BSTALN - A COMPUTER IMPLEMENTATION OF AN ALGORITHM FOR THE BEST MECHANICAL ALIGNMENT PROBLEM

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Abstract

BSTALN is a Fortran implementation of a recently developed minimax approach to the best mechanical alignment problem in two dimensions. The program employs the MMLC package for linearly constrained minimax optimization, which must be made available. The BSTALN program is composed of a main segment and nine subroutines. The listing contains 941 lines, 335 of which are comments. The program and documentation have been developed for the CDC 170/730 system with the NOS 1.4 level 552 operating system and the Fortran Extended (FTN) version 4.8 compiler. This document contains a Fortran listing of the program.

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I. INTRODUCTION

A recently developed minimax approach to the best mechanical alignment problem in two dimensions [1] has been implemented as a Fortran IV program [2] for the CDC 170/730 system. The BSTALN program for solving the problem employs the MMLC package for linearly constrained minimax optimization [3], which must be made available when BSTALN is used.

The data files, created according to the format described in [2], must also be supplied.

The BSTALN program is composed of a main segment and nine subroutines. The listing contains 941 lines, 335 of which are comments.

The program and documentation have been developed for the CDC 170/730 system with NOS 1.4 level 552 operating system and the Fortran Extended (FTN) version 4.8 compiler.

This document contains a Fortran listing of the program.

II. REFERENCES

[1] J.W. Bandler, M.A. El-Kady, W. Kellermann and W.M. Zuberek, "A minimax approach to the best mechanical alignment problem", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-10-R, 1982. Also to appear in ASME J. of Mechanisms, Transmissions, and Automation in Design.

[2] J.W. Bandler, M.A. El-Kady, W. Kellermann and W.M. Zuberek, "BSTALN - a computer implementation of an algorithm for the best mechanical alignment problem", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-83-13-U, 1983.

[3] J.W. Bandler and W.M. Zuberek, "MMLC - a Fortran package for linearly constrained minimax optimization", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-5-U/L, 1982.

III. LISTING OF THE BSTALN PROGRAM

Subroutine	Number of lines (source text)	Number of words (compiled code)	Listing from page
BSTALN	183	1171	4
PRSRCH	49	144	6
SEARCH	169	625	7
INSRCH	74	301	10
SOLVER	106	605	11
FDF	146	557	12
TOLCIR	40	61	15
TOLXY	55	112	15
TOLXR	60	125	16
TOLYR	59	125	17

```
      PROGRAM BSTALN(SAMPLE,OUTPUT,TAPE1=SAMPLE,TAPE6=OUTPUT)                  000001
C                                                                              000002
C     THIS PROGRAM SOLVES THE BEST ALIGNMENT PROBLEM USING                     000003
C     MINIMAX OPTIMIZATION (PACKAGE MMLC).                                     000004
C                                                                              000005
C       XA  - VECTOR OF ACTUAL X DIMENSIONS(ABSOLUTE)                          000006
C       YA  - VECTOR OF ACTUAL Y DIMENSIONS(ABSOLUTE)                          000007
C       KTC - TOLERANCE CODE VECTOR                                            000008
C       KOC - ORIGIN CODE VECTOR                                               000009
C       T1  - TOLERANCE REGION PARAMETER VECTOR(ABSOLUTE)                      000010
C       T2  - TOLERANCE REGION PARAMETER VECTOR(ABSOLUTE)                      000011
C       T3  - TOLERANCE REGION PARAMETER VECTOR(ABSOLUTE)                      000012
C       T4  - TOLERANCE REGION PARAMETER VECTOR(ABSOLUTE)                      000013
C       T10 - TOLERANCE REGION PARAMETER VECTOR(RELATIVE)                      000014
C       T20 - TOLERANCE REGION PARAMETER VECTOR(RELATIVE)                      000015
C       T30 - TOLERANCE REGION PARAMETER VECTOR(RELATIVE)                      000016
C       T40 - TOLERANCE REGION PARAMETER VECTOR(RELATIVE)                      000017
C       XP  - VECTOR OF ACTUAL X DIMENSIONS(RELATIVE)                          000018
C       YP  - VECTOR OF ACTUAL Y DIMENSIONS(RELATIVE)                          000019
C       P   - PARAMETER SELECTING CANDIDATES FOR DELETING                      000020
C       MD  - MODE VECTOR INDICATING THE TYPE OF A POINT                       000021
C             MD(I)=0  REGULAR POINT                                           000022
C             MD(I)>0  REFERENCE POINT                                         000023
C             MD(I)<0  REFERENCED POINT                                        000024
C       NRF - VECTOR OF CURRENT RESIDUAL FUNCTION ORDERING                     000025
C       NRFF- VECTOR OF RESIDUAL FUNCTION ORDERING AT THE SOLUTION             000026
C       N   - NUMBER OF INITIAL VARIABLES                                      000027
C       M   - TOTAL NUMBER OF RESIDUAL FUNCTIONS                               000028
C       X   - VECTOR OF INITIAL VALUES OF VARIABLES                            000029
C       XX  - VECTOR OF THE BEST SOLUTION                                      000030
C       W   - WORKSPACE FOR *SEARCH* AND MINIMAX                               000031
C       IW  - LENTGH OF W                                                      000032
C       IM  - LENTGH OF WORKSPACE FOR MINIMAX                                  000033
C       NUM - NUMBER OF ELIMINATED RESIDUAL FUNCTIONS                          000034
C       MM  - CURRENT NUMBER OF RESIDUAL FUNCTIONS                             000035
C       IFLG- RETURN FLAG FROM *PRSRCH*                                        000036
C       L   - COUNTER OF RESIDUAL FUNCTIONS WITH POSITIVE VALUE                000037
C                                                                              000038
      DIMENSION X(13),W(2000),T(4),NRFF(20),XX(13)                             000039
      COMMON /BL1/XA(20),YA(20)                                                000040
      COMMON /BL2/KTC(20),T1(20),T2(20),T3(20),T4(20)                          000041
      COMMON /BL3/T10(20),T20(20),T30(20),T40(20)                              000042
      COMMON /BL4/KOC(20),MD(20)                                               000043
      COMMON /BL5/NRF(20)                                                      000044
      COMMON /BL6/XP(20),YP(20)                                                000045
      COMMON /BL7/PARAM                                                        000046
      DATA T(1)/10HHOLES C   /                                                 000047
      CALL SECOND(TIME1)                                                       000048
      CALL DATE(DAT)                                                           000049
      CALL TIME(TIM)                                                           000050
      REWIND 1                                                                 000051
C                                                                              000052
C       READ AND PRINT INPUT DATA FOR THE PROBLEM                              000053
C                                                                              000054
      WRITE(6,100)DAT,TIM                                                      000055
  100 FORMAT(/" INPUT DATA FOR THE BEST ALIGNMENT PROBLEM  DATE :",            000056
     1A9,"  TIME :",A10/)                                                      000057
      READ(1,200)M,PARAM,T(2),T(3),T(4)                                        000058
  200 FORMAT(I2,F6.4,2X,3A10)                                                  000059
      WRITE(6,300)M,T(1),T(2),T(3),T(4)                                        000060
  300 FORMAT(/" TOTAL NUMBER OF HOLES OF THE SAMPLE:",I3,5X,4A10/)             000061
      WRITE(6,600)                                                             000062
  600 FORMAT(//2X,"I",6X,"KTC(I)",1X,"KOC(I)",8X,"XA(I)",9X,                   000063
     1"YA(I)",9X,"T1(I)",9X,"T2(I)",9X,"T3(I)",9X,"T4(I)")                     000064
      DO 10 I=1,M                                                              000065
```

```
      READ(1,400)KTC(I),KOC(I),XA(I),YA(I),T1(I),T2(I),T3(I),T4(I)          000066
  400 FORMAT(2I3,6F8.0)                                                     000067
      WRITE(6,500)I,KTC(I),KOC(I),XA(I),YA(I),T1(I),T2(I),T3(I),T4(I)       000068
  500 FORMAT(/1X,I2,6X,I5,2X,I5,1X,6(F13.6,1X))                             000069
   10 CONTINUE                                                              000070
C                                                                           000071
C       FORM VECTORS XP AND YP                                              000072
C                                                                           000073
      DO 20 I=1,M                                                           000074
      XP(I)=XA(I)                                                           000075
      YP(I)=YA(I)                                                           000076
   20 CONTINUE                                                              000077
C                                                                           000078
C       FORM VECTORS T10,T20,T30,T40                                        000079
C                                                                           000080
      DO 25 I=1,M                                                           000081
      T10(I)=T1(I)                                                          000082
      T20(I)=T2(I)                                                          000083
      T30(I)=T3(I)                                                          000084
      T40(I)=T4(I)                                                          000085
   25 CONTINUE                                                              000086
      IW=2000                                                               000087
      IM=1402                                                               000088
C                                                                           000089
C       SET INITIAL VALUES OF VARIABLES                                     000090
C                                                                           000091
      X(1)=0.0                                                              000092
      X(2)=0.0                                                              000093
      X(3)=0.0                                                              000094
C                                                                           000095
C       CALCULATE ABSOLUTE DIMENSIONS XA,YA AND                             000096
C       TOLERANCE REGION PARAMETERS T1,T2,T3,T4                             000097
C                                                                           000098
      DO 30 I=1,M                                                           000099
      J=KOC(I)                                                              000100
      IF(J.EQ.0)GO TO 30                                                    000101
      XA(I)=XA(I)+XA(J)                                                     000102
      YA(I)=YA(I)+YA(J)                                                     000103
      IF(KTC(I).EQ.0)GO TO 40                                               000104
      IF(KTC(I).EQ.12)GO TO 50                                              000105
      IF(KTC(I).EQ.13)GO TO 60                                              000106
      IF(KTC(I).EQ.23)GO TO 70                                              000107
   40 T1(I)=T1(I)+XA(J)                                                     000108
      T2(I)=T2(I)+YA(J)                                                     000109
      GO TO 30                                                              000110
   50 T1(I)=T1(I)+XA(J)                                                     000111
      T2(I)=T2(I)+XA(J)                                                     000112
      T3(I)=T3(I)+YA(J)                                                     000113
      T4(I)=T4(I)+YA(J)                                                     000114
      GO TO 30                                                              000115
   60 T1(I)=T1(I)+XA(J)                                                     000116
      T2(I)=T2(I)+XA(J)                                                     000117
      GO TO 30                                                              000118
   70 T1(I)=T1(I)+YA(J)                                                     000119
      T2(I)=T2(I)+YA(J)                                                     000120
   30 CONTINUE                                                              000121
C                                                                           000122
C       INITIALIZE VECTOR OF CURRENT RESIDUAL FUNCTION ORDERING             000123
C                                                                           000124
      DO 33 I=1,M                                                           000125
   33 NRF(I)=I                                                              000126
C                                                                           000127
C       INITIALIZE MODE VECTOR                                              000128
C                                                                           000129
      DO 37 J=1,M                                                           000130
```

