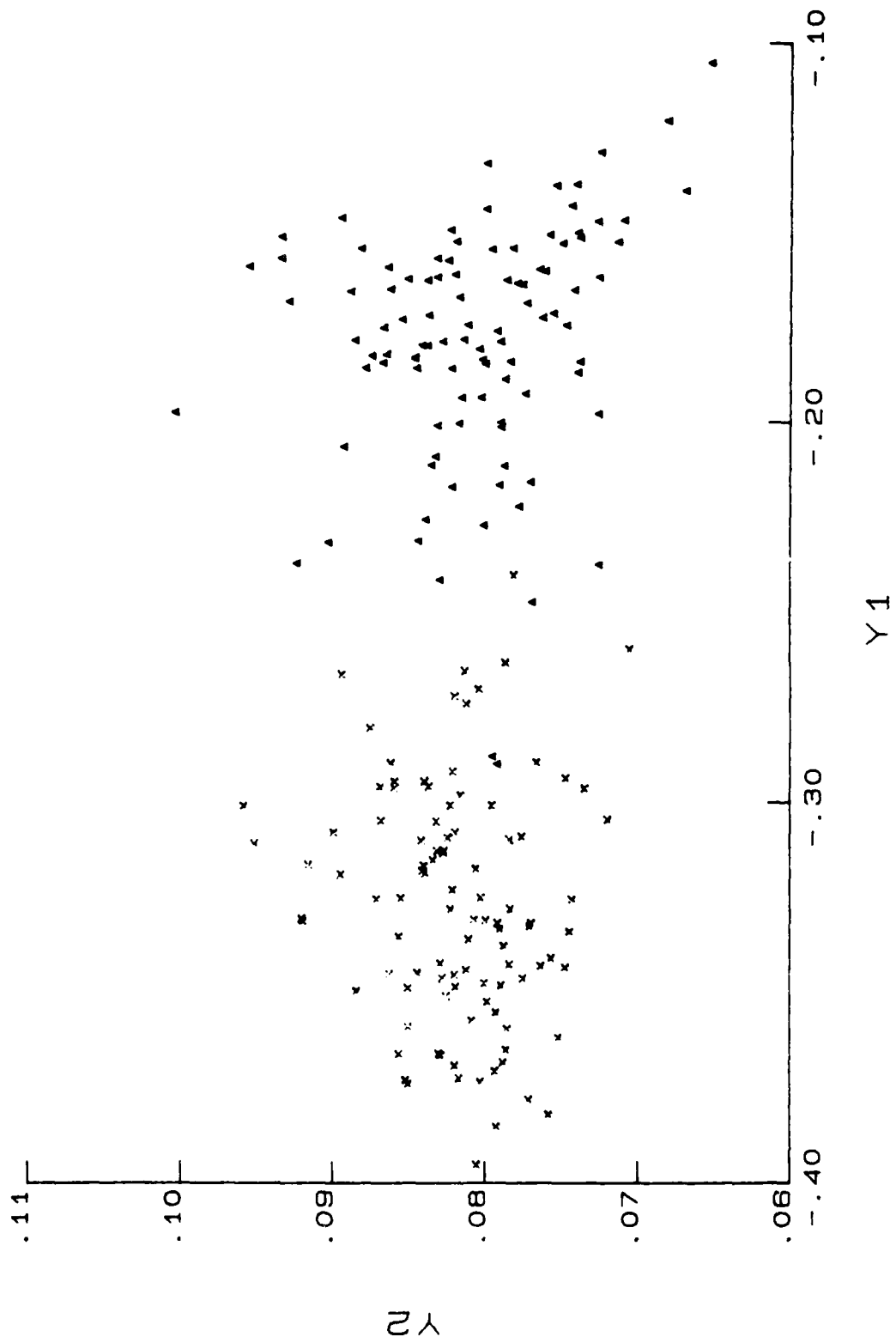
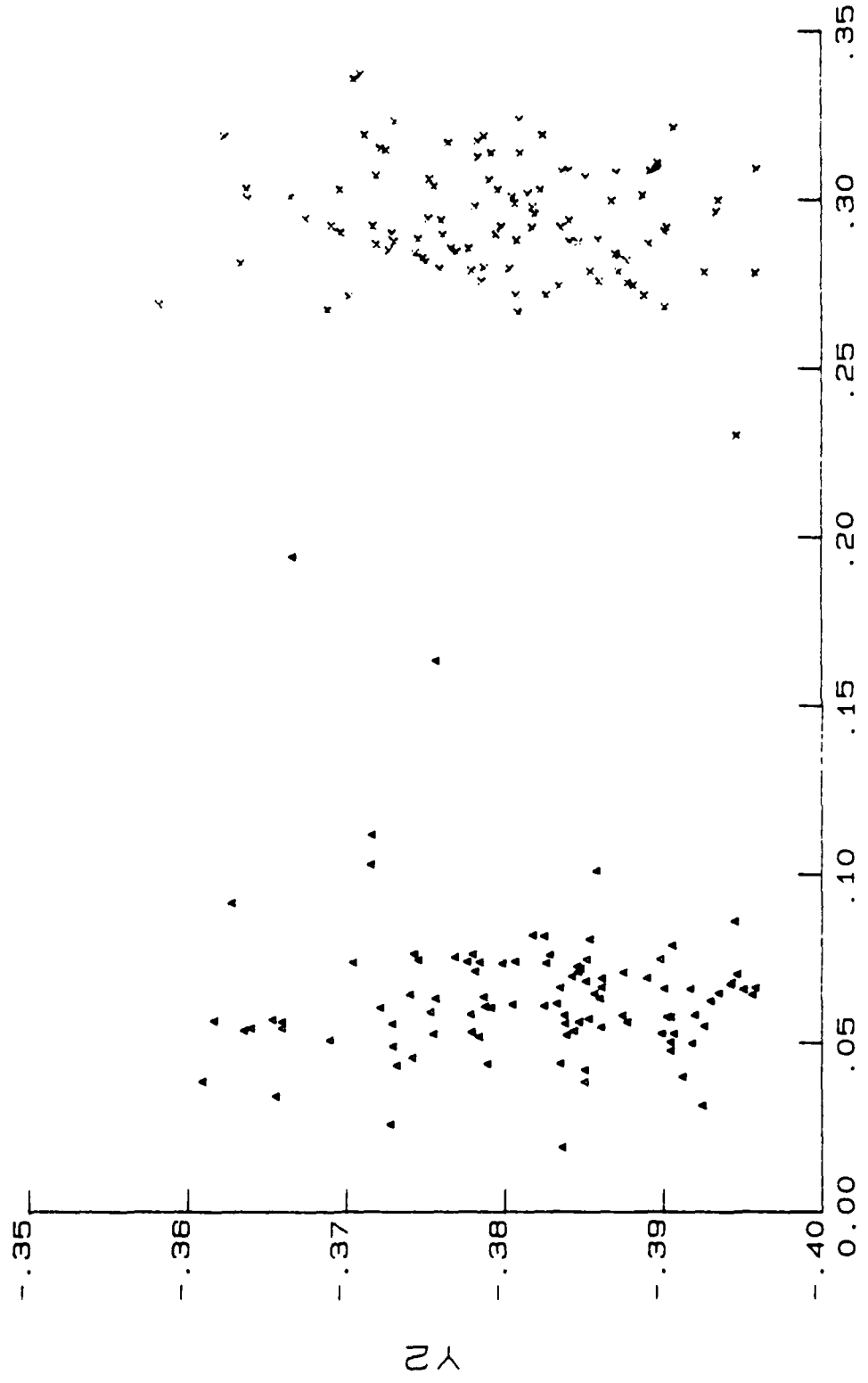
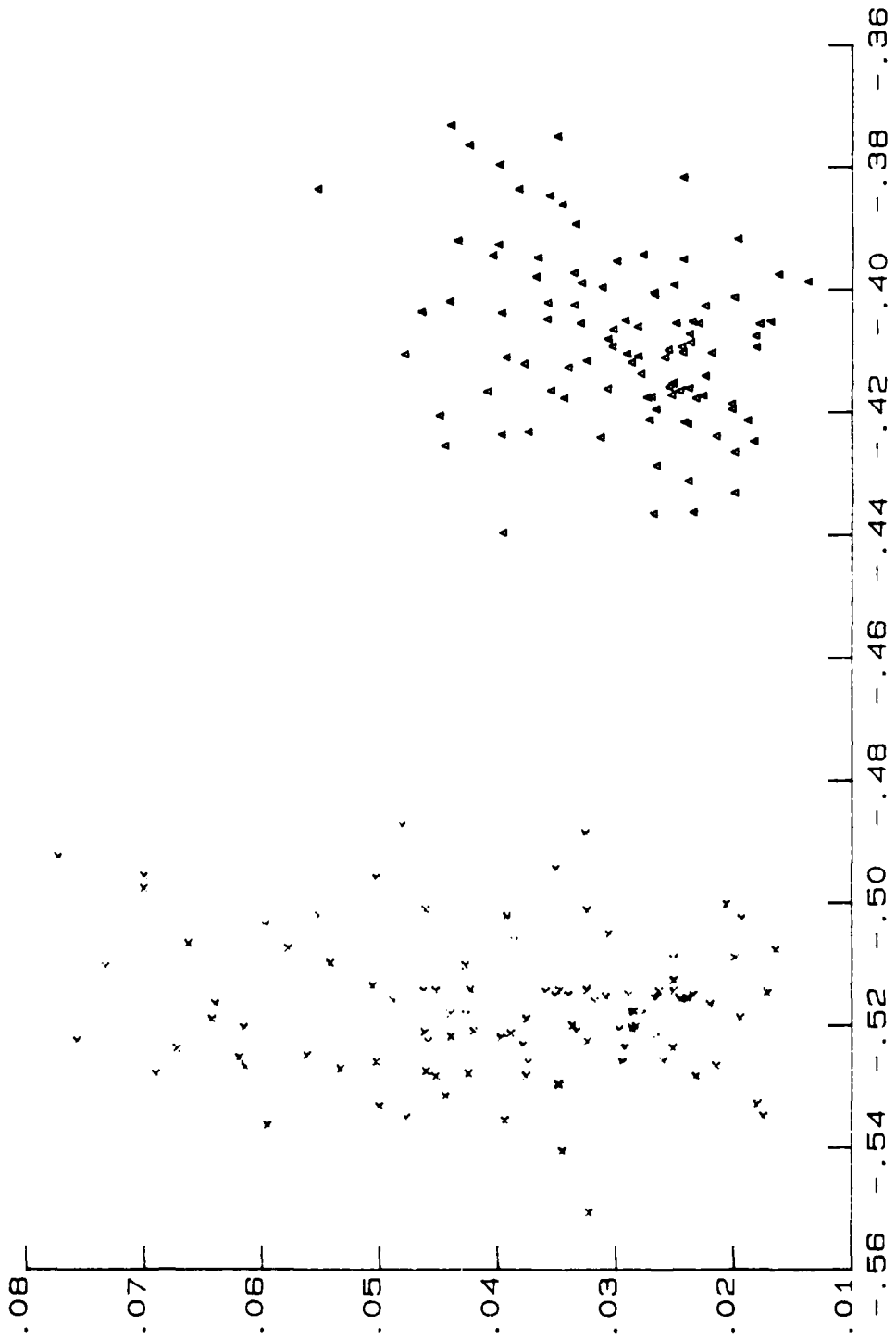


