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Technical Report

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NOTE ON COMPUTER GRAPHICS FOR
MAXIMUM ENTROPY SPECTRAL ANALYSIS

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NOTE ON COMPUTER GRAPHICS FOR
MAXIMUM ENTROPY SPECTRAL ANALYSIS

Summary: Computer graphics provides an effective three-dimensional display of power spectral density for varying parameters. Based on the software we have developed, the computer-graphics display is presented for Burg's maximum entropy spectral analysis and Fougere's (nonlinear) maximum entropy spectral analysis. The significantly greater dynamic range of the Fougere's spectrum clearly illustrates the superiority of the Fougere's method. The graphics software listing is provided in the Appendix of the report.

Spectral Display of Sunspot Numbers

Fig. 1a is a plot of January Zürich sunspot numbers for 200 data points for the period 1779 to 1978. Fig. 1b is the display of Burg's spectrum of Fig. 1a for filter weights 10 to 58 and frequency interval 0.05 to 0.15 cycles per year. All spectrum plots are in logarithmic scale with base 10. The three numbers on the top of the photo are A= minimum spectral magnitude, B= maximum spectral magnitude, and C= difference between B and A, in log scale. For Fig. 1b, A=2.798, B=5.113, C=2.315. In all graphical displays of the report, 450 points are used for computation in frequency and weight number axes even though only 225 points are actually used for display (See Appendix).

Fig. 2a is a section of 25 data points from Fig. 1a to cover the period 1954-1978. Fig. 2a is the Burg's spectra for filter weights of 1 to 17. The dynamic range is A=6.281, B=14.424,

Distribution/	
Availability Codes	
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A	

C=8.143. Fig. 2c is the Fougere's spectra of Fig. 2a for filter weights of 1 to 17. The dynamic range is A=4.403, B=17.225 and C=12.822. The increase in dynamic range by using the Fougere's method is about 46.8dB.

Spectral Display of Sinewaves

Figure 3a is the sinewave considered which is given by the equation

$$x(t) = \sin(2\pi ft + \theta) + \text{SNR} \times n(t)$$

with DT(sampling period)=0.05, $f=1$, $\theta=45^\circ$, SNR=50dB, and $n(t)$ is zero mean, unit variance Gaussian noise. 25 data points are used in spectral analysis. Fig. 3b is the Burg's spectra for filter weights of 1 to 17 and frequency interval of 0 to 2.7 Hz. The dynamic range is A=-14.108, B=3.085, C=17.193. Fig. 3c is the Fougere's spectra for the same filter weights and frequency interval. The dynamic range is A=-14.584, B=10.353, C=24.937. The increase in dynamic range of the spectral magnitude by using the Fougere's method is about 77.5dB.

Useful References:

1. C. H. Chen, "Spectral resolution of Fougere's maximum entropy spectral analysis", Proc. of the IEEE, June 1981.
2. C. H. Chen, J. Chen and C. Yen, "A Minicomputer implementation of Fougere's maximum entropy spectrum analysis method", Technical Report, SMU-EE-TR-80-7, August 20, 1981.