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   37 MD(J)=0                                                          000131
C                                                                      000132
C       CALCULATE RESIDUAL FUNCTIONS AT THE STARTING POINT             000133
C                                                                      000134
      CALL FDF(3,M,X,W(M+1),W(1))                                      000135
      WRITE(6,700)(I,W(I),I=1,M)                                       000136
  700 FORMAT(////" ERROR FUNCTIONS AT THE STARTING POINT"//(25X,       000137
     1I3,1X,1PE15.7))                                                  000138
C                                                                      000139
C       CHECK THE SIGN OF RESIDUAL FUNCTIONS AT THE STARTING POINT     000140
C                                                                      000141
      L=0                                                              000142
      DO 19 I=1,M                                                      000143
      IF(W(I).GT.0.0)L=L+1                                             000144
   19 CONTINUE                                                         000145
C                                                                      000146
C       BEGIN THE ALIGNMENT                                            000147
C                                                                      000148
      CALL PRSRCH(13,3,M,X,XX,NUM,FM,NRFF,L,W,IW,IM,IFLG)              000149
      IF(IFLG.LT.0)GO TO 90                                            000150
C                                                                      000151
C       PRINT FINAL RESULTS OF THE ALIGNMENT                           000152
C                                                                      000153
      WRITE(6,800)IFLG,XX(1),XX(2),XX(3),FM                            000154
  800 FORMAT(///" SOLUTION (TYPE:",I2,")"/,3(/29X,1PE15.7)//           000155
     1" MAX ERROR AT THE SOLUTION:",2X,1PE15.7/)                       000156
      MM=M-NUM                                                         000157
      WRITE(6,810) (NRFF(I),W(I),I=1,MM)                               000158
  810 FORMAT(25X,I3,1X,1PE15.7)                                        000159
      WRITE(6,820)NUM                                                  000160
  820 FORMAT(/" NUMBER OF DELETIONS:",20X,I3/)                         000161
      MM=MM+1                                                          000162
      IF(NUM.LE.0)GO TO 999                                            000163
      L=2                                                              000164
      DO 75 I=MM,M                                                     000165
      IF(W(I).GT.0.)GO TO 76                                           000166
      L=L+2                                                            000167
      WRITE(6,830)NRFF(I),W(I),XX(L),XX(L+1)                           000168
  830 FORMAT(25X,I3,1X,1PE15.7,3X,2(1PE15.7))                          000169
      GO TO 75                                                         000170
   76 WRITE(6,830)NRFF(I),W(I)                                         000171
   75 CONTINUE                                                         000172
      GO TO 999                                                        000173
      STOP                                                             000174
   90 WRITE(6,990)IFLG                                                 000175
  990 FORMAT(///" ERROR RETURN FROM SEARCH:",I3/)                      000176
  999 CALL SECOND(TIME2)                                               000177
      EXTIME=TIME2-TIME1                                               000178
      WRITE(6,805) EXTIME                                              000179
  805 FORMAT(/" TOTAL EXECUTION TIME :",F7.3," SECONDS")               000180
      STOP                                                             000181
      END                                                              000182
C                                                                      000183
C                                                                      000184
      SUBROUTINE PRSRCH(NX,N,M,X,XX,NUM,FM,NRFF,LIM,W,LW,LM,IFLG)      000185
      DIMENSION X(N),XX(NX),NRFF(M),W(LW)                              000186
C                                                                      000187
C   THIS SUBROUTINE ORGANIZES WORKSPACE MEMORY FOR *SEARCH* AND SETS   000188
C   THE RETURN FLAG *IFLG* :                                           000189
C       -2  ERROR RETURN FROM *SOLVER* OR MINIMAX,                     000190
C       -1  INSUFFICIENT WORKSPACE,                                    000191
C        0  SOLUTION OBTAINED,                                         000192
C        1  LARGER WORKSPACE REQUIRED,                                 000193
C        2  LIMIT OF LEVELS REACHED.                                   000194
C                                                                      000195
```