FIGURE 3. Cities and fields DX = 2 DY = 4.



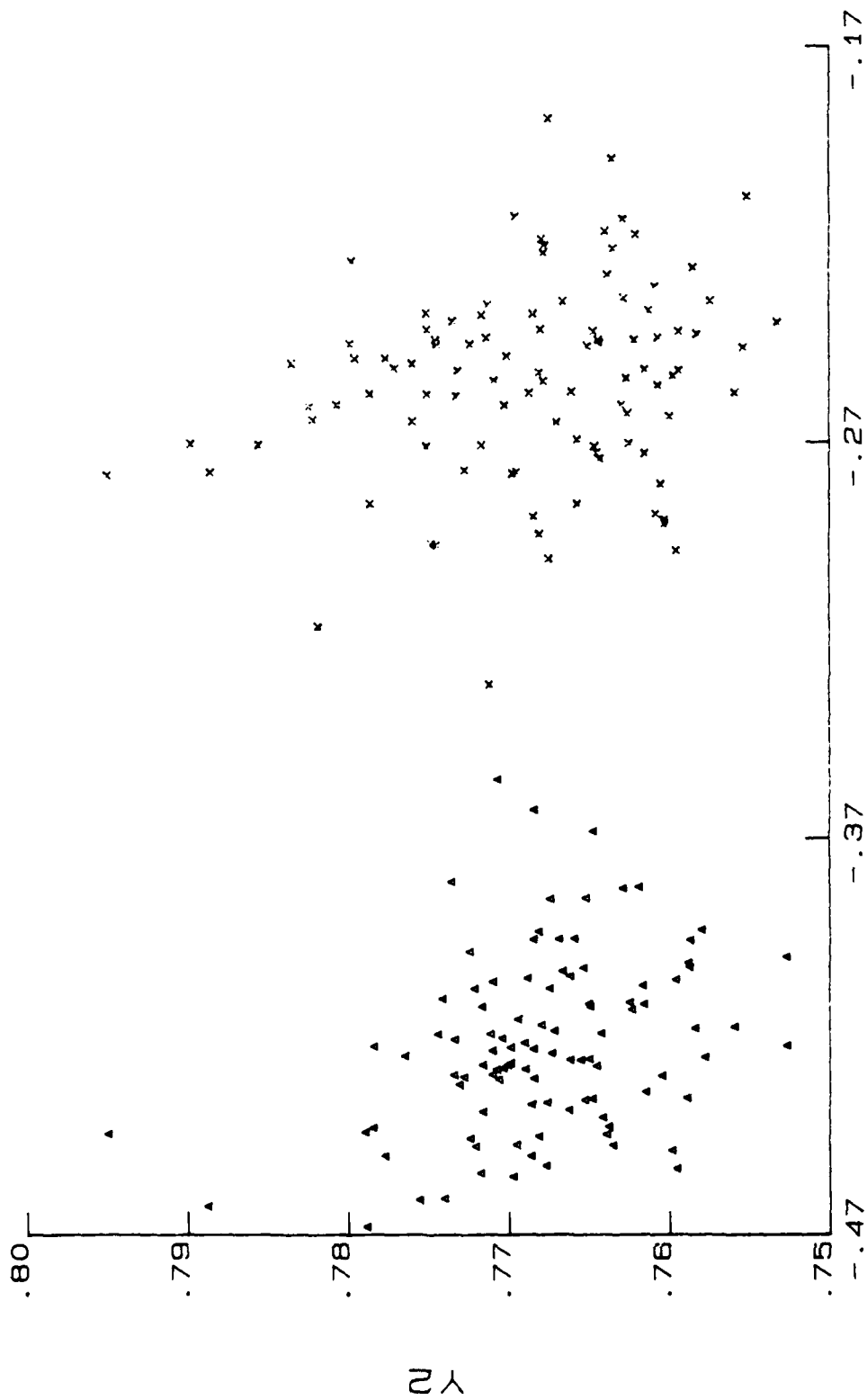
Y 1

FIGURE 4. Cities and water DX = 1 DY = 0.



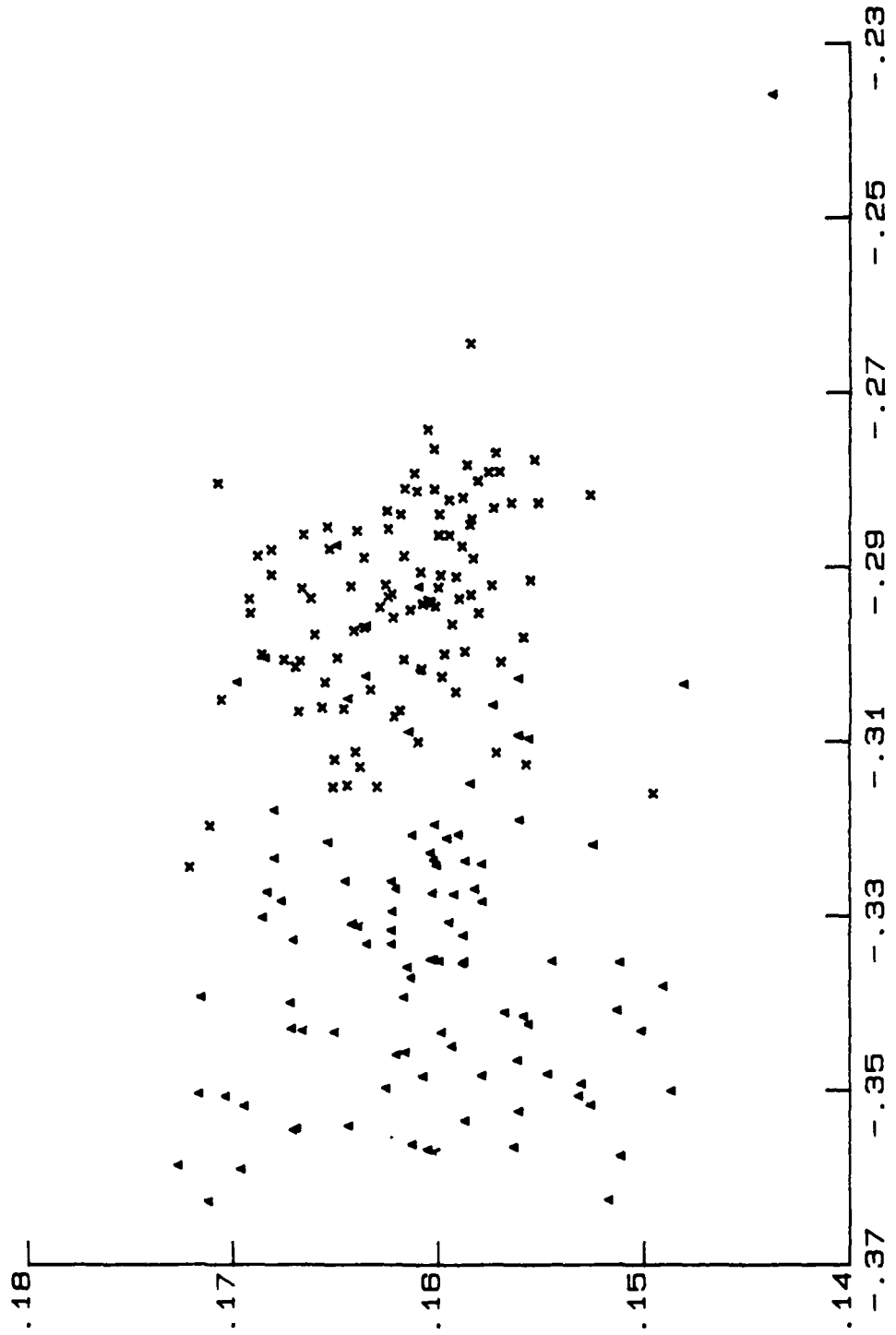
Y 1
 DX = 1 DY = 0.
 FIGURE 5. Forest and water

Y 2



Y 1

FIGURE 6. Fields and water DX = 1 DY = 0.



