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Technical Report

A Multispectral Data Simulation Technique

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TECHNICAL REPORT

A MULTISPECTRAL DATA SIMULATION TECHNIQUE

By

M. J. Muasher

and

P. H. Swain

This report describes activity carried out
in the Supporting Research Project.

PURDUE UNIVERSITY

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16. Abstract

In remote sensing data analysis, several assumptions are made that are not always precisely met. These assumptions include that the classes in the data are normally distributed, that training data are representative of the area of interest, that the number of classes is known, and that all pixels are pure.

In testing new algorithms, deviations from the assumptions may obscure the action of the new process. One way to clarify the situation is to apply the algorithm first to a data set satisfying the assumptions.

A method is presented to obtain an artificial data set through simulation. While retaining the natural spatial and spectral information in the scene by basing the simulation on a classification, the data set provides the analyst with an exact number of classes in the scene, true distributions of these classes, independent measurements and "pure" pixels.

Program listings in both Fortran and C-Language are provided in the appendices.

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A MULTISPECTRAL DATA SIMULATION TECHNIQUE*

Marwan J. Muasher and Philip H. Swain

For remote sensing data analysis, several assumptions are commonly made. These assumptions are usually that the data are class-conditionally distributed multivariate normal and that the data used to train the classifier are representative of the area of interest. This second assumption actually has several parts. The assumption is made that in the process of training, all classes present in the scene are found, and all spectral subclasses of each class are also represented in the training data. Furthermore, the parameters of the distribution of each subclass are also assumed to be known from the training data. Each pixel is assumed to come from one of the training classes, and also is assumed to be entirely of one cover type.

In actual practice, these assumptions are not met. The number of spectral classes in the area is not known and clustering or some other method is used to determine the number of subclasses, in addition to estimating the statistics of those subclasses. Some of these methods also lead to non-normal subclasses. In particular, the clustering algorithm available through LARSYS truncates the tails of the subclass distributions and so leads to non-normal distributions.

There are also questions relating to a single picture element. A single pixel in Landsat data covers an area approximately 80 meters by 50 meters. More than one cover type may be present in this area and result in a "mixture pixel" observation. It is not clear how the distribution of the spectral response of mixture pixels can be related to the distribution of the spectral response of "pure pixels."

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There has been much speculation in the remote sensing community as to the effect of the non-satisfaction of the basic assumptions. Whenever new algorithms are brought forth, the old questions are raised again, indicating that there is insufficient understanding of the interaction of the real attributes of the data and the theory of the algorithms. At times it is not clear whether a particular result is due to aspects of the algorithm or to the extent the data set deviates from the assumptions.

In testing new algorithms, deviations from the assumptions may obscure the action of the new process. One way to clarify the situation is to apply the algorithm first to a data set satisfying the assumptions.

Such a data set could be obtained artificially, through simulation. The analyst could then know: how many classes exist in the data; the true distributions of the classes, including normality if desired; the observations could really be independent; and no pixel would be a "mixture pixel." New algorithms could be studied on such a data set with the knowledge that any "strange" effects are indeed algorithm rather than data problems.

In many cases where simulated data have been used in the past, the data were too artificial, in the sense that all aspects of the image were controlled, removing the natural variation in object size, position, and relationship which occur in real data. This limited the use of the simulated data sets in testing new algorithms.

The natural spatial information occurring in multispectral data could be retained in a simulated image by spatially basing the simulation on a classification. It would be even better to base the simulated data on a digitized "ground truth" map if the spectral characteristics of the cover types were known. By basing the simulation on a classification, the number of classes, their exact distributions, and the class of each pixel in the

area are known. If the classification was sufficiently accurate, then the spatial information held in the classification map will be close to the actual cover type map and actual spatial content of the original data. For each pixel in the area, a random vector distributed according to the pixel's class statistics could be generated. This becomes the simulated data vector.

Statistical Background

From the classification chosen as a basis for the simulation, the following are known: the number of classes K, the set of classes $\{\omega_i, i=1,\ldots,K\}$, the class distributions $\{f(\omega_i), i=1,\ldots,K\}$, their means and covariances $\{\mu_i$ and $\Sigma_i, i=1,\ldots,K\}$, the number of channels p, and the class of every pixel in the scene.

From classifical statistics:

(1) Let X:pxl, A:pxp and b:pxl.
If $X \sim N(0, I_p)$, then $Y = AX + b \sim N(b, AI_pA^T = AA^T)$
(where I_p is the identity matrix having dimensionality p).

(2) Let Σ be a symmetric, positive definite matrix. Then there exists A, such that

$$AA^T = \Sigma \qquad (A \text{ is denoted } \Sigma^{\frac{1}{2}})$$

To simulate a pixel which was a member of class i in the base classification, $N(0, I_p)$ (the random vector for each pixel is indepedent of other vectors) is generated. (See Appendix I.) Next $Y = \Sigma_i^{\frac{1}{2}} X + \mu_i$ is calculated; it is then a random vector from the population $N(\mu_i, \Sigma_i)$. This process is repeated for each pixel of the base classification and the random vectors thus generated are stored appropriately, i.e., so as to correspond to their simulated spatial location.

The program requires as an input a classification map stored on a results tape. The results tape has the class statistics

for p-dimensions also stored on it. The program, then, uses the results map and the stored statistics to generate a p-dimensional data set, which is stored on a user specified output tape in LARSYS format.

Appendix I provides a mathematical derivation related to the generation of normally distributed samples. Appendix II provides the Fortran program listing for the simulation program. Appendix III provides the C program listing for the same program.

APPENDIX I

APPENDIX I

Let U_1 and U_2 be two random variables independent and identically distributed Uniform (0,1).

Then let $Z_1 = (-2 \ln U_1)^{\frac{1}{2}} \cos 2\pi U_2$

and $Z_2 = (-2 \ln U_1)^{\frac{1}{2}} \sin 2\pi U_2$

then Z_1 and Z_2 are independent and identically distributed normal (0,1).

Proof:

$$f(U_1,U_2) = \begin{cases} 1 & 0<U_1<1,\ 0<U_2<1 \\ 0 & \text{otherwise} \end{cases}$$

is the probability density function of two independent uniforms.

$$U_1 = \exp\left[-\tfrac{1}{2}(Z_1^2 + Z_2^2)\right]$$

$$U_2 = \frac{1}{2\pi} \arctan\left(\frac{Z_2}{Z_1}\right)$$

The Jacobian of the transformation is:

$$J = -\frac{1}{2\pi} \exp\left[-\tfrac{1}{2}(Z_1^2 + Z_2^2)\right]$$

$$f(Z_1,Z_2) = f(U_1,U_2) \cdot |J|$$

$$= \frac{1}{2\pi} \exp\left[-\tfrac{1}{2}(Z_1^2 + Z_2^2)\right] \qquad 0 < \left[\exp -\tfrac{1}{2}(Z_1^2 + Z_2^2)\right] < 1$$

$$0 < \frac{1}{2\pi} \arctan\left(\frac{Z_2}{Z_1}\right) < 1$$

$$= 0 \quad \text{otherwise}$$

$$\therefore f(Z_1) \sim N(0,1) \qquad f(Z_2) \sim N(0,1)$$

The side conditions give $-\infty < Z_1 < \infty$, $-\infty < Z_2 < \infty$. Strictly speaking, Z_1 cannot equal zero; however, prob $(Z_1 = 0) = 0$ as we are working with continuous densities.