```
C     NX      - MAXIMUM NUMBER OF VARIABLES,                                  000196
C     N       - NUMBER OF INITIAL VARIABLES,                                  000197
C     M       - TOTAL NUMBER OF RESIDUAL FUNCTIONS,                           000198
C     X       - VECTOR OF INITIAL VALUES OF VARIABLES,                        000199
C     XX      - VECTOR OF VARIABLES AT THE BEST SOLUTION,                     000200
C     NUM     - NUMBER OF ELIMINATED RESIDUAL FUNCTIONS,                      000201
C     FM      - VALUE OF MINIMAX FUNCTION AT SOLUTION,                        000202
C     NRFF    - VECTOR OF RESIDUAL FUNCTION ORDERING AT SOLUTION,             000203
C     LIM     - LIMIT OF ELIMINATED RESIDUAL FUNCTIONS,                       000204
C     W       - WORKSPACE (FOR *SEARCH* AND MINIMAX),                         000205
C     LW      - LENGTH OF *W*,                                                000206
C     LM      - LENGTH OF WORKSPACE FOR MINIMAX,                              000207
C     IFLG    - RETURN FLAG.                                                  000208
C                                                                             000209
C     DATE : 82.06.15 (W.M.ZUBEREK)                                           000210
C                                                                             000211
      LOGICAL FIN,EXH                                                         000212
      JM=LW-LM+1                                                              000213
      JFF=1                                                                   000214
      JXR=JFF+M                                                               000215
      JNRF=JXR+NX                                                             000216
      JLACT=JNRF+M                                                            000217
      JLLIND=JLACT+M                                                          000218
      LLI=JM-JLLIND                                                           000219
      IFLG=-1                                                                 000220
      IF(LLI.LT.5*M) RETURN                                                   000221
      LCH=6                                                                   000222
      IFLG=-2                                                                 000223
      CALL SEARCH(NX,N,M,X,XX,W(JXR),NUM,FM,W(JFF),NRFF,W(JNRF),LIM,          000224
     1            W(JLACT),W(JLLIND),LLI,W(JM),LM,LCH,FIN,EXH,IERR)           000225
      IF(IERR.LT.0) RETURN                                                    000226
      IFLG=2                                                                  000227
      IF(EXH) IFLG=1                                                          000228
      IF(FIN) IFLG=0                                                          000229
      RETURN                                                                  000230
      END                                                                     000231
C                                                                             000232
C                                                                             000233
      SUBROUTINE SEARCH (NX,N,M,X,XX,XR,NUM,FMIN,FF,NRFF,NRF,LIM,LACT,        000234
     1                   LLIND,LLI,W,LW,LCH,FINISH,CLOSED,IER)                000235
      DIMENSION X(N),XX(NX),XR(N),FF(M),NRFF(M),NRF(M),LACT(M),               000236
     1          LLIND(LLI),W(LW)                                              000237
      LOGICAL FINISH,CLOSED                                                   000238
C                                                                             000239
C     NX     - MAXIMUM NUMBER OF VARIABLES,                                   000240
C     N      - NUMBER OF INITIAL VARIABLES,                                   000241
C     M      - TOTAL NUMBER OF RESIDUAL FUNCTIONS,                            000242
C     X      - VECTOR OF INITIAL VALUES OF VARIABLES,                         000243
C     XX     - VECTOR OF BEST SOLUTION,                                       000244
C     XR     - VECTOR OF CURRENT SUBPROBLEM SOLUTION,                         000245
C     NUM    - NUMBER OF ELIMINATED RESIDUAL FUNCTIONS,                       000246
C     FMIN   - VALUE OF MINIMAX FUNCTION AT SOLUTION,                         000247
C     FF     - VECTOR OF RESIDUAL FUNCTION VALUES AT SOLUTION,                000248
C     NRFF   - VECTOR OF RESIDUAL FUNCTION ORDERING AT SOLUTION,              000249
C     NRF    - VECTOR OF CURRENT RESIDUAL FUNCTION ORDERING,                  000250
C     LACT   - VECTOR OF CURRENT COUNTS,                                      000251
C     LLIND  - INDEX AND SUBSCRIPTS OF DECISION-TREE STRUCTURE,               000252
C     LLI    - LEGTH OF LLIND,                                                000253
C     W      - WORKSPACE FOR MINIMAX,                                         000254
C     LW     - LENGTH OF W,                                                   000255
C     LCH    - OUTPUT CHANNEL NUMBER,                                         000256
C     FINISH - OPTIMAL SOLUTION INDICATOR (IF .TRUE. - SOLUTION FOUND)        000257
C     CLOSED - MEMORY EXTEND INDICATOR (IF .TRUE. - MORE MEMORY NEEDED)       000258
C     IER    - RETURN FLAG FROM *SEARCH*.                                     000259
C                                                                             000260
```

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C     NOTE: FOR L-LEVEL SEARCH OF K-DECISION-TREE THE LENGTH "LLI"          000261
C           OF WORKSPACE "LLIND" SHOULD BE APPROXIMATELY K**(L+1).          000262
C                                                                           000263
C     FOR SUBPROBLEM MINIMAX OPTIMIZATION SUBROUTINE *SOLVER* IS            000264
C     CALLED:                                                               000265
C                                                                           000266
C        CALL SOLVER (NN,MM,M,XR,F,NRF,LLIND,LL,NR,W,LW,IERR)               000267
C                                                                           000268
C     NN     - NUMBER OF VARIABLES,                                         000269
C     MM     - CURRENT NUMBER OF RESIDUAL FUNCTIONS,                        000270
C     M      - TOTAL NUMBER OF RESIDUAL FUNCTIONS,                          000271
C     XR     - VECTOR OF INITIAL VALUES AND MINIMAX SOLUTION,               000272
C     F      - VALUE OF MINIMAX FUNCTION AT SOLUTION,                       000273
C     NRF    - VECTOR OF CURRENT RESIDUAL FUNCTION ORDERING,                000274
C     LLIND  - SUBSCRIPTS OF DECISION-TREE STRUCTURE,                       000275
C     LL     - CURRENT LENGTH OF LLIND,                                     000276
C     NR     - INDEX OF LAST VALUE STORED IN LLIND,                         000277
C     W      - WORKSPACE FOR MINIMAX,                                       000278
C     LW     - LENGTH OF W,                                                 000279
C     IERR   - RETURN FLAG FROM *SOLVER*.                                   000280
C                                                                           000281
C     NOTE: IT IS ASSUMED THAT THE SUBROUTINE *SOLVER* STORES IN LLIND      000282
C           NUMBERS (INDEXES) OF THOSE RESIDUAL FUNCTIONS WHICH ARE         000283
C           CANDIDATES FOR ELIMINATION IN FURTHER STEPS. NUMBER OF          000284
C           THOSE CANDIDATES FOR CURRENT SUBPROBLEM IS ASSUMED TO BE        000285
C           RETURNED AS "IERR" (IERR=0 INDICATES FINAL SOLUTION, I.E.       000286
C           NO CANDIDATES FOR ELIMINATION). ENTERING CANDIDATE NUMBERS      000287
C           INTO *LLIND* SHOULD FOLLOW THE SEQUENCE:                        000288
C                                                                           000289
C               IF (NR.GE.LL) GO TO 123                                     000290
C               NR=NR+1                                                     000291
C               LLIND(NR)=CURRENT.NUMBER.OF.CANDIDATE.RESIDUAL.FUNCTION     000292
C           123 CONTINUE                                                    000293
C                                                                           000294
C           NEGATIVE VALUES OF *IERR* INDICATE ERRORS DETECTED IN           000295
C           MINIMAX OR *SOLVER*.                                            000296
C                                                                           000297
C     DATE : 82.06.21 (W.M.ZUBEREK)                                         000298
C                                                                           000299