Y1

FIGURE 7. Forests and fields DX = 2 DY = 0.

APPENDIX A

FEATURE VECTOR COMPONENTS

The following first and second order histogram measures were used to construct a thirteen dimensional feature vector:

$$\text{Mean} \quad \bar{b} = \sum_{b=0}^{L-1} bP(b) = x_1$$

$$\text{Variance} \quad \sigma_b^2 = \sum_{b=0}^{L-1} (b-\bar{b})^2 P(b) = x_2$$

$$\text{Skewness} \quad b_S = \frac{1}{\sigma_b^3} \sum_{b=0}^{L-1} (b-\bar{b})^3 P(b) = x_3$$

$$\text{Kurtosis} \quad b_K = \frac{1}{\sigma_b^4} \sum_{b=0}^{L-1} (b-\bar{b})^4 P(b) - 3 = x_4$$

$$\text{Energy} \quad b_N = \sum_{b=0}^{L-1} [P(b)]^2 = x_5$$

$$\text{Entropy} \quad b_E = -\sum_{b=0}^{L-1} P(b) \log_2 [P(b)] = x_6$$

$$\text{Autocorrelation} \quad B_A = \sum_{a=0}^{L-1} \sum_{b=0}^{L-1} abP(a,b) = x_7$$

$$\text{Covariance} \quad B_C = \sum_{a=0}^{L-1} \sum_{b=0}^{L-1} (a-\bar{a})(b-\bar{b}) P(a,b) = x_8$$

$$\text{Inertia} \quad B_I = \sum_{a=0}^{L-1} \sum_{b=0}^{L-1} (a-b)^2 P(a,b) = x_9$$

$$\text{Absolute Value} \quad B_V = \sum_{a=0}^{L-1} \sum_{a=0}^{L-1} |a-b| P(a,b) = x_{10}$$

$$\text{Inverse Difference} \quad B_D = \sum_{a=0}^{L-1} \sum_{b=0}^{L-1} \frac{P(a,b)}{1+(a-b)^2} = x_{11}$$

$$\text{Energy} \quad B_N = \sum_{a=0}^{L-1} \sum_{b=0}^{L-1} [P(a,b)]^2 = x_{12}$$

$$\text{Entropy} \quad B_E = -\sum_{a=0}^{L-1} \sum_{b=0}^{L-1} P(a,b) \log_2 [P(a,b)] = x_{13}$$

where L is the number of grey levels and $P(b)$ and $P(a,b)$ are given below

$$P(b) = \frac{Q(b)}{M}$$

M is the total number of pixels in the sample window. In this case M was equal to 1024. $Q(b)$ is the number of pixels of greytone b which occur in the sample window.

$$P(a,b) = \frac{Q(a,b)}{M}$$

$Q(a,b)$ is the number of times greytone a is located next to greytone b by the displacement Δx and Δy .

APPENDIX B.

Computer Program for Calculating J_1 and the Transformation Matrix A

```

0001 C-----
0002 C-----
0003 C-----
0004 C THIS PROGRAM PERFORMS FEATURE EXTRACTION FOR
0005 C ANALYSED DISTRIBUTIONS BY MAXIMIZING THE VALUE OF
0006 C J1
0007 C-----
0008 PROGRAM ESFEEX1000
0009 DIMENSION I(1015) IMAX(1024) X(100,15) IP(144) J(11,3)
0010 DIMENSION A(13,2) C(1,15,2) S(1,15) C(3,13) XND(13) P(1)
0011 CALL RMPAR(001)
0012 CD=00000
0013 CALL ERLE(0)
0014 I=0
0015 DO 80 NJ=1,80
0016 WRITE(0,5)
0017 5 FORMAT('ENTER THE NUMBER OF IMAGE SAMPLES TO BE ANALYZED (1-100)')
0018 READ(0,6)NDATA
0019 6 FORMAT(I5)
0020 WRITE(0,10)
0021 10 FORMAT('ENTER THE FILE NAME FOR THE DATA FILE')
0022 READ(0,12)FILE
0023 12 FORMAT(A25)
0024 WRITE(0,15)
0025 15 FORMAT('DISK UNIT NUMBER')
0026 READ(0,210)IDLU
0027 WRITE(0,2100)
0028 2100 FORMAT('ENTER A VALUE FOR IDLU')
0029 READ(0,210)IDX
0030 210) FORMAT(I2)
0031 WRITE(0,2100)
0032 2200 FORMAT('ENTER A VALUE FOR IDY')
0033 READ(0,210)IDY
0034 WRITE(6,1400)IDX, IDY
0035 1400 FORMAT(2X, 'IDX=' , I5, ' IDY=' , I5)
0036 WRITE(6,200)FILE
0037 200) FORMAT(1X, 'A')
0038 CALL OPEN(0,0) JERR=FILE(0,0) (0,0)
0039 IF (JERR.LT.0) GO TO 2000
0040 GO TO 14
0041 2000 WRITE(0,2000) JERR
0042 2010 FORMAT('OPEN FILE ERROR' , I5)
0043 GO TO 999
0044 14) ICONT=1
0045 13) J=1
0046 DO 16 I=1,8
0047 CALL READ(0,0) JERR=IMAGE(0)
0048 16) J=J+128
0049 IF (JERR.LT.0) GO TO 3000
0050 GO TO 18
0051 3000) ICONT=NDATA
0052 WRITE(0,2020) JERR
0053 2020) FORMAT('READ FILE ERROR' , I5)
0054 GO TO 999
0055 18) NGRAY=16
0056 CALL ISCAL(IMAGE, IMAGE, 1024, 0, 15)
0057 CALL FEVAL(IMAGE, AVG, VAR, SKW, XKT, ENGL, ENT, APT, COV, XII,
0058 IARSS, XID, ENT, ENR, NGRAY, IDX, IDY)

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APPENDIX B (Continued)

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0059 C
0060 C STORE RESULTS IN AN ARRAY
0061 C
0062 X(COUNT,1)=RUB
0063 X(COUNT,2)=VAR
0064 X(COUNT,3)=SRW
0065 X(COUNT,4)=XK1
0066 X(COUNT,5)=XNG
0067 X(COUNT,6)=ENT
0068 X(COUNT,7)=RUI
0069 X(COUNT,8)=LOU
0070 X(COUNT,9)=K11
0071 X(COUNT,10)=ABS5
0072 X(COUNT,11)=X1P
0073 X(COUNT,12)=ENY
0074 X(COUNT,13)=LNK
0075 IF (COUNT.NDATA).EQ.0.GOTO
0076 20
0077 DO 10 I=1,3
0078 22 CALL CLUSE(CPUB)
0079 WRITE (LU,24)N,I,TELE
0080 24 FORMAT("N=" I1,3X,"SA=" I1)
0081 CALL COVERNDATA(CPUB,NJ,X,D)
0082 WRITE (6,70)D5
0083 70 FORMAT(1X,"THE INTERSET DISTANCE=" E15.6)
0084 WRITE (6,140)
0085 140 FORMAT(1X,"COVARIANCE MATRIX")
0086 DO 142 K=1,13
0087 WRITE (6,144)C(K,N,N),N-1,13)
0088 144 FORMAT(1X,13(13F4.1X))
0089 142 CONTINUE
0090 80 CONTINUE
0091 150 DO 152 NJ=1,NC
0092 WRITE (LU,154)NJ
0093 154 FORMAT("NJ=" I1,2X,"ENTER THE APRIORI PROBABILITY OF THIS CLASS")
0094 READ (LU,28)PNT)
0095 28 FORMAT(10,F)
0096 WRITE (6,156)NT,PNT)
0097 156 FORMAT(1X,"N=" I1,3X,"P(NJ)=" F10.6)
0098 152 CONTINUE
0099 DO 90 I=1,NC-1
0100 DO 90 J=I+1,NC
0101 90 S2(C,J)=0.0
0102 DO 72 I=1,NC-1
0103 DO 72 J=I+1,NC
0104 DO 72 M=1,13
0105 S2(C,J)=S2(C,J)+(ACM(I,ACM(J))**2
0106 72 CONTINUE
0107 DO 91 I=1,NC-1
0108 DO 91 J=I+1,NC
0109 S2(C,J)=SQRT(S2(C,J))
0110 91 CONTINUE
0111 WRITE (6,73)
0112 73 FORMAT(1X,"THE INTERSET DISTANCES")
0113 DO 92 I=1,NC-1
0114 DO 92 J=I+1,NC
0115 WRITE (6,74)I,J,S2(C,J)
0116 74 FORMAT(1X,"I=" I1,3X,"J=" I1,3X,"D(C,I,J)=" E15.6)
0117 92 CONTINUE
0118 DO 30 I=1,13

