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SPLA CONTROL NUMBER:

This form should be completed and submitted with the program package to the SHARE Program Library Agency at the address shown above. Standards and instructions for submitting programs are in the SHARE Reference Manual, Section 6.

(1) Program Number (to be filled by SPLA) 360D-13.6.007

(2) Title of Program . . . . . NONLINEAR LEAST-SQUARES CURVE-FITTING PROGRAM (NONLINWOOD)

(3) System Type(s) (Machine) S/360

(4) Search Key(s) . . . . . NONLINEAR LEAST-SQUARES
CURVE-FITTING
MULTIPLE REGRESSION ANALYSIS
GAUSHUS

(5) Programming Systems/Languages . . . . FORTRAN 66 & FORTRAN 77 (VS Release 3.0, OPT3)

(6) Primary Subject Code 13.6

(7) Minimum System Requirements OS360

(8) New (N) or Revision (R) (if revision, show prior Program Number in Item 1) R

(9) Date of Submittal 6/1/84

(10) Documentation (number of original pages submitted) 13

(11) Author's Name and Address . . . . . FRED S. WOOD, CONSULTING STATISTICIAN
FRED WOOD & ASSOCIATES
1414 DEL VISTA DRIVE
VALPARAISO, INDIANA 46383
(219) 462-4017

(12) Direct Technical Inquiries to Name & Address (if different than Author)

(13) Submitter's Installation Membership Code . . . . .

(14) Abstract (should contain sufficient information for a reader to determine the value of the program). Listed on the reverse side of this form are subjects which may serve as a guide for a descriptive abstract.

1984 Changes in the NONLINWOOD Program

The 1984 NONLINWOOD program has been revised to provide computer centers with a choice of versions for their users. Support programs, REPLACE and MODIFY, are included along with the appropriate card images to automatically make versions that are either in FORTRAN IV (66) or in FORTRAN 77. The resulting source code is designed to be compiled either with the FORTRAN H EXTENDED (ENHANCED), Version 1.3.0, opt 3 compiler or with the VS FORTRAN, Version 1.3.0, opt 3 compiler. If desired, versions can be provided which allow users to observe on their terminal-scope (KTTY) file both summary statistics and error messages. Users can then follow the progress of the calculations and decide whether to take action to remedy any difficulty with the data or model, or to wait for the more detailed printout.

Four versions are provided to handle different size problems. They are:

Maximum		
Coefficients	Variables	Observations
20	20	170
20	20	1000
43	15	170
80	80	170

Versions with other combinations of maximum coefficients, variables and observations are relatively easy to make with modified replacement cards.

SHARE PROGRAM LIBRARY SUBMITTAL FORM

Subject Guide:

a. Purpose
b. Programming Language used
c. Version and modification level or release number
d. Field of application
e. Type of routine (main program, subroutine, etc.)
f. Specific description of machine requirements

SEE ATTACHED

(Please attach additional pages if necessary) . . . . . Total pages attached 2

An "Acknowledgement of Assistance" statement must be attached to this Submittal Form.

Permission to Publish

"I hereby give the SHARE Program Library Agency permission to reprint, reproduce, and distribute this program"

(15) Signature of Submitter and Date 6/1/84

(15) Signature of Installation Addressee _____

SPLA 1001 (R) Revised 11-76

LINWOOD and NONLINWOOD—Linear and Nonlinear Least Squares Curve-Fitting Programs

1. INTRODUCTION

The LINWOOD and NONLINWOOD linear and nonlinear least squares curve-fitting programs are designed for the analysis of both *global* and *interior* characteristics of data—determining the influence of each observation on the fit, assessing the plausibility of assumptions, searching for influential subsets of variables, estimating measurement error to judge the fit of candidate equations, providing statistics on the range and relative influence of variables to recognize the strengths and limitations of the fit, and checking the validity of fitted equations as additional observations become available.

This summary considers the programs dated January 1980. Documentation is found in the second edition of *Fitting Equations to Data* by Daniel and Wood (1980), including the user's manuals and glossary of terms used in the programs. Supplementary information is issued with the programs from the various program libraries as changes occur. For the past six years, the programs have been the most requested programs in both the SHARE Library (double precision for IBM computers) and the VIM Library (single precision for CDC computers). They are also now available from libraries for Burroughs, DECsystem, Honeywell, and UNIVAC computers. The cost for transmitting each program and associated test problems on tape varies from $35 to $64, depending on the library. (A list of program libraries and their addresses can be found in the appendix at the end of this article.)

Because of the many options and voluminous output (to see by means of plots and tables if anything unexpected is going on), the programs are run in the batch mode from cards or selected files. Some users, however, submit jobs and view portions of the output from interactive computer terminals. This summary describes some of the analytical options and features of the programs.

2. FEATURES

In addition to the usual statistics, the linear program lists the minimum and maximum values of each variable as well as its mean, range, and root mean square. The program also calculates the "relative influence" of each variable. If a coefficient has a moderate-size t value and its variable has been varied over a relatively small range, its relative influence may be far less than one with a smaller t value carried over a larger range. Thus, the relative influence of each variable provides useful insight into both the data and the fitted equation.