      FINISH=.FALSE.                                                        000300
      CLOSED=.FALSE.                                                        000301
      IER=-1                                                                000302
      LIMIT=MIN0(LIM,M-1)                                                   000303
      DO 9 I=1,N                                                            000304
    9 XR(I)=X(I)                                                            000305
      DO 10 I=1,M                                                           000306
      NRFF(I)=I                                                             000307
   10 NRF(I)=I                                                              000308
      NUM=0                                                                 000309
      NR=0                                                                  000310
      NN=N                                                                  000311
      CALL SOLVER(NN,M,M,XR,FMIN,NRF,LLIND,LLI,NR,W,LW,IE)                  000312
      IF(IE.LT.0) RETURN                                                    000313
      DO 11 I=1,M                                                           000314
   11 FF(I)=W(I)                                                            000315
      NMX=NN                                                                000316
      DO 12 I=1,NN                                                          000317
   12 XX(I)=XR(I)                                                           000318
      IF(IE.EQ.0) GOTO 80                                                   000319
      LLIND(LLI)=NR                                                         000320
      LLC=LLI-1                                                             000321
      MAXLEV=0                                                              000322
      M1=M+1                                                                000323
   15 IF(LCH.GT.0) WRITE(LCH,111) MAXLEV,FMIN                               000324
  111 FORMAT(///" STAGE:",I3,14X,"FMAX:",1PE15.7/)                          000325
```

```
      IF(LCH.GT.0) WRITE(LCH,112) (I,NRFF(I),FF(I),I=1,M                000326
  112 FORMAT(18X,2I4,3X,1PE15.7)                                        000327
      MAXLEV=MAXLEV+1                                                   000328
      LEV=1                                                             000329
      LL=1                                                              000330
   20 L=1                                                               000331
      IF(LEV.GT.1) L=LL+1                                               000332
      LL=1                                                              000333
      LR=LLI+1-L                                                        000334
      IF(L.GT.1) LL=LLIND(LR+1)+1                                       000335
      LACT(LEV)=LL                                                      000336
   30 J=LLIND(LL)                                                       000337
      IF(J.GT.0) GOTO 35                                                000338
      IF(NR.GE.LLC) GOTO 33                                             000339
      NR=NR+1                                                           000340
      LLIND(NR)=0                                                       000341
   33 LLIND(LLC)=NR                                                     000342
      LLC=LLC-1                                                         000343
      IF(LLC.LE.NR) CLOSED=.TRUE.                                       000344
      GOTO 55                                                           000345
   35 JJ=M1-LEV                                                         000346
      I=NRF(J)                                                          000347
      NRF(J)=NRF(JJ)                                                    000348
      NRF(JJ)=I                                                         000349
      IF(LEV.EQ.MAXLEV) GOTO 40                                         000350
      LEV=LEV+1                                                         000351
      GOTO 20                                                           000352
   40 MM=M-MAXLEV                                                       000353
      NN=N                                                              000354
      NRR=NR+1                                                          000355
      DO 41 I=1,N                                                       000356
   41 XR(I)=X(I)                                                        000357
      CALL SOLVER(NN,MM,M,XR,F,NRF,LLIND,LLC,NR,W,LW,IE)                000358
      IF(IE.LT.0) RETURN                                                000359
      IF(FMIN.LE.F) GOTO 44                                             000360
      FMIN=F                                                            000361
      DO 42 I=1,NN                                                      000362
   42 XX(I)=XR(I)                                                       000363
      NMX=NN                                                            000364
      DO 43 I=1,M                                                       000365
      FF(I)=W(I)                                                        000366
   43 NRFF(I)=NRF(I)                                                    000367
      NUM=LEV                                                           000368
   44 IF(IE.NE.0) GOTO 45                                               000369
      FINISH=.TRUE.                                                     000370
      GOTO 50                                                           000371
   45 IF(CLOSED) GOTO 50                                                000372
      IF(LLC.LE.NR) CLOSED=.TRUE.                                       000373
      LLIND(LLC)=NR                                                     000374
      LLC=LLC-1                                                         000375
      IF(CLOSED.OR.FINISH) GOTO 50                                      000376
      CALL INSRCH(NRR,NR,MAXLEV,M,NRF,LLIND,LLI,W,W(M1))                000377
   50 I=NRF(J)                                                          000378
      NRF(J)=NRF(JJ)                                                    000379
      NRF(JJ)=I                                                         000380
   55 IF(LACT(LEV).GE.LLIND(LR)) GOTO 60                                000381
      LL=LACT(LEV)+1                                                    000382
      LACT(LEV)=LL                                                      000383
      GOTO 30                                                           000384
   60 LEV=LEV-1                                                         000385
      IF(LEV.EQ.0) GOTO 70                                              000386
      L=1                                                               000387
      IF(LEV.GT.1) L=LACT(LEV-1)+1                                      000388
      LR=LLI+1-L                                                        000389
      LL=LACT(LEV)                                                      000390
```

```
      J=LLIND(LL)                                                       000391
      JJ=M1-LEV                                                         000392
      GOTO 50                                                           000393
   70 IF(FINISH.OR.CLOSED) GOTO 90                                      000394
      IF(MAXLEV.GE.LIMIT) GOTO 90                                       000395
      GOTO 15                                                           000396
   80 FINISH=.TRUE.                                                     000397
   90 IER=0                                                             000398
      RETURN                                                            000399
      END                                                               000400
C                                                                       000401
C                                                                       000402
      SUBROUTINE INSRCH(NRR,NR,MAXLEV,M,NRF,LLIND,LLI,LACT,NFF)         000403
      DIMENSION NRF(M),LLIND(LLI),LACT(M),NFF(M)                        000404
C                                                                       000405
C     THIS SUBROUTINE ELIMINATES IDENTICAL ENTRIES IN DECISION-TREE     000406
C     STRUCTURE DESCRIBED IN *LLIND*.                                   000407
C                                                                       000408
C       NRR    - LOCATION OF THE FIRST OF NEW ENTRIES,                  000409
