

SHORT NOTE

FORTRAN-V PROGRAM FOR CONTOURING POINT DENSITY ON PI-DIAGRAMS USING A MICROCOMPUTER

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INTRODUCTION

The PI-diagram and contour diagram are used widely in structure analysis of geological problems. The manual construction of the diagrams however, is boring and time consuming. In the past, there have been some works concerned with the computer-aided construction of the diagram, but no handy package utilizing a low-cost electric plotter. This paper provides a FORTRAN-V program which has been tested on a CDC Cyber 170, Data General Eclipse S140, and APPLE IIe system. Equipped with an inexpensive electric plotter such as the Watanabe MP1000 satisfactory drawings are obtained which can be used immediately.

PREPROCESSOR

The construction of a PI-diagram must be done by first projecting the positions of field data on an equal-area projection net, then computing the frequency distribution, and finally contouring the diagram. The projection procedure and the calculation of the frequency distribution are contained in any text on structural geology. Program PIPE1 executes these procedures.

CONTOURING

Contouring of regularly and irregularly distributed data has been discussed by many authors. The value for the PI-diagram to be contoured at any point can be evaluated as long as the raw data have been projected and the pole positions located. Basically, because there are no interpolation problems involved, the procedure is easier than for other contouring problems.

In this paper the author used a local patchwise algorithm to execute the contouring procedure. After the pole positions of the raw data have been located and the frequency distribution evaluated at nodal points of a proper mesh (the author used a 21×21 mesh), the gradient in both vertical and horizontal directions was approximated using an algorithm similar to that proposed by Akima (1978). Then the mesh was triangulated automatically with each of the vertices of the triangles located in the grid points where the value and its gradient in both X and Y directions were evaluated.

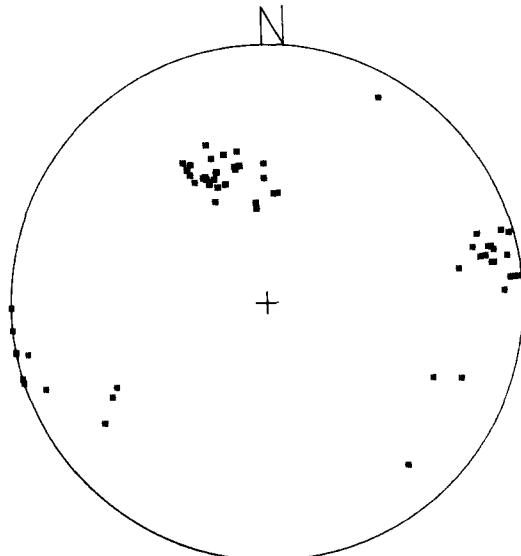


Figure 1A. PI-diagram of 40 joint and 45 bedding measurements collected in field survey (plotter output).

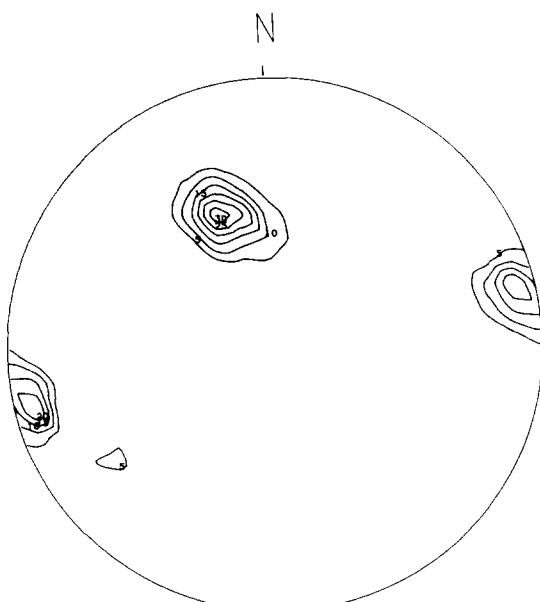


Figure 1B. Contour diagram of same data shown in Figure 1A (plotter output).

The patchwise contouring procedure begins by assuming a cubic plane to represent the value distribution in the triangle, with the value and gradient known at the vertices, there are nine equations to solve for the ten unknowns to evaluate the coefficients of the proposed polynomial. Although a complete cubic polynomial insures C^0 continuity (that is, the continuity of the value), the continuity of the slope is not automatic. By forcing the normal gradients across the triangle boundaries to be linear this defect can be removed (Allman, 1971).

This gives three more equations. By using the Lagrangian multiplier method the ten coefficients of the cubic plane which analytically approximates the value distribution of the triangle can be solved. After this, the locations passed by any optionally selected contour line can be located easily by solving a third-order linear equation. The plotting procedure follows this procedure to complete the diagram desired.

