CONMIN USER'S MANUAL

NASA Technical Memorandum X-62282, 1978

Addendum to Technical Memorandum, 1978
Original Technical Memorandum, 1973

[Cover]

NASA TECHNICAL MEMORANDUM

NASA TM X-62,282

CONMIN - A FORTRAN PROGRAM FOR CONSTRAINED

FUNCTION MINIMIZATION

USER'S MANUAL

Garret N. Vanderplaats

Ames Research Center and U.S. Army Air Mobility
R&D Laboratory, Moffett Field, Calif. 94035 August, 197y

This version of CONMIN is identified by a comment card near the beginning of subroutine CONMIN:

```
C * * MAY, 1978 VERSION * * .
```

During execution, the arrays `g`, `a`, and `isc`

The definition of the finite difference gradient parameter, `NFDG` has changed. The current definition is:

```
NFDG = 0:  all gradient information is calculated by finite difference
           within CONMIN.

NFDG = 1:  all gradient information is supplied by the user.

NFDG = 2:  the gradient of OBJ is supplied by the user and the
           gradients of constraints are calculated by finite
           difference within CONMIN.
```

Additional printing is now available using the IPRINT parameter:

G(J) is the value of the Jth inequality constraint, which is also a function of the X(I). NCON is the number of constraints, G(J). NCON may be zero. VLB(I) and VUB(I) are lower and upper bounds respectively on variable X(I), and are referred to as side constraints. NSIDE = 0 indicates that no lower or upper bounds are prescribed. If NCON = 0 and NSIDE = 0, the objective function is said to be unconstrained. NDV is the total number of decision variables, X(I).

Constraint G(J) is defined as active if CT.LE.G(J).LE.ABS(CT) and violated if G(J).GT.ABS(CT), where constraint thickness, CT, is a small specified negative number. The numerno l significance of CT may be understood by referring to Fig. 1, which shows a single constraint in a two variable design space. Constraint G(J) is mathematno lly equal to zero along a single curve in design space. However, on a digital computer, the exact value of G(J) = 0 can seldom be obtained. Therefore, the "curve" becomes a thick band with constraint thickness of 2*ABS(CT) over12 0 0 20 10m (hwith coni 440802.5 Tm (over Tm (ss (,6 6

```
G(3) = 2*X(1)**2 + 2*X(1) + X(2)**2 - X(2) +
       X(3)**2 - X(4) - 5                  .LE. 0
```

This problem has four decision variables and three constraints, (`NDV = 4, NCON = 3`). No lower or upper bounds `VLB(I)` or `VUB(I)` are prescribed so control parameter `NSIDE` is specified as `NSIDE = 0` to indicate this. It is necessary to provide a set of initial values for `X(I)`, and from this the constrained optimum is obtained by CONMIN and its associated routines. This problem will be solved using CONMIN in SECTION VIII.

The minimization algorithm is based on Zoutendijk’s method of feasible directions (ref. 2). The algorithm has been modified to improve efficiency and numerte l stability and to solve optimization problems in which one or more constraints, `G(J)`

many such constraints there are (NAC = Number of active and violated constraints). Calculate the analytic gradients of the objective function and all active or violated constraints. Values of the objective function, constraint parameter, BETA, printed under this option approaches zero as the optimum objective is achieved.

4: Complete debug. Print all of above plus gradients of constraints are calculated by finite difference in CONMIN. This option is desirable if the gradient of the objective function is easily obtained in closed form, but gradients of constraint functions, G(J), are unobtainable. This option may improve efficiency if several variables are limited by lower or upper bounds.

FDCH   Default value = 0.01. Not used if NFDG = 0. Relative change in decision variable X(I) in calculating finite difference gradients. For example, FDCH = 0.01 corresponds to a finite difference step of one percent of the value of the decision variable.

FDCHM   Default value = 0.01. Not used if NFDG = 0. Minimui 54re

dj 0 -2.1 TD (FDCH   Defaulrerof the d)Tj 0 -1.05 TD (ifferenceT* = 0e

J), iable.