C       NR     - LOCATION OF THE LAST OF NEW ENTRIES,                   000410
C       MAXLEV - CURRENT NUMBER OF LEVELS,                              000411
C       M      - TOTAL NUMBER OF RESIDUAL FUNCTIONS,                    000412
C       NRF    - ORDERING OF RESIDUAL FUNCTIONS,                        000413
C       LLIND  - INDEX AND SUBSCRIPTS OF DECISION-TREE STRUCTURE,       000414
C       LLI    - LENGTH OF *LLIND*,                                     000415
C       LACT   - VECTOR OF CURRENT COUNTS (WORKSPACE),                  000416
C       NFF    - CURRENT ORDERING OF RESIDUAL FUNCTIONS.                000417
C                                                                       000418
C       DATE : 82.06.21 (W.M.ZUBEREK)                                   000419
C                                                                       000420
      DIMENSION NPW(20)                                                 000421
      DATA NPW/1,2,4,8,16,32,64,128,256,512,1024,2048,4096,8192,16384,  000422
     1         32768,65536,131072,262144,524288/                        000423
      M1=M+1                                                            000424
      NRN=0                                                             000425
      MM=M1-MAXLEV                                                      000426
      DO 10 I=MM,M                                                      000427
      K=NRF(I)                                                          000428
   10 NRN=OR(NRN,NPW(K))                                                000429
      DO 60 I=NRR,NR                                                    000430
      DO 15 J=1,M                                                       000431
   15 NFF(J)=J                                                          000432
      K=LLIND(I)                                                        000433
      K=NRF(K)                                                          000434
      NRA=OR(NRN,NPW(K))                                                000435
      LEV=0                                                             000436
      LL=1                                                              000437
   20 LEV=LEV+1                                                         000438
      L=1                                                               000439
      IF(LEV.GT.1) L=LL+1                                               000440
      LL=1                                                              000441
      LR=LLI+1-L                                                        000442
      IF(L.GT.1) LL=LLIND(LR+1)+1                                       000443
      LACT(LEV)=LL                                                      000444
   30 IF(LL.GE.NRR) GOTO 60                                             000445
      J=LLIND(LL)                                                       000446
      IF(J.EQ.0) GOTO 45                                                000447
      JJ=M1-LEV                                                         000448
      K=NFF(J)                                                          000449
      NFF(J)=NFF(JJ)                                                    000450
      NFF(JJ)=K                                                         000451
      IF(AND(NRA,NPW(K)).EQ.0) GOTO 40                                  000452
      IF(LEV.LE.MAXLEV) GOTO 20                                         000453
      LLIND(I)=0                                                        000454
      GOTO 60                                                           000455
```

```
   40 JJ=M1-LEV                                                          000456
      K=NFF(J)                                                           000457
      NFF(J)=NFF(JJ)                                                     000458
      NFF(JJ)=K                                                          000459
   45 IF(LACT(LEV).GE.LLIND(LR)) GOTO 50                                 000460
      LL=LACT(LEV)+1                                                     000461
      LACT(LEV)=LL                                                       000462
      GOTO 30                                                            000463
   50 LEV=LEV-1                                                          000464
      IF(LEV.EQ.0) GOTO 60                                               000465
      L=1                                                                000466
      IF(LEV.GT.1) L=LACT(LEV-1)+1                                       000467
      LR=LLI+1-L                                                         000468
      LL=LACT(LEV)                                                       000469
      J=LLIND(LL)                                                        000470
      GOTO 40                                                            000471
   60 CONTINUE                                                           000472
      RETURN                                                             000473
      END                                                                000474
C                                                                        000475
C                                                                        000476
      SUBROUTINE SOLVER(NN,M,MF,X,F,NFR,LIND,LL,NR,W,IW,IERR)            000477
      DIMENSION X(1),LIND(LL),W(IW),NFR(1)                               000478
C                                                                        000479
C     THIS SUBROUTINE PREPARES PARAMETERS AND CALLS MINIMAX OPTIMIZATION 000480
C     ROUTINE MMLA1Q, ALSO PRINTS RESULTS OF MINIMAX OPTIMIZATION.       000481
C                                                                        000482
C       NN  - NUMBER OF VARIABLES                                        000483
C       M   - CURRENT NUMBER OF RESIDUAL FUNCTIONS                       000484
C       MF  - TOTAL NUMBER OF RESIDUAL FUNCTIONS                         000485
C       X   - VECTOR OF INITIAL VALUES AND MINIMAX SOLUTION              000486
C       F   - VALUE OF MINIMAX FUNCTION AT THE SOLUTION                  000487
C       NFR - VECTOR OF CURRENT RESIDUAL FUNCTION ORDERING               000488
C       LIND- SUBSCRIPTS OF DECISION-TREE STRUCTURE                      000489
C       LL  - CURRENT LENGTH OF LIND                                     000490
C       NR  - INDEX OF LAST VALUE STORED IN LIND                         000491
C       W   - WORKSPACE FOR MINIMAX                                      000492
C       IW  - LENGTH OF W                                                000493
C       IERR- RETURN FLAG FROM *SOLVER*                                  000494
C                                                                        000495
      COMMON /BL1/XA(20),YA(20)                                          000496
      COMMON /BL4/KOC(20),MD(20)                                         000497
      COMMON /BL7/PARAM                                                  000498
      COMMON /BL5/ NRF(20)                                               000499
      EXTERNAL FDF                                                       000500
      DATA SP/1H /,ST/1H*/                                               000501
      MM=M                                                               000502
      DO 5 I=1,MF                                                        000503
    5 NRF(I)=NFR(I)                                                      000504
      DO 10 I=1,MF                                                       000505
   10 MD(I)=0                                                            000506
      IF(M.EQ.MF)GO TO 50                                                000507
      M1=M+1                                                             000508
      DO 30 I=M1,MF                                                      000509
      DO 20 J=1,M                                                        000510
      K=NRF(J)                                                           000511
      IF(KOC(K).EQ.NRF(I))GO TO 25                                       000512
   20 CONTINUE                                                           000513
      GO TO 30                                                           000514
   25 MM=MM+1                                                            000515
      NRR=NRF(I)                                                         000516
      NRF(I)=NRF(MM)                                                     000517
      NRF(MM)=NRR                                                        000518
      X(NN+1)=XA(NRR)                                                    000519
      X(NN+2)=YA(NRR)                                                    000520
```