EXAMPLE

Figure 1 shows (A) the PI-diagram, and (B) the contoured diagram for 40 joint and 45 bedding measurements collected in a field survey using the programs PIPE1 and PIPE2. The results were checked, and are promising.

DISCUSSION

(1) By taking advantage of the local patchwise algorithm, the program does not need a large computer memory. This makes the program executable on a 64K-RAM microcomputer such as the APPLE IIe system.

(2) A properly selected mesh and approximation procedure makes the drawings of the contour diagram accurate and smooth, while the job is not time con-

suming. (Of course, to run the program on a 8-bit microcomputer takes more time.)

THE PROGRAM

Program PIPE1 (Appendix 1) reads in field data such as measurements of bedding planes, joints, or linear structural data in their natural strike and dip form, for example N65° E30°W. Then it plots the pole positions and computes the frequency distribution. The program outputs two data files. File 'CHECK' is for the rough distribution in digital form which aids in the selection of the proper values to be contoured. File 'PIGRAM' serves as input to program PIPE2. Program PIPE2 (Appendix 2) does not need extra input except for several controlling parameters such as the radius of a projection net, total number of contour lines, and value of each line to be contoured. It uses File 'PIGRAM' to execute the contouring procedure.

The plotting routine, which drives the plotter, was written to be compatible to the CALCOMP plotter package which is a popular plotter package. The subroutines CALL PLOT(X,Y,2), CALL PLOT(X,Y,3), CALL NUMBER . . . , CALL SYMBOL . . . , etc. drive the plotter. CALL BEGIN and CALL FINISH initiates and resets the plotter. For the Watanbee MP1000 plotter, the program needs only minor modifications. The program was written basically in FORTRAN-V. For a different computer, only the I/O needs to be modified.

REFERENCES

- Akima, H., 1978, A method of bivariate interpolation and smooth surface fitting for irregularly distributed data points: ACM Trans. Math. Software v. 4, no. 2, p. 148-159.
 Allman, D. J., 1971, Triangular plate element for plate bending with constant and linearly varying bending moments: Highspeed Comp. Elastic Struct., 1, Liège, Belgium, p. 105-136.

APPENDIX 1

PIPE1

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CC      PROGRAM FOR CONSTRUCTION OF PI-DIAGRAM AND EVALUATING DENSITY
CC      FREQUENCY DISTRIBUTION
CC      I/O CHANNEL: 6-MONITER OUTPUT,5-KEYBOARD INPUT
CC          20-INPUT DATA FILE OF BEDDING;JOINT...ECT
CC          33-OUTPUT DATA FILE "CHECK" TO AID THE CHOICE OF THE
CC          VALUE TO BE CONTOURED
CC          23-OUTPUT DATA FILE "PIGRAM"--INPUT OF PROGRAM "PIPE2"
CC      SUBROUTINE CALLED: POLPLOT,MESH,EVA,CIRCLE
C
COMMON/LB3/X(200),Y(200)
COMMON/LB2/XS(500),YS(500),ZS(500)
WRITE(6,229)
229 FORMAT(1X,'INPUT DATA FILE=?')
READ(5,1) IFLE
1 FORMAT(S20)
CALL FOPEN(20,IFLE)
CALL FOPEN(33,'CHECK')
CALL FOPEN(23,'PIGRAM')
WRITE(6,119)
119 FORMAT("RADIUS OF PROJECTION NET=")
READ(5,*) RS
ING=0.
CALL EVA(RS,N)

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CALL POLPLOT(RS,N)
CALL MESH(RS)

C
C EVALUATING DENSITY FREQUENCY OF EACH GRID POINT
C

DO 100 I=1,21*21
M=0
DO 300 K=1,N
DT=SQRT((XS(I)-X(K))*(XS(I)-X(K))+(YS(I)-Y(K))*(YS(I)-
+Y(K)))
IF(DT.LE.RS/10) M=M+1
DS=SQRT(XS(I)*XS(I)+YS(I)*YS(I))
IF(ABS(DS-RS).GT.RS/10) GO TO 300
DT=SQRT((XS(I)+X(K))*(XS(I)+X(K))+(YS(I)+Y(K))*(YS(I)-
+Y(K)))
IF(DT.LE.RS/10) M=M+1
CONTINUE
300 PM=(FLOAT(M)/FLOAT(N))*100.
ZS(I)=PM
CONTINUE
100 WRITE(33,338) (ZS(K),K=1,21*21)
338 FORMAT(21F3.0)
WRITE(23,20) (XS(K),YS(K),ZS(K),K=1,21*21)
20 FORMAT(1X,21F6.2)
CALL FINISH
STOP
END

C
C SUBROUTINE FOR PLOTTING PI-DIAGRAM
C

SUBROUTINE POLPLOT(RS,L)
COMMON/LB3/X(200),Y(200)
CALL BEGIN
DO 100 J=1,L
CALL PLOT(X(J)+RS,Y(J)+RS,3)
CALL SYMBOL(X(J)+RS,Y(J)+RS,0.07,3,0.0,-1)
CALL CIRCLE(RS)
RETURN
END

