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DECUS NO.	FOCAL8-200
TITLE	SIMEQR - 20 SIMULTANEOUS EQUATIONS IN 8K FOCAL
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SOURCE LANGUAGE	FOCAL8

SIMEQR - 20 SIMULTANEOUS EQUATIONS IN 8K FOCAL

DECUS Program Library Write-up — DECUS NO. FOCAL8-200

Program description

This program uses a Gauss elimination scheme adapted from a FORTRAN program given by McCracken[1]. As adapted for 8K FOCAL in SIMEQR-F2, this algorithm can handle as many as 20 equations. In addition to 8K FOCAL, this program requires a patch FP (available[2] as DECUS FOCAL8-XXX), which provides Field-1 storage of variables. (This FP patch is a modification for FOCAL,1969 of an earlier FNEW patch by Wrege[3].)

SIMEQR assumes that the equations are arranged in the following form:

$$A_{11}x_1 + A_{12}x_2 + \ldots + A_{1n}x_n = B_1$$

$$A_{21}x_1 + A_{22}x_2 + \ldots + A_{2n}x_n = B_2$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot$$

$$A_{n1}x_1 + A_{n2}x_2 + \ldots + A_{nn}x_n = B_n$$

or $[A]\ [x] = [B]$ in matrix form

Each of the A's must be identified with its row-column subscript, and each of the B's must be identified with its row number.

The structure of the complete program may be arranged into three principal blocks. The first block comprises the mainline statements contained in FOCAL group 10, with

[1] McCracken, D.D., "FORTRAN with Engineering Applications," Wiley, 1967; Case Study 24, p. 154.

[2] Pike, A.L., "FOCAL Patch for Function FP," DECUS FOCAL8-XXX, DECUS Library, Maynard, Mass.

[3] Wrege, D.E., "STRIP FOCAL - Storage of Data Arrays," DECUS FOCAL8-7, DECUS Library, Maynard, Mass.

calls to I/O structures in groups 11 and 12. The second block is a "put" routine, written in group 13 to handle the format problems of listing a 20 x 20 matrix, or smaller. Finally, the mathematical algorithm is controlled from group 7, which in turn calls groups 2 through 6 for rapid execution of special elements in the procedure. The program listing, given at the end of these notes, contains comment lines for ready identification of these components.

Operating instructions

After loading 8K FOCAL,1969, use BIN to load the FP overlay. Then, load the SIMEQR source tape with the usual FOCAL methods for either the high-speed reader or for the teletype. Start SIMEQR by typing GO and a RETURN. SIMEQR announces itself with its version number and asks if paper-tape input is wanted. Answer this question by typing Y or N, followed by a space bar (the space bar may be used to terminate every input.)

For keyboard input, the teletype requests the number n of equations to be solved. Type the number and a space. Then the program asks for the values in the A matrix. On each line, the teletype requests a ROW number. Type this number and a space. Then the program requests a COL number. Enter the column number and a space. Next the program requests the value of the corresponding coefficient in the A matrix. After you type this value and a space, the program outputs a carriage return and prepares to accept the next data. Because each A is identified with its own subscripts, the values may be entered in any order (column-major, row-major, or scrambled) as long as all values are supplied.

When n^2 coefficients have been entered, the program requests the B vector of constant right-hand terms. For each line, the teletype requests a ROW number, then the constant value. When n constants have been supplied to the B vector, the program tabulates all of the input data; then the program uses its elimination algorithm to determine the n solutions. After all solutions have been found, the program tabulates these answers for x in a simple column.

Sparse-matrix feature

In practical problems, the coefficient matrix A often has many zero values. To avoid the request for all of the constants, the program zeros the necessary storage space as soon as the number n of equations has been entered. For a sparse matrix, all of the nonzero coefficients may be entered in any suitable order. When the next ROW number request is made, type 99 (or 21 or any other row number greater than 20.) The program uses the 99 as a sparse-matrix trigger to terminate reading into the A matrix. The sequence moves on into the input section for the B vector of constants. Similarly, the nonzero constants in B may be entered in any appropriate order. Then the ROW request may be answered with 99 to terminate the reading sequence for B.

Use of the 99-trigger to terminate both reading sequences would be particularly advantageous for the 10 equations that would be needed for a 10-loop ladder network in electric-circuit analysis, especially if the network had only one source (that is, only one B element.) Instead of 100 total entries into the A matrix, perhaps only 30 nonzero items would be required, with only one entry needed into the B vector. For accurate verification of the input data (which the algorithm destroys during execution), all the values (zero and nonzero) are printed on the teletype by the tabulating routines.