To test the effectiveness of the pseudo random vectors in the multivariate case, random vectors distributed $N(0,I_p)$ were generated and then tested with a Kolmogorov-Smirnov test. Since the multivariate normal cdf is difficult to evaluate, the sum of squares was calculated and compared to the χ_p^2 distribution.

For sample sizes greater than 100, the pseudo random vectors were distributed properly. For sample sizes less than 100, the K-S test is not valid. Since we would generally (over an entire area) be working with more than 100 points per class, this was not pursued further.

In addition, the sample covariance matrices were tested for homogeneity against the true class statistics. For sample runs of up to 2000 points, there were not significant differences at the $\alpha = 0.10$ level.

APPENDIX II

```
FILE: SWRITE   FORTRAN  A   PURDUE / LARS 3031

      DO 100 IP=1,NOCLAS                                                    SWRC3170
      DO 100 IQ=1,NOCHAN                                                    SWRC3180
      IF(CLAPNT(IP).LE.0) GO TO 98                                          SWRC3190
      RMEAN(IP,IQ)=FLOAT(IMEAN(IP,IQ))/FLOAT(CLAPNT(IP))                   SWRC3200
   98 DO 100 IT=IQ,NOCHAN                                                   SWRC3210
      IF(CLAPNT(IP).LE.1) GO TO 100                                         SWRC3220
      REPNT=FLOAT(CLAPNT(IP))                                               SWRC3230
      REVAR=FLOAT(IVAR(IP,IQ,IT))                                           SWRC3240
      RMEAN=FLOAT(IMEAN(IP,IQ))                                             SWRC3250
      SMEAN=FLOAT(IMEAN(IP,IT))                                             SWRC3260
      RVAR(IP,IQ,IT)=(1./(REPNT-1.))*(REVAR-RMEAN*SMEAN/REPNT)              SWRC3270
      RVAR(IP,IT,IQ)=RVAR(IP,IQ,IT)                                         SWRC3280
  100 CONTINUE                                                              SWRC3290
      DO 645 IP=1,NOCLAS                                                    SWRC3300
      WRITE(6,605)IP,CLAPNT(IP)                                             SWRC3310
  605 FORMAT(1H1/5X,'CLASS NUMBER',I3,5X,I8,' POINTS'///)                   SWRC3320
      WRITE(6,610)                                                          SWRC3330
  610 FORMAT(37X,'ACTUAL',4X,'SIMULATED')                                   SWRC3340
      WRITE(6,615)                                                          SWRC3350
  615 FORMAT(38X,'MEAN',7X,'MEAN'/)                                         SWRC3360
      DO 622 IX=1,NOCHAN                                                    SWRC3370
      NINC=NOCOMP*NOCLAS*(IP-1)+NOCHAN                                      SWRC3380
      WRITE(6,620)FETVC3(IX),FRQCAL(1,FETVC3(IX)),FRQCAL(2,FETVC3(IX)),Z    SWRC3390
     &2(NINC+IX),RMEAN(IP,IX)                                               SWRC3400
  620 FORMAT(5X,'CHANNEL',I3,2X,':',F5.2,'-',F5.2,')',5X,F8.3,3X,F8.3)      SWRC3410
  622 CONTINUE                                                              SWRC3420
      WRITE(6,625)                                                          SWRC3430
  625 FORMAT(/////5X,'ACTUAL COVARIANCE MATRIX')                            SWRC3440
      DO 630 NO=1,NOCOMP                                                    SWRC3450
      NINC=(IP-1)*NOCOMP                                                    SWRC3460
  630 A(NO)=(22)+NINC+NO)                                                   SWRC3470
      CALL WRTMTX(A,NOCHAN,FRQCAL,THREE,FETVC3)                             SWRC3480
      WRITE(6,635)                                                          SWRC3490
  635 FORMAT(////5X,'SIMULATED COVARIANCE MATRIX')                          SWRC3500
      NO=0                                                                  SWRC3510
      DO 640 IQ=1,NOCHAN                                                    SWRC3520
      DO 640 IN=1,IQ                                                        SWRC3530
      NO=NO+1                                                               SWRC3540
  640 A(NO)=RVAR(IP,IQ,IN)                                                  SWRC3550
      CALL WRTMTX(A,NOCHAN,FRQCAL,THREE,FETVC3)                             SWRC3560
  645 CONTINUE                                                              SWRC3570
      CALL TOPEF(12,IER)                                                    SWRC3580
      DO 650 IX=3,200                                                       SWRC3590
  650 IDREC(IX)=0                                                           SWRC3600
      CALL TOPWR(12,80C,IER,IDREC)                                          SWRC3610
      IF(IER.NE.0) WRITE(6,234)IER                                          SWRC3620
      IF(IER.GT.0) GO TO 310                                                SWRC3630
      GO TO 320                                                             SWRC3640
  234 FORMAT(5X,'ERROR IS',I5)                                              SWRC3650
C*****************************************************************        SWRC3660
C ERROR MESSAGES                                                            SWRC3670
C*****************************************************************        SWRC3680
C                                                                           SWRC3690
  300 WRITE(6,305)                                                          SWRC3700
  305 FORMAT(5X,'ERROR -1')                                                 SWRC3710
  310 WRITE(6,315)                                                          SWRC3720
  315 FORMAT(5X,'ERROR GT 1')                                               SWRC3730
  320 STOP                                                                  SWRC3740
      END                                                                   SWRC3750
                                                                            SWRC3760
```

```
FILE: SWRITE   FORTRAN  A   PURDUE / LARS 3031

C 150 CONTINUE                                                                  SWR C2380
C                                                                               SWR C2390
      CALL TOPWR(12,800,IER,IOREC)                                              SWR C2400
      IF(IER.NE.0) WRITE(16,234)IER                                             SWR C2410
      IF(IER.GT.0) GO TO 31C                                                    SWR C2420
      DO 50 MA=1,NOCLAS                                                         SWR C2430
      CLAPNT(MA)=0                                                              SWR C2440
      DO 50 MB=1,NOCHAN                                                         SWR C2450
      IMEAN(MA,MB)=0                                                            SWR C2460
      RMEAN(MA,MB)=0.0                                                          SWR C2470
      DO 50 MC=1,NOCHAN                                                         SWR C2480
      IVAR(MA,MB,MC)=0                                                          SWR C2490
   50 RVAR(MA,MB,MC)=0.0                                                        SWR C2500
      LNWRT = 0                                                                 SWR C2510
   55 READ(11)J,K,LINENO,(PNTCLS(IX),IX=1,NOPNTS)                               SWR C2520
      IF(J.GT.0) GO TO 95                                                       SWR C2530
      LNWRT=LNWRT+1                                                             SWR C2540
      IF(MOD(LNWRT,25).EQ.0) WRITE(16,57)LNWRT,NOLINS                           SWR C2550
   57 FORMAT(5X,I4,' LINES OUT OF ',I4,' ARE COMPLETED')                        SWR C2560
C                                                                               SWR C2570
C*****************************************************************            SWR C2580
C  GENERATE AND WRITE DATA POINTS                                               SWR C2590
C*****************************************************************            SWR C2600
C                                                                               SWR C2610
   60 I2=ILIN(2)                                                                SWR C2620
      DATOUT(1)=L1(1)                                                           SWR C2630
      DATOUT(2)=L1(2)                                                           SWR C2640
      I2=32767                                                                  SWR C2650
      DATOUT(3)=L1(1)                                                           SWR C2660
      DATOUT(4)=L1(2)                                                           SWR C2670
      I2=0                                                                      SWR C2680
      ICOUNT=4                                                                  SWR C2690
      DO 90 IX=1,NOPNTS                                                         SWR C2700
      ICOUNT=ICOUNT+1                                                           SWR C2710
      I2=PNTCLS(IX)                                                             SWR C2720
      L1(1)=.FALSE.                                                             SWR C2730
      IPOL=(I2-1)*NOCHAN                                                        SWR C2740
      IBEG=(I2-1)*NOCOMP                                                        SWR C2750
      K=IBEG                                                                    SWR C2760
      DO 65 IY=1,NOCHAN                                                         SWR C2770
      DO 65 IZ=1,IY                                                             SWR C2780
      K=K+1                                                                     SWR C2790
      B(IY,IZ)=Z(K)                                                             SWR C2800
      IF(IY.EQ.IZ) GO TO 65                                                     SWR C2810
      B(IZ,IY)=0.0                                                              SWR C2820
   65 CONTINUE                                                                  SWR C2830
      DO 70 IY=1,NOCH                                                           SWR C2840
      CALL RANDU(ISTART(IY),NXINP,A2(IY))                                       SWR C2850
      ISTART(IY)=NXINP                                                          SWR C2860
      CALL RANDU(ISTART(IY),NXINP,A(IY))                                        SWR C2870
      ISTART(IY) = NXINP                                                        SWR C2880
      A(IY)=SQRT(-2.*ALOG(A2(IY)))*COS(6.2831*A(IY))                            SWR C2890
   70 CONTINUE                                                                  SWR C2900
      CLAPNT(I2)=CLAPNT(I2)+1                                                   SWR C2910
      DO 80 IY=1,NOCHAN                                                         SWR C2920
      DATA(IY)=0.0                                                              SWR C2930
      IQ=NOPOOL*NOCOMP+IPOL+IY                                                  SWR C2940
      DO 75 IZ=1,NOCHAN                                                         SWR C2950
   75 DATA(IY)=DATA(IY)+B(IY,IZ)*A(IZ)                                          SWR C2960
      DATA(IY)=DATA(IY)+Z(IQ)                                                   SWR C2970
      INTDAT=DATA(IY)+.5                                                        SWR C2980
      IF(INTDAT.LT.0) INTDAT=0                                                  SWR C2990
      IF(INTDAT.GT.255) INTDAT=255                                              SWR C3000
      ISTAT(IY)=INTDAT                                                          SWR C3010
      DATOUT(1(IY-1)*NOSAM+ICOUNT)=LOGDAT(2)                                    SWR C3020
      DO 92 IZ=1,6                                                              SWR C3030
   92 DATOUT(1(IY-1)*NOSAM+ICOUNT+IZ)=.FALSE.                                   SWR C3040
   80 CONTINUE                                                                  SWR C3050
      DO 90 II=1,NOCHAN                                                         SWR C3060
      IMEAN(I2,II)=IMEAN(I2,II)+ISTAT(II)                                       SWR C3070
      DO 90 JJ=II,NOCHAN                                                        SWR C3080
      IVAR(I2,II,JJ)=IVAR(I2,II,JJ)+ISTAT(II)*ISTAT(JJ)                        SWR C3090
   90 CONTINUE                                                                  SWR C3100
      NOBYTE=4*NOCHAN*NOSAM                                                     SWR C3110
      CALL TOPWR(12,NOBYTE,IER,DATOUT)                                          SWR C3120
      IF(IER.NE.0) WRITE(16,234)IER                                             SWR C3130
      IF(IER.GT.0) GO TO 31C                                                    SWR C3140
      GO TO 55                                                                  SWR C3150
   95 CONTINUE                                                                  SWR C3160
```