```

/

APPENDIX B
(Continued)

```

0119      DO 30 J=1,13
0120      S2(1,J)=0.0
0121      30 S1(1,J)=0.0
0122      DO 32 I=1,13
0123      DO 32 J=1,13
0124      DO 32 K=1,NC
0125      32 S2(I,J)=S2(I,J)+C(I,J,K)*P(K)
0126      DO 34 J=1,13
0127      34 X60(J)=0.0
0128      DO 40 J=1,13
0129      DO 40 M=1,13
0130      40 S1(J,M)=C(J,M,1)+C(J,M,2)+(A(J,1)-A(J,2))*(A(M,1)-A(M,2))
0131      DO 160 J=1,13
0132      DO 160 I=1,13
0133      K=I+13*(J-1)
0134      R(K)=S1(I,J)
0135      R(K)=S2(I,J)
0136      160 CONTINUE
0137      DO 41 I=1,13
0138      41 XMO(I)=0.0
0139      CALL NROUT(13,R,B,XMO,I)
0140      DO 165 J=1,13
0141      DO 165 I=1,13
0142      K=I+13*(J-1)
0143      S2(I,J)=R(K)
0144      165 CONTINUE
0145      WRITE(6,42)
0146      42 FORMAT(2X,"EIGENVALUES")
0147      WRITE(6,46)(XMO(I),I=1,13)
0148      46 FORMAT(1X,13(E9.3,1X))
0149      WRITE(6,48)
0150      48 FORMAT(2X,"EIGENVECTORS")
0151      DO 50 I=1,13
0152      WRITE(6,76)(S2(I,J),J=1,13)
0153      76 FORMAT(1X,13(E8.5,1X))
0154      50 CONTINUE
0155      64 WRITE(LU,52)
0156      52 FORMAT("ENTER A VALUE FOR M.(E,NC)")
0157      READ(LU,4)M
0158      X11=0.0
0159      DO 54 I=1,M
0160      54 XJ1=XJ1+XMO(I)
0161      WRITE(6,56)XJ1,M
0162      56 FORMAT(2X,"THE VALUE OF J1="F10.4,5X,"M=",11)
0163      CALL IRMAT(S2,S1,13,13,0)
0164      WRITE(6,58)
0165      58 FORMAT(2X,"THE TRANSFORMATION MATRIX A")
0166      DO 60 I=1,M
0167      WRITE(6,46)(S1(I,J),J=1,13)
0168      60 CONTINUE
0169      WRITE(LU,62)
0170      62 FORMAT("DO YOU WANT TO CHANGE THE VALUE OF M? IF YES TYPE 1 IF
0171      1NO TYPE 2")
0172      READ(LU,4)I2
0173      4 FORMAT(11)
0174      IF(I2.EQ.1)GO TO 64
0175      WRITE(LU,82)
0176      82 FORMAT("DO YOU WANT TO CHANGE THE VALUES OF THE APRIORI PROBABIL
0177      ITIES? IF YES TYPE 1,IF NO TYPE 2")
0178      READ(LU,4)I2Z

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APPENDIX B
(Continued)

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0179      IF (JAZ.EQ.1) GO TO 150
0180      WRITE(LU,68)
0181      68 FORMAT("DO YOU WANT TO CHANGE THE VALUES OF IDX AND IDY? IF YES
0182      TYPE 1, IF NO TYPE 2.")
0183      READ(LU,4)IXZ
0184      IF (IXZ.EQ.1) GO TO 1
0185      999 STOP
0186      END
0187      SUBROUTINE COVER(KK,LUU AU,MENT X,DS)
0188      DIMENSION XC(100,15),UC(15,15),ACC(50,2)(100,15),EUV(15,15,20),AV(15
0189      1,2),VAR(15)
0190      KK=KK
0191      DO 50 K=1,N
0192      ACC=0.0
0193      DO 45 J=1,KK
0194      45 ACC=ACC+X(J,K)
0195      50 ACC=ACC/ZA
0196      DO 55 K=1,N
0197      VAR(K)=0.0
0198      DO 54 J=1,KK
0199      54 VAR(K)=VAR(K)+X(J,K)*X(J,K)
0200      55 CONTINUE
0201      DO 60 K=1,N
0202      60 VAR(K)=VAR(K)/ZAK+1.0
0203      DS=0.0
0204      DO 65 K=1,N
0205      65 DS=DS+VAR(K)
0206      DS=2.0*DS
0207      DO 110 K=1,N
0208      DO 115 J=1,KK
0209      115 Z(J,K)=X(J,K)/ACC
0210      110 CONTINUE
0211      DO 120 K=1,N
0212      DO 125 M=1,M
0213      125 UCK(M)=0.0
0214      DO 130 J=1,KK
0215      130 UCK(M)=UCK(M)+Z(J,K)*Z(J,K)
0216      UCK(M)=UCK(M)/ZAK
0217      120 CONTINUE
0218      120 CONTINUE
0219      DO 135 K=1,N
0220      DO 135 M=1,M
0221      135 UCK(M)=UCK(M)
0222      135 UCK(M)=UICK(M)
0223      END
0224      SUBROUTINE NR001(CO,IB,AL,KO)
0225      DIMENSION OCTA(20),OCTA2(20),XC(100,15),K(15)
0226      DO 100 I=1,10
0227      O=OACT(I)
0228      DO 100 J=1,2
0229      O=I+J
0230      K=K(I)
0231      100 B(K)=B(K)
0232      100 B(K)=B(K)
0233      CALL FLEND(CO,IB,AL)
0234      C=0
0235      DO 100 J=1,10
0236      C=C+1

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APPENDIX B
(Continued)

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0239      110 X(C)=1./SQRT(ABS(CR(C)))
0240      K=0
0241      DO 115 J=1,M
0242      DO 115 L=1,M
0243      K=K+1
0244      115 R(K)=X(K)*X(L)
0245      DO 120 I=1,N
0246      N2=0
0247      DO 120 J=1,M
0248      N1=N*K(L)
0249      C=N*X(C)
0250      X(C)=0.0
0251      DO 120 K=1,M
0252      N1=N1+1
0253      N2=N2+1
0254      120 X(C)=X(C)+R(C)*X(C)
0255      C=0
0256      DO 130 J=1,M
0257      DO 130 L=1,M
0258      N1=1
0259      N2=N*K(L)
0260      E=1+1
0261      X(C)=0.0
0262      DO 130 K=1,M
0263      N1=N1+1
0264      N2=N2+1
0265      130 C=C+X(C)*X(N1)*R(C)
0266      140 E=1+1+R(C)*X(N1)
0267      C=0
0268      DO 140 L=1,M
0269      C=C+1
0270      140 X(C)=X(C)
0271      DO 150 J=1,M
0272      N2=0
0273      DO 150 L=1,M
0274      N1=1
0275      C=N*K(L)
0276      X(C)=0.0
0277      DO 150 K=1,M
0278      N1=N1+1
0279      N2=N2+1
0280      150 C=C+X(C)*X(N1)*R(C)
0281      E=0
0282      C=0
0283      DO 160 J=1,M
0284      C=0
0285      DO 170 L=1,M
0286      C=C+1
0287      170 X(C)=X(C)+R(C)*X(C)
0288      C=0
0289      DO 180 J=1,M
0290      DO 180 L=1,M
0291      X(C)=X(C)+R(C)*X(L)
0292      C=0
0293      DO 190 J=1,M
0294      DO 190 L=1,M
0295      X(C)=X(C)+R(C)*X(L)
0296      C=0
0297      DO 200 J=1,M
0298      DO 200 L=1,M
0299      X(C)=X(C)+R(C)*X(L)
0300      C=0
0301      DO 210 J=1,M
0302      DO 210 L=1,M
0303      X(C)=X(C)+R(C)*X(L)
0304      C=0
0305      DO 220 J=1,M
0306      DO 220 L=1,M
0307      X(C)=X(C)+R(C)*X(L)
0308      C=0
0309      DO 230 J=1,M
0310      DO 230 L=1,M
0311      X(C)=X(C)+R(C)*X(L)
0312      C=0
0313      DO 240 J=1,M
0314      DO 240 L=1,M
0315      X(C)=X(C)+R(C)*X(L)
0316      C=0
0317      DO 250 J=1,M
0318      DO 250 L=1,M
0319      X(C)=X(C)+R(C)*X(L)
0320      C=0
0321      DO 260 J=1,M
0322      DO 260 L=1,M
0323      X(C)=X(C)+R(C)*X(L)
0324      C=0
0325      DO 270 J=1,M
0326      DO 270 L=1,M
0327      X(C)=X(C)+R(C)*X(L)
0328      C=0
0329      DO 280 J=1,M
0330      DO 280 L=1,M
0331      X(C)=X(C)+R(C)*X(L)
0332      C=0
0333      DO 290 J=1,M
0334      DO 290 L=1,M
0335      X(C)=X(C)+R(C)*X(L)
0336      C=0
0337      DO 300 J=1,M
0338      DO 300 L=1,M
0339      X(C)=X(C)+R(C)*X(L)
0340      C=0
0341      DO 310 J=1,M
0342      DO 310 L=1,M
0343      X(C)=X(C)+R(C)*X(L)
0344      C=0
0345      DO 320 J=1,M
0346      DO 320 L=1,M
0347      X(C)=X(C)+R(C)*X(L)
0348      C=0
0349      DO 330 J=1,M
0350      DO 330 L=1,M
0351      X(C)=X(C)+R(C)*X(L)
0352      C=0
0353      DO 340 J=1,M
0354      DO 340 L=1,M
0355      X(C)=X(C)+R(C)*X(L)
0356      C=0
0357      DO 350 J=1,M
0358      DO 350 L=1,M
0359      X(C)=X(C)+R(C)*X(L)
0360      C=0
0361      DO 360 J=1,M
0362      DO 360 L=1,M
0363      X(C)=X(C)+R(C)*X(L)
0364      C=0
0365      DO 370 J=1,M
0366      DO 370 L=1,M
0367      X(C)=X(C)+R(C)*X(L)
0368      C=0
0369      DO 380 J=1,M
0370      DO 380 L=1,M
0371      X(C)=X(C)+R(C)*X(L)
0372      C=0
0373      DO 390 J=1,M
0374      DO 390 L=1,M
0375      X(C)=X(C)+R(C)*X(L)
0376      C=0
0377      DO 400 J=1,M
0378      DO 400 L=1,M
0379      X(C)=X(C)+R(C)*X(L)
0380      C=0
0381      DO 410 J=1,M
0382      DO 410 L=1,M
0383      X(C)=X(C)+R(C)*X(L)
0384      C=0
0385      DO 420 J=1,M
0386      DO 420 L=1,M
0387      X(C)=X(C)+R(C)*X(L)
0388      C=0