C
C SUBROUTINE FOR DATA INPUT AND PROJECTIONS ON AN EQUAL-AREA NET
C

THE INPUT DATA FORMAT: N40.5E 30.0W ,THE STRIKE MUST BE N**E OR
N**W, THE DIP MUST BE EITHER E OR W
C

SUBROUTINE EVA(RS,J)
COMMON/LB/X(200),Y(200),Z(200)
COMMON/LB3/XX(200),YY(200)
J=1
10 READ(20,20,ERR=100,END=100) IS1,STK,IS2,DIP,IDP
20 FORMAT(A1,F4.1,A1,1X,F4.1,A1)
WRITE(6,20) IS1,STK,IS2,DIP,IDP
IF((IS2.EQ."E").AND.(IDP.EQ."E")) STK=STK+270
IF((IS2.EQ."E").AND.(IDP.EQ."W")) STK=STK+90
IF((IS2.EQ."W").AND.(IDP.EQ."E")) STK=270-STK
IF((IS2.EQ."W").AND.(IDP.EQ."W")) STK=90-STK
STK=(STK/180)*3.14159265
DIP=(DIP/180)*3.14159265
X(J)=RS*SIN(DIP)*SIN(STK)
Y(J)=RS*SIN(DIP)*COS(STK)
Z(J)=RS*COS(DIP)
RR=(SQRT(2.)*RS*SIN(DIP/2.))/SQRT(X(J)*X(J)+Y(J)*Y(J))
XX(J)=X(J)*ABS(RR)
YY(J)=Y(J)*ABS(RR)
J=J+1
GO TO 10
100 J=J-1
WRITE(6,101) J
101 FORMAT("J=",1X,I4)
RETURN
END

C
C ROUTINE TO DRAW A CIRCLE
C

SUBROUTINE CIRCLE(RS)
CALL PLOT(RS,2*RS+0.07,3)
CALL SYMBOL(RS,2*RS+0.07,0.14,13,0.0,-1)
CALL PLOT(RS-0.1,2*RS+0.8,3)
CALL SYMBOL(RS-0.1,2*RS+0.8,0.21,1HN,0.0,1)

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CALL PLOT(2*RS,RS,3)
DO 100 I=1,101
DP=(3.14159265/50)*(I+1)
CALL PLOT(RS*COS(DP)+RS,RS*SIN(DP)+RS,2)
100 CONTINUE
CALL PLOT(0.,0.,3)
RETURN
END
C
C SUBROUTINE MESH
C
SUBROUTINE MESH(RS)
COMMON/LB2/XM(500),YM(500),ZM(500)
X=0.1
Y=X
DO 100 I=1,21
D=Y*(I-1)-1.
DO 200 J=1,21
P1=D
P2=(J-1)*Y-1.
XM(21*(I-1)+J)=P2*RS
YM(21*(I-1)+J)=P1*RS
200 CONTINUE
100 CONTINUE
RETURN
END

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APPENDIX 2

PIPE2

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CC PROGRAM PIPE2 FOR AUTOMATIC CONTOURING OF THE PI-DIAGRAM
CC I/O CHANNEL: 6-MONITER OUTPUT,5-KEYBOARD INPUT
CC           23-DATA FILE "PIGRAM" (OUTPUT FROM *PIPE1*)
CC SUBROUTINE CALLED: PPLOT,GAUSS,REF2,REF3,SOL,CIRCLE
C
DIMENSION X(5,21),Y(5,21),V(5,21),PX(2,30),PY(2,30),PP(3)
DIMENSION P(30,3),IFMT(10),IIN(30),F(30),PPR(3,3)
DIMENSION SS(50),KN(10)
COMMON/LB/XX(3),S(3),YY(3),VV(3),PPX(3),PPY(3),B(3),C(3),VAL(10)
DATA RE,SI/2.,0.1/
DATA NC,NR,NS,NE,ID,JJK/21,21,1,21,1,-1/
CALL FOPEN(23,"PIGRAM")
CALL BEGIN
WRITE(6,399)
399 FORMAT(1X,'RADIUS OF THE PROJECTION NET=?')
READ(5,*) RSD
CALL PLOT(RSD,RSD,-3)
C
C * KEY IN THE OPTIONAL CHOOSING VALUE TO BE CONTOURED *
C
WRITE(6,188)
188 FORMAT(1X,"NUMBER AND VALUE OF CONTOUR=")
READ(5,*) NPO,(VAL(K),K=1,NPO)
WRITE(6,199)
199 FORMAT(1X,'DO YOU WANT TO MARK THE VALUE ON THE DIAGRAM (Y/N) ?')
READ(5,177) IAA
177 FORMAT(A1)
DO 55 I=1,NPO
55 KN(I)=0
DO 1111 I=1,NR
DO 1111 J=1,2
PX(J,I)=0.
PY(J,I)=0.
LA=NS-ID
LC=NS+ID
C
C READ IN FILE 'PIGRAM' WHICH IS THE FREQUENCY DISTRIBUTION TO BE
C CONTOURED
C
110 DO 120 I=1,LC-LA+2
IF(I+LA-1.LE.0) GO TO 120