2.1 Influence of Outlying and Far-Out Observations

The weighted squared standardized distance (WSSD) of each observation from the centroid of all observations is calculated. This helps the user ascertain whether the response to the outlying observations is the same as the response to inner observations. The outer points will be controlling and often are the most closely fitted of all the data. They may represent start-up conditions, unstable process conditions, or unusual sales conditions, which should be fitted separately. The WSSD of each observation is weighted by the sum of the squares of the $b_i(x_{ij} - \bar{x}_i)$ components of the equation (where b_i is the coefficient, x_{ij} the independent variable, $\bar{x}_i$ its mean, i the index of the variable, and j the index of the observation). There is little interest in observations that are far out in dimensions that are not influential. However, there is always the possibility that a defective far-out observation is controlling and making a variable appear to have little influence. To allow the analyst to check this possibility, the ratio of the variance of each fitted observation to the variance of its residual is calculated. These values depend solely on the relative location of the observation. Hence, far-out observations of both influential and noninfluential variables can be easily spotted.

2.2 Estimates of Measurement Error

In order to determine how well an equation fits the data, one must have some knowledge of measurement error. If the data have been obtained from a well-designed experiment, this information is usually available. If the data have been taken by observing "normal" operations, there are seldom exact duplicates. Therefore, the program estimates the standard deviation of the measurement error from near neighbors (points separated by small standardized distances). This criterion provides a basis on which to decide when to stop modeling.

2.3 Information From Residuals

The programs list all residuals—the differences between the observed and fitted values of the dependent variable—both in the sequence in which observations were given to the computer and in the order of the magnitude of the residuals. Plots of the residuals are made to indicate (a) whether they are (roughly) normally distributed, (b) how they are distributed over the fitted values of the dependent variable, and (c) how they are distributed over each of the independent variables. With this information, potential outliers can be spotted. Studentized residuals are

Historical Operation of LINWOOD and NONLINWOOD Programs

These programs have operated satisfactorily using the following compilers and IBM computer systems:

Compilers: H with Opt=2, H EXTENDED with Opt=2, and H Extended (ENHANCED) with Opt=3 with and without overlays.
G and G1, with and without overlays.
VS FORTRAN, Version 1.3.0 with Opt=3.

Computer Systems:

360 -	50	PCP
	65	EMFT
	75	EMFT
	85	MVT
370 -	138	DOS-VS
	145	DOS-VS
	155	MVT
	158	VS2
	165	MVT
	168	MVT
	168	MVS
	195	MVT
3033 -		MVS
		CMS

For future reference, please notify the undersigned of your experience in operating with other compiler and/or computer-system configurations.

Fred S. Wood

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Table of Contents

NONLINWOOD, Computer Nonlinear Least-Squares Curve-Fitting Program

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NONLINWOOD NONLINEAR LEAST-SQUARES CURVE-FITTING PROGRAM

ABSTRACT

Examples on the use of the LINWOOD and NONLINWOOD linear and nonlinear least-squares curve-fitting programs are described in detail in the second edition of FITTING EQUATIONS TO DATA, Computer Analysis of Multifactor Data, by Cuthbert Daniel and Fred Wood, Wiley Publisher, 1980. Examples on the use of these programs are provided together with interpretation of results, glossary of terms, and User's Manual. For the past six years, these have been the most requested programs in both the SHARE library for IBM computers and the VIM library for CDC computers.

The program allows the user to estimate the coefficients of a nonlinear equation such as $Y = A / (x + B)^2$ and $Y = 1 / (A + B^{-Cx})$ -- equations that are nonlinear in the coefficients. An iterative technique is used; the estimates at each iteration are obtained by Marquardt's Maximum Neighborhood Method which combines the Gauss (Taylor Series) Method and the Method of Steepest Descent.

Since numerous forms of equations can be used, the user must specify the form by providing a subroutine to compute the values of the equation's coefficients. In addition, the user must provide a control card, a format card for reading data, and estimates of the starting values of the coefficients. Selected observations can be deleted if so desired. Information cards and coefficient name cards also can be read for display on the printout. Such displays are helpful to record the form of equation, the purpose of the run, and any additional information that may help identify the printout in the future. Identification of the coefficients by name is particularly helpful when working with large or complex equations.

The output of the program is a printed report which includes a description of the problem, the starting values of the coefficients, the size of the incremental steps, a summary of each iteration, and a summary of the final fit.

Listings are made of the observed and fitted values of the dependent variable -- both in the sequence in which observations were given to the computer, and in the order of the magnitude of the differences between the observed and fitted values. Plots are made to indicate (1) whether these differences are normally distributed and (2) how they are distributed over all the fitted values of the dependent variable. Plots of these differences versus each of the independent variables can be used to choose the appropriate form of the equation and to visualize the distribution of the observations over the range of each independent variable.

Acknowledgements

The linear and nonlinear programs have been converted for use on a number of computer systems and are available from the appropriate libraries (not restricted to library membership).

James D. Murat and Thomas R. Zeisler, University of Wisconsin, converted the programs for BURROUGHS 4700 and 6700 computers. The project was initiated by David S. Rumsey of Burroughs. CUBE Library*, WIS/LINWOOD and WIS/NONLINWOOD.