FILE: SWRITE FORTRAN A PURDUE / LARS 3031

```
      IBEG=1                                                                    SWRC1590
C                                                                               SWRC1600
C*****************************************************************           SWRC1610
C FACTOR COVARIANCE MATRICES                                                    SWRC1620
C*****************************************************************           SWRC1630
C                                                                               SWRC1640
      DO 30 IX=1,NOPOOL                                                         SWRC1650
      IDONE=IBEG+NOCOMP-1                                                       SWRC1660
      K=0                                                                       SWRC1670
      DO 20 IY=IBEG,IDONE                                                       SWRC1680
      K=K+1                                                                     SWRC1690
   20 A(K)=Z(IY)                                                                SWRC1700
      CALL MFSD(A,NOCHAN,EPS,IER)                                               SWRC1710
      IF(IER.EQ.-1) GO TO 300                                                   SWRC1720
      IF(IER.GE.1) GO TO 310                                                    SWRC1730
      K=0                                                                       SWRC1740
      DO 25 IY=IBEG,IDONE                                                       SWRC1750
      K=K+1                                                                     SWRC1760
   25 Z(IY)=A(K)                                                                SWRC1770
   30 IBEG=IBEG+NOCOMP                                                          SWRC1780
C                                                                               SWRC1790
C*****************************************************************           SWRC1800
C GENERATE STARTING POINTS                                                      SWRC1810
C*****************************************************************           SWRC1820
C                                                                               SWRC1830
   29 WRITE(6,31)                                                               SWRC1840
   31 FORMAT(5X,'DO YOU WANT TO SPECIFY THE STARTING POINTS FOR THE'/5X          SWRC1850
     $,'RANDOM NUMBER GENERATOR? (TYPE YES OR NO)')                             SWRC1860
      READ(5,32)INPUT                                                           SWRC1870
   32 FORMAT(A4)                                                                SWRC1880
      IF(INPUT.EQ.NO) GO TO 36                                                  SWRC1890
      IF(INPUT.EQ.YES) GO TO 33                                                 SWRC1900
      GO TO 29                                                                  SWRC1910
   33 DO 39 IX=1,NOCHAN                                                         SWRC1920
      WRITE(6,41)IX                                                             SWRC1930
   41 FORMAT(5X,'SPECIFY STARTING POINT FOR CHANNEL',I3/5X,'(TYPE A NINE        SWRC1940
     $ DIGIT ODD NUMBER)')                                                      SWRC1950
      READ(5,42)ISTART(IX)                                                      SWRC1960
   42 FORMAT(I9)                                                                SWRC1970
   39 CONTINUE                                                                  SWRC1980
      GO TO 43                                                                  SWRC1990
   36 CALL GTSERL(ISERL)                                                        SWRC2000
      ISERL=(ISERL/10)*8+1                                                      SWRC2010
      DO 40 I=1,NOCH                                                            SWRC2020
      ISERL=ISERL+10000000                                                      SWRC2030
      ISTART(I)=ISERL                                                           SWRC2040
   40 CONTINUE                                                                  SWRC2050
   43 WRITE(6,34)                                                               SWRC2060
   34 FORMAT('1'///5X,'STARTING POINTS FOR RANDOM NUMBER GENERATOR'//)          SWRC2070
      DO 44 I=1,NOCHAN                                                          SWRC2080
      WRITE(6,35)I,ISTART(I)                                                    SWRC2090
   35 FORMAT(5X,'STARTING POINT FOR CHANNEL  ',I2,' IS ',I9)                    SWRC2100
   44 CONTINUE                                                                  SWRC2110
C                                                                               SWRC2120
C*****************************************************************           SWRC2130
C READ CLASSIFICATIONS                                                          SWRC2140
C*****************************************************************           SWRC2150
C                                                                               SWRC2160
      IDREC(1)=TAPEND                                                           SWRC2170
      IDREC(2)=JFILE                                                            SWRC2180
      IDREC(3) = RUNNO                                                          SWRC2190
      NOLD = IDREC(5)                                                           SWRC2200
      IDREC(5) = NOCHAN                                                         SWRC2210
      IDREC(6) = 4*(NOPNTS + 5)/4                                               SWRC2220
      NOSAM = IDREC(6)                                                          SWRC2230
      IDREC(7) = FLGT                                                           SWRC2240
      DO 141 II=1,3                                                             SWRC2250
      IDREC(II+16) = DATE(II)                                                   SWRC2260
  141 CONTINUE                                                                  SWRC2270
      IDREC(20) = NOLINE                                                        SWRC2280
C     DO 145 II= 1, NOCHAN                                                      SWRC2290
C     INEW = FETVC3(II)                                                         SWRC2300
C     DO 145 II2 = 1,5                                                          SWRC2310
C     FRQCAL(II2,II) = FRQCAL(II2,INEW)                                         SWRC2320
C 145 CONTINUE                                                                  SWRC2330
C     LIP = NOCHAN + 1                                                          SWRC2340
C     DO 150 II = LIP,NOLD                                                      SWRC2350
C     DO 150 II2 = 1,5                                                          SWRC2360