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      MD(NRR)=NN+1                                                          000521
      DO 26 J=1,M                                                           000522
      K=NRF(J)                                                              000523
      IF(KOC(K).EQ.NRR) MD(K)=-NN-1                                         000524
   26 CONTINUE                                                              000525
      NN=NN+2                                                               000526
   30 CONTINUE                                                              000527
   50 L=0                                                                   000528
      LEQ=0                                                                 000529
      IC=0                                                                  000530
      DX=0.001                                                              000531
      EPS=1.E-6                                                             000532
      MAXF=25                                                               000533
      KEQS=3                                                                000534
      CALL MMLA1Q(FDF,NN,MM,L,LEQ,W,W,IC,X,DX,EPS,MAXF,KEQS,W,IW,IFL)       000535
      IF(IFL.LT.0)GO TO 99                                                  000536
      F=W(1)                                                                000537
      DO 52 I=2,MM                                                          000538
   52 F=AMAX1(F,W(I))                                                       000539
      WRITE(6,100) IFL,F,MAXF,KEQS                                          000540
  100 FORMAT(/" RESULT OF MINIMAX OPTIMIZATION (RETURN:",I2,                000541
     1")",1PE15.7,5X,"N.IT:",I3,3X,"N.SH:",I3/)                             000542
      IF(F.GT.0.0) GOTO 60                                                  000543
      NM=MAX0(NN,MM)                                                        000544
      DO 55 I=1,NM                                                          000545
      Z=SP                                                                  000546
      J=NRF(I)                                                              000547
      IF(MD(J).GT.0)Z=ST                                                    000548
      IF(I.LE.NN.AND.I.LE.MM)WRITE(6,101)I,X(I),NRF(I),W(I),Z               000549
      IF(I.GT.NN)WRITE(6,102)NRF(I),W(I),Z                                  000550
      IF(I.GT.MM)WRITE(6,101)I,X(I)                                         000551
   55 CONTINUE                                                              000552
  101 FORMAT(5X,I3,1X,1PE15.7,I4,1X,1PE15.7,1X,A1)                          000553
  102 FORMAT(25X,I3,1X,1PE15.7,1X,A1)                                       000554
   60 IERR=0                                                                000555
      DO 70 I=1,M                                                           000556
      IF(W(I).LE.PARAM*F)GO TO 70                                           000557
      IERR=IERR+1                                                           000558
      IF(NR.GE.LL)GO TO 70                                                  000559
      NR=NR+1                                                               000560
      LIND(NR)=I                                                            000561
   70 CONTINUE                                                              000562
      ME=MF-M                                                               000563
      IF(ME.EQ.0) GOTO 90                                                   000564
      MB=MM                                                                 000565
      DO 81 I=1,ME                                                          000566
      J=MF+1-I                                                              000567
      K=NFR(J)                                                              000568
      Z=1.E99                                                               000569
      IF(MD(K).LE.0) GOTO 80                                                000570
      Z=W(MB)                                                               000571
      MB=MB-1                                                               000572
   80 W(J)=Z                                                                000573
   81 CONTINUE                                                              000574
   90 RETURN                                                                000575
   99 WRITE(6,900) IFL                                                      000576
  900 FORMAT(///" ERROR RETURN FROM MINIMAX:",I3)                           000577
      IERR=-1                                                               000578
      RETURN                                                                000579
      END                                                                   000580
C                                                                           000581
C                                                                           000582
      SUBROUTINE FDF(N,M,X,DF,F)                                            000583
      DIMENSION X(N),F(M),DF(M,N),DX3(20),DY3(20),XA1(20),YA1(20)           000584
C                                                                           000585
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C   THIS SUBROUTINE PERFORMS TRANSFORMATION OF COORDINATES,                000586
C   EVALUATES RESIDUAL FUNCTIONS AND CALCULATES FINAL                      000587
C   DERIVATIVES.                                                           000588
C                                                                          000589
C     N   - NUMBER OF VARIABLES                                            000590
C     M   - NUMBER OF RESIDUAL FUNCTIONS                                   000591
C     X   - VECTOR OF VALUES OF VARIABLES                                  000592
C     DF  - MATRIX OF RESIDUAL FUNCTION DERIVATIVES W.R.T.                 000593
C           OPTIMIZATION VARIABLES AT POINT X                              000594
C     F   - VECTOR OF VALUES OF RESIDUAL FUNCTIONS AT POINT X              000595
C                                                                          000596
      COMMON /BL1/XA(20),YA(20)                                            000597
      COMMON /BL2/KTC(20),T1(20),T2(20),T3(20),T4(20)                      000598
      COMMON /BL3/T10(20),T20(20),T30(20),T40(20)                          000599
      COMMON /BL4/KOC(20),MD(20)                                           000600
      COMMON /BL5/NRF(20)                                                  000601
      COMMON /BL6/XP(20),YP(20)                                            000602
      X1=X(1)                                                              000603
      X2=X(2)                                                              000604
      X3=X(3)                                                              000605
C                                                                          000606
C       TRANSFORMATION OF COORDINATES                                      000607
C                                                                          000608
      SN=SIN(X3)                                                           000609
      CS=COS(X3)                                                           000610
      DO 10 I=1,M                                                          000611
      J=NRF(I)                                                             000612
      XA1(J)=XA(J)*CS-YA(J)*SN+X1                                          000613
   10 YA1(J)=XA(J)*SN+YA(J)*CS+X2                                          000614
C                                                                          000615
C       JACOBIAN OF THE TRANSFORMATION                                     000616
C                                                                          000617
      DX1=1.                                                               000618
      DX2=0.                                                               000619
      DY1=0.                                                               000620
      DY2=1.                                                               000621
      DO 20 I=1,M                                                          000622
      J=NRF(I)                                                             000623
      DX3(J)=-XA(J)*SN-YA(J)*CS                                            000624
   20 DY3(J)=XA(J)*CS-YA(J)*SN                                             000625
C                                                                          000626
C       FUNCTIONS AND DERIVATIVES                                          000627
C                                                                          000628
      IF(N.EQ.3)GO TO 40                                                   000629
      DO 30 I=4,N                                                          000630
      DO 30 J=1,M                                                          000631
   30 DF(J,I)=0.0                                                          000632
   40 DO 50 I=1,M                                                          000633
      J=NRF(I)                                                             000634
      K=KTC(J)                                                             000635
      IR=KOC(J)                                                            000636
      NZ=IABS(MD(J))                                                       000637
      XA1P=XA1(J)                                                          000638
      YA1P=YA1(J)                                                          000639
      T1P=T1(J)                                                            000640
      T2P=T2(J)                                                            000641
      T3P=T3(J)                                                            000642
      T4P=T4(J)                                                            000643
      IF(K.EQ.0)GO TO 100                                                  000644
      IF(K.EQ.12)GO TO 120                                                 000645
      IF(IR.EQ.0)GO TO 131                                                 000646
      T5P=XP(IR)                                                           000647
      T6P=YP(IR)                                                           000648
      GO TO 132                                                            000649
  131 T5P=0.                                                               000650
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      T6P=0.                                                            000651
  132 IF(K.EQ.13)GO TO 130                                              000652
      IF(K.EQ.23)GO TO 230                                              000653
C                                                                       000654
C       PARAMETERS FOR TOLCIR                                           000655
C                                                                       000656
  100 IF(MD(J).EQ.0)GO TO 110                                           000657
      IF(MD(J).LT.0)GO TO 105                                           000658