Michael P. Kelly and Eric R. Ziegel, Standard Oil (Indiana), converted the programs for DECsystem-10/20 computers. DECUS Library**, LINWOOD-10-257 and NONLIN-10-258. David F. Zarnow, Naval Avionics, converted the programs for DECsystem PDP-11 computers, DECUS Library**, LINWOOD-11-419 and NONLIN-11-420.

David Zarnow also converted the programs for Honeywell 600/6000 computers. They were updated by James L. Maxwell and John E. Mc Leod, CPC International. HLSUA Library***, GES-1206 and GES-1207.

SHARE Library**** for IMB 360-370 System Computers, 360D-13.6.008 and 360D-13.6.007.

James E. Keith, Johnson Space Center*****, converted the programs for UNIVAC 1108 computer, LINWOOD and NONLINWOOD.

Neil H. Timm, University of California (Berkeley), adapted the programs for the CDC 6400 computer in single precision. They were updated by Eli Cohen and Bruce E. Foster, Northwestern University. VIM Library******, NUCC-LINWOOD and NUCC-NLWOOD.

* CUBE Librarian, Center for Computer and Information Services, Seton Hall University, South Orange, New Jersey 07079.

** Digital Equipment Computer User's Society, One Iron Way, Marlboro, Massachusetts 01752.

*** Software Library, Mail Station K16, Honeywell Information Systems, Post Office Box 6000, Phoenix, Arizona 85005.

**** Triangle Universities Computation Center, Post Office Box 12076, Research Triangle Park, North Carolina 27709.

***** Johnson Space Center, Code SN3, Houston, Texas 77058.

****** Software Distribution Department, ARH230, Control Data Corporation, 4201 North Lexington Avenue, St. Paul, Minnesota 55112. Also Vogelbeck Computing Center, Northwestern University, 2129 Sheridan Road, Evanston, Illinois 60201.

FILE 1 DOC DOCUMENTATION OF CONTENTS OF TAPE 1/84 NONLINWOOD PROGRAM

MAGNETIC TAPE KEY

TAPE IS UNLABLED. TRACK AND DENSITY AS ORDERED.
FILES 1-12, DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000)
FILES 13-14, DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3059)

CONTENTS OF TAPE

```
**********************************************************************
*                                                                    *
* NOTE: WHEN COPYING THE FILES OF THIS TAPE, DO NOT RESEQUENCE THE   *
* CARD IMAGES.  THE SEQUENCE NUMBERS ARE USED IN THE REPLACEMENT     *
* PROGRAM TO IDENTIFY AND CHANGE THE DIMENSIONS OF THE PROGRAM.      *
*                                                                    *
**********************************************************************
```

NONLINWOOD PROGRAM

FILE		CARD IMAGES
1	DOC CONTENTS OF TAPE AND INSTRUCTIONS ON USE OF FORTRAN REPLACEMENT PROGRAM (1) TO REPLACE CARDS TO MAKE LARGER VERSIONS OF PROGRAM AND (2) TO MAKE A FORTRAN 77 VERSION OF PROGRAM FROM THE FORTRAN IV SOURCE DECK. INSTRUCTIONS ARE ALSO INCLUDED ON THE USE OF THE FORTRAN MODIFICATION PROGRAM TO INSERT CARDS TO PRINT SUMMARY STATISTICS AND ERROR MESSAGES ON USERS TERMINAL SCOPE IF DESIRED.	95
2	F4 FORTRAN IV SOURCE DECK OF NONLINEAR LEAST-SQUARES CURVE-FITTING PROGRAM. AS DIMENSIONED, THE PROGRAM WILL HANDLE 20 VARIABLES, 20 COEFFICIENTS AND 170 OBSERVATIONS.	1701
3	TEST SAMPLE TEST PROBLEMS FROM BOOK FITTING EQUATIONS TO DATA BY DANIEL AND WOOD, SECOND EDITION, WILEY PUBLISHER.	377
4	RPL FORTRAN SOURCE DECK OF REPLACEMENT PROGRAM.	52
	REPLACEMENT PROGRAM INSTRUCTIONS AFTER COMPILING THE REPLACEMENT PROGRAM FROM TAPE FILE 4, THE ORIGINAL F4 FORTRAN SOURCE OF THE NONLINWOOD PROGRAM IS READ FROM TAPE FILE 2 ON UNIT 8. THE REPLACEMENT CARDS ARE READ FROM ANY TAPE FILE 5 THROUGH 9 ON UNIT 5. THE CHANGES ARE PRINTED ON UNIT 6 AND THE NEW FORTRAN SOURCE PROGRAM IS PUNCHED OR PUT IN CARD IMAGES ON UNIT 7.	
5	R20 FORTRAN REPLACEMENT CARDS TO MAKE PROGRAM OF 20 MAX VARIABLES, 20 MAX COEFFICIENTS AND 170 MAX OBSERVATIONS.	11
6	RM2 FORTRAN REPLACEMENT CARDS TO INCREASE PROGRAM TO 20 MAX VARIABLES, 20 MAX COEFFICIENTS AND 1000 MAX OBSERVATIONS.	11
7	R43 FORTRAN REPLACEMENT CARDS TO INCREASE PROGRAM TO 15 MAX VARIABLES, 43 MAX COEFFICIENTS AND 170 MAX OBSERVATIONS.	11
8	R80 FORTRAN REPLACEMENT CARDS TO INCREASE PROGRAM TO 80 MAX VARIABLES 80 MAX COEFFICIENTS AND 170 MAX OBSERVATIONS.	11