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IF(I+LA-1.GT.NC) GO TO 120
READ(23,20) (X(I,J),Y(I,J),V(I,J),J=1,NR)
9771 CONTINUE
120 CONTINUE
20 FORMAT(1X,21F6.2)
LB=1
LO=NS-1
C
C EVALUATE THE GRADIEND IN BOTH X- & Y-DIRECTION
C
700 DO 1000 I=1,NR
LK=I-ID
IF(LK.LT.1) LK=1
LM=I+ID
IF(LM.GT.NR) LM=NR
DO 201 NL=1,3
DO 202 ML=1,30
P(ML,NL)=0.
202 F(ML)=0.
201 PP(NL)=0.
MG=LC-ID+LB-LA
NG=I
MP=1
DO 200 JJ=1,LC-LA+1
J=JJ
IF(LB.EQ.2) J=J+1
IF(J+LA-1.LE.0) GO TO 200
IF(J+LA-1.GT.NC) GO TO 200
DO 300 K=LK,LM
IF(J.EQ.MG.AND.K.EQ.NG) GO TO 300
P(MP,1)=X(J,K)-X(MG,NG)
P(MP,2)=Y(J,K)-Y(MG,NG)
P(MP,3)=V(J,K)-V(MG,NG)
SS(MP)=SQRT(P(MP,1)*P(MP,1)+P(MP,2)*P(MP,2))
F(MP)=ATAN2(P(MP,2),P(MP,1))
IF(F(MP).LT.0.) F(MP)=F(MP)+3.14159265*2.
MP=MP+1
300 CONTINUE
200 CONTINUE
MP=MP-1
IM=1
277 SSS=SS(1)
PPP=F(1)
ILP=1
IKP=0
IMP=0
DO 175 IO=1,MP
255 IF(F(IO).GT.PPP) GO TO 175
IF(F(IO).NE.PPP) GO TO 176
IF(SS(IO).EQ.SSS) GO TO 175
IF(SS(IO).GT.SSS) GO TO 177
IMP=IMP+1
IIN(IMP)=IPK
176 PPP=F(IO)
SSS=SS(IO)
ILP=IO
GO TO 175
177 IMP=IMP+1
IIN(IMP)=IO
175 IPK=ILP
IF(IM.EQ.1) GO TO 388
OS=PPP-PPS
OS=SIN(OS)
IF(OS.LE.SIN(3.14)) GO TO 877
GO TO 788
877 IKP=1
788 CONTINUE
388 F(ILP)=F(MP)
SS(ILP)=SS(MP)
DO 1007 KO=1,IMP
IF(IIN(KO).NE.MP) GO TO 1007
IIN(KO)=ILP
1007 CONTINUE
DO 179 KH=1,3
IF(IM.EQ.1) PPR(3,KH)=P(ILP,KH)
PPR(IM,KH)=P(ILP,KH)
P(ILP,KH)=P(MP,KH)
MP=MP-1
PPS=PPP