C     FRQCAL(II2,II) = 0.0                                                      SWRC2370
```

```
FILE: SWRITE   FORTRAN  A   PURDUE / LARS 3031

      DATA  PLOT /'SIM '/                                                    SWR00800
      EPS=1.E-5                                                              SWR00810
C                                                                            SWR00820
C*************************************************************************  SWR00830
C LOAD TAPES AND READ PARAMETERS                                             SWR00840
C*************************************************************************  SWR00850
C                                                                            SWR00860
      WRITE(16,500)                                                          SWR00870
  500 FORMAT(//5X,'SPECIFY TAPE NUMBER ON WHICH RESULTS FILE IS LOCATED'SWR00880
     $/5X,'(TYPE EIGHT DIGIT TAPE NUMBER)')                                  SWR00890
      READ(16,505)INTAP                                                      SWR00900
  505 FORMAT(I8)                                                             SWR00910
      WRITE(16,510)                                                          SWR00920
  510 FORMAT(5X,'SPECIFY FILE NUMBER AT WHICH RESULTS FILE IS LOCATED'/5SWR00930
     $X,'(TYPE THREE DIGIT FILE NUMBER)')                                    SWR00940
      READ(16,515)IFILE                                                      SWR00950
  515 FORMAT(I3)                                                             SWR00960
      CALL MNTAPE(INTAP,IFILE,C)                                             SWR00970
      WRITE(16,570)                                                          SWR00980
  570 FORMAT(//5X,'SPECIFY THE TAPE NUMBER ONTO WHICH SIMULATED DATA IS SWR00990
     $TO BE WRITTEN'/5X,'(TYPE EIGHT DIGIT TAPE NUMBER)')                    SWR01000
      READ(16,575)TAPEND                                                     SWR01010
  575 FORMAT(I8)                                                             SWR01020
      WRITE(16,580)                                                          SWR01030
  580 FORMAT(5X,'SPECIFY FILE NUMBER AT WHICH SIMULATED DATA IS TO BE WRSWR01040
     $ITTEN'/5X,'(TYPE THREE DIGIT FILE NUMBER)')                            SWR01050
      READ(16,585)JFILE                                                      SWR01060
  585 FORMAT(I3)                                                             SWR01070
      WRITE(16,590)                                                          SWR01080
  590 FORMAT(//5X,'SPECIFY THE RUN NUMBER FOR THE SIMULATED DATA RUN'/       SWR01090
     1    5X,'(TYPE EIGHT DIGIT RUN NUMBER)')                               SWR01100
      READ(16,575) RUNNO                                                     SWR01110
      CALL MOUNT(TAPEND,12,'RI')                                             SWR01120
      MARG=JFILE-1                                                           SWR01130
      IF(MARG.LE.0) GO TO 3                                                  SWR01140
      DO 3 LIP=1,MARG                                                        SWR01150
      CALL TOPFF(12)                                                         SWR01160
    3 CONTINUE                                                               SWR01170
    5 READ(11)I                                                              SWR01180
      IF(I.NE.1) GO TO 310                                                   SWR01190
      READ(11)I,J,NOCLAS,NOCHAN,NOFLDS,NOPOOL,(FETVC3(IX),IX=1,NOCHAN)       SWR01200
      NOCH=(NOCHAN+1)/2*2                                                    SWR01210
      NOCOMP=NOCHAN*(NOCHAN+1)/2                                             SWR01220
      ISTOP=NOCOMP*NOPOOL                                                    SWR01230
      IEND=ISTOP+NOCHAN*NOPOOL                                               SWR01240
   15 READ(11)I,J,K                                                          SWR01250
      IF(I.LT.3) GO TO 15                                                    SWR01260
      IF(K.NE.EOS) GO TO 15                                                  SWR01270
      READ(11)I,J,(Z(IX),IX=1,IEND)                                          SWR01280
      DO 17 IX=1,IEND                                                        SWR01290
      Z2(IX)=Z(IX)                                                           SWR01300
   17 CONTINUE                                                               SWR01310
   45 READ(11)I,AREANO,NOPNTS,NOLINE,INFO,IDREC                              SWR01320
      NOFET3=NOCHAN                                                          SWR01330
      IF(I.NE.5) GO TO 45                                                    SWR01340
      WRITE(6,520)                                                           SWR01350
  520 FORMAT(1H1////5X,'+++++++++++++++++++++++++++++++++++++++')            SWR01360
      WRITE(6,525)                                                           SWR01370
  525 FORMAT(5X,'+DATA SIMULATION USING MCCABES EQUATION+')                  SWR01380
      WRITE(6,530)                                                           SWR01390
  530 FORMAT(5X,'+++++++++++++++++++++++++++++++++++++++')                   SWR01400
      WRITE(6,535) RUNNO, IDREC(3)                                           SWR01410
  535 FORMAT(////5X,'SIMULATED DATA RUN IS',I9,' FROM RUN',I9)               SWR01420
      WRITE(6,537)INFO(4),INFO(5),INFO(7),INFO(8)                            SWR01430
  537 FORMAT(/5X,'LINE',I5,' TO LINE',I5,' AND COLUMN',I5,' TO COLUMN',I5)SWR01440
     $5)                                                                     SWR01450
      WRITE(6,540)INTAP,IFILE                                                SWR01460
  540 FORMAT(/5X,'INPUT RESULTS FILE IS ON TAPE',I9,' FILE',I4)              SWR01470
      WRITE(6,545)TAPEND,JFILE                                               SWR01480
  545 FORMAT(/5X,'SIMULATED DATA IS ON TAPE',I9,' FILE',I4)                  SWR01490
      WRITE(6,550)                                                           SWR01500
  550 FORMAT(/5X,'CHANNELS USED')                                            SWR01510
      DO 560 IX=1,NOCHAN                                                     SWR01520
      WRITE(6,555)FETVC3(IX),FROCAL(1,IX),FROCAL(2,IX)                       SWR01530
  555 FORMAT(5X,I2,2X,F5.2,'-',F5.2)                                         SWR01540
  560 CONTINUE                                                               SWR01550
      CALL GTDATE(DATE)                                                      SWR01560
      WRITE(6,565)DATE                                                       SWR01570
  565 FORMAT(/5X,'DATE OF SIMULATION IS ',3A4)                               SWR01580
```