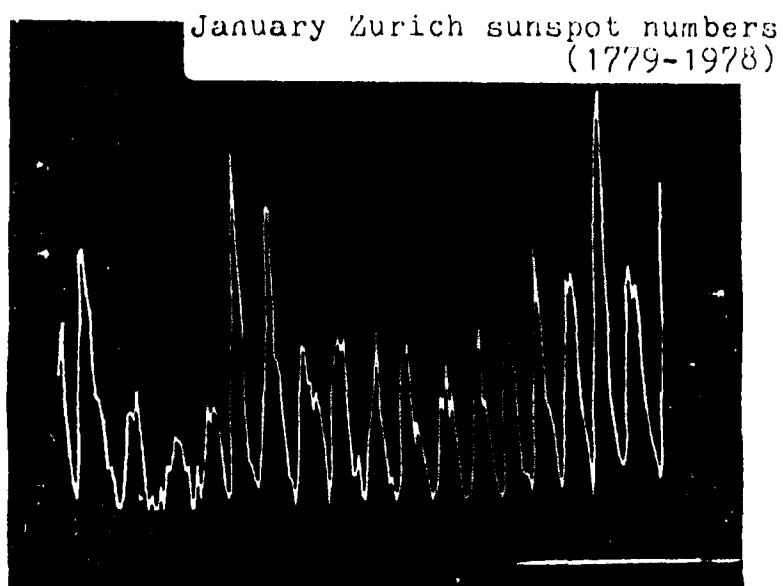


Fig. 1a

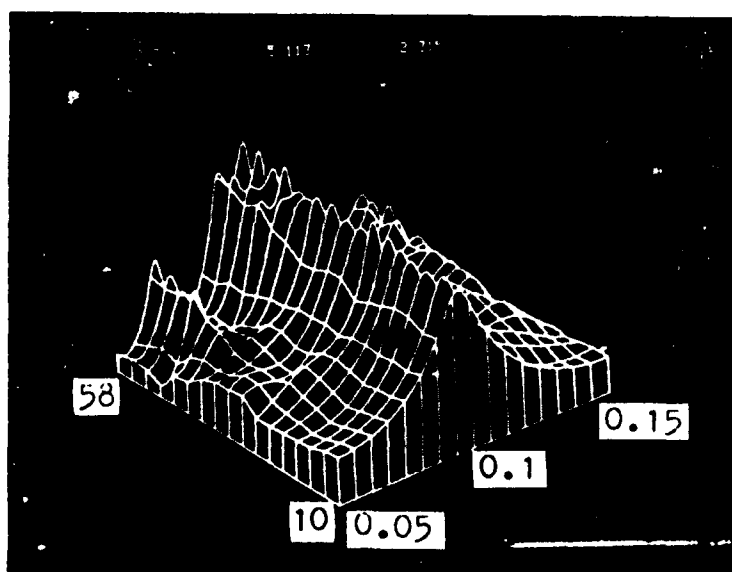


Fig. 1b

January Zurich sunspot numbers
(1954-1978)