Data entry by high-speed punched paper tape

For many sets of equations, it may be worthwhile to punch a paper tape with all the needed data. This task may be done off-line, or with a PDP-8 editor program. The format may be conveniently organized as follows:

number of equations n and a RETURN

row, space, column, space, A value, RETURN

row, space, column, space, A value, RETURN

... etc., through n^2 values for A (or until

99 and RETURN begin a new line), and then

row, space, B value, RETURN

row, space, B value, RETURN

... etc., through n values (or to

99 and RETURN for the sparse-data trigger.)

(The data tape may be identified with a comment after all of the B values are entered; FOCAL will not read this comment if the numbering is satisfactory for all the subscripts.) Note: if the data tape is prepared off-line, each RETURN must be followed by a LINE FEED for proper printing - the editor programs supply this character automatically, however.

Although this program does not handle a data tape satisfactorily in the teletype reader unless additional interrupt patches are made to FOCAL itself, SIMEQR has been tested on an 8K PDP-8e having only the ASR33 reader. With the DEC patch[4] appropriate for the 8e only, reading and writing interleave successfully without any adjustment in SIMEQR.

Execution time

The implementation of the algorithm has been reasonably optimized for rapid running in the 8K FOCAL system. There is a wait of several seconds to zero the data space for the 20-equation case. However, solution of a sample 20-equation run (with

[4] Digital Software News for PDP-8, FOCAL17: "Optimum Use of the PDP-8e for FOCAL,1969 - DEC-08-AJAE," Nov. 1971

420 nonzero data items entered by high-speed paper tape) required only 3 minutes and 40 seconds for computation time. Of course, additional printing time is required to tabulate the input data and to list the answers. For only 3 equations, FOCAL's interrupt system permits computation to overlap completely with printing.