9 RFT77 32
REPLACEMENT CARDS TO MAKE A FORTRAN 77 SOURCE DECK FROM THE FILE 2, F4 FORTRAN IV SOURCE DECK.

10 MOD 98
FORTRAN SOURCE DECK OF PROGRAM MODIFY.

PROGRAM MODIFY INSTRUCTIONS
AFTER COMPILING THE PROGRAM MODIFY FROM TAPE FILE 10, THE ORIGINAL F4 FORTRAN IV SOURCE OF THE LINWOOD PROGRAM IS READ FROM TAPE FILE 2 ON UNIT 8. THE MODIFY CARDS ARE READ FROM FILE 11. THE CHANGES ARE PRINTED ON UNIT 6 AND THE NEW FORTRAN SOURCE PROGRAM IS PUNCHED OR PUT IN CARD IMAGES ON UNIT 7.

11 MKTTY 84
MODIFICATION CARDS TO INCLUDE KTTY WRITE STATEMENTS TO A SCOPE TERMINAL (FILE 30) FOR VIEWING THE SUMMARY OF RESULTS AND ALL ERROR MESSAGES BEFORE REQUESTING PRINTING OF OUTPUT. CAN BE USED WITH EITHER THE FORTRAN IV OR 77 VERSIONS OF NONLINWOOD.

12 JCL 146
EXAMPLES OF JOB CONTROL LANGUAGE CARDS TO COMPILE, LINK WITH OVERLAY, PLACE IN LIBRARY, RUN FROM LIBRARY, AND COMPILE LINK AND GO WITH THE REPLACEMENT PROGRAM. EXAMPLES OF DOS JCL ARE ALSO GIVEN.

13 PRINT
PRINTOUT OF TEST PROBLEMS.

14 PRINT
PRINT OF SUMMARY STATICTICS ON USERS TERMINAL-SCOPE.

TOTAL NUMBER OF CARD IMAGES = 2629

NONLINWOOD NONLINEAR LEAST-SQUARES CURVE-FITTING PROGRAM

USER'S INSTRUCTIONS

CONTROL CARD

COLUMN -----DESCRIPTION----- (NOTE: BLANKS = 0)

1-20 IDENTIFICATION OF PROBLEM.
21 0 OBSERVATIONS READ FROM CARDS OR FILE.
1 REUSE DATA FROM PREVIOUS PROBLEM.
23-24 NUMBER OF COEFFICIENTS TO BE ESTIMATED.
25-26 FILE NUMBER IF DATA ARE TO BE READ FROM SEPARATE FILE. NO END CARD(S) IF ONLY ONE SET OF DATA IS ON EACH FILE.
27-28 NUMBER OF INDEPENDENT VARIABLES TO BE READ.
31-32 NUMBER OF THE EQUATION TO BE USED.

33-36 STARTING VALUE FOR LAMBDA, F4.2, (E.G. 0.1), USED AS A MULTIPLIER TO SCALE THE SPACE OR SIZE STEPS TAKEN.
37-40 VALUE OF NU, F4.0, (E.G. 10.), DIVISOR AND MULTIPLIER TO CHANGE SIZE OF LAMBDA DEPENDING ON WHETHER SUM OF SQUARES OF ITERATION IS NEAR OR FAR FROM MINIMUM.
43-44 MAXIMUM NUMBER OF ITERATIONS, I2, (E.G. 20).
45-48 MULTIPLIER USED TO INCREMENT VALUE OF COEFFICIENTS, F4.3 (E.G. 0.01).

NOTE: IF VALUES IN COLUMNS 33-48 ARE NOT DEFINED ON THE CONTROL CARD, THEIR LEVEL WILL BE SET AUTOMATICALLY TO THE ABOVE E.G. VALUES.

CRITERIA FOR ENDING CONVERGING ITERATIONS.
49-56 SUM OF SQUARES CRITERION, F8.7, (E.G. 0.0001, A CHANGE OF LESS THAN 0.0001 IN THE RESIDUAL SUM OF SQUARES).
57-64 RATIO OF COEFFICIENTS CRITERION , F8.7, (E.G. 0.001, A CHANGE OF LESS THAN 0.001 IN THE RATIOS OF ALL COMPARABLE COEFFICIENTS).

NOTE: VALUES IN COLS. 49-64 CAN BE SET AT 0.0 IF CONTROL OF EITHER OR BOTH IS NOT DESIRED.