[illegible] ifgr[illegible]seatindireTj T*

(upper bound) of X(I). If one or more variables, X(I), do not have upper bounds, the corresponding VUB(I) must be initialized

SECTION VII

REQUIRED DIMENSIONS OF ARRAYS

parameters. Then the control parameters are defined as:

```
IPRINT = 1, NDV = 2, NCON = 6, NSIDE = 1, NFDG = 2, LINOBJ = 1,
ITMAX = ICNDIR = NSCAL = ITRM = DABFUN = 0,
FDCH = FDCHM = CT = CTMIN = CTL = CTLMIN = THETA = PHI = DELFUN = 0.
```

```
CALL CONMIN (SUB1, OBJ)

CALL SUB1(INFO, OBJ)
```

DELFUN	0.001	Minimum relative change in objective function, OBJ, to indicate convergence.
DABFUN	0.001*initial OBJ	Minimum absolute change in objective function, OBJ, to indicate convergence.
LINOBJ		Linear objective function identifier. LINOBJ = 1 if OBJ is specifically known to be linear in X(I). LINOBJ = 0 if OBJ is nonlinear.
.TRM	3	Number of consecutive iterations to indicate convergence by relative or absolute changes, DELFUN or DABFUN.
X		Vector of decision variables.
VLB		Vector of lower bounds on decision variables.
VUB		Vector of upper bounds on decision variables.
SCAL		Vector of s ecion variables.

```
      COMMON /VARABLE/ AOBJ,X(6),G(11)
      COMMON /ANDATA/ LOOPCNT
      NAMELIST /CONPAR/ INFOG,INFO,NFDG,IPRINT,NDV,ITMAX,NCON,NSIDE,
     .                  ICNDIR,NSCAL,FDCH,FDCHM,CT,CTMIN,CTLMIN,THETA,
     .                  PHI,DELFUN,DABFUN,LINOBJ,ITRM,X,VLB,VUB,
     .                  N1,N2,N3,N4,N5,ALPHAX,ABOBJ1,CTL,ISC,SCAL
C
C     THIS PROGRAM EXECUTES THE EXAMPLE PROBLEM ONE OF THE CON
C     MANUAL.
C
C
C  INITIALIZE
C
      INFOG=0
      INFO=0
      NFDG=0
      IPRINT=2
      NDV=4
      ITMAX=40
      NCON=3
      NSIDE=0
      ICNDIR=0
      NSCAL=0
      FDCH=0.0
      FDCHM=0.0
      CT=0.0
      CTMIN=0.0
      CTL=0.0
      CTLMIN=0.0
      THETA=0.0
      PHI=0.0
      DELFUN=0.0
      DABFUN=0.0
      LINOBJ=0.0
      ITRM=0
      N1=6
      N2=11
      N3=11
      N4=11
      N5=22
      ALPHAX=0.0
      ABOBJ1=0.0
      CTL=0.0
      DA 1 CTL=0.0
```

```
      IGOTO = 0
C
C     ITERATIVE PART OF ANALYSIS
C
      DO 1000 I = 1,NLIM
        LOOPCNT=I
C
C       CALL THE OPTIMIZATION ROUTINE CONMIN
C
        CALL CONMIN(X,VLB,VUB,G,SCAL,DF,A,S,G1,G2,B,C,ISC,IC,MS1,N1,N2,
     .              N3,N4,N5)
C
        IF(IGOTO.EQ.0) LOOPCNT=-999
C
C       ANALYSIS MODULE
C
        CALL ANALYS
        OBJ=AOBJ
        IF (IGOTO.EQ.0) GO TO 1100
 1000 CONTINUE
C
C
 1100 CONTINUE
      STOP
      END
CCCCC
```

LISTING 2

ANALYSIS SUBROUTINE FOR EXAMPLE 1

```
CCCCC
      SUBROUTINE ANALYS
      COMMON /VARABLE/ AOBJ,X(6),G(11)
C
C   ROUTINE TO CALCULATE OBJECTIVE FUNCTION AND
C   CONSTRAINTS
C
C
C  OBJECTIVE FUNCTION
C
      AOBJ = X(1)**2 - 5.*X(1) + X(2)**2 - 5.*X(2) + 2.*X(3)**2
     .       - 21.*X(3) + X(4)**2 + 7.0*X(4) + 50.
C
C
C   CONSTRAINT VALUES
C
      G(1) = X(1)**2 + X(1) + X(2)**2 - X(2) + X(3)**2 + X(3)
     .       + X(4)**2 - X(4) - 8.0
C
      G(2) = X(1)**2 - X(1) + 2. * X(2)**2 + X(3)**2 + 2.*X(4)**2
     .       - X(4) - 10.0
C
      G(3) = 2.*X(1)**2 + 2.*X(1) + X(2)**2 - X(2) + X(3)**2 - X(4) -5.0
C
      RETURN
      END
```

```
CCCCC
```