FILE: SWRITE FORTRAN A PURDUE / LARS 3031

```
C     ****************************************************************     SWRC0010
C     WRITTEN BY: BILL PFAFF                                               SWRC0020
C     EDITED BY: MARWAN MUASHER  JUNE 14,1980                              SWRC0030
C     ****************************************************************     SWRC0040
C                                                                          SWRC0050
C     ****************************************************************     SWRC0060
C          THIS PROGRAM GENERATES SIMULATED DATA BASED ON A                SWRC0070
C     CLASSIFICATION MAP OR A GROUND TRUTH MAP.  EACH PIXEL                SWRC0080
C     GENERATED THUS COMES FROM A KNOWN CLASS DISTRIBUTION.  THE           SWRC0090
C     METHOD USED IS AS FOLLOWS:                                           SWRC0100
C     1. A GOOD CLASSIFICATION IS CHOSEN AS A BASE FOR                     SWRC0110
C        SIMULATED DATA                                                    SWRC0120
C     2. FROM THIS CLASSIFICATION WE KNOW THE NUMBER OF CLASSES, THE       SWRC0130
C        CLASS STATISTICS, AND THE CLASS OF EACH PIXEL IN THE              SWRC0140
C        AREA CLASSIFIED.                                                  SWRC0150
C     3. A STREAM OF UNIFORM RANDOM NUMBERS IS GENERATED FOR               SWRC0160
C        EACH CHANNEL.  THEY ARE CHANGED TO NORMAL (0,1) DEVIATES.         SWRC0170
C     4. FOR EACH PIXEL, A RANDOM N(0,I)VECTOR IS TRANSFORMED TO           SWRC0180
C        BE DISTRIBUTED ACCORDING TO THE CLASS STATISTICS OF THAT          SWRC0190
C        PIXEL.  THIS IS THE SIMULATED DATA VECTOR.                        SWRC0200
C     5. AS EACH LINE IS COMPLETED, IT IS WRITTEN TO AN OUTPUT TAPE.       SWRC0210
C        TO RUN THE PROGRAM, YOU NEED TO HAVE THE FOLLOWING                SWRC0220
C     EXEC FILE ON YOUR DISK:                                              SWRC0230
C                                                                          SWRC0240
C     GETDISK LARSYS                                                       SWRC0250
C     GETDISK DVSYS                                                        SWRC0260
C     GLOBAL TXTLIB CMSLIB FORTRAN SSP370                                  SWRC0270
C     FILEDEF 6 PRINTER                                                    SWRC0280
C     FILEDEF 16 TERMINAL                                                  SWRC0290
C     FILEDEF 12 TAP2                                                      SWRC0300
C     FILEDEF 11 TAP1 (RECFM VS LRECL 1500 BLKSIZE 1500)                   SWRC0310
C     LOAD SWRITE GLOCOM MMTAPE TAPOP 3COVAL GTSERL GTDATE MFSD            SWRC0320
C     RANDU WRTMTX                                                         SWRC0330
C     START SWRITE                                                         SWRC0340
C                                                                          SWRC0350
C          THE PROGRAM WILL ASK FOR INFORMATION SUCH AS                    SWRC0360
C     TAPE NUMBERS, FILE NUMBERS, ..ETC.  FROM HERE ON, IT                 SWRC0370
C     SHOULD BE EASY TO FOLLOW.                                            SWRC0380
C     ****************************************************************     SWRC0390
C                                                                          SWRC0400
C     ****************************************************************     SWRC0410
C    VARIABLES USED IN TPRINT                                              SWRC0420
C                                                                          SWRC0430
C    A      =COVARIANCE STORAGE FOR FACTORING                              SWRC0440
C    AREANO=AREA NUMBER OF CLASSIFICATION                                  SWRC0450
C    B      =COVARIANCE STORAGE FOR MULTIPLICATION                         SWRC0460
C    DATA   =DATA POINT STORAGE                                            SWRC0470
C    DATVAL=LINE NUMBER AND ROLL PARAMETER                                 SWRC0480
C    ICAL   =CALIBRATION INFORMATION                                       SWRC0490
C    IDREC  =IDENTIFICATION RECORD STORAGE                                 SWRC0500
C    ISTART=STARTING POINTS FOR GAUSS                                      SWRC0510
C    LOGDAT=DATA POINTS IN LOGICAL FORMAT                                  SWRC0520
C    NOCHAN=NUMBER OF CHANNELS IN CLASSIFICATION                           SWRC0530
C    NOCLAS=NUMBER OF CLASSES IN ORIGINAL STATISTICS                       SWRC0540
C    NOFLDS=NUMBER OF TEST FIELDS                                          SWRC0550
C    NOPOOL=NUMBER OF POOLED CLASSES                                       SWRC0560
C    PNTCLS=CLASSIFICATIONS ARRAY                                          SWRC0570
C    Z      =STATISTICS STORAGE                                           SWRC0580
C     ****************************************************************     SWRC0590
C                                                                          SWRC0600
C*****************************************************************       SWRC0610
C INITIALIZATION                                                           SWRC0620
C*****************************************************************       SWRC0630
C                                                                          SWRC0640
      INTEGER*2 I2,INTDAT,ICAL(3),ILIN(2),PNTCLS(1000),ISTAT(4),           SWRC0650
     $          FETVC(30)                                                  SWRC0660
      LOGICAL*1 L1(2),LOGDAT(2),LCAL(6),DATOLT(1200)                       SWRC0670
      REAL*4 A(78),A2(12),Z(27000),B(12,12),DATA(12),                      SWRC0680
     $       RMEAN(30,12),RVAR(30,12,12),Z2(27000),FRQCAL(5,30)            SWRC0690
      INTEGER*4 ISTART(12),EOS,INFO(17),AREANO,IDREC(200),TAPENO,THREE,    SWRC0700
     $          CLAPNT(30),IMEAN(30,12),IVAR(30,12,12),YES,NO,DATE(3)      SWRC0710
      INTEGER*4 RUNNO,FLG1                                                 SWRC0720
      EQUIVALENCE (I2,L1),(INTDAT,LOGDAT),(ICAL,LCAL),(LUNRT,ILIN)         SWRC0730
      EQUIVALENCE (FRQCAL(1,1),IDREC(51))                                  SWRC0740
      DATA EOS,S,AM /'EOS ',1.0,0.0 /                                      SWRC0750
      DATA YES,NO,THREE /'YES ','NO  ',3/                                  SWRC0760
```