      XA1P=X(NZ)                                                        000659
      YA1P=X(NZ+1)                                                      000660
      GO TO 110                                                         000661
  105 T1P=T10(J)+X(NZ)                                                  000662
      T2P=T20(J)+X(NZ+1)                                                000663
  110 CALL TOLCIR(XA1P,YA1P,T1P,T2P,T3P,FF,D1,D2,D3,D4)                 000664
      GO TO 60                                                          000665
C                                                                       000666
C       PARAMETERS FOR TOLXY                                            000667
C                                                                       000668
  120 IF(MD(J).EQ.0)GO TO 125                                           000669
      IF(MD(J).LT.0)GO TO 122                                           000670
      XA1P=X(NZ)                                                        000671
      YA1P=X(NZ+1)                                                      000672
      GO TO 125                                                         000673
  122 T1P=T10(J)+X(NZ)                                                  000674
      T2P=T20(J)+X(NZ)                                                  000675
      T3P=T30(J)+X(NZ+1)                                                000676
      T4P=T40(J)+X(NZ+1)                                                000677
  125 CALL TOLXY(XA1P,YA1P,T1P,T2P,T3P,T4P,FF,D1,D2,D3,D4)              000678
      GO TO 60                                                          000679
C                                                                       000680
C       PARAMETERS FOR TOLXR                                            000681
C                                                                       000682
  130 IF(MD(J).EQ.0)GO TO 135                                           000683
      IF(MD(J).LT.0)GO TO 133                                           000684
      XA1P=X(NZ)                                                        000685
      YA1P=X(NZ+1)                                                      000686
      GO TO 135                                                         000687
  133 T1P=T10(J)+X(NZ)                                                  000688
      T2P=T20(J)+X(NZ)                                                  000689
      T5P=X(NZ)                                                         000690
      T6P=X(NZ+1)                                                       000691
  135 CALL TOLXR(XA1P,YA1P,T1P,T2P,T3P,T4P,T5P,T6P,FF,D1,D2,D3,D4)      000692
      GO TO 60                                                          000693
C                                                                       000694
C       PARAMETERS FOR TOLYR                                            000695
C                                                                       000696
  230 IF(MD(J).EQ.0)GO TO 235                                           000697
      IF(MD(J).LT.0)GO TO 233                                           000698
      XA1P=X(NZ)                                                        000699
      YA1P=X(NZ+1)                                                      000700
      GO TO 235                                                         000701
  233 T1P=T10(J)+X(NZ+1)                                                000702
      T2P=T20(J)+X(NZ+1)                                                000703
      T5P=X(NZ)                                                         000704
      T6P=X(NZ+1)                                                       000705
  235 CALL TOLYR(XA1P,YA1P,T1P,T2P,T3P,T4P,T5P,T6P,FF,D1,D2,D3,D4)      000706
C                                                                       000707
C       FINAL DERIVATIVES                                               000708
C                                                                       000709
   60 DF(I,1)=D1*DX1+D2*DY1                                             000710
      DF(I,2)=D1*DX2+D2*DY2                                             000711
      DF(I,3)=D1*DX3(J)+D2*DY3(J)                                       000712
      F(I)=FF                                                           000713
      IF(N.EQ.3)GO TO 50                                                000714
      IF(MD(J).EQ.0)GO TO 50                                            000715
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      IF(MD(J).LT.0)GO TO 65                                            000716
      DO 80 JJ=1,3                                                      000717
   80 DF(I,JJ)=0.                                                       000718
      DF(I,NZ)=D1                                                       000719
      DF(I,NZ+1)=D2                                                     000720
      GO TO 50                                                          000721
   65 DF(I,NZ)=D3                                                       000722
      DF(I,NZ+1)=D4                                                     000723
   50  CONTINUE                                                        000724
      RETURN                                                            000725
      END                                                               000726
C                                                                       000727
C                                                                       000728
      SUBROUTINE TOLCIR(XA1P,YA1P,T1P,T2P,T3P,F,D1,D2,D3,D4)            000729
C                                                                       000730
C   THIS SUBROUTINE CALCULATES ERROR FUNCTION AND ITS DERIVATIVES       000731
C   FOR CIRCULAR TOLERANCE REGION.                                      000732
C                                                                       000733
C     XA1P - TRANSFORMED ACTUAL X COORDINATE OF A POINT OR              000734
C            ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT             000735
C            AND CANDIDATE FOR DELETING                                 000736
C     YA1P - TRANSFORMED ACTUAL Y COORDINATE OF A POINT OR              000737
C            ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT             000738
C            AND CANDIDATE FOR DELETING                                 000739
C     T1P  - NOMINAL X COORDINATE OF A POINT                            000740
C     T2P  - NOMINAL Y COORDINATE OF A POINT                            000741
C     T3P  - RADIUS OF CIRCULAR TOLERANCE REGION                        000742
C     F    - RESIDUAL FUNCTION VALUE                                    000743
C     D1   - PARTIAL DERIVATIVE OF F W.R.T. X COORDINATE                000744
C     D2   - PARTIAL DERIVATIVE OF F W.R.T. Y COORDINATE                000745
C     D3   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE         000746
C            (COORDINATE X OF A REFERENCE POINT)                        000747
C     D4   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE         000748
C            (COORDINATE Y OF A REFERENCE POINT)                        000749
C                                                                       000750
      A=T1P-XA1P                                                        000751
      B=T2P-YA1P                                                        000752
      D=SQRT(A*A+B*B)                                                   000753
      F=D-T3P                                                           000754
      IF(D.GT.1.E-20)GO TO 15                                           000755
      D1=0.                                                             000756
      D2=0.                                                             000757
      D3=0.                                                             000758
      D4=0.                                                             000759
      GO TO 20                                                          000760
   15 D1=(-A/D)                                                         000761
      D2=(-B/D)                                                         000762
      D3=-D1                                                            000763
      D4=-D2                                                            000764
   20 RETURN                                                            000765
      END                                                               000766
C                                                                       000767
C                                                                       000768
      SUBROUTINE TOLXY(XA1P,YA1P,T1P,T2P,T3P,T4P,F,D1,D2,D3,D4)         000769
C                                                                       000770
C   THIS SUBROUTINE CALCULATES ERROR FUNCTION AND ITS DERIVATIVES       000771
C   FOR RECTANGULAR TOLERANCE REGION.                                   000772
C                                                                       000773
C     XA1P - TRANSFORMED ACTUAL X COORDINATE OF A POINT OR              000774
C            ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT             000775
C            AND CANDIDATE FOR DELETING                                 000776
C     YA1P - TRANSFORMED ACTUAL Y COORDINATE OF A POINT OR              000777
C            ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT             000778
C            AND CANDIDATE FOR DELETING                                 000779
C     T1P  - XMIN DIMENSION OF RECTANGULAR TOLERANCE REGION             000780
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C      T2P  - XMAX DIMENSION OF RECTANGULAR TOLERANCE REGION                000781
C      T3P  - YMIN DIMENSION OF RECTANGULAR TOLERANCE REGION                000782
C      T4P  - YMAX DIMENSION OF RECTANGULAR TOLERANCE REGION                000783
C      F    - RESIDUAL FUNCTION VALUE                                       000784
C      D1   - PARTIAL DERIVATIVE OF F W.R.T. X COORDINATE                   000785
C      D2   - PARTIAL DERIVATIVE OF F W.R.T. Y COORDINATE                   000786
C      D3   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE            000787
C             (COORDINATE X OF A REFERENCE POINT)                           000788
C      D4   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE            000789
C             (COORDINATE Y OF A REFERENCE POINT)                           000790
C                                                                           000791
      E1=T1P-XA1P                                                           000792
      E2=XA1P-T2P                                                           000793
      E3=T3P-YA1P                                                           000794
      E4=YA1P-T4P                                                           000795
      F=AMAX1(E1,E2,E3,E4)                                                  000796
      IF(F.EQ.E1)GO TO 10                                                   000797
      IF(F.EQ.E2)GO TO 20                                                   000798
      IF(F.EQ.E3)GO TO 30                                                   000799
      IF(F.EQ.E4)GO TO 40                                                   000800