65-66 NUMBER OF INFORMATION CARDS TO BE READ FOR DISPLAY ON PRINTOUT IF DESIRED, 72 COL. EACH.
68 1 READ NAMES OF COEFFICIENTS FROM CARDS FOR DISPLAY ON PRINTOUT, 1ST 6 OF 10 COLS. / COEFFICIENT, 7 / CARD.
69 3 PLOT RESIDUALS VS. EACH INDEPENDENT VARIABLE.
70 NUMBER OF DELETE-OBSERVATIONS CARDS, OBSERVATION IDENTIFICATION IN 1ST 6 OF 10 COLS., 7 / CARD.

NONLINWOOD NONLINEAR LEAST-SQUARES CURVE-FITTING PROGRAM

USER'S INSTRUCTIONS CONTINUED

FORMAT CARD TO READ DATA

COL. 1-72 E.G. (A6, F6.0, (NOIND*F6.0)
IDENT IDENTIFICATION OF OBSERVATION, A6
Y(J) DEPENDENT VARIABLE, J-TH OBSERVATION, F6.0
X(I,J) INDEPENDENT VARIABLE, I-TH VARIABLE, J-TH OBSERVATION, NOIND*(F6.0)

EXAMPLE OF SUBROUTINE MODEL

EQUATIONS TO BE USED WILL BE WRITTEN IN FORTRAN AND PLACED IN SUBROUTINE MODEL1, 2, 3, 4, OR 5 AS FOLLOWS:

```
SUBROUTINE MODEL1 (NPROB, B, FY, NOB, NC, X, NVARX, NOBMAX, NCMAX)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION  B(NCMAX), FY(NOBMAX), X(NVARX,NOBMAX)

DO 10  J = 1, NOB
                EXAMPLE OF EQUATION
FY(J) = B(1)*X(1,J)**B(2) + B(3)

10 CONTINUE
RETURN
END
```

NOTE: ALL EQUATIONS ARE TO BE WRITTEN SO THAT THE COEFFICIENTS ESTIMATED AND CALCULATED WILL BE POSITIVE. IN SINGLE PRECISION PROGRAMS DELETE THE ABOVE IMPLICIT REAL*(A-H,O-Z) STATEMENT.

ORDER OF CARDS FOR EACH PROBLEM

1 CONTROL CARD.
2 FORMAT CARD (72COL). E.G. (A6,F6.0,(NOIND*F6.0)) TO READ DATA.
3 DELETE-OBSERVATIONS CARD(S), IF ANY
(1ST 6 OF 10 COLS. / OBSERVATION DELETED, 7 / CARD).
4 STARTING VALUES (GUESSES) OF COEFFICIENTS (10COL/COEF, 7/CARD).
5 INFORMATION CARDS FOR PRINTOUT,IF ANY (72COL/CARD, 12 CARDS MAX).
6 NAMES OF COEFFICIENTS CARD(S) FOR PRINTOUT, IF ANY
(1ST 6 OF 10 COLS. / COEFFICIENT, 7 / CARD).
7 DATA CARDS (IF NOT READ FROM A FILE).
8 END CARD (END IN FIRST 3 POSITIONS OF IDENTIFICATION).

NOTE: FORMAT, DELETE, DATA AND END CARDS ARE NOT NEEDED IN SUBSEQUENT PROBLEMS IF SAME INPUT DATA ARE REUSED.

Nonlinear Least-Squares Curve Fitting Program

Name | Date

I. CONTROL CARD

Problem Identification

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

21
- 0 = READ DATA WITH FORMAT CARD
- 1 = REUSE DATA FROM PREVIOUS PROBLEM

23-24 NUMBER OF COEFFICIENTS TO BE ESTIMATED
25-26 FILE NO. IF DATA READ FROM DIFFERENT FILE
27-28 NO. OF INDEPENDENT VARIABLES TO BE READ
32 NO. OF THE EQUATION TO BE USED
33-36 STARTING VALUE FOR LAMBDA (E.G. 0.1)*
37-40 VALUE OF NU (E.G. 10.0)*
43-44 MAXIMUM NO. OF ITERATIONS (E.G. 20)*

*Note: If not defined, level will be set automatically to the E.G. value

45-48 MULTIPLIER USED TO INCREMENT VALUE OF COEFFICIENTS (E.G. 0.01)*

CRITERIA FOR ENDING CONVERGING ITERATIONS

49-56 SUM OF SQUARES (E.G. 0.0001)
57-64 RATIO OF COEFFICIENTS (E.G. 0.001)

65-66 NUMBER OF INFORMATION CARDS
68
- 1 = READ NAMES OF COEFFICIENTS

69
- 3 = PLOT RESIDUALS VS. EACH INDEPENDENT VARIABLE

70 NUMBER OF DELETE OBSERVATIONS CARDS

II. FORMAT CARD - MUST INCLUDE THE FOLLOWING:

a) IDENTIFICATION OF OBSERVATION, A6 b) DEPENDENT VARIABLE, (E.G. F4.3) c) INDEPENDENT VARIABLE(S), (E.G. F6.0, 2F5.1) E.G. FORMAT CARD COLS 1-72: (A6, 6X, F4.3, F6.0, 2F5.1)

73 | User's Option | 80

III. DELETE OBSERVATIONS CARD(S) – OPTIONAL (IDENTIFICATION NUMBER OF OBSERVATION(S) TO BE DELETED, IN SAME ORDER AS GIVEN TO COMPUTER.)