APPENDIX III

```
/************************************************
*
*  Read data from LARS Results Tape
*  and simulate data from it
*  using the Box Muller relationship
*
************************************************
*
*  Swrite.c has been translated from
*  the Lars Fortran Version of Swrite into
*  the language 'c' for the Unix O.S.
*  run on the DEC PDP-11/45
*
************************************************
*
*  Variables used in Swrite:
*
*     a        == Covariance storage for factoring
*     b        == Covariance storage for multiplication
*     data     == Data point storage
*     nochan   == Number of channels in Classification
*     noclas   == Number of classes in original statistics
*     nopool   == Number of pooled classes
*     pntcls   == Classifications array
*     z        == Statistics storage
*
************************************************
*
*  compile with      cc swrite.c -lp -lp  /usr/lib/pdslib
*
************************************************
*
*  Initialize all variables used in swrite
*  External variables are available to all functions
*  within which they are declared
*/
main(){
  extern int noclas, nochan, nopool, fd1, nopnts, noline, recnum;
  extern int ier, fd2;
  extern float eps, upper[5], lower[5];
  int i, k, fetvc3[5], debug, info[17], pntcls[1000], jj, ipol;
  int ii, idone, iy, ma, mb, mc;
  int noch, nocomp, istop, iend, ix, ibeg;
  int lnwrt, i2, icount, iz, i9, intdat, istat[6], ip, io, it, ninc, no, in;
  int nosam, pos, pfd1;
  int fd3, fd4, err5;
  char buf[1500], *delim, *c1, *c2, *c3, datout[2100], obuf[2100];
  char pname[30], ttl[41];
  char mufile[30], cmfile[30], opname[30];
  float z[610], rcnt, r;
  float b[6][6];
  double rmean[31][6];
  float data[13], z2[610];
  float clcnt[35];
  float mobuf[30];
  double ivar[31][6][6], revar, imean[31][6], t1float, t2float, remean, semean;
  double temp1, temp2, temp0, a[20], a2[6];
  double sqrt(), log(), cos(), fmod(), s, t, f;
/* begin main program
*  if debug is set to minus one the following is
```

```
*  printed out for verification on usr terminal:
*     nochan, nopool, fetvc3, info, pntcls, nopnts, noline, z, upper, lower;
*/
  debug = 1;
  eps = .00001;
/*  read records 2,4,5,&6 off results tape*/
/*  skip records 1,3   */
  readito5(buf, fetvc3, z, info);
  noch = (((nochan+1)/2)*2);
  nocomp = (nochan*(nochan+1)/2);
  istop = nocomp * nopool;
  iend = nochan * nopool + istop;
  nosam = 4 * ((nopnts + 9)/4);
  if(nochan>5) {
    printf("Number of channels is %d but internal", nochan);
    printf(" storage only allows 5\n");
    printf("Execution terminated abnormally \n");
    exit();
    }
  if(nopool>29) {
    printf("Number of pooled classes is %d but internal", nopool);
    printf(" storage only allows 29\n");
    printf("Execution terminated abnormally \n");
    exit();
    }
  if(nopnts>=1000) {
    printf("Number of points per line is %d but internal", nopnts);
    printf(" storage only allows 1000\n");
    printf("Execution terminated abnormally \n");
    exit();
    }
  printf("nochan=%d, nopool=%d\n", nochan, nopool);
  if(debug == -1) {
    for(k=0; k<nochan; ++k)
       printf("fetvc3[%d] = %d \n", k, fetvc3[k]);
    for(k=0; k<iend; k = k+10) {
       for(j=k; j<=k+9; ++j)
          printf("  %f", z[j]);
       printf("\n");
       }
    printf("\nField size:");
    printf("\n          line %d to %d with interval %d",
            info[4], info[5], info[6]);
    printf("\n          cols %d to %d with interval %d\n",
            info[7], info[8], info[9]);
    printf("Number of lines classified is %d\n", noline);
    printf("Number of points classified per line is %d\n", nopnts);
    for(j=0; j<nochan; ++j) {
       printf("upper[%d] = %f ", j, upper[j]);
       printf("   lower[%d] = %f \n", j, lower[j]);
       }
    }
  read6rec(buf, pntcls);
  if(debug == -1) {
    printf("\nFirst line of record %d follows\n", recnum);
    for(j=0; j<=nopnts; j=j+10) {
       for(k=j; k<=j+9; ++k)
          printf("   %d", pntcls[k]);
       printf("\n");
       }
```

```
    }
/* make a copy of statistics array z */
  for(ix=1;ix<=iend;++ix)
     z2[ix] = z[ix-1];
/*  Create output file  */
  gets("\nSpecify lineprinter output file pathname:  ",orname);
  fd2 = creat(orname,0777);
  if(fd2<0)
    printf("Cannot creat lp output file %s\n",orname);
  pfd1 = 1;
  gets("Specify simulated data PDS file pathname:  ",pname);
  gets("enter a 40 char title:\n",ttl);
  gets("\nSpecify mean vector file pathname:  ",mvfile);
  gets("\nSpecify covariance matrix file pathname:  ",cmfile);
  rdsopen(pfd1,pname);
  putfmt(pfd1,1,nosam,noline,8,nochan);
  putttl(pfd1,ttl);
  fd3 = creat(mvfile,0777);
  if(fd3<0)
    printf("Cannot creat mvfile %s  (MAIN)\n",mvfile);
  fd4 = creat(cmfile,0777);
  if(fd4<0)
    printf("Cannot creat cmfile %s  (MAIN)\n",cmfile);
/* write output page one */
  delim = "     ++++++++++++++++++++++++++++++++++++++++++++++++";
  c1 =    "     +Data Simulation Using Box-Muller Relationship+";
  printf(fd2,"\n\n\n\n%s\n%s\n%s\n",delim,c1,delim);
  printf(fd2,"\n   Line %d to line %d with interval %d \n",
         info[4],info[5],info[6]);
  printf(fd2,"\n   Column %d to column %d with interval %d \n",
         info[7],info[8],info[9]);
  printf(fd2,"\n     channels used \n");
  for(ix=1;ix<=nochan;++ix)
     printf(fd2,"     %d   %f - %f\n",fetwo3[ix-1],lower[ix-1],
           upper[ix-1]);
/* output new page character */
  printf(fd2,"\014");
/*  Factor covariance matrices  */
  ibeg = 1;
  for(ix=1;ix<=norool;++ix) {
     idone = ibeg + nocomp - 1;
     k = 0;
     for(iy=ibeg;iy<=idone;++iy) {
        k = k + 1;
        a[k] = z[iy-1];
        }
 /* call function to perform factoring  */
     mfsd(a);
     if(ier == -1)
       printf(fd2,"Error -1\n");
     if(ier>=1)
       printf(fd2,"Error at 1\n");
     if((ier == -1) || (ier >= 1))
       exit(1);