LISTING 3

OPTIMIZATION RESULTS FOR EXAMPLE 1

```
1$CONPAR
INFOG   = 0,
INFO    = 0,
NFDG    = 0,
IPRINT  = 2,
NDV     = 4,
ITMAX   = 40,
NCON    = 3,
NSIDE   = 0,
ICNDIR  = 0,
NSCAL   = 0,
FDCH    = 0.0,
FDCHM   = 0.0,
CT      = 0.0,
CTMIN   = 0.0,
CTLMIN  = 0.0,
THETA   = 0.0,
PHI     = 0.0,
DELFUN  = 0.0,
DABFUN  = 0.0,
LINOBJ  = 0,
ITRM    = 0,
X       = .1E+01, .1E+01, .1E+01, .1E+01, 0.0, 0.0,
VLB     = -.99999E+05, -.99999E+05, -.99999E+05, -.99999E+05, 0.0, 0.0,
VUB     = .99999E+05, .99999E+05, .99999E+05, .99999E+05, 0.0, 0.0,
N1      = 6,
N2      = 11,
N3      = 11,
N4      = 11,
N5      = 22,
ALPHAX  = 0.0,
ABOBJ1  = 0.0,
CTL     = 0.0,
ISC     = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
SCAL    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
$END

            * * * * * * * * * * * * * * * * * * * * * * * * * * *
            *                                                   *
            *                   C O N M I N                     *
            *                                                   *
            *               FORTRAN PROGRAM FOR                 *
            *                                                   *
            *         CONSTRAINED FUNCTION MINIMIZATION         *
            *                                                   *
            * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

CONSTRAINED FUNCTION MINIMIZATION

CONTROL PARAMETERS

IPRINT	NDV	ITMAX	NCON	NSIDE	ICNDIR	NSCAL	NFDG
2	4	40	3	0	5	0	0

LINOBJ	ITRM	N1	N2	N3	N4	N5
0	3	6	11	11	11	22

CT	CTMIN	CTL	CTLMIN
-.10000E+00	.40000E-02	-.10000E-01	.10000E-02

THETA	PHI	DELFUN	DABFUN
.10000E+01	.50000E+01	.10000E-03	.31000E-01

FDCH	FDCHM	ALPHAX	ABOBJ1
.10000E-01	.10000E-01	.10000E+00	.10000E+00

ALL CONSTRAINTS ARE NON-LINEAR

INITIAL FUNCTION INFORMATION

OBJ = .310000E+02

DECISION VARIABLES (X-VECTOR)
1) .10000E+01 .10000E+01 .10000E+01 .10000E+01

CONSTRAINT VALUES (G-VECTOR)
1) -.40000E+01 -.60000E+01 -.10000E+01

ITER = 1 OBJ = .25484E+02

DECISION VARIABLES (X-VECTOR)
1) .10436E+01 .10436E+01 .12479E+01 .86847E+00

CONSTRAINT VALUES (G-VECTOR)
1) -.31307E+01 -.55788E+01 -.56843E-13

ITER = 2 OBJ = .12204E+02

DECISION VARIABLES (X-VECTOR)
1) -.65498E+00 .10325E+01 .23572E+01 .13804E+00

CONSTRAINT VALUES (G-VECTOR)
1) -.39775E+00 -.13275E+01 -.76739E-12

ITER = 3 OBJ = .83763E+01

DECISION VARIABLES (X-VECTOR)