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IF(IM.EQ.1) PPT=PPP
IF(IMP.EQ.0) GO TO 477
IF(MP.LE.IMP) GO TO 477
DO 266 NZ=1,IMP
F(IIN(NZ))=F(MP-NZ+1)
SS(IIN(NZ))=SS(MP-NZ+1)
DO 189 KH=1,3
189 P(IIN(NZ),KH)=P(MP-NZ+1,KH)
IF(NZ+1.GT.IMP) GO TO 266
DO 1008 NY=NZ+1,IMP
IF(IIN(NY).NE.MP-NZ+1) GO TO 1008
IIN(NY)=IIN(NZ)
1008 CONTINUE
266 CONTINUE
MP=MP-IMP
477 IF(IM.EQ.2) GO TO 1999
IM=IM+1
IF(IM.GE.2) GO TO 277
1999 IF(IKP.EQ.1) GO TO 377
PP(1)=PP(1)+PPR(1,2)*PPR(2,3)-PPR(1,3)*PPR(2,2)
PP(2)=PP(2)+PPR(1,3)*PPR(2,1)-PPR(1,1)*PPR(2,3)
PP(3)=PP(3)+PPR(1,1)*PPR(2,2)-PPR(1,2)*PPR(2,1)
377 CONTINUE
DO 299 IZ=1,3
299 PPR(1,IZ)=PPR(2,IZ)
IF(MP.GT.0.) GO TO 277
OS=PPT-PPP
OS=SIN(OS)
IF(OS.LE.SIN(3.14)) GO TO 577
PP(1)=PP(1)+PPR(1,2)*PPR(3,3)-PPR(1,3)*PPR(3,2)
PP(2)=PP(2)+PPR(1,3)*PPR(3,1)-PPR(1,1)*PPR(3,3)
PP(3)=PP(3)+PPR(1,1)*PPR(3,2)-PPR(1,2)*PPR(3,1)
577 CONTINUE
PX(LB,I)=-(PP(1)/PP(3))
PY(LB,I)=-(PP(2)/PP(3))
1000 CONTINUE
IF(LB.EQ.1) GO TO 500
LO=LO+1
IF(LO.EQ.NE) GO TO 801
GO TO 600.
500 LB=LB+1
IF(LB.EQ.2) GO TO 700
GO TO 907
505 CONTINUE
605 CONTINUE
600 DO 602 I=1,NR-1
JJK=JJK+2
WRITE(6,*) JJK
LD=LC-LA+1-ID
XX(1)=X(LD,I+1)
XX(2)=X(LD+1,I)
XX(3)=X(LD,I)
YY(1)=Y(LD,I+1)
YY(2)=Y(LD+1,I)
YY(3)=Y(LD,I)
VV(1)=V(LD,I+1)
VV(2)=V(LD+1,I)
VV(3)=V(LD,I)
PPX(1)=PX(1,I+1)
PPX(2)=PX(2,I)
PPX(3)=PX(1,I)
PPY(1)=PY(1,I+1)
PPY(2)=PY(2,I)
PPY(3)=PY(1,I)
CALL PPLOT(NPO,SI,RE,KN,RSD,IAA)
777 XX(3)=XX(2)
YY(3)=YY(2)
VV(3)=VV(2)
PPX(3)=PPX(2)
PPY(3)=PPY(2)
XX(2)=X(LD+1,I+1)
YY(2)=Y(LD+1,I+1)
VV(2)=V(LD+1,I+1)
PPX(2)=PX(2,I+1)
PPY(2)=PY(2,I+1)
KKJ=JJK+1
CALL PPLOT(NPO,SI,RE,KN,RSD,IAA)
602 CONTINUE
IF(LO.EQ.NE-1) GO TO 801

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LA=LA+1
DO 900 K=1,NR
PX(1,K)=PX(2,K)
PY(1,K)=PY(2,K)
DO 800 I=2,1D*2+2
V(I-1,K)=V(I,K)
X(I-1,K)=X(I,K)
Y(I-1,K)=Y(I,K)
800 CONTINUE
900 CONTINUE
509 LC=LC+1
MM=LC-LA+2
521 READ(23,20,END=666) (X(MM,K),Y(MM,K),V(MM,K),K=1,NR)
666 GO TO 700
801 CALL CIRCLE(RSD)
907 STOP
END

C
C CONTOURING USING PATCHWISE ALGORITM
C
SUBROUTINE PPLOT(NPO,SI,RE,KN,RSD,IAA)
DIMENSION PX(90),LQQ(20),PY(90),SS(90),NA(9)
DIMENSION SL(3),PL(10),ROOT(3),SLD(2)
DIMENSION XPX(10,50),YPY(10,50),KN(10)
COMMON/LB/XX(3),S(3),YY(3),V(3),PPX(3),PPY(3),B(3),C(3),VAL(10)
MO=3
102 DO 240 J=1,3
LK=J+1
LL=J-1
IF(LK.GT.3) LK=1
IF(LL.LT.1) LL=3
230 B(J)=YY(LK)-YY(LL)
C(J)=XX(LL)-XX(LK)
S(J)=SQRT(B(J)*B(J)+C(J)*C(J))
240 CONTINUE
SPXD=(AMAX1(S(1),S(2),S(3)))*SI*.2.
93 CONTINUE
CALL REF2(PL)
DO 100 K=1,NPO
IF(VAL(K).GT.AMAX1(V(1),V(2),V(3)).OR.VAL(K).LT.AMIN1(V(1),V(2),
,V(3))) GO TO 100
LOP=K
DL=0.
KM=1
NW=0
303 DO 300 M=1,3
IR=M
CALL SOL(DL,IR,LOP,ROOT,PL,MO)
IR=M
DO 301 IL=1,3
IF((ROOT(IL).LT.0.).OR.(ROOT(IL).GT.1.)) GO TO 301
L1=IR+1
L2=IR-1
IF(L1.GT.3) L1=1
IF(L2.LT.1) L2=3
111 SL(L1)=1.-DL-ROOT(IL)
SL(L2)=DL
SL(IR)=ROOT(IL)
IF((SL(L1).GT.1.).OR.(SL(L1).LT.0.).OR.(SL(L2).GT.1.).OR.
+(SL(L2).LT.0.)) GO TO 301
PX(KM)=XX(1)*SL(1)+XX(2)*SL(2)+XX(3)*SL(3)
PY(KM)=YY(1)*SL(1)+YY(2)*SL(2)+YY(3)*SL(3)
PPGY=PX(KM)*PX(KM)+PY(KM)*PY(KM)
IF(PPGY.GT.RSD*RSD) GO TO 301
IF(DL.NE.0.) GO TO 525
NW=NW+1
NA(NW)=KM
KN(K)=KN(K)+1
IF(KN(K).GT.50) KN(K)=1
NKN=KN(K)
XPX(K,NKN)=PX(KM)
YPY(K,NKN)=PY(KM)
525 KM=KM+1
301 CONTINUE
300 CONTINUE
IF(NW.LT.1.) GO TO 100
DL=DL+SI
IF(DL.GT.1.) GO TO 646
GO TO 303