   10 D1=-1.                                                                000801
      D2=0.                                                                 000802
      D3=1.                                                                 000803
      D4=0.                                                                 000804
      GO TO 50                                                              000805
   20 D1=1.                                                                 000806
      D2=0.                                                                 000807
      D3=-1.                                                                000808
      D4=0.                                                                 000809
      GO TO 50                                                              000810
   30 D1=0.                                                                 000811
      D2=-1.                                                                000812
      D3=0.                                                                 000813
      D4=1.                                                                 000814
      GO TO 50                                                              000815
   40 D1=0.                                                                 000816
      D2=1.                                                                 000817
      D3=0.                                                                 000818
      D4=-1.                                                                000819
   50 RETURN                                                                000820
      END                                                                   000821
C                                                                           000822
C                                                                           000823
      SUBROUTINE TOLXR(XA1P,YA1P,T1P,T2P,T3P,T4P,T5P,T6P,F,D1,D2,D3,D4)     000824
C                                                                           000825
C     THIS SUBROUTINE CALCULATES ERROR FUNCTION AND ITS DERIVATIVES         000826
C     FOR X-R TOLERANCE REGION.                                             000827
C                                                                           000828
C     XA1P - TRANSFORMED ACTUAL X COORDINATE OF A POINT OR                  000829
C            ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT                 000830
C            AND CANDIDATE FOR DELETING                                     000831
C     YA1P - TRANSFORMED ACTUAL Y COORDINATE OF A POINT OR                  000832
C            ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT                 000833
C            AND CANDIDATE FOR DELETING                                     000834
C     T1P  - XMIN DIMENSION OF X-R TOLERANCE REGION                         000835
C     T2P  - XMAX DIMENSION OF X-R TOLERANCE REGION                         000836
C     T3P  - RMIN DIMENSION OF X-R TOLERANCE REGION                         000837
C     T4P  - RMAX DIMENSION OF X-R TOLERANCE REGION                         000838
C     T5P  - X COORDINATE OF A REFERENCE POINT                              000839
C     T6P  - Y COORDINATE OF A REFERENCE POINT                              000840
C     F    - RESIDUAL FUNCTION VALUE                                        000841
C     D1   - PARTIAL DERIVATIVE OF F W.R.T. X COORDINATE                    000842
C     D2   - PARTIAL DERIVATIVE OF F W.R.T. Y COORDINATE                    000843
C     D3   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE             000844
C            (COORDINATE X OF A REFERENCE POINT)                            000845
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C      D4    - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE          000846
C              (COORDINATE Y OF A REFERENCE POINT)                         000847
C                                                                          000848
       E1=T1P-XA1P                                                         000849
       E2=XA1P-T2P                                                         000850
       A=XA1P-T5P                                                          000851
       B=YA1P-T6P                                                          000852
       D=SQRT(A*A+B*B)                                                     000853
       E3=T3P-D                                                            000854
       E4=D-T4P                                                            000855
       F=AMAX1(E1,E2,E3,E4)                                                000856
       IF(F.EQ.E1)GO TO 10                                                 000857
       IF(F.EQ.E2)GO TO 20                                                 000858
       IF(F.EQ.E3)GO TO 30                                                 000859
       IF(F.EQ.E4)GO TO 40                                                 000860
    10 D1=-1.                                                              000861
       D2=0.                                                               000862
       D3=1.                                                               000863
       D4=0.                                                               000864
       GO TO 50                                                            000865
    20 D1=1.                                                               000866
       D2=0.                                                               000867
       D3=-1.                                                              000868
       D4=0.                                                               000869
       GO TO 50                                                            000870
    30 D1=-A/D                                                             000871
       D2=-B/D                                                             000872
       D3=-D1                                                              000873
       D4=-D2                                                              000874
       GO TO 50                                                            000875
    40 D1=A/D                                                              000876
       D2=B/D                                                              000877
       D3=-D1                                                              000878
       D4=-D2                                                              000879
    50 RETURN                                                              000880
       END                                                                 000881
C                                                                          000882
C                                                                          000883
       SUBROUTINE TOLYR(XA1P,YA1P,T1P,T2P,T3P,T4P,T5P,T6P,F,D1,D2,D3,D4)    000884
C                                                                          000885
C     THIS SUBROUTINE CALCULATES ERROR FUNCTION AND ITS DERIVATIVES        000886
C     FOR Y-R TOLERANCE REGION.                                            000887
C                                                                          000888
C       XA1P - TRANSFORMED ACTUAL X COORDINATE OF A POINT OR               000889
C              ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT              000890
C              AND CANDIDATE FOR DELETING                                  000891
C       YA1P - TRANSFORMED ACTUAL Y COORDINATE OF A POINT OR               000892
C              ADDITIONAL VARIABLE IF IT IS A REFERENCE POINT              000893
C              AND CANDIDATE FOR DELETING                                  000894
C       T1P  - YMIN DIMENSION OF Y-R TOLERANCE REGION                      000895
C       T2P  - YMAX DIMENSION OF Y-R TOLERANCE REGION                      000896
C       T3P  - RMIN DIMENSION OF Y-R TOLERANCE REGION                      000897
C       T4P  - RMAX DIMENSION OF Y-R TOLERANCE REGION                      000898
C       T5P  - X COORDINATE OF A REFERENCE POINT                           000899
C       T6P  - Y COORDINATE OF A REFERENCE POINT                           000900
C       F    - RESIDUAL FUNCTION VALUE                                     000901
C       D1   - PARTIAL DERIVATIVE OF F W.R.T. X COORDINATE                 000902
C       D2   - PARTIAL DERIVATIVE OF F W.R.T. Y COORDINATE                 000903
C       D3   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE          000904
C              (COORDINATE X OF A REFERENCE POINT)                         000905
C       D4   - PARTIAL DERIVATIVE OF F W.R.T. ADDITIONAL VARIABLE          000906
C              (COORDINATE Y OF A REFERENCE POINT)                         000907
C                                                                          000908
       E1=T1P-YA1P                                                         000909
       E2=YA1P-T2P                                                         000910
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      A=XA1P-T5P                                                    000911
      B=YA1P-T6P                                                    000912
      D=SQRT(A*A+B*B)                                               000913
      E3=T3P-D                                                      000914
      E4=D-T4P                                                      000915
      F=AMAX1(E1,E2,E3,E4)                                          000916
      IF(F.EQ.E1)GO TO 10                                           000917
      IF(F.EQ.E2)GO TO 20                                           000918
      IF(F.EQ.E3)GO TO 30                                           000919
      IF(F.EQ.E4)GO TO 40                                           000920
   10 D1=0.                                                         000921
      D2=-1.                                                        000922
      D3=0.                                                         000923
      D4=1.                                                         000924
      GO TO 50                                                      000925
   20 D1=0.                                                         000926
      D2=1.                                                         000927
      D3=0.                                                         000928
      D4=-1.                                                        000929
      GO TO 50                                                      000930
   30 D1=-A/D                                                       000931
      D2=-B/D                                                       000932
      D3=-D1                                                        000933
      D4=-D2                                                        000934
      GO TO 50                                                      000935
   40 D1=A/D                                                        000936
      D2=B/D                                                        000937
      D3=-D1                                                        000938
      D4=-D2                                                        000939
   50 RETURN                                                        000940
      END                                                           000941
```