	1–6	11–16	21–26	31–36	41–46	51–56	61–66	73–80
1								D O C 1
2								D O C 2

IV. STARTING VALUE CARD(S) - STARTING VALUES (GUESSES) OF COEFFICIENTS

	1–10	11–20	21–30	31–40	41–50	51–60	61–70	73–80
1-7								S V 1
8-14								S V 2
15-21								S V 3

V. INFORMATION CARD(S) - OPTIONAL

1		I N F 1
2		I N F 2
3		I N F 3
4		I N F 4
5		I N F 5
6		I N F 6
7		I N F 7
8		I N F 8

VI. NAMES OF COEFFICIENT CARD(S) - OPTIONAL

	1–6	11–16	21–26	31–36	41–46	51–56	61–66	73–80
1-7								N A M E 1
8-14								N A M E 2
15-21								N A M E 3

VII. DATA CARDS

VIII. END CARDS

"END" IN FIRST THREE POSITIONS OF IDENTIFICATION OF OBSERVATION FIELD

Form 33-48 (3-78)

LINEAR LEAST - SQUARES CURVE FITTING PROGRAM

III STANDARD DATA-CARD ENTRY FORM

ENTER WEIGHTING FACTOR, IF ANY, AS LAST ENTRY.
"END" CARD MUST BE LAST CARD.

IDENT.	OBSV. NO.	SEQ NO.	x1-11-21	x2-12-22	x3-13-23	x4-14-24	x5-15-25	x6-16-26	x7-17-27	x8-18-28	x9-19-29	x10-20-30	USER'S OPTION
1 2 3 4 5 6	7 8 9 0	1 2	3 4 5 6 7 8	9 0 1 2 3 4	5 6 7 8 9 0	1 2 3 4 5 6	7 8 9 0 1 2	3 4 5 6 7 8	9 0 1 2 3 4	5 6 7 8 9 0	1 2 3 4 5 6	7 8 9 0 1 2	3 4 5 6 7 8 9 0