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646 KM=KM-1
    IF(NW.LE.0) GO TO 100
    MK=0
    DO 188 LJ=1,NW
    NK=NA(LJ)
    IF(NKN-NW.LT.1) GO TO 321
    DO 177 LU=1,NKN-NW
    POX=XPX(K,LU)-PX(NK)
    POY=YPY(L,LU)-PY(NK)
    PPOXY=SQRT(POX*POX+POY*POY)
    IF(PPOXY.GT.0.005) GO TO 177
    MK=MK+1
    PX(NK)=PX(NA(MK))
    PY(NK)=PY(NA(MK))
    PX(NA(MK))=XPX(K,LU)
    PY(NA(MK))=YPY(K,LU)
    MMM=NA(MK)
    NA(MK)=NK
    NK=MMM
    GO TO 188
177 CONTINUE
188 CONTINUE
321 CONTINUE
    IF(IAA.EQ."N ".OR.NKN.GT.3.OR.MK.GE.1) GO TO 199
    CALL NUMBER(PX(NK),PY(NK),0.14/RE,VAL(K),0.0,-1)
199 DO 441 NB=1,NW
    NK=NA(NB)
    CALL PLOT(PX(NK),PY(NK),3)
656 IF(KM.GT.1) GO TO 454
    GO TO 100
454 DO 412 IP=1,KM
    SAS=(PX(IP)-PX(NK))*(PX(IP)-PX(NK))
    SBS=(PY(IP)-PY(NK))*(PY(IP)-PY(NK))
    SS(IP)=SQRT(SAS+SBS)
    IF(IP.EQ.NK) SS(IP)=1000.
412 CONTINUE
    DO 297 I=1,KM-1
    IF(SS(I).LE.SS(I+1)) GO TO 298
    SSS=SS(I+1)
    GO TO 398
298 SSS=SS(I)
398 SS(I+1)=SSS
297 CONTINUE
409 DO 413 IQ=1,KM
    IF(SS(IQ).EQ.SSS) GO TO 414
413 CONTINUE
414 IF(SSS.LE.SPXD) GO TO 408
    GO TO 441
408 CALL PLOT(PX(IQ),PY(IQ),2)
400 DO 437 NC=NB,NW
    ND=NA(NC)
    IF((PX(IQ).EQ.PX(ND)).AND.(PY(IQ).EQ.PY(ND))) GO TO 441
437 CONTINUE
    PX(NK)=PX(IQ)
    PY(NK)=PY(IQ)
    PX(IQ)=PX(KM)
    PY(IQ)=PY(KM)
    KM=KM-1
    GO TO 656
441 CONTINUE
100 CONTINUE
410 RETURN
END
C
C      SUBROUTINE FOR GAUSS ELIMINATION
C
        SUBROUTINE GAUSS1(N,A,C)
        DIMENSION A(N,N),C(N),CO(10)
        NDM=N-1
        DO 1002 I=1,NDM
        DO 20 J=I+1,N
        IF(ABS(A(J,I)).LE.ABS(A(I,I))) GO TO 20
        DO 15 K=1,N
        TEMP=A(I,K)
        A(I,K)=A(J,K)
        A(J,K)=TEMP
15      CONTINUE
        TENP=C(I)
        C(I)=C(J)