     k = 0;
     for(iy=ibeg;iy<=idone;++iy) {
        k = k + 1;
        z[iy-1] = a[k];
        }
     ibeg = ibeg + nocomp;
```

```
    }
/*  initialize random number generator */
  srand(1);
/*  initialize arrays   */
  for(ma=1;ma<=noclas;++ma) {
     clarnt[ma] = 0.0;
     for(mb=1;mb<=nochan;++mb) {
        imean[ma][mb] = 0.0;
        rmean[ma][mb] = 0.0;
        for(mc=1;mc<=nochan;++mc) {
           ivar[ma][mb][mc] = 0.0;
           }
        }
     }
  t = 25.0;
  lnwrt = 0;
/*  this while loop is repeated for each line in the classification  */
  while(recnum == 6) {
    lnwrt = lnwrt + 1;
    s = lnwrt;
    f = fmod(s,t);
    if(f == 0.0)
      printf("%d  Lines out of %d are completed\n",
            lnwrt,noline);
    i2 = 0;
    icount = 4;
    for(ix=1;ix<=nornts;++ix) {
       icount = icount + 1;
       i2 = entels[ix-1];
       irol = (i2-1) * nochan;
       ibeg = (i2-1) * nocomp;
       k = ibeg;
       for(iy=1;iy<=nochan;++iy) {
          for(iz=1;iz<=iy;++iz) {
             k = k + 1;
             b[iy][iz] = z[k-1];
             if(iy != iz)
               b[iz][iy] = 0.0;
             }
          }
       for(iy=1;iy<=noch;++iy) {
          a2[iy] = rand();
          a[iy] = rand();
          a2[iy] = a2[iy] / 32767.;
          a[iy] = a[iy] / 32767.;
          a[iy] = sqrt( -2.0 * log(a2[iy])) * cos(6.28318 * a[iy]);
          }
       clarnt[i2] = clarnt[i2] + 1.0;
       for(iy=1;iy<=nochan;++iy) {
          data[iy] = 0.0;
          is = nopool * nocomp + irol + iy;
          for(iz=1;iz<=nochan;++iz)
             data[iy] = data[iy] + b[iy][iz] * a[iz];
          data[iy] = data[iy] + z[is-1];
          intdat = data[iy] + .5;
          if(intdat<0)  intdat = 0;
          if(intdat>255)  intdat = 255;
          istat[iy] = intdat;
          pos = (iy-1)*nosam + icount - 5;
          if(pos>2100) printf("datout internal buffer full\n");
```

```
            datout[pos] = intdat & 0377;
            for(iz=1;iz<=6;++iz)
               datout[pos+iz] = 0;
            }
          for(ii=1;ii<=nochan;++ii) {
            imean[i2][ii] = imean[i2][ii] + istat[ii];
            for(jj=ii;jj<=nochan;++jj) {
              temp0 = istat[ii];
              temp1 = istat[jj];
              ivar[i2][ii][jj] = ivar[i2][ii][jj] + temp0 * temp1;
               }
            }
          }
        ii = 0;
        for(iy=0;iy<nosam;++iy) {
           for(iz=0;iz<nochan;++iz)
              obuf[ii++] = datout[nosam*iz + iy];
           }
        pdslpos(pfd1,lnwrt-1);
        if(putline(pfd1,lnwrt-1,obuf,nosam*nochan) != 0)
          printf("Putline to PDS output failed\n");
        readbrec(buf,pntols);
        }
/*  end of while loop  */
/*
  for(i2=1;i2<=18;++i2) {
    printf(fd2,"\n %d \n",i2);
    for(ii=1;ii<=nochan;++ii) {
      for(jj=ii;jj<=nochan;++jj) {
         printf(fd2," %f  ",ivar[i2][ii][jj]);
         }
      printf(fd2,"\n");
      }
   }
  for(i2=1;i2<=18;++i2) {
     printf(fd2,"\n");
     for(ii=1;ii<=nochan;++ii) {
        printf(fd2," %f \n",imean[i2][ii]);
        }
     }
*/
  for(ip=1;ip<=noclas;++ip) {
     for(io=1;io<=nochan;++io) {
        if(clapnt[ip]>0.0) {
          tlfloat = imean[ip][io];
          t2float = clapnt[ip];
          rmean[ip][io] = tlfloat/t2float;
          }
        for(it=io;it<=nochan;++it) {
           if(clapnt[ip]>1.0) {
             repnt = clapnt[ip];
             revar = ivar[ip][io][it];
             remean = imean[ip][io];
             semean = imean[ip][it];
             temp0 = revar/(repnt-1.0);
             temp1 = remean/repnt;
             temp2 = semean/(repnt-1.0);
             ivar[ip][io][it] = temp0 - (temp1*temp2);
             ivar[ip][it][io] = ivar[ip][io][it];
             }
```

```
            }
          }
        }
/*  output results  */
  for(ip=1;ip<=noclas;++ip) {
     printf(fd2,"     Class number %d     %f   points\n\n\n",
           ip,clarnt[ip]);
     printf(fd2,"                                                    Actual     Simulated\n");
     printf(fd2,"                                                     Mean       mean\n");
     for(ix=1;ix<=nochan;++ix) {
        ninc = nocomp * noclas + (ip - 1) * nochan;
        printf(fd2,"     Channel %d  ( %6.3f - %6.3f )      %6.3f    %6.3f\n",
               fetvc3[ix-1],lower[ix-1],upper[ix-1],z2[ninc+ix],
               rmean[ip][ix]);
        mobuf[ix-1] = rmean[ip][ix];
        }
     err5 = write(fd3,mobuf,4*nochan);
     if(err5<0)
       printf("Error occurred writing Mean Vector file (MAIN) \n");
     printf(fd2,"\n\n\n\n\n\n     Actual Covariance Matrix\n");
     for(no=1;no<=nocomp;++no) {
        ninc = (ip-1) * nocomp;
        a[no] = z2[ninc+no];
        }
     wrtmtx(a,fetvc3);
     printf(fd2,"\n\n\n\n\n     Simulated Covariance Matrix\n");
     no = 0;
     for(io=1;io<=nochan;++io) {
        for(in=1;in<=io;++in) {
           no = no + 1;
           a[no] = ivar[ip][io][in];
           mobuf[no-1] = ivar[ip][io][in];
           }
        }
     wrtmtx(a,fetvc3);
     err5 = write(fd4,mobuf,4*nocomp);
     if(err5<0)
       printf("Error occurred writing cm file  (MAIN) \n");
     printf(fd2,"\014");
     }
/* cexit terminates activities on open files and flushes
*  the output buffer   cexit is part of the c library  */
  printf("swrite.c is finished\n");
  printf("\n The simulated data (in PDS format) is at %s \n",pname);
  printf("The linerprinter output file is at %s \n",prname);
  printf("The Mean vector file is at %s \n",mvfile);
  printf("The Covariance Matrix file is at %s \n",cmfile);
  pdsclose(pfd1);
  cexit();
}
/*  end of main program  */
/*******************************************************/
/*   function to read records 1 thru 5 follows        */
readit05(buf,fetvc3,word,info)
  int *fetvc3,*info;
  char *buf;
  float *word;
{
  extern int noclas,nochan,nopool,fd1,nopnts,noline;
  extern float  upper[5],lower[5];