1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0
	1	2	3	4	5	6	7	8

FORM B-56 REV. 3-69

```
//* EXAMPLE OF JCL TO RUN NONLINEAR LEAST-SQUARES CURVE FITTING PROGRAM JCL 0010
//*  20 VARIABLES                                                       JCL 0020
//*  FILE 30 PRINTS OR SHOWS SUMMARY STATISTICS ON USERS TERMINAL-SCOPE JCL 0021
//JOBLIB DD DSNAME=CAP.LDLIBTW,DISP=(SHR,PASS)                         JCL 0030
//       EXEC PGM=AT1190AC,REGION=128K                                 JCL 0040
//GO.FT06F001 DD SYSOUT=A,                                             JCL 0050
//   DCB=(RECFM=FBA,BLKSIZE=1995,LRECL=133),SPACE=(133,(10000,0))      JCL 0060
//GO.FT30F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)       JCL 0061
//GO.FT05F001 DD   *                                                   JCL 0070
                DATA GO BEFORE THIS CARD                               JCL 0080
NOTE PROGRAM AT1190AC IS IN LOAD LIBRARY CAP.LDLIBTW.                  JCL 0090
TO RUN PUT /* IN COLUMNS 1 AND 2 ON JCL 0080                          JCL 0100
```

```
//*  EXAMPLE OF JCL TO COMPILE MODEL(S), LINK AND RUN NONLINEAR LEAST- JCL 0010
//* SQUARES CURVE FITTING PROGRAM - 20 VARIABLES                       JCL 0020
//* PROGRAM AT1190AC IS IN LOAD LIBRARY CAP.LDLIBTW                    JCL 0030
//*  FILE 30 PRINTS OR SHOWS SUMMARY STATISTICS ON USERS TERMINAL-SCOPE JCL 0031
// EXEC FRTNGCLG,LR='OVLY',GREG=128K                                   JCL 0040
//COMP.SYSIN  DD *   FORTRAN MODEL(S)(1-5) FOLLOW THIS CARD            JCL 0050
//LINK.WOOD   DD DSN=CAP.LDLIBTW,DISP=(SHR,PASS)                       JCL 0060
//LINK.SYSIN  DD *                                                     JCL 0070
      INCLUDE WOOD(AT1190AC)                                           JCL 0080
     INSERT DATA01,DATA02,DATA04,MINMAX                                JCL 0090
     OVERLAY AAA                                                       JCL 0100
     INSERT READIN                                                     JCL 0110
     OVERLAY AAA                                                       JCL 0120
     INSERT GAUSHS,TTEST,EIGENJ,MATINV                                 JCL 0130
     OVERLAY BBB                                                       JCL 0140
     INSERT MODEL1                                                     JCL 0150
     OVERLAY BBB                                                       JCL 0160
     INSERT MODEL2                                                     JCL 0170
     OVERLAY BBB                                                       JCL 0180
     INSERT MODEL3                                                     JCL 0190
     OVERLAY BBB                                                       JCL 0200
     INSERT MODEL4                                                     JCL 0210
     OVERLAY BBB                                                       JCL 0220
     INSERT MODEL5                                                     JCL 0230
     OVERLAY AAA                                                       JCL 0240
     INSERT SORT                                                       JCL 0250
     OVERLAY AAA                                                       JCL 0260
     INSERT PITCHA,GRID,PACK,FORCE                                     JCL 0270
     ENTRY MAIN                                                        JCL 0280
//GO.FT06F001 DD SYSOUT=A,                                             JCL 0290
//   DCB=(RECFM=FBA,BLKSIZE=1995,LRECL=133),SPACE=(133,(10000,0))      JCL 0300
//* AT OPTION OF THE USER SOME OF THE DATA ARE READ FROM FILE 9        JCL 0310
//GO.FT09F001 DD DISP=SHR,LABEL=(,,,IN),DSN=CSD.SOR.WOOD.DATA(W3499072) JCL 0320
//GO.FT30F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)       JCL 0321
//GO.FT05F001  DD  *                                                   JCL 0330
                DATA GO BEFORE THIS CARD                               JCL 0340
TO RUN PUT /* IN COLUMNS 1 AND 2 ON JCL 0340                          JCL 0350
```

```
//*  EXAMPLE OF JCL TO COMPILE, LINK WITH OVERLAY AND PLACE IN LIBRARY.  JCL 0010
//* NONLINEAR LEAST-SQUARES CURVE FITTING PROGRAM - 20 VARIABLES         JCL 0020
// EXEC FRTNHCL,PARM.COMP='MAP,XREF,OPT=3',LR='XREF,OVLY'               JCL 0030
//COMP.SYSIN  DD *    FORTRAN DECK FOLLOWS THIS CARD                   JCL 0040
//LINK.SYSLMOD  DD DSN=CAP.LDLIBTW,DISP=SHR                            JCL 0050
//LINK.SYSIN  DD *                                                     JCL 0060
     INSERT DATA01,DATA02,DATA04,MINMAX                                JCL 0070
     OVERLAY AAA                                                       JCL 0080
     INSERT READIN                                                     JCL 0090
     OVERLAY AAA                                                       JCL 0100
     INSERT GAUSHS,TTEST,EIGENJ,MATINV                                 JCL 0110
     OVERLAY BBB                                                       JCL 0120
     INSERT MODEL1                                                     JCL 0130
     OVERLAY BBB                                                       JCL 0140
     INSERT MODEL2                                                     JCL 0150
     OVERLAY BBB                                                       JCL 0160
     INSERT MODEL3                                                     JCL 0170
     OVERLAY BBB                                                       JCL 0180
     INSERT MODEL4                                                     JCL 0190
     OVERLAY BBB                                                       JCL 0200
     INSERT MODEL5                                                     JCL 0210
     OVERLAY AAA                                                       JCL 0220
     INSERT SORT                                                       JCL 0230
     OVERLAY AAA                                                       JCL 0240
     INSERT PITCHA,GRID,PACK,FORCE                                     JCL 0250
     ENTRY MAIN                                                        JCL 0260
      NAME AT1190AC(R)                                                 JCL 0270