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C(J)=TENP
CONTINUE
DO 40 J=I+1,N
CO(J)=A(J,I)/A(I,I)
DO 41 K=I+1,N
41 A(J,K)=A(J,K)-A(I,K)*CO(J)
40 C(J)=C(J)-C(I)*CO(J)
1002 CONTINUE
I=N
C(I)=C(I)/A(I,I)
DO 100 J=1,N-1
IB=N-J
DO 101 K=1,J
101 C(IB)=C(IB)-C(IB+K)*A(IB,IB+K)
100 C(IB)=C(IB)/A(IB,IB)
RETURN
END
C
C SUBROUTINE FOR EVALUATION OF COEFFICIENTS OF THE CUBIC POLINOMIAL
C
SUBROUTINE REF2(PF)
DIMENSION P(10),D(3),E(3),TE(5),PF(10),PP(10,10),PQ(3,4)
COMMON/LB/X(3),S(3),Y(3),V(3),PX(3),PY(3),B(3),C(3),VAL(10)
DO 43 I=1,10
DO 41 J=1,10
PP(I,J)=0.
41 CONTINUE
PF(I)=0.
43 CONTINUE
DO 1 I=1,3
PP(I,1)=X(I)*X(I)*X(I)
PP(I,2)=X(I)*X(I)*Y(I)
PP(I,3)=X(I)*Y(I)*Y(I)
PP(I,4)=Y(I)*Y(I)*Y(I)
PP(I,5)=X(I)*X(I)
PP(I,6)=X(I)*Y(I)
PP(I,7)=Y(I)*Y(I)
PP(I,8)=X(I)
PP(I,9)=Y(I)
PP(I,10)=1.
PF(I)=V(I)
PF(I+3)=PX(I)
PF(I+6)=PY(I)
PF(10)=0.
DO 2 J=3,6,3
IF(J.EQ.3) GO TO 4
PP(I+J,4)=3*Y(I)*Y(I)
PP(I+J,3)=2.*X(I)*Y(I)
PP(I+J,2)=X(I)*X(I)
PP(I+J,7)=2.*Y(I)
PP(I+J,6)=X(I)
PP(I+J,9)=1.
GO TO 2
4 PP(I+J,1)=3.*X(I)*X(I)
PP(I+J,2)=2.*X(I)*Y(I)
PP(I+J,3)=Y(I)*Y(I)
PP(I+J,5)=2.*X(I)
PP(I+J,6)=Y(I)
PP(I+J,8)=1.
2 CONTINUE
J=I-1
K=I+1
IF(J.LE.0.) J=3
IF(K.GT.3) K=1
D(I)=C(I)/S(I)
E(I)=-B(I)/S(I)
TE(1)=X(K)*X(K)+D(I)*X(K)*S(I)+D(I)*D(I)*S(I)*S(I)/3.
TE(2)=X(K)*Y(K)+(D(I)*Y(K)+E(I)*X(K))*S(I)/2.+D(I)*E(I)
+*S(I)*S(I)/3.
TE(3)=Y(K)*Y(K)+E(I)*Y(K)*S(I)+E(I)*E(I)*S(I)*S(I)/3.
TE(4)=X(K)+D(I)*S(I)/2.
TE(5)=Y(K)+E(I)*S(I)/2.
PP(10,1)=PP(10,1)+3*B(I)*TE(1)
PP(10,2)=PP(10,2)+C(I)*TE(1)+2*B(I)*TE(2)
PP(10,3)=PP(10,3)+2*C(I)*TE(2)+B(I)*TE(3)
PP(10,4)=PP(10,4)+3*C(I)*TE(3)
PP(10,5)=PP(10,5)+2*B(I)*TE(4)
PP(10,6)=PP(10,6)+C(I)*TE(4)+B(I)*TE(5)
PP(10,7)=PP(10,7)+2*C(I)*TE(5)