0389      DO 430 J=1,M
0390      DO 430 L=1,M
0391      X(C)=X(C)+R(C)*X(L)
0392      C=0
0393      DO 440 J=1,M
0394      DO 440 L=1,M
0395      X(C)=X(C)+R(C)*X(L)
0396      C=0
0397      DO 450 J=1,M
0398      DO 450 L=1,M
0399      X(C)=X(C)+R(C)*X(L)
0400      C=0
0401      DO 460 J=1,M
0402      DO 460 L=1,M
0403      X(C)=X(C)+R(C)*X(L)
0404      C=0
0405      DO 470 J=1,M
0406      DO 470 L=1,M
0407      X(C)=X(C)+R(C)*X(L)
0408      C=0
0409      DO 480 J=1,M
0410      DO 480 L=1,M
0411      X(C)=X(C)+R(C)*X(L)
0412      C=0
0413      DO 490 J=1,M
0414      DO 490 L=1,M
0415      X(C)=X(C)+R(C)*X(L)
0416      C=0
0417      DO 500 J=1,M
0418      DO 500 L=1,M
0419      X(C)=X(C)+R(C)*X(L)
0420      C=0
0421      DO 510 J=1,M
0422      DO 510 L=1,M
0423      X(C)=X(C)+R(C)*X(L)
0424      C=0
0425      DO 520 J=1,M
0426      DO 520 L=1,M
0427      X(C)=X(C)+R(C)*X(L)
0428      C=0
0429      DO 530 J=1,M
0430      DO 530 L=1,M
0431      X(C)=X(C)+R(C)*X(L)
0432      C=0
0433      DO 540 J=1,M
0434      DO 540 L=1,M
0435      X(C)=X(C)+R(C)*X(L)
0436      C=0
0437      DO 550 J=1,M
0438      DO 550 L=1,M
0439      X(C)=X(C)+R(C)*X(L)
0440      C=0
0441      DO 560 J=1,M
0442      DO 560 L=1,M
0443      X(C)=X(C)+R(C)*X(L)
0444      C=0
0445      DO 570 J=1,M
0446      DO 570 L=1,M
0447      X(C)=X(C)+R(C)*X(L)
0448      C=0
0449      DO 580 J=1,M
0450      DO 580 L=1,M
0451      X(C)=X(C)+R(C)*X(L)
0452      C=0
0453      DO 590 J=1,M
0454      DO 590 L=1,M
0455      X(C)=X(C)+R(C)*X(L)
0456      C=0
0457      DO 600 J=1,M
0458      DO 600 L=1,M
0459      X(C)=X(C)+R(C)*X(L)
0460      C=0
0461      DO 610 J=1,M
0462      DO 610 L=1,M
0463      X(C)=X(C)+R(C)*X(L)
0464      C=0
0465      DO 620 J=1,M
0466      DO 620 L=1,M
0467      X(C)=X(C)+R(C)*X(L)
0468      C=0
0469      DO 630 J=1,M
0470      DO 630 L=1,M
0471      X(C)=X(C)+R(C)*X(L)
0472      C=0
0473      DO 640 J=1,M
0474      DO 640 L=1,M
0475      X(C)=X(C)+R(C)*X(L)
0476      C=0
0477      DO 650 J=1,M
0478      DO 650 L=1,M
0479      X(C)=X(C)+R(C)*X(L)
0480      C=0
0481      DO 660 J=1,M
0482      DO 660 L=1,M
0483      X(C)=X(C)+R(C)*X(L)
0484      C=0
0485      DO 670 J=1,M
0486      DO 670 L=1,M
0487      X(C)=X(C)+R(C)*X(L)
0488      C=0
0489      DO 680 J=1,M
0490      DO 680 L=1,M
0491      X(C)=X(C)+R(C)*X(L)
0492      C=0
0493      DO 690 J=1,M
0494      DO 690 L=1,M
0495      X(C)=X(C)+R(C)*X(L)
0496      C=0
0497      DO 700 J=1,M
0498      DO 700 L=1,M
0499      X(C)=X(C)+R(C)*X(L)
0500      C=0
0501      DO 710 J=1,M
0502      DO 710 L=1,M
0503      X(C)=X(C)+R(C)*X(L)
0504      C=0
0505      DO 720 J=1,M
0506      DO 720 L=1,M
0507      X(C)=X(C)+R(C)*X(L)
0508      C=0
0509      DO 730 J=1,M
0510      DO 730 L=1,M
0511      X(C)=X(C)+R(C)*X(L)
0512      C=0
0513      DO 740 J=1,M
0514      DO 740 L=1,M
0515      X(C)=X(C)+R(C)*X(L)
0516      C=0
0517      DO 750 J=1,M
0518      DO 750 L=1,M
0519      X(C)=X(C)+R(C)*X(L)
0520      C=0
0521      DO 760 J=1,M
0522      DO 760 L=1,M
0523      X(C)=X(C)+R(C)*X(L)
0524      C=0
0525      DO 770 J=1,M
0526      DO 770 L=1,M
0527      X(C)=X(C)+R(C)*X(L)
0528      C=0
0529      DO 780 J=1,M
0530      DO 780 L=1,M
0531      X(C)=X(C)+R(C)*X(L)
0532      C=0
0533      DO 790 J=1,M
0534      DO 790 L=1,M
0535      X(C)=X(C)+R(C)*X(L)
0536      C=0
0537      DO 800 J=1,M
0538      DO 800 L=1,M
0539      X(C)=X(C)+R(C)*X(L)
0540      C=0
0541      DO 810 J=1,M
0542      DO 810 L=1,M
0543      X(C)=X(C)+R(C)*X(L)
0544      C=0
0545      DO 820 J=1,M
0546      DO 820 L=1,M
0547      X(C)=X(C)+R(C)*X(L)
0548      C=0
0549      DO 830 J=1,M
0550      DO 830 L=1,M
0551      X(C)=X(C)+R(C)*X(L)
0552      C=0
0553      DO 840 J=1,M
0554      DO 840 L=1,M
0555      X(C)=X(C)+R(C)*X(L)
0556      C=0
0557      DO 850 J=1,M
0558      DO 850 L=1,M
0559      X(C)=X(C)+R(C)*X(L)
0560      C=0
0561      DO 860 J=1,M
0562      DO 860 L=1,M
0563      X(C)=X(C)+R(C)*X(L)
0564      C=0
0565      DO 870 J=1,M
0566      DO 870 L=1,M
0567      X(C)=X(C)+R(C)*X(L)
0568      C=0
0569      DO 880 J=1,M
0570      DO 880 L=1,M
0571      X(C)=X(C)+R(C)*X(L)
0572      C=0
0573      DO 890 J=1,M
0574      DO 890 L=1,M
0575      X(C)=X(C)+R(C)*X(L)
0576      C=0
0577      DO 900 J=1,M
0578      DO 900 L=1,M
0579      X(C)=X(C)+R(C)*X(L)
0580      C=0
0581      DO 910 J=1,M
0582      DO 910 L=1,M
0583      X(C)=X(C)+R(C)*X(L)
0584      C=0
0585      DO 920 J=1,M
0586      DO 920 L=1,M
0587      X(C)=X(C)+R(C)*X(L)
0588      C=0
0589      DO 930 J=1,M
0590      DO 930 L=1,M
0591      X(C)=X(C)+R(C)*X(L)
0592      C=0
0593      DO 940 J=1,M
0594      DO 940 L=1,M
0595      X(C)=X(C)+R(C)*X(L)
0596      C=0
0597      DO 950 J=1,M
0598      DO 950 L=1,M
0599      X(C)=X(C)+R(C)*X(L)
0600      C=0
0601      DO 960 J=1,M
0602      DO 960 L=1,M
0603      X(C)=X(C)+R(C)*X(L)
0604      C=0
0605      DO 970 J=1,M
0606      DO 970 L=1,M
0607      X(C)=X(C)+R(C)*X(L)
0608      C=0
0609      DO 980 J=1,M
0610      DO 980 L=1,M
0611      X(C)=X(C)+R(C)*X(L)
0612      C=0
0613      DO 990 J=1,M
0614      DO 990 L=1,M
0615      X(C)=X(C)+R(C)*X(L)
0616      C=0
0617      DO 1000 J=1,M
0618      DO 1000 L=1,M
0619      X(C)=X(C)+R(C)*X(L)
0620      C=0
0621      DO 1010 J=1,M
0622      DO 1010 L=1,M
0623      X(C)=X(C)+R(C)*X(L)
0624      C=0
0625      DO 1020 J=1,M
0626      DO 1020 L=1,M
0627      X(C)=X(C)+R(C)*X(L)
0628      C=0
0629      DO 1030 J=1,M
0630      DO 1030 L=1,M
0631      X(C)=X(C)+R(C)*X(L)
0632      C=0
0633      DO 1040 J=1,M
0634      DO 1040 L=1,M
0635      X(C)=X(C)+R(C)*X(L)
0636      C=0
0637      DO 1050 J=1,M
0638      DO 1050 L=1,M
0639      X(C)=X(C)+R(C)*X(L)
0640      C=0
0641      DO 1060 J=1,M
0642      DO 1060 L=1,M
0643      X(C)=X(C)+R(C)*X(L)
0644      C=0
0645      DO 1070 J=1,M
0646      DO 1070 L=1,M
0647      X(C)=X(C)+R(C)*X(L)
0648      C=0
0649      DO 1080 J=1,M
0650      DO 1080 L=1,M
0651      X(C)=X(C)+R(C)*X(L)
0652      C=0
0653      DO 1090 J=1,M
0654      DO 1090 L=1,M
0655      X(C)=X(C)+R(C)*X(L)
0656      C=0
0657      DO 1100 J=1,M
0658      DO 1100 L=1,M
0659      X(C)=X(C)+R(C)*X(L)
0660      C=0
0661      DO 1110 J=1,M
0662      DO 1110 L=1,M
0663      X(C)=X(C)+R(C)*X(L)
0664      C=0
0665      DO 1120 J=1,M
0666      DO 1120 L=1,M
0667      X(C)=X(C)+R(C)*X(L)
0668      C=0
0669      DO 1130 J=1,M
0670      DO 1130 L=1,M
0671      X(C)=X(C)+R(C)*X(L)
0672      C=0
0673      DO 1140 J=1,M
0674      DO 1140 L=1,M
0675      X(C)=X(C)+R(C)*X(L)
0676      C=0
0677      DO 1150 J=1,M
0678      DO 1150 L=1,M
0679      X(C)=X(C)+R(C)*X(L)
0680      C=0
0681      DO 1160 J=1,M
0682      DO 1160 L=1,M
0683      X(C)=X(C)+R(C)*X(L)
0684      C=0
0685      DO 1170 J=1,M
0686      DO 1170 L=1,M
0687      X(C)=X(C)+R(C)*X(L)
0688      C=0
0689      DO 1180 J=1,M
0690      DO 1180 L=1,M
0691      X(C)=X(C)+R(C)*X(L)
0692      C=0
0693      DO 1190 J=1,M
0694      DO 1190 L=1,M
0695      X(C)=X(C)+R(C)*X(L)
0696      C=0
0697      DO 1200 J=1,M