```

```
  int err1,j,k,recnum,statsize;
  char tbuf[4];
  float ibmdec();
  fd1 = open("/dev/rmt0",0);
  if(fd1<0)
    printf("Cannot open 9 trk tape file   (READ1TO5) \n");
/* skip record 1 */
  err1 = read(fd1,buf,1500);
  if(err1 == -1)
    printf("Error occurred in reading record 1 (READ1TO5) \n");
/* read record 2 */
  err1 = read(fd1,buf,1500);
  if(err1 == -1)
    printf("Error occurred reading record 2  (READ1TO5) \n");
  noclas = buf[19];
  nochan = buf[23];
  norool = buf[31];
  for(j=0,k=33; j<nochan; ++j,k=k+4)
     fetwo3[j] = buf[k];
  for(k=32+4*nochan,j=0; j<2*nochan; ++j,k=k+4) {
     tbuf[0] = buf[k];
     tbuf[1] = buf[k+1];
     tbuf[2] = buf[k+2];
     tbuf[3] = buf[k+3];
     if(j<nochan)
       lower[j] = ibmdec(tbuf);
     else upper[j-nochan] = ibmdec(tbuf);
     }
/* skip record 3 */
  err1 = read(fd1,buf,1500);
  if(err1 == -1)
    printf("Error occurred reading record 3 (READ1TO5) \n");
  recnum = buf[11];
  while(recnum == 3) {
     err1 = read(fd1,buf,1500);
     if(err1 == -1)
       printf("Error occurred reading record three (READ1TO5)\n");
     recnum = buf[11];
     }
/* Handle record 4 */
  statsize = nochan*norool + (nochan*(nochan+1)/2)*norool;
  for(k=0,j=16; k<statsize; ++k,j=j+4) {
     tbuf[0] = buf[j];
     tbuf[1] = buf[j+1];
     tbuf[2] = buf[j+2];
     tbuf[3] = buf[j+3];
     word[k] = ibmdec(tbuf);
     }
  err1 = read(fd1,buf,1500);
  if(err1 == -1)
    printf("Error occurred reading record 5 (READ1TO5) \n");
  nopnts = (buf[18]<<8 | (buf[19] & 0377));
  noline = (buf[22]<<8 | (buf[23] & 0377));
  info[4] = (buf[38]<<8 | (buf[39] & 0377));
  info[5] = (buf[42]<<8 | (buf[43] & 0377));
  info[6] = (buf[46]<<8 | (buf[47] & 0377));
  info[7] = (buf[50]<<8 | (buf[51] & 0377));
  info[8] = (buf[54]<<8 | (buf[55] & 0377));
  info[9] = (buf[58]<<8 | (buf[59] & 0377));
}
```

```
int noolas, nopool, noohan, fdi, nornts, noline;
float upper[5], lower[5];
float ibmdec(buf)
   char *buf;
{
  int k, l, m, tint;
  char nbuf[2], tchar, temr3, byte[4], sign;
  float word;
  m = 0;
  sign = 0000;
  if(buf[0] < 0)
    sign =0200;
  tint=(((buf[0] & 0177) - 64) * 4);
  while(buf[1] > 0) {
       buf[1]=((buf[1]<<1) & 0376);
       ++m;
       }
  k = 8-m;
  nbuf[0]=buf[2];
  nbuf[1]=buf[3];
  for(l=1; l<=k; ++l)
     nbuf[0]=((nbuf[0]>>1) & 0177);
     nbuf[1]=((nbuf[1]>>1) & 0177);
     }
  for(l=1; l<=m; ++l) {
     buf[2]=((buf[2]<<1) & 0376);
     buf[3]=((buf[3]<<1) & 0376);
     }
  buf[1]=(buf[1] | nbuf[0]);
  buf[2]=(buf[2] | nbuf[1]);
  tint = tint-m+128;
  if(tint < 0) tchar = 0000;
  else if(tint > 255) tchar = 0377;
  else tchar = tint;
  buf[1]=(buf[1] & 0177);
  temr3 = tchar<<7;
  temr3 = temr3 & 0200;
  buf[1] = temr3 | buf[1];
  buf[0] = tchar>>1;
  buf[0] = buf[0] & 0177;
  buf[0] = buf[0] | sign;
  byte[0] = buf[1] & 0377;
  byte[1] = buf[0] & 0377;
  byte[2] = buf[3] & 0377;
  byte[3] = buf[2] & 0377;
  pack(byte,&word);
  return(word);
}
/* the function pack takes the 4 8-bit character bytes
*  that have been rearranged by ibmdec and packs
*  them into a floating point word  */
 pack(byte, cword)
    char *byte,*cword; {
  int j;
  for(j=0; j<4; ++j)
     cword[j] = byte[j];
 }
/*************************************************************/
/*  function to read record & follow    */
readbrec(buf, rntcl:)
```

```
 int *pntols;
 char *buf; {
extern int nopnts,recnum,fd1;
int j,n,err1,k;
n = 0;
err1=read(fd1,buf,1500);
if(err1 == -1)
  printf("Error occurred reading record 6\n");
recnum=buf[1];
for(j=20,k=0; k<nopnts; k++,j=j+2) {
   pntols[n]=(buf[j+1] & 0377);
   ++n;
   }
 }
int recnum;
/*********************************************************/
/* Mfsd factors the matrices passed by the main program.
*  Mfsd is a direct translation from the Lars
*  fortran version of the same name  */
mfsd(a)
   double *a; {
 extern int nochan,ier;
 extern float eps;
 int kpiv,k,ind,lend,i,lanf,l,lind;
 double tol,dsum,dpiv,y,fabs();
 double done,sqrt(),x;
 done = 1.0;
 ier = 0;
 kpiv = 0;
 for(k=1;k<=nochan;++k) {
    kpiv = kpiv+k;
    ind = kpiv;
    lend = k-1;
    y = eps*a[kpiv];
    tol = fabs(y);
    for(i=k;i<=nochan;++i){
       dsum = 0.0;
       if(lend != 0) {
         for(l=1,l<=lend,++l) {
            lanf = kpiv-l;
            lind = ind-l;
            dsum = (dsum+(a[lanf]*a[lind]));
            }
         }
       dsum = a[ind]-dsum;
       if((i-k) == 0) {
         if(((dsum-tol) <= 0.0) && (dsum > 0.0) && (ier<=0))
           ier = k-1;
         if(((dsum-t..) <= 0.0) && (dsum <= 0.0)) {
           ier = -1;
           printf("E.r.r -1\n");
           exit(1);
           }
         x = dsum;
         dpiv = sqrt(x);
         a[kpiv] = dpiv;
         dpiv = done/dpiv;
         }
       if((i-k) != 0)
         a[ind] = dsum*dpiv;
```

```
            ind = ind+1;
            }
         }
      }
   int ier;
   float ers;
/*********************************************************/
/* the write matrix function writes to the output
*  file the lower half of the nochan*nochan covariance matrix
*  which is passed through the parameter a.    */
wrtmtx(a,fetus3)
    int *fetus3;
    double *a;    {
   extern int fd2,nochan;
   extern float upper[5],lower[5];
   int j,k,m;
   m = 0;
   printf(fd2,"\n      Spectral          ");
   for(j=0;j<nochan;++j)
      printf(fd2,"%7.5f -      ",lower[j]);
   printf(fd2,"\n      Band              ");
   for(j=0;j<nochan;++j)
      printf(fd2,"%7.5f        ",upper[j]);
   for(j=0; j<nochan; ++j) {
      printf(fd2,"\n\n      %7.5f -\n",lower[j]);
      printf(fd2,"       %7.5f          ",upper[j]);
      for(k=0; k<=j; ++k) {
         printf(fd2,"%7.3f        ",a[++m]);
         }
      }
   }
  int fd2;
/*********************************************************/
setr(p,s)
char *p,*s; {
   char c,*p1;
   printf(p);
   p1 = s;
   while((c = getchar()) != '\n')
        *p1++ = c;
   *p1 = 0;
}
```