- 4 -

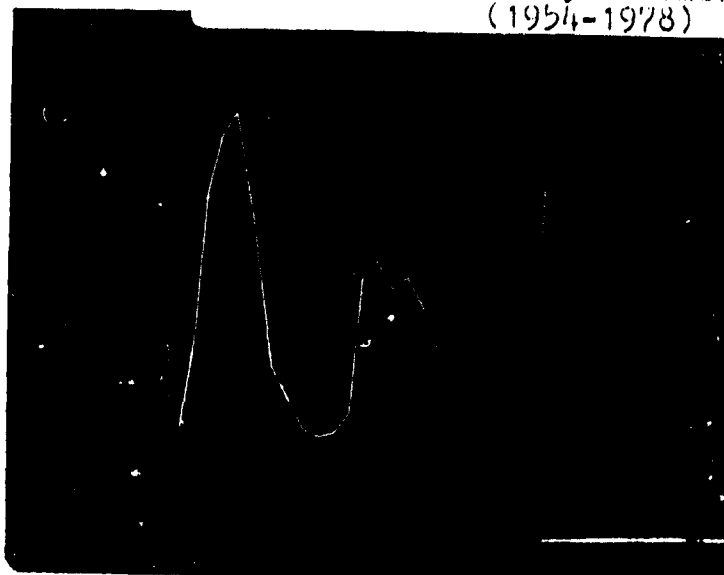


Fig. 2a

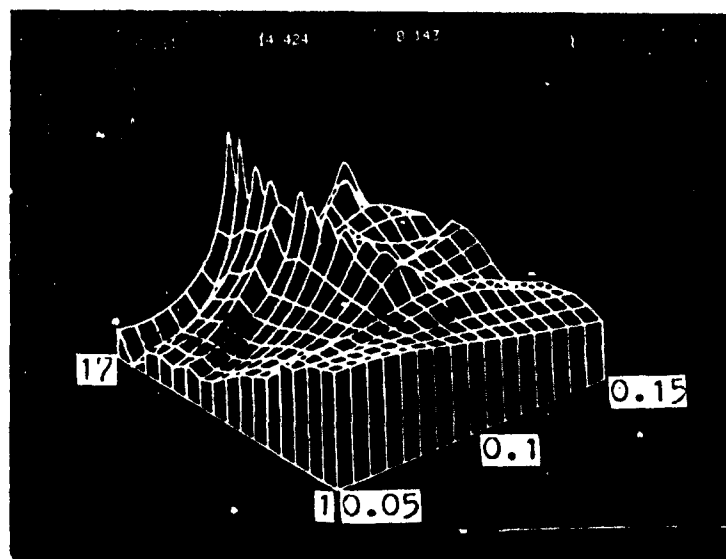
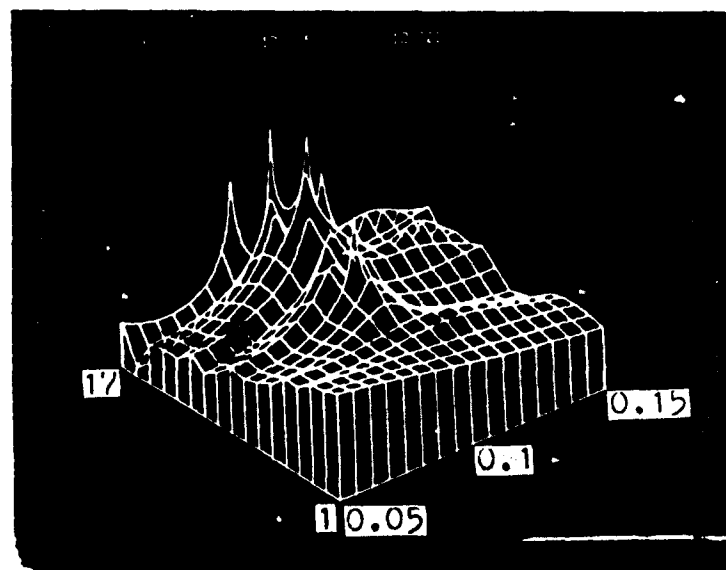