0698      DO 1200 L=1,M
0699      X(C)=X(C)+R(C)*X(L)
0700      C=0
0701      DO 1210 J=1,M
0702      DO 1210 L=1,M
0703      X(C)=X(C)+R(C)*X(L)
0704      C=0
0705      DO 1220 J=1,M
0706      DO 1220 L=1,M
0707      X(C)=X(C)+R(C)*X(L)
0708      C=0
0709      DO 1230 J=1,M
0710      DO 1230 L=1,M
0711      X(C)=X(C)+R(C)*X(L)
0712      C=0
0713      DO 1240 J=1,M
0714      DO 1240 L=1,M
0715      X(C)=X(C)+R(C)*X(L)
0716      C=0
0717      DO 1250 J=1,M
0718      DO 1250 L=1,M
0719      X(C)=X(C)+R(C)*X(L)
0720      C=0
0721      DO 1260 J=1,M
0722      DO 1260 L=1,M
0723      X(C)=X(C)+R(C)*X(L)
0724      C=0
0725      DO 1270 J=1,M
0726      DO 1270 L=1,M
0727      X(C)=X(C)+R(C)*X(L)
0728      C=0
0729      DO 1280 J=1,M
0730      DO 1280 L=1,M
0731      X(C)=X(C)+R(C)*X(L)
0732      C=0
0733      DO 1290 J=1,M
0734      DO 1290 L=1,M
0735      X(C)=X(C)+R(C)*X(L)
0736      C=0
0737      DO 1300 J=1,M
0738      DO 1300 L=1,M
0739      X(C)=X(C)+R(C)*X(L)
0740      C=0
0741      DO 1310 J=1,M
0742      DO 1310 L=1,M
0743      X(C)=X(C)+R(C)*X(L)
0744      C=0
0745      DO 1320 J=1,M
0746      DO 1320 L=1,M
0747      X(C)=X(C)+R(C)*X(L)
0748      C=0
0749      DO 1330 J=1,M
0750      DO 1330 L=1,M
0751      X(C)=X(C)+R(C)*X(L)
0752      C=0
0753      DO 1340 J=1,M
0754      DO 1340 L=1,M
0755      X(C)=X(C)+R(C)*X(L)
0756      C=0
0757      DO 1350 J=1,M
0758      DO 1350 L=1,M
0759      X(C)=X(C)+R(C)*X(L)
0760      C=0
0761      DO 1360 J=1,M
0762      DO 1360 L=1,M
0763      X(C)=X(C)+R(C)*X(L)
0764      C=0
0765      DO 1370 J=1,M
0766      DO 1370 L=1,M
0767      X(C)=X(C)+R(C)*X(L)
0768      C=0
0769      DO 1380 J=1,M
0770      DO 1380 L=1,M
0771      X(C)=X(C)+R(C)*X(L)
0772      C=0
0773      DO 1390 J=1,M
0774      DO 1390 L=1,M
0775      X(C)=X(C)+R(C)*X(L)
0776      C=0
0777      DO 1400 J=1,M
0778      DO 1400 L=1,M
0779      X(C)=X(C)+R(C)*X(L)
0780      C=0
0781      DO 1410 J=1,M
0782      DO 1410 L=1,M
0783      X(C)=X(C)+R(C)*X(L)
0784      C=0
0785      DO 1420 J=1,M
0786      DO 1420 L=1,M
0787      X(C)=X(C)+R(C)*X(L)
0788      C=0
0789      DO 1430 J=1,M
0790      DO 1430 L=1,M
0791      X(C)=X(C)+R(C)*X(L)
0792      C=0
0793      DO 1440 J=1,M
0794      DO 1440 L=1,M
0795      X(C)=X(C)+R(C)*X(L)
0796      C=0
0797      DO 1450 J=1,M
0798      DO 1450 L=1,M
0799      X(C)=X(C)+R(C)*X(L)
0800      C=0
0801      DO 1460 J=1,M
0802      DO 1460 L=1,M
0803      X(C)=X(C)+R(C)*X(L)
0804      C=0
0805      DO 1470 J=1,M
0806      DO 1470 L=1,M
0807      X(C)=X(C)+R(C)*X(L)
0808      C=0
0809      DO 1480 J=1,M
0810      DO 1480 L=1,M
0811      X(C)=X(C)+R(C)*X(L)
0812      C=0
0813      DO 1490 J=1,M
0814      DO 1490 L=1,M
0815      X(C)=X(C)+R(C)*X(L)
0816      C=0
0817      DO 1500 J=1,M
0818      DO 1500 L=1,M
0819      X(C)=X(C)+R(C)*X(L)
0820      C=0
0821      DO 1510 J=1,M
0822      DO 1510 L=1,M
0823      X(C)=X(C)+R(C)*X(L)
0824      C=0
0825      DO 1520 J=1,M
0826      DO 1520 L=1,M
0827      X(C)=X(C)+R(C)*X(L)
0828      C=0
0829      DO 1530 J=1,M
0830      DO 1530 L=1,M
0831      X(C)=X(C)+R(C)*X(L)
0832      C=0
0833      DO 1540 J=1,M
0834      DO 1540 L=1,M
0835      X(C)=X(C)+R(C)*X(L)
0836      C=0
0837      DO 1550 J=1,M
0838      DO 1550 L=1,M
0839      X(C)=X(C)+R(C)*X(L)
0840      C=0
0841      DO 1560 J=1,M
0842      DO 1560 L=1,M
0843      X(C)=X(C)+R(C)*X(L)
0844      C=0
0845      DO 1570 J=1,M
0846      DO 1570 L=1,M
0847      X(C)=X(C)+R(C)*X(L)
0848      C=0
0849      DO 1580 J=1,M
0850      DO 1580 L=1,M
0851      X(C)=X(C)+R(C)*X(L)
0852      C=0
0853      DO 1590 J=1,M
0854      DO 1590 L=1,M
0855      X(C)=X(C)+R(C)*X(L)
0856      C=0
0857      DO 1600 J=1,M
0858      DO 1600 L=1,M
0859      X(C)=X(C)+R(C)*X(L)
0860      C=0
0861      DO 1610 J=1,M
0862      DO 1610 L=1,M
0863      X(C)=X(C)+R(C)*X(L)
0864      C=0
0865      DO 1620 J=1,M
0866      DO 1620 L=1,M
0867      X(C)=X(C)+R(C)*X(L)
0868      C=0
0869      DO 1630 J=1,M
0870      DO 1630 L=1,M
0871      X(C)=X(C)+R(C)*X(L)
0872      C=0
0873      DO 1640 J=1,M
0874      DO 1640 L=1,M
0875      X(C)=X(C)+R(C)*X(L)
0876      C=0
0877      DO 1650 J=1,M
0878      DO 1650 L=1,M
0879      X(C)=X(C)+R(C)*X(L)
0880      C=0
0881      DO 1660 J=1,M
0882      DO 1660 L=1,M
0883      X(C)=X(C)+R(C)*X(L)
0884      C=0
0885      DO 1670 J=1,M
0886      DO 1670 L=1,M
0887      X(C)=X(C)+R(C)*X(L)
0888      C=0
0889      DO 1680 J=1,M
0890      DO 1680 L=1,M
0891      X(C)=X(C)+R(C)*X(L)
0892      C=0
0893      DO 1690 J=1,M
0894      DO 1690 L=1,M
0895      X(C)=X(C)+R(C)*X(L)
0896      C=0
0897      DO 1700 J=1,M
0898      DO 1700 L=1,M
0899      X(C)=X(C)+R(C)*X(L)
0900      C=0
0901      DO 1710 J=1,M
0902      DO 1710 L=1,M
0903      X(C)=X(C)+R(C)*X(L)
0904      C=0
0905      DO 1720 J=1,M
0906      DO 1720 L=1,M
0907      X(C)=X(C)+R(C)*X(L)
0908      C=0
0909      DO 1730 J=1,M
0910      DO 1730 L=1,M
0911      X(C)=X(C)+R(C)*X(L)
0912      C=0
0913      DO 1740 J=1,M
0914      DO 1740 L=1,M
0915      X(C)=X(C)+R(C)*X(L)
0916      C=0
0917      DO 1750 J=1,M
0918      DO 1750 L=1,M
0919      X(C)=X(C)+R(C)*X(L)
0920      C=0
0921      DO 1760 J=1,M
0922      DO 1760 L=1,M
0923      X(C)=X(C)+R(C)*X(L)
0924      C=0
0925      DO 1770 J=1,M
0926      DO 1770 L=1,M
0927      X(C)=X(C)+R(C)*X(L)
0928      C=0
0929      DO 1780 J=1,M
0930      DO 1780 L=1,M
0931      X(C)=X(C)+R(C)*X(L)
0932      C=0
0933      DO 1790 J=1,M
0934      DO 1790 L=1,M
0935      X(C)=X(C)+R(C)*X(L)
0936      C=0
0937      DO 1800 J=1,M
0938      DO 1800 L=1,M
0939      X(C)=X(C)+R(C)*X(L)
0940      C=0
0941      DO 1810 J=1,M
0942      DO 1810 L=1,M
0943      X(C)=X(C)+R(C)*X(L)
0944      C=0
0945      DO 1820 J=1,M
0946      DO 1820 L=1,M
0947      X(C)=X(C)+R(C)*X(L)
0948      C=0
0949      DO 1830 J=1,M
0950      DO 1830 L=1,M
0951      X(C)=X(C)+R(C)*X(L)
0952      C=0
0953      DO 1840 J=1,M
0954      DO 1840 L=1,M
0955      X(C)=X(C)+R(C)*X(L)
0956      C=0
0957      DO 1850 J=1,M
0958      DO 1850 L=1,M
0959      X(C)=X(C)+R(C)*X(L)
0960      C=0
0961      DO 1860 J=1,M
0962      DO 1860 L=1,M
0963      X(C)=X(C)+R(C)*X(L)
0964      C=0
0965      DO 1870 J=1,M
0966      DO 1870 L=1,M
0967      X(C)=X(C)+R(C)*X(L)
0968      C=0
0969      DO 1880 J=1,M
0970      DO 1880 L=1,M
0971      X(C)=X(C)+R(C)*X(L)
0972      C=0
0973      DO 1890 J=1,M
0974      DO 1890 L=1,M
0975      X(C)=X(C)+R(C)*X(L)
0976      C=0
0977      DO 1900 J=1,M
0978      DO 1900 L=1,M
0979      X(C)=X(C)+R(C)*X(L)
0980      C=0
0981      DO 1910 J=1,M
0982      DO 1910 L=1,M
0983      X(C)=X(C)+R(C)*X(L)
0984      C=0
0985      DO 1920 J=1,M
0986      DO 1920 L=1,M
0987      X(C)=X(C)+R(C)*X(L)
0988      C=0
0989      DO 1930 J=1,M
0990      DO 1930 L=1,M
0991      X(C)=X(C)+R(C)*X(L)
0992      C=0
0993      DO 1940 J=1,M
0994      DO 1940 L=1,M
0995      X(C)=X(C)+R(C)*X(L)
0996      C=0
0997      DO 1950 J=1,M
0998      DO 1950 L=1,M
0999      X(C)=X(C)+R(C)*X(L)
1000      C=0