                                                                       JCL 0280
NOTE PROGRAM AT1190AC IS PLACED IN LOAD LIBRARY CAP.LDLIBTW.           JCL 0290
TO RUN PUT /* IN COLUMNS 1 AND 2 ON JCL 0280                           JCL 0300
```

```
//* THE FOLLOWING JCL ASSUMES THAT SOME OF THE FILES ON THE SHARE TAPE  JCL 4010
//* HAVE BEEN STORED AS FOLLOWS: FILE 2 = NLNFTN, 4 = NLNRPL,          JCL 4020
//*                                    7 = NLNR43 AND 8 = NLNR80.      JCL 4030
//*                                                                    JCL 4040
//*  JCL TO COMPILE REPLACEMENT PROGRAM, LINK AND GO REPLACEMENT CARDS  JCL 4050
//* TO INCREASE DIMENSIONS OF PROGRAM WITH NLNR43.                     JCL 4060
//*  (TO FURTHER INCREASE DIMENSIONS, CHANGE NLNR43 TO NLNR80 AND      JCL 4061
//* NLNWOOD4 TO NLNWOOD8).                                             JCL 4062
//*  SUBSTITUTE YOUR COMPUTER CENTER'S COMPILER NAME FOR FTNG1CLG.      JCL 4070
//*  FILE 30 PRINTS OR SHOWS SUMMARY STATISTICS ON USERS TERMINAL-SCOPE JCL 4071
//COPY EXEC PGM=IEBGENER,REGION=64K                                    JCL 4080
//SYSIN DD DUMMY                                                       JCL 4090
//SYSPRINT DD SYSOUT=A                                                 JCL 4100
//SYSUT1 DD DISP=(OLD,KEEP),DSN=CSP.SORCELIB.YURFILE(NLNR43)           JCL 4110
//SYSUT2 DD DISP=(NEW,PASS),DSN=&&TEMP,UNIT=SYSDA,SPACE=(80,300,RLSE),  JCL 4120
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000)                                JCL 4130
// EXEC FTNG1CLG                                                       JCL 4140
//COMP.SYSIN DD DISP=SHR,DSN=CSP.SORCELIB.YURFILE(NLNRPL),DCB=OPTCD=W  JCL 4150
//GO.FT06F001 DD SYSOUT=A                                             JCL 4160
//GO.FT07F001 DD DISP=(NEW,PASS),DSN=&&TEMP2,UNIT=SYSDA,              JCL 4170
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),SPACE=(80,5000,RLSE)          JCL 4180
//GO.FT08F001 DD DISP=SHR,DSN=CSP.SORCELIB.YURFILE(NLNFTN),           JCL 4190
// DCB=OPTCD=W,LABEL=(,,,IN)                                          JCL 4200
//GO.FT30F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=6118)      JCL 4201
//GO.FT05F001 DD DISP=(OLD,DELETE),DSN=&&TEMP                         JCL 4210
//COPZ EXEC PGM=IEBGENER,REGION=64K                                   JCL 4220
//SYSIN DD DUMMY                                                      JCL 4230
//SYSPRINT DD SYSOUT=A                                                JCL 4240
//SYSUT1      DD DISP=(OLD,DELETE),DSN=&&TEMP2                        JCL 4250
//SYSUT2 DD DISP=(OLD,KEEP),DSN=CSP.SORCELIB.YURFILE(NLNWOOD4)        JCL 4260
TO RUN PUT /* IN COLUMNS 1 AND 2 ON JCL                               JCL 4270
```

```
//* EXAMPLE OF DOS JCL TO RUN LINWOOD PROGRAM.                    JCL 5010
// JOB JOBNAME  LINWOOD                                           JCL 5020
// EXEC JOBNAME                                                   JCL 5030
                CONTROL AND DATA CARDS GO BEFORE THIS CARD        JCL 5040
TO RUN PUT /* IN COLUMNS 1 AND 2 OF THE PREVIOUS CARD.            JCL 5050
```

```
//* EXAMPLE OF DOS JCL TO COMPILE NONLINWOOD, LINK AND PLACE IN LIBRARY.JCL 6010
// JOBNAME NONLINWOOD CATAL TO C/I/L                              JCL 6020
// OPTION CATAL                                                   JCL 6030
 PHASE JOBNAME,*                                                 JCL 6040
// EXEC FFORTRAN                                                  JCL 6050
      FORTRAN DECK GOES BEFORE THIS CARD                         JCL 6060
TO RUN PUT /* IN COLUMNS 1 AND 2 OF THE PREVIOUS CARD.           JCL 6070
 INCLUDE ILFGHTAB                                                JCL 6080
// EXEC LNKEDT                                                    JCL 6090
                                                                  JCL 6100
TO RUN PUT /* IN COLUMNS 1 AND 2 OF THE PREVIOUS CARD.           JCL 6110
```

```
//* JCL TO LIST FILES FROM NONLABELED SHARE TAPE CALLED "SHARE1", NONLINWOOD PGM
//* JCL TO LIST FILE 1, DOCUMENTATION OF TAPE FILES.
//COPY EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(1,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 2, FORTRAN SOURCE DECK OF NONLINWOOD.
//COP2 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(2,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 3, CARDS OF SAMPLE TEST PROBLEMS.
//COP3 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(3,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 4, FORTRAN SOURCE DECK OF REPLACEMENT PROGRAM.
//COP4 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(4,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 5. FORTRAN REPLACEMENT CARDS TO MAKE 43 COEF. PGM.
//COP5 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(5,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 6. FORTRAN REPLACEMENT CARDS TO MAKE 80 COEF. PGM.
//COP6 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(6,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 7. EXAMPLES OF JOB CONTROL LANGUAGE CARDS.
//COP7 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(7,NL,,IN),VOL=SER=SHARE1,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=4000),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
//* JCL TO LIST FILE 8, PRINTOUT OF TEST PROBLEMS.
//COP8 EXEC PGM=IEBGENER,REGION=64K
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=CSD.SHARE,UNIT=T9,LABEL=(8,NL,,IN),VOL=SER=SHARE1,
//          DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3059),DISP=(OLD,KEEP)
//SYSUT2 DD SYSOUT=A
TO RUN PUT /* IN COLUMNS 1 AND 2 OF LAST CARD IN DECK.
```

Machine Requirements

FORTRAN Compiler

Card Reader (file 5, set in MAIN, card 01CT 2222)

Printer (file 6, set in MAIN, card 01CT 2226)

Scope-Terminal (optional, file 30, set in MAIN, card 01CT 2232)

Dimensions for Loading Various Versions of Program

	FORTRAN IV H Compiler
80 Coefficients, 80 Variables, 170 Obs.	457K
43 Coefficients, 15 Variables, 170 Obs.	206K
20 Coefficients, 20 Variables, 170 Obs.	145K
20 Coefficients, 20 Variables, 1000 Obs.	438K

Effect of Various Options:

With Scope-Terminal File	Add	2K
With VS FORTRAN Compiler	Add	84K
With VS FORTRAN Compiler and Scope-Terminal File	Add	89K