Fig. 2b



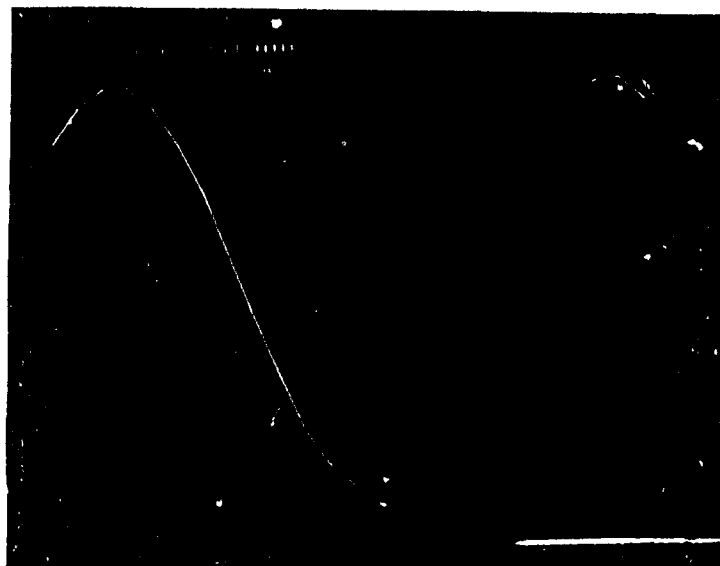


Fig. 3a

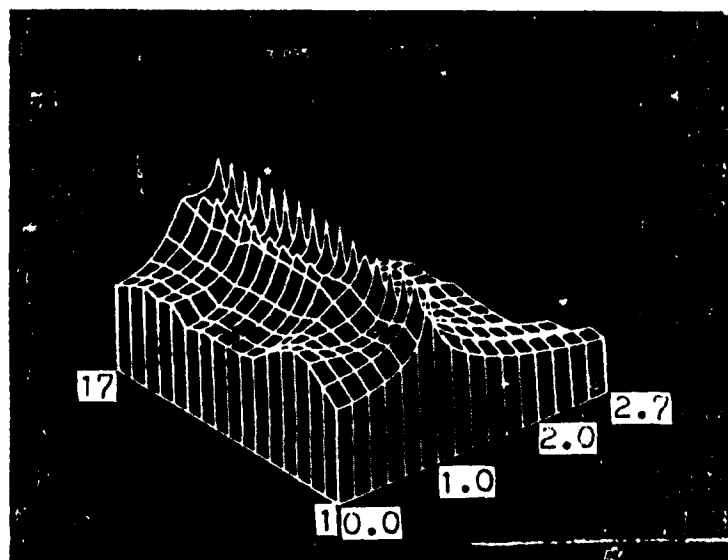


Fig. 3b

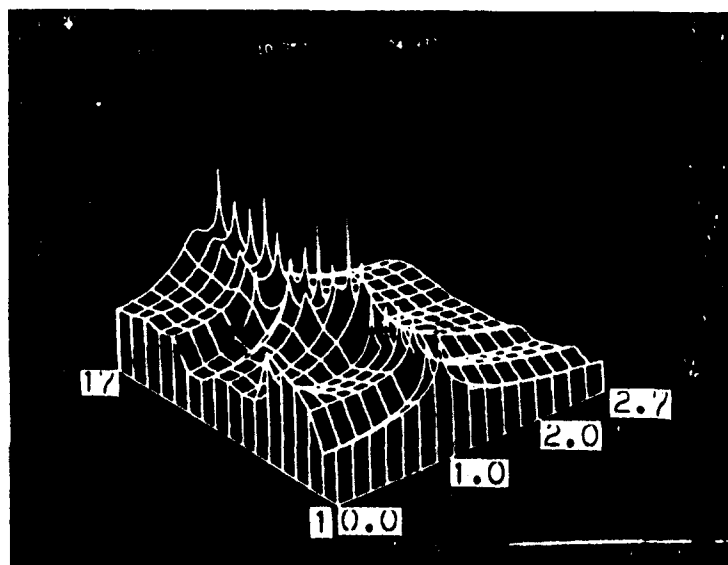


Fig. 3c

APPENDIX

FORTRAN V04.13

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```

C
C      NAME CMCF I200,2001
C
0001      REAL Y(225),YY(17),X(225)
0002      INTEGER IX(6),IY(6),IX1(6),IY1(6),IXX(4),IYY(4)
0003      INTEGER IYC(225),XY(17,225),IX2(2),IY2(2),EN
0004      DATA IX/445,445,882,882,98,98/
0005      DATA IY/73,349,229,505,234,560/
0006      DATA IX1/445,445,98,98,882,882/
0007      DATA IY1/3,349,234,560,229,505/
C
C      IN THIS CASE I CREATE A HORIZONTAL FILE IN FILE 7
C      AND A VERTICAL FILE IN FILE 3
C      1ST STEP: TO CREATE A VERTICAL FILE WHICH HAS LN LINES
C      AND EN PTS OF ONE LINE
C
0008      LN=17
0009      EN=225
0010      IEN=EN#2
0011      NFU1=7
0012      NFU2=3
0013      LSG=LN-1
0014      IO=(EN-1)/LSG
0015      IF((IO*LSG+1).NE.EN)GO TO 270
0016      DO 30 I=1,LN
0017      DEFINE FILE NFU1(LN,IEN,U,LINE)
0018      DO 30 J=1,LN
0019      LINE=J
0020      READ(NFU1(LINE))Y
0021      K=(I-1)*IO+1
0022      YY(J)=Y(K)
0023      30      CONTINUE
0024      END FILE NFU1
0025      DO 50 LL=1,LSG
0026      KK=LL+1
0027      DIS=(YY(KK)-YY(LL))/IO
0028      DO 40 NM=1,IO
0029      NM=(LL-1)*IO+NM
0030      X(NM)=YY(LL)+DIS*FLOAT(NM-1)
0031      40      CONTINUE
0032      50      CONTINUE
0033      X(EN)=YY(LN)
0034      DEFINE FILE NFU2(LN,IEN,U,INDEX)
0035      INDEX=1
0036      WRITE(NFU2(INDEX))X
0037      END FILE NFU2
0038      60      CONTINUE
0039      CALL BELI
C
C      2ND STEP: TO NORMALIZE THE BOTH OF TWO FILES
C
0040      DEFINE FILE NFU1(LN,IEN,U,LINE)
0041      LINE=1
0042      READ(NFU1(LINE))Y
0043      FMIN=Y(1)

```