```

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APPENDIX B
(Continued)

```

0299      VAR=0.0
0300      SKW=0.0
0301      XKI=0.0
0302      ENG=0.0
0303      ENI=0.0
0304      AJI=0.0
0305      COV=0.0
0306      XTE=0.0
0307      ABS5=0.0
0308      XID=0.0
0309      ENY=0.0
0310      ENR=0.0
0311      DO 10 J=1,32
0312      DO 10 I=1,32
0313      M=I-1
0314      10  TAR(I,J)=IMAGE(I+M*32)
0315      M=I-1
0316      DO 20 K=1,NGRAY
0317      20  CONT(K)=0.0
0318      DO 30 I=1,32
0319      DO 30 J=1,32
0320      CR=TAR(I,J)
0321      CONT(CR+1)=CONT(CR+1)+1.
0322      30  CONTINUE
0323      XM=M
0324      DO 32 K=1,NGRAY
0325      DO 32 M=1,NGRAY
0326      32  COU(K,M)=0.0
0327      MX=32+IDX
0328      IF(32-MX)2,14,16
0329      12  ENCR=MX-32
0330      NXB=1
0331      NXF=32-ENCR
0332      GO TO 19
0333      14  NXB=1
0334      RXL=32
0335      GO TO 19
0336      16  ENCR=32-MX
0337      NXB=1+ENCR
0338      RXL=32-NXB
0339      19  H=32+IDY
0340      IF(32-MY)21,23,25
0341      21  ENCR=MY-32
0342      NYB=1
0343      NYF=32-IDCB
0344      GO TO 22
0345      23  NYB=1
0346      RYL=32
0347      GO TO 22
0348      25  ENCR=32-PO
0349      NYB=1+ENCR
0350      RYL=32-NYB
0351      22  CONTINUE
0352      DO 35 I=1,NXL
0353      DO 35 J=1,NXL
0354      CR=TAR(CR+1)=TAR(CR+1)+CONT(CR+1)
0355      CR=TAR(CR+1)=TAR(CR+1)+CONT(CR+1)
0356      CR=TAR(CR+1)=TAR(CR+1)+CONT(CR+1)
0357      35  CONTINUE
0358      DO 40 K=1,NGRAY

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APPENDIX B
(Continued)