Accuracy

Because the elimination algorithm is known to yield unusable results for ill-conditioned sets of equations, no statement of accuracy can be made that is independent of the data. However, useful solutions have been found with many practical sets of data. Doubtful solutions should be tested by independent substitutions. Other numerical-analysis techniques than elimination may be required to obtain solutions when doubtful results have been shown to be false.

```
C - SIMEQR-F2-11/13/71-PIKE

01.10 C 10.10
C - ZEROING LOOPS, SUBSCRIPT POINTERS
01.40 S T=FP(420+I,0)
01.50 S T=FP(400+I,0)
01.60 F K=1,N;D 1.70;S T=FP(IK,0)
01.70 S IK=I+20*(K-1)
01.80 S IJ=I+20*(J-1)
01.90 S KJ=K+20*(J-1)

C - SUBTRACTION FOR ROW K+1
02.10 D 1.80;D 1.90
02.30 S T=FP(IJ,FP(IJ)-RA*FP(KJ))

C - ELIMINATION BELOW DIAGONAL, COLUMN K
03.20 D 1.70;S KK=K+20*(K-1)
03.30 S RA=FP(IK)/FP(KK)
03.40 F J=KP,N;D 2
03.50 S X=FP(400+I,FP(400+I)-RA*FP(400+K))

C - ROW INTERCHANGE, RIGHT SIDE OF DIAGONAL
04.20 D 1.90;S LJ=L+20*(J-1)
04.30 S T=FP(KJ)
04.40 S X=FP(KJ,FP(LJ))
04.50 S X=FP(LJ,T)

C - SEARCH ROUTINE DOWN COLUMN K
05.20 D 1.70;S LK=L+20*(K-1)
05.30 I (FABS(FP(IK)) - FABS(FP(LK)))5.50,5.50,5.40
05.40 S L=I
05.50 R

C - CONDENSATION, PIVOT ROW K
06.10 S KP=K+1;S L=K
06.15 F I=KP,N;D 5
06.20 I (L-K)6.25,6.45,6.25
06.25 F J=K,N;D 4
06.30 S T=FP(400+K)
06.35 S X=FP(400+K,FP(400+L))
06.40 S X=FP(400+L,T)
06.45 F I=KP,N;D 3

C - GAUSS ELIMINATION ROUTINE
07.10 S NM=N-1;I (NM-1)7.30;
07.20 F K=1,NM;D 6
C - BACK SUBSTITUTION
07.30 S NN=N+20*(N-1)
07.40 S X=FP(420+N,FP(400+N)/FP(NN))
07.50 S I=NM;I (NM-1)7.90;
07.60 S IP=I+1;S SM=0
07.70 F J=IP,N;D 1.80;S SM=SM+FP(IJ)*FP(420+J)
07.75 S II=I+20*(I-1)
07.80 S X=FP(420+I,(FP(400+I)-SM)/FP(II))
07.85 S I=I-1;I (I-1)7.90,7.60,7.60
07.90 R
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C - SIMEQR-F2-11/13/71

C - MAINLINE, I/O HANDLERS
1Ø.1Ø T !"SIMEQR-F2"!!
1Ø.12 A "TAPE INPUT? TYPE Y OR N: "X,!
1Ø.14 I (X-ØY)1Ø.16,1Ø.18;
1Ø.16 S X=Ø;T !"ENTER NO. OF EQS: ";C 1Ø.2Ø
1Ø.18 S X=-1;*
1Ø.2Ø A N;S NQ=N*N
1Ø.21 I (N)12.3Ø,12.3Ø,1Ø.22
1Ø.22 I (N-2Ø)1Ø.24,1Ø.24,12.3Ø
1Ø.24 F I=1,N;D 1.4Ø;D 1.5Ø;D 1.6Ø
1Ø.26 I (X)1Ø.28;T !!"ENTER MATRIX A:"!
1Ø.28 S I=Ø
1Ø.3Ø S I=I+1;D 11
1Ø.32 I (2Ø-RO)1Ø.34;I (I-NQ)1Ø.3Ø;
1Ø.34 I (X)1Ø.36;T !!"ENTER VECTOR B:"!
1Ø.36 S I=Ø
1Ø.38 S I=I+1;D 12
1Ø.4Ø I (2Ø-RO)1Ø.41;I (I-N)1Ø.38;
1Ø.41 I (X)1Ø.42,1Ø.43,1Ø.43
1Ø.42 *
1Ø.43 T !!!!"INPUT DATA====="
1Ø.44 D 13
1Ø.46 T %2,!!!!"VECTOR B WITH"N," CONSTANTS"!!
1Ø.48 S I=Ø
1Ø.5Ø S I=I+1
1Ø.52 T %2,"      ROW"I,%,"  "FP(4ØØ+I),!
1Ø.54 I (I-N)1Ø.5Ø;
1Ø.56 D 7
1Ø.58 T !!!!!"TABULATED SOLUTIONS====="!
1Ø.6Ø F I=1,N;D 12.2Ø
1Ø.7Ø T !!!!!;QUIT

C - MATRIX INPUT ROUTINE
11.1Ø I (X)11.12;T !"ROW: "
11.12 A RO;I (2Ø-RO)11.24;
11.16 I (X)11.18;T "  COL: "
11.18 A CL;I (X)11.2Ø;T "   A? "
11.2Ø A T;S RC=RO+2Ø*(CL-1)
11.22 S T=FP(RC,T)
11.24 R

C - VECTOR INPUT ROUTINE
12.1Ø I (X)12.12;T !"ROW: "
12.12 A RO;I (2Ø-RO)12.18;
12.14 I (X)12.16;T "   B? "
12.16 A T;S T=FP(4ØØ+RO,T)
12.18 R
12.2Ø T %2,!"      X("I,")  = "%,FP(42Ø+I),!
12.3Ø T !!!"IMPROPER NO. OF EQS.  QUIT"
12.4Ø C 1Ø.7Ø
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C - PUT ROUTINE FOR SQUARE MATRIX
13.10 S J=1;S ND=4;S LD=20
13.11 S LS=1
13.12 T %2,!!!"SQUARE MATRIX A  - "N," ROWS  AND"N," COLS"!
13.13 S JN=J+ND-1
13.14 I (JN-N)13.16,13.16;S JN=N
13.16 T %2,!"           COLUMN    "
13.18 S JC=J;T JC
13.20 S JC=JC+1;I (JN-JC)13.26;
13.22 T "                "JC;C 13.20
13.26 T !
13.28 S LT=LS+LD-1
13.30 S L=LS-1
13.32 S L=L+1
13.34 T %2,!"      ROW"L
13.36 S K=0
13.38 S K=K+1;S KK=K;S JT=J+K-1
13.40 S LJ=L+20*(JT-1)
13.42 S T(K)=FP(LJ)
13.44 I (JT-N)13.45,13.46,13.46
13.45 I (K-ND)13.38;
13.46 F JW=1,KK;T %,"  "T(JW)
13.48 I (N-L)13.56,13.56;
13.50 I (L-LT)13.32;
13.52 S LS=LS+LD
13.54 C 13.12
13.56 I (JT-N)13.58,13.62,13.62
13.58 S J=JT+1
13.60 C 13.11
13.62 R
*
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