```
  1)     .22440E+00   .99268E+00   .20345E+01  -.31841E+00

CONSTRAINT VALUES (G-VECTOR)
  1)    -.11388E+01  -.35427E+01  -.85265E-13



ITER =    4     OBJ =    .69420E+01

DECISION VARIABLES (X-VECTOR)
  1)    -.34392E+00   .10043E+01   .21498E+01  -.80388E+00

CONSTRAINT VALUES (G-VECTOR)
  1)    -.11369E-12  -.80266E+00  -.21613E-01



ITER =    5     OBJ =    .63271E+01

DECISION VARIABLES (X-VECTOR)
  1)    -.67566E-01   .10136E+01   .20734E+01  -.81323E+00

CONSTRAINT VALUES (G-VECTOR)
  1)    -.20225E+00  -.14382E+01   .28422E-13



ITER =    6     OBJ =    .61723E+01

DECISION VARIABLES (X-VECTOR)
  1)    -.94581E-01   .99247E+00   .20400E+01  -.96346E+00

CONSTRAINT VALUES (G-VECTOR)
  1)    -.56843E-13  -.94507E+00  -.53852E-01



ITER =    7     OBJ =    .60706E+01

DECISION VARIABLES (X-VECTOR)
  1)     .74640E-01   .98928E+00   .19478E+01  -.10562E+01

CONSTRAINT VALUES (G-VECTOR)
  1)    -.16766E-01  -.10302E+01  -.28422E-13



ITER =    8     OBJ =    .60218E+01

DECISION VARIABLES (X-VECTOR)
  1)    -.17653E-01   .10038E+01   .20139E+01  -.97523E+00

CONSTRAINT VALUES (G-VECTOR)
  1)    -.17726E-01  -.10338E+01  0.
```

```
 ITER =    9     OBJ =    .60182E+01

 DECISION VARIABLES (X-VECTOR)
   1)     .23921E-01   .99428E+00   .19869E+01  -.10102E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.15891E-01  -.10472E+01   .11747E-02



 ITER =   10     OBJ =    .60133E+01

 DECISION VARIABLES (X-VECTOR)
   1)    -.17147E-01   .10055E+01   .20139E+01  -.97533E+00

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.15050E-01  -.10270E+01   .29211E-02



 ITER =   11     OBJ =    .60098E+01

 DECISION VARIABLES (X-VECTOR)
   1)     .19441E-01   .99482E+00   .19908E+01  -.10058E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.13894E-01  -.10474E+01   .34703E-02


FINAL OPTIMIZATION INFORMATION

 OBJ =    .600982E+01

 DECISION VARIABLES (X-VECTOR)
   1)     .19441E-01   .99482E+00   .19908E+01  -.10058E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.13894E-01  -.10474E+01   .34703E-02
```

LISTING 4

ANALYSIS SUBROUTINE FOR EXAMPLE 2

```
CCCCC6),G1(11),G2(11),B(11,11),C(11),MS1(22) 6),VUB(6),SCAL(6) 11),IC(11),DF(6),A(6,11)
```

```
      VLB(I)=-99999.
      VUB(I)= 99999.
```

```
OBJ =   0.601078E+01

DECISION VARIABLES (X-VECTOR)
  1)    0.26916E-01  0.99458E+00  0.19848E+01 -0.10128E+01

CONSTRAINT VALUES (G-VECTOR)
  1)   -0.14837E-01 -0.10438E+01  0.21458E-02

THERE ARE    2 ACTIVE CONSTRAINTS
CONSTRAINT NUMBERS ARE
    1    3

THERE ARE    0 VIOLATED CONSTRAINTS

TERMINATION CRITERION
     ABS(OBJ(I)-OBJ(I-1))   LESS THAN DABFUN FOR  3 ITERATIONS

NUMBER OF ITERATIONS =   11

OBJECTIVE FUNCTION WAS E-0.1ATED           34  TIMES

CONSTRAINT FUNCTIONS WERE E-0.1ATED        34  TIMES

GRADIENT OF OBJECTIVE WAS CALCULATED       11  TIMES

GRADIENTS OF CONSTRAINTS WERE CALCULATED   11  TIMES
```

LISTING 6

```
      INFOG=0
      INFO=0
      NFDG=2
      IPRINT=1
      NDV=2
      ITMAX=40
      NCON=6
      NSIDE=1
      ICNDIR=0
      NSCAL=0
      FDCH=0.0
      FDCHM=0.0
      CT=0.0
      CTMIN=0.0
      CTL=0.0
      CTLMIN=0.0
      THETA=0.0
      PHI=0.0
      DELFUN=0.0
      DABFUN=0.0
      LINOBJ=1
      ITRM=0
      N1=4
      N2=10
      N3=10
      N4=10
      N5=20
      ALPHAX=0.0
      ABOBJ1=0.0
      CTL=0.0
      DO 5 I=1,NDV
        X(I)=1.0
        VLB(I)=0.001
        VUB(I)= 1.0E+10
    5 CONTINUE
C
      DO 6 J=1,NCON
        ISC(J)=0
    6 CONTINUE
C
C     READ THE PARAMETERS FOR CONMIN
C
CCC   READ(5,CONPAR)      USE DEFAULT VALUES
      WRITCAAgf2D0SI   =DV=2 *(T* +5) T* (    6 CONTINUE)Tj TNON-UESRATIVj T* T OF ANALYSIS T
```

C

ASCE, Pittsburgh, PA, Sept. 1960.