```

0041      FMAX=Y(1)
0042      DO 80 I=1, LN
0043      LINE=I
0044      READ(NFU, LINE) Y
0045      DO 70 J=1, EN
0046      IF (Y(J).GT.FMAX) FMAX=Y(J)
0047      IF (Y(J).LT.FMIN) FMIN=Y(J)
0048      70      CONTINUE
0049      80      CONTINUE
0050      END FILE NFU1
0051      FMAX=FMAX-FMIN
0052      CALL NEWFAG
0053      WRITE(6, 90) FMIN, FMAX, FMAX
0054      90      FORMAT(1X, 3F15.3)
0055      DO 120 I=1, 2
0056      IF (I.EQ.1) NFU=NFU1
0057      IF (I.EQ.2) NFU=NFU2
0058      DO 110 I=1, LN
0059      DEFINE FILE NFU(I, IBN, U, LINE)
0060      LINE=I
0061      READ(NFU, LINE) Y
0062      END FILE NFU
0063      DO 100 J=1, EN
0064      Y(J)=Y(J)-FMIN
0065      100     CONTINUE
0066      DEFINE FILE NFU(I, IBN, U, IDX)
0067      110     IDX=I
0068      WRITE(NFU, IDX) Y
0069      END FILE NFU
0070      120     CONTINUE
0071      110     CONTINUE
0072      120     CONTINUE
0073      CALL BELI
0074
0075      C
0076      C      3RD STEP: TO CHANGE DATA VALUES TO ABSOLUTE COORDINATE VALUES
0077      C
0078      IH=IY(2)-IY(1)
0079      DO 140 L=1, 2
0080      IF (L.EQ.1) NFU=NFU1
0081      IF (L.EQ.2) NFU=NFU2
0082      DO 130 M=1, LN
0083      DEFINE FILE NFU(I, IBN, U, LINE)
0084      LINE=M
0085      READ(NFU, LINE) Y
0086      END FILE NFU
0087      CALL MAXMIN(Y, YMAX, YMIN, EN)
0088      RATE=YMAX/YMIN
0089      IF (NFU.EQ.NFU1) CALL CNCO(IX, IY, IXX, IYY, M, RATE, LSG, IH)
0090      IF (NFU.EQ.NFU2) CALL CNCO(IX1, IY1, IXX, IYY, M, RATE, LSG, IH)
0091      CALL CRDT1(IYC, Y, EN, IXX(1), IXX(3), IYY(1), IYY(2), IYY(3), M)
0092      DEFINE FILE NFU(LN, IBN, U, LINE)
0093      LINE=M
0094      WRITE(NFU, LINE) (IYC(NNN), NNN=1, EN)
0095      END FILE NFU
0096      130     CONTINUE
0097      140     CONTINUE
0098      CALL BELI

```

C
C
C

4TH STEP: TO MOVE OUT THE HIDDEN POINTS

```

0097      DO 220 L=1,2
0098      IF (L.EQ.1) NFU=NFU1
0099      IF (L.EQ.2) NFU=NFU2
0100      DEFINE FILE NFU(LN,IBN,U,LINE)
0101      DO 160 I=1,LN
0102      LINE=I
0103      READ(NFU,LINE)(IYC(NNN),NNN=1,EN)
0104      DO 150 J=1,EN
0105      XY(I,J)=IYC(J)
0106      CONTINUE
0107      END FILE NFU
0108      DO 190 I=2,LN
0109      KI=I-1
0110      DO 180 K=1,KI
0111      ITT=INT(FLOAT(I-K)*RATE)
0112      NN=ITT+1
0113      IF(NN.GT.EN)GO TO 180
0114      DO 170 N=NN,EN
0115      MM=N-ITT
0116      IF(MM.LE.0)GO TO 170
0117      IF(XY(I,N).LT.0)GO TO 170
0118      IF(XY(I,N).GT.XY(K,MM))GO TO 170
0119      XY(I,N)=-XY(I,N)
0120      CONTINUE
0121      CONTINUE
0122      CONTINUE
0123      DO 210 I=1,LN
0124      LINE=I
0125      DO 200 J=1,EN
0126      IYC(J)=XY(I,J)
0127      WRITE(NFU,LINE)(IYC(NNN),NNN=1,EN)
0128      CONTINUE
0129      END FILE NFU
0130      CONTINUE
0131      DO 230 L=1,2
0132      CALL BELL
0133      CONTINUE

```

C
C
C

5TH STEP: TO DRAW THE 3-DIMENSION PICTURE ON THE SCREEN