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PP(10,8)=PP(10,8)+B(I)
PP(10,9)=PP(10,9)+C(I)
1  CONTINUE
    CALL GAUSS1(10,PP,PF)
    RETURN
    END
C
C   SUBROUTINE FOR 3-ORDER LINEAR EQATION SOLUTION
C
SUBROUTINE SOL(DL,I,LOP,SD,PL,MO)
DIMENSION PL(10),SD(3),PM(4)
COMMON/LB/X(3),S(3),Y(3),V(3),PX(3),PY(3),B(3),C(3),VAL(10)
DO 7 MQ=1,3
7  SD(MQ)=-1.
DLO=1.-DL
K=I+1
J=I-1
IF(K.GT.3) K=1
IF(J.LT.1) J=3
1  CALL REF3(DL,DLO,PL,PM,I,K,J)
PM(4)=PM(4)-VAL(LOP)
IF(ABS(PM(1)).LE.1E-10) GO TO 69
PPP=PM(1)
DO 2 J=1,4
2  PM(J)=PM(J)/PPP
PD=PM(3)-PM(2)*PM(2)/3.
QD=2.*PM(2)*PM(2)*PM(2)/27.-PM(2)*PM(3)/3.+PM(4)
IF(ABS(PD).EQ.0.) GO TO 61
PD=PD/3.
QD=QD/2.
D=QD*QD+PD*PD*PD
IF(D-0.) 3,4,5
3  CONTINUE
R=SQRT(ABS(PD*PD*PD))
ANG=-(QD)/R
ANGS=SQRT(ABS(1.-ANG*ANG))
ANG=ATAN2(ANGS,ANG)
IF(ANG.LT.0.) ANG=ANG+3.14159265
ANG=ANG/3.
PR=R**(.1./3.)
SD(1)=2.*PR*COS(ANG)
SD(2)=2.*PR*COS(ANG+3.14159*2./3.)
SD(3)=2.*PR*COS(ANG+3.14159*4./3.)
DO 51 MN=1,3
51  SD(MN)=SD(MN)-PM(2)/3.
RETURN
4  CONTINUE
IF(-(QD).LT.0.) GO TO 94
IF(QD.EQ.0.) GO TO 38
SD(1)=(-QD)**(.1./3.)
GO TO 95
38  SD(1)=0.
GO TO 95
94  CONTINUE
SD(1)=-(QD**(.1./3.))
95  SD(2)=-SD(1)
SD(1)=2.*SD(1)
DO 52 MN=1,2
52  SD(MN)=SD(MN)-PM(2)/3.
GO TO 6
5  SD(1)=-QD+D**0.5
SD(2)=-QD-D**0.5
DO 96 NN=1,2
96  IF(SD(NN)-0.) 98,99,97
    SD(NN)=SD(NN)**(.1./3.)
    GO TO 96
99  SD(NN)=0.
GO TO 96
98  SD(NN)=-(SD(NN))**(.1./3.)
96  CONTINUE
    SD(1)=SD(1)+SD(2)
    SD(2)=-1.
    SD(1)=SD(1)-PM(2)/3.
    GO TO 6
69  BB=PM(3)
    AA=PM(2)
    CC=PM(4)
    IF(ABS(AA).LE.1E-10) GO TO 22
    DD=BB*BB-4.*AA*CC

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71   IF(DD) 71,72,73
72   RETURN
72   SD(1)=-BB/(2.*AA)
    RETURN
73   SD(1)=(-BB+(DD**0.5))/(2.*AA)
    SD(2)=-(BB+(DD**0.5))/(2.*AA)
    RETURN
22   IF(ABS(BB).LE.1E-10) RETURN
    SD(1)=-(CC/BB)
    RETURN
61   IF(QD) 81,84,82
81   SD(1)=(-QD)**(1./3.)
    GO TO 83
82   SD(1)=-(QD***(1./3.))
    GO TO 83
84   SD(1)=0.
83   SD(1)=SD(1)-PM(2)/3.
6   RETURN
END
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SUBROUTINE REF3(DL,DLO,PF,PM,I,K,J)
DIMENSION PF(10),PM(4)
COMMON/LB/X(3),S(3),Y(3),V(3),PX(3),PY(3),B(3),C(3),VAL(10)
XD=DLO*X(K)+DL*X(J)
YD=DLO*Y(K)+DL*Y(J)
PM(1)=PF(1)*(-C(J)*C(J)*C(J))+PF(3)*(-C(J)*B(J)*B(J))+PF(2)
+*C(J)*C(J)*B(J)+PF(4)*B(J)*B(J)*B(J)
PM(2)=PF(1)*3.*C(J)*C(J)*XD+PF(3)*(-2.*C(J)*B(J)*YD+B(J)*B(J)*XD)
++PF(2)*(C(J)*C(J)*YD-2.*B(J)*C(J)*XD)+PF(4)*3.*B(J)*B(J)*YD
++PF(5)*C(J)*C(J)+PF(6)*(-B(J)*C(J))+PF(7)*B(J)*B(J)
PM(3)=PF(1)*(-3.*C(J)*XD*XD)+PF(3)*(2.*B(J)*XD*YD-YD*YD*C(J))
++PF(2)*(-2.*C(J)*XD*YD+XD*XD*B(J))+PF(4)*3.
+*B(J)*YD*YD+PF(5)*(-2.*C(J)*XD)+PF(6)*(B(J)*XD-C(J)*YD)+PF(7)
+*2.*B(J)*YD+PF(8)*(-C(J))+PF(9)*B(J)
PM(4)=PF(1)*XD*XD*XD+PF(3)*XD*YD*YD+PF(2)*XD*XD*YD+PF(4)*YD*YD*YD
++PF(5)*XD*XD+PF(6)*XD*YD+PF(7)*YD*YD+PF(8)*XD+PF(9)*YD+PF(10)
RETURN
END
C
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C
SUBROUTINE CIRCLE(RS)
CALL PLOT(RS,0.,3)
DO 100 I=1,101
DP=(3.14159265/50)*(I-1)
CALL PLOT(RS*COS(DP),RS*SIN(DP),2)
CONTINUE
CALL PLOT(0.,0.,3)
RETURN
END
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