```

0359      40 P(K)=CONT(K)/XM
0360      DO 45 K=1,NGRAY
0361      45 AVG=AVG+(K-1)*P(K)
0362      DO 50 K=1,NGRAY
0363      50 VAR=VAR+(K-1-AVG)**2)*P(K)
0364      STD=SQR(VAR)
0365      DO 55 K=1,NGRAY
0366      55 SKW=SKW+(K-1-AVG)**3)*P(K)
0367      SKW=SKW/STD**3
0368      DO 60 K=1,NGRAY
0369      60 XKT=XKT+(K-1-AVG)**4)*P(K)
0370      XKT=(XKT/(STD**4))-3.
0371      DO 65 K=1,NGRAY
0372      65 ENG=ENG+P(K)*P(K)
0373      DO 70 K=1,NGRAY
0374      IF(P(K).EQ.0.0)GO TO 70
0375      ENT=ENT+3.321929*P(K)*ALOGT(P(K))
0376      70 CONTINUE
0377      ENT=-ENT
0378      DO 75 K=1,NGRAY
0379      DO 75 M=1,NGRAY
0380      75 PP(K,M)=CONT(K,M)/XM
0381      DO 80 K=1,NGRAY
0382      DO 80 M=1,NGRAY
0383      AUT=AUT+(K-1)*(M-1)*PP(K,M)
0384      80 CONTINUE
0385      AVGK=0.0
0386      AVGM=0.0
0387      DO 85 K=1,NGRAY
0388      DO 85 M=1,NGRAY
0389      AVCK=AVCK+(K-1)*PP(K,M)
0390      85 AVGM=AVGM+(M-1)*PP(K,M)
0391      DO 90 K=1,NGRAY
0392      DO 90 M=1,NGRAY
0393      90 XJE=XJE+(K-M)*(K-M)*PP(K,M)
0394      DO 95 K=1,NGRAY
0395      DO 95 M=1,NGRAY
0396      ABS=ABS+(JABS(K-M))*PP(K,M)
0397      95 CONTINUE
0398      DO 100 K=1,NGRAY
0399      DO 100 M=1,NGRAY
0400      100 XJD=XJD+PP(K,M)/(1.0+(K-M)**2)
0401      DO 105 K=1,NGRAY
0402      DO 105 M=1,NGRAY
0403      105 ENY=ENY+PP(K,M)*PP(K,M)
0404      DO 110 K=1,NGRAY
0405      DO 110 M=1,NGRAY
0406      IF(PP(K,M).EQ.0.0)GO TO 110
0407      ENR=ENR+3.321929*PP(K,M)*ALOGT(PP(K,M))
0408      110 CONTINUE
0409      ENR=-ENR
0410      DO 115 K=1,NGRAY
0411      DO 115 M=1,NGRAY
0412      COV=COV+(K-1-AVGK)*(M-1-AVGM)*PP(K,M)
0413      115 CONTINUE
0414      RETURN
0415      END
0416      END$
0417

```

APPENDIX C.

Computer Program for Calculating the Transformed Feature Vector $Y = AX$

```

ATAXIR T=00004 IS ON CR00011 USING 00013 BLKS R=0000

0001 FIN4.L
0002 CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
0003 C THIS PROGRAM COMPUTES THE TRANSFORMATION C
0004 C Y=AX WHERE A IS COMPUTED FROM ANOTHER C
0005 C PROGRAM AND IS INPUT HERE C
0006 CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
0007 PROGRAM YAXIR(3,1000)
0008 DIMENSION LUOT(5),IMAGE(1024),X(100,13),Y(100,2),A(2,13)
0009 DIMENSION IUCB(144),IFILE(3),AM(2),VAR(2)
0010 DIMENSION AV(6,6),D(2,2)
0011 EQUIVALENCE (IMAGE,Y)
0012 CALL RMPAR(LUOT)
0013 LU=LUOT(1)
0014 CALL FRLU(LU)
0015 NC=2
0016 4 FORMAT(I1)
0017 WRITE(LU,6)
0018 6 FORMAT("ENTER THE VALUE FOR M THE NUMBER OF ROWS IN THE TRANSFOR
0019 MATION MATRIX A")
0020 READ(LU,4)M
0021 WRITE(LU,8)
0022 8 FORMAT("ENTER THE TRANSFORMATION MATRIX A")
0023 DO 10 I=1,M
0024 DO 10 J=1,13
0025 WRITE(LU,12)I,J
0026 12 FORMAT("I=",J2,2X,"J=",J2,"A(I,J)=")
0027 READ(LU,14)A(I,J)
0028 14 FORMAT(E9,3)
0029 10 CONTINUE
0030 WRITE(6,79)
0031 79 FORMAT(1X,"THE TRANSFORMATION MATRIX A")
0032 DO 78 I=1,M
0033 WRITE(6,77)(A(I,J),J=1,13)
0034 77 FORMAT(1X,13(E9,3,1X))
0035 78 CONTINUE
0036 DO 80 NJ=1,NC
0037 WRITE(LU,16)
0038 16 FORMAT("ENTER THE NUMBER OF IMAGE SAMPLES TO BE ANALYZED (.LE.100")
0039 READ(LU,18)NDATA
0040 18 FORMAT(I3)
0041 WRITE(LU,20)
0042 20 FORMAT("ENTER THE FILE NAME FOR THE DATA SET")
0043 READ(LU,22)IFILE
0044 22 FORMAT(3A2)
0045 WRITE(LU,15)
0046 15 FORMAT("DISK LU NUMBER?")
0047 READ(LU,2101)IDLU
0048 WRITE(LU,2100)
0049 2100 FORMAT("ENTER A VALUE FOR IDX")
0050 READ(LU,2101)IDX
0051 2101 FORMAT(I2)
0052 WRITE(LU,2200)
0053 2200 FORMAT("ENTER A VALUE FOR IDY")
0054 READ(LU,2101)IDY
0055 WRITE(6,1400)IDX,IDY
0056 1400 FORMAT(2X,"IDX=",J2,5X,"IDY=",J2)
0057 WRITE(6,200)IFILE
0058 200 FORMAT(1X,3A2)

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APPENDIX C.
(Continued)

```

0059      CALL OPEN(DCB,IERR,JFILE,0,0,-IDLU)
0060      IF(IERR.LT.0)GO TO 2000
0061      GO TO 24
0062  2000 WRITE(LU,2010)IERR
0063  2010 FORMAT("OPEN FILE ERROR",I5)
0064      GO TO 999
0065      24 ICONT=1
0066      CALL LABIN(DCB,6)
0067      13 J=1
0068      DO 19 I=1,8
0069      CALL READF(DCB,IERR,IMAGE(J))
0070      19 J=J+128
0071      IF(IERR.LT.0)GO TO 3000
0072      GO TO 26
0073  3000 ICONT=NDATA
0074      WRITE(LU,2020)IERR
0075  2020 FORMAT("READ FILE ERROR",I5)
0076      GO TO 999
0077      26 NGRAY=16
0078      CALL JSCAL(IMAGE,IMAGE,1024,0,15)
0079      CALL FEVEC(IMAGE,AVG,VAR,SKW,XKT,ENG,ENT,AUT,COV,XIE,ARSS,XJD,
0080      LENY,ENR,NGRAY,IDX,IDY)
0081      X(ICONT,1)=AVG
0082      X(ICONT,2)=VAR
0083      X(ICONT,3)=SKW
0084      X(ICONT,4)=XKT
0085      X(ICONT,5)=ENG
0086      X(ICONT,6)=ENT
0087      X(ICONT,7)=AUT
0088      X(ICONT,8)=COV
0089      X(ICONT,9)=XIE
0090      X(ICONT,10)=ARSS
0091      X(ICONT,11)=XJD
0092      X(ICONT,12)=ENY
0093      X(ICONT,13)=ENR
0094      IF(ICONT=NDATA)28,30,30
0095      28 ICONT=ICONT+1
0096      GO TO 13
0097      30 WRITE(LU,32)NJ,TELL
0098      32 FORMAT("NJ=",I1,3X,3A2)
0099      DO 34 J=1,NDATA
0100      DO 34 K=1,N
0101      34 Y(J,K)=0.0
0102      DO 36 I=1,NDATA
0103      DO 36 K=1,M
0104      DO 36 MK=1,13
0105      36 Y(J,K)=Y(J,K)+A(K,MK)*X(I,MK)
0106      CALL GPLDI(Y(I,1),Y(I,2),100,TELL,NJ)
0107      DO 50 K=1,M
0108      AM(K)=0.0
0109      AK=NDATA
0110      DO 45 J=1,NDATA
0111      45 AM(K)=AM(K)+Y(J,K)
0112      50 AM(K)=AM(K)/XK
0113      DO 55 K=1,M
0114      VAR(K)=0.0
0115      DO 54 J=1,NDATA
0116      54 VAR(K)=VAR(K)+(Y(J,K)-AM(K))**2
0117      55 CONTINUE
0118      DO 60 K=1,M

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APPENDIX C.
(Continued)

```
0119      60 VAR(K)=VAR(K)/(XK-1.)
0120      D3=0.0
0121      DO 65 K=1,M
0122      65 D3=D3+VAR(K)
0123      D3=2.*D3
0124      DO 70 K=1,M
0125      70 AV(K,NJ)=AM(K)
0126      80 CONTINUE
0127      CALL GPUT(Y(1,1),Y(1,2),-100,-10,2)
0128      DO 81 I=1,NC-1
0129      DO 81 J=J+1,NC
0130      81 D(I,J)=0.0
0131      DO 82 I=1,NC-1
0132      DO 82 J=I+1,NC
0133      DO 82 K=1,M
0134      82 D(I,J)=D(I,J)+(AV(K,I)-AV(K,J))**2
0135      DO 83 I=1,NC-1
0136      DO 83 J=J+1,NC
0137      83 D(I,J)=SQRT(D(I,J))
0138      WRITE(6,B7)
0139      B7 FORMAT(1X,"THE INTERSET DISTANCES")
0140      DO 86 I=1,NC-1
0141      DO 86 J=I+1,NC
0142      WRITE(6,B4)I,J,D(I,J)
0143      84 FORMAT(1X,"I=",I1,2X,"J=",J1,2X,"D(I,J)=",E15,B)
0144      86 CONTINUE
0145      CALL CLOSE(JDCB)
0146      999 STOP
0147      END
0148      ENDS
```

FILM