```

0134      DO 260 L=1,2
0135      IF (L.EQ.1) NFU=NFU1
0136      IF (L.EQ.2) NFU=NFU2
0137      DO 240 I=1,EN
0138      Y(I)=FLOAT(I)
0139      DEFINE FILE NFU(LN,IBN,U,LINE)
0140      DO 250 M=1,LN
0141      LINE=M
0142      READ(NFU,LINE)(IYC(NNN),NNN=1,EN)
0143      IF(NFU.EQ.NFU1)CALL CNCO1(IX,IY,IX2,IY2,M,LSG)
0144      IF(NFU.EQ.NFU2)CALL CNCO1(IX1,IY1,IX2,IY2,M,ISG)
0145      CALL LKBP(Y,IYC,EN,IX2(1),IX2(2),IY2(1),IY2(2),M)
0146      CONTINUE

```

```

0147      END FILE NFD
0148      260      CONTINUE
0149      270      CALL BELL
0150      CALL EXIT
0151      END
    
```

ROUTINES CALLED

FLOAT , BELL , NEVPAG, MAXMIN, CNCD , CRDT1 , INT
 CNCD1 , LKBP , EXIT

OPTIONS =/OPI2

BLOCK	LENGTH
MAIN	10580 (051750)*

```

**COMPILER ----- CORE**
  PHASE      USED  FREE
DECLARATIVES 00622 14756
EXECUTABLES  01183 14195
ASSEMBLY      01821 18197
    
```

```

0001      SUBROUTINE UNCO1 (IX, IY, IXX, IYY, I, KK)
0002      INTEGER IX(1), IY(1), IXX(1), IYY(1)
0003      DX=FLOAT (IX(2))-IX(1)
0004      DY=FLOAT (IY(2))-IY(1)
0005      DZ=SQRT (DX*DX+DY*DY)
0006      DZS=DZ/FLOAT (KK)
0007      TH=ATAN2 (DY, DX)
0008      A=COS (TH)
0009      B=SIN (TH)
0010      IXX(1)=INT (FLOAT (IX(1))-FLOAT (I-1)*A*DZS)
0011      IYY(1)=INT (FLOAT (IY(1))+FLOAT (I-1)*B*DZS)
0012      IXX(2)=INT (FLOAT (IX(3))+FLOAT (I-1)*A*DZS)
0013      IYY(2)=INT (FLOAT (IY(3))+FLOAT (I-1)*B*DZS)
0014      RETURN
0015      END
    
```

ROUTINES CALLED.

FLOAT , SQRT , ATAN2 , COS , SIN , INT

OPTIONS =/OP:2

BLOCK	LENGTH
CNCO1	384 (001400)*

```

**COMPILER ----- CORE**
      PHASE      USED  FREE
DECLARATIVES 00622 14756
EXECUTABLES  00843 17515
ASSEMBLY      01097 18921
    
```

```

0001      SUBROUTINE CRD11(IY, Y, NPT, IX1, IX2, IY11, IY12, IY21, KK)
0002      DIMENSION Y(NPT), IY(NPT)
0003      CALL MAXMIN(Y, YMAX, YMIN, NPT)
0004      YMIN=0.
0005      YS=FLOAT(IY12-IY11)/(YMAX-YMIN)
0006      IY(1)=INT((Y(1)-YMIN)*YS+ 5)+IY11
0007      XX=FLOAT(IX2-IX1)
0008      YY=FLOAT(IY21-IY11)
0009      TH=ATAN2(YY, XX)
0010      R=SQRT(XX*XX+YY*YY)
0011      RS=R/FLOAT(NPT-1)
0012      B=SIN(TH)
0013      DO 2 I=2, NPT
0014      IY(I)=INT((Y(I)-YMIN)*YS+ 5+(FLOAT(I-1)*RS*B))+IY11
0015      CONTINUE
0016      RETURN
0017      END

```

ROUTINES CALLED:

MAXMIN, FLOAT, INT, ATAN2, SQRT, SIN

OPTIONS = /CP 3

BLOCK	LENGTH
CRD11	372 (001204)*

```

**COMPILER ----- CURP**
      PHASE      USED      FREE
DERIVATIVES 00622 14756
EXECUTABLES 00548 14435
ASSEMBLY    01137 19681

```

```

0001      SUBROUTINE LLEBP(X, IYC, NPT, IX1, IX2, IY11, IY21, KK)
0002      DIMENSION X(NPT), IYC(NPT)
0003      CALL INITT(0)
0004      CALL MAXMIN(X, XMAX, XMIN, NPT)
0005      XS=FLOAT(IX2-IX1)/(XMAX-XMIN)
0006      IX=INT((X()-XMIN)*XS+.5)-IX1
0007      CALL MOVABS(IX1, IY11)
0008      CALL DRWABS(IX, IYC(1))
0009      DO 2 I=2, NPT
0010      IX=INT((X(I)-XMIN)*XS+.5)-IX1
0011      IF(IYC(I).LT.0)CALL MOVABS(IX, IABS(IYC(I)))
0012      IF(IYC(I).GT.0)CALL DRWABS(IX, IYC(I))
0013      2    CONTINUE
0014      IF(KK.GT.1)GO TO 3
0015      CALL DRWABS(IX2, IY21)
0016      CALL DRWABS(IX1, IY11)
0017      3    CALL FINITT(0, 780)
0018      RETURN
0019      END

```

ROUTINES CALLED:

INITI, MAXMIN, FLOAT, INT, MOVABS, DRWABS, IABS
FINITT

OPTIONS =/OP:2

BLOCK LENGTH

LLEBP 332 (001204)*

COMPILER ----- CORE

PHASE USED FREE

DECLARATIVES 00622 14756

EXECUTABLES 00863 14515

ASSEMBLY 01153 18865

```

0001      SUBROUTINE MAXMIN(Y, YMAX, YMIN, NPT)
0002      REAL Y(NPT)
0003      YMAX=Y(1)
0004      YMIN=Y(1)
0005      DO 10 I=2, NPT
0006          IF(Y(I).GT. YMAX) YMAX=Y(I)
0007          IF(Y(I).LT. YMIN) YMIN=Y(I)
0008 10      CONTINUE
0009      RETURN
0010      END
    
```

OPTIONS =/OPI:2

MODEL LENGTH
 MAXMIN 103 (000372)*

COMPILER ----- CORP
 PHASE USED FREE
 DECLARATIVES 00622 14756
 EXECUTABLES 00702 14473
 ASSEMBLY 00937 19031

```

0001      SUBROUTINE CHUD(IX,IY,IXX,IYY,I,RATE,KK,IH)
0002      INTEGER IX(1),IY(1),IXX(1),IYY(1)
0003      DX=FLOAT(IX(5)-IX(1))
0004      DY=FLOAT(IY(5)-IY(1))
0005      DZ=SQRT(DX*DX+DY*DY)
0006      DZS=DZ/FLOAT(KK)
0007      TH=ATAN2(DY,DX)
0008      A=COS(TH)
0009      B=SIN(TH)
0010      IC=INT(RATE*FLOAT(IH))
0011      IXX(1)=INT(FLOAT(IX(1))+FLOAT(1-1)*A*DZS)
0012      IYY(1)=INT(FLOAT(IY(1))+FLOAT(1-1)*B*DZS)
0013      IXX(2)=IXX(1)
0014      IYY(2)=IYY(1)+IC
0015      IXX(3)=INT(FLOAT(IX(3))+FLOAT(1-1)*A*DZS)
0016      IYY(3)=INT(FLOAT(IY(3))+FLOAT(1-1)*B*DZS)
0017      IXX(4)=IXX(3)
0018      IYY(4)=IYY(3)+IC
0019      RETURN
0020      END

```

ROUTINES CALLED

FLOAT , SQRT , ATAN2 , COS , SIN , INT

OPTIONS =/OP 2

BLOCK	LENGTH
CHUD	459 (001626)*

COMPILER ----- CORE		
PHASE	USED	FREE
DECLARATIVES	00622	14756
EXECUTABLES	00943	14435
ASSEMBLY	01125	18893

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