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Integer Programming -Fortran-

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INTEGER PROGRAMMING
-FORTRAN-

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TABLE OF CONTENTS

ADDENDUM

"Integer Programming - FORTRAN"

The program has been converted to FORTRAN IV for use on the IBM 360/40. Data formats are the same as specified in the basic publication. Exceptions are in the dimensions of the problem and the setting of sense switches. For the 360/40 version, sense switch settings are entered on the header card. Enter zero if switch is to be off, one if On, as follows

1) Switch #1 - Cols. 25-28.

2) Switch #2 - Cols. 29-32.

3) Switch #3 - Cols. 33-36.

4) Switch #4 - Cols. 37-40.

In addition information previously typed when switch #4 was On is to be printed when using the System 360.

Integer Programming
-FORTRAN-

by

Verner G. Hurt*

A. General - This program follows the dual simplex and/or the simplex procedure for the solution of general linear programming or mixed-integer problems. In addition, price and/or resource levels may be varied for general linear programming problems but not for mixed-integer problems. The solution scheme followed is controlled by information entered on the header card and by the Sense Switches.

A starting basis does not have to be entered as part of the data input. Neither do artificial variables have to be entered for inequalities of the form

$$b_i \leq \sum_j a_{ij} X_j \qquad (1)$$

Such inequalities are converted to the form

$$-b_i \geq -\sum_j a_{ij} X_j \qquad (2)$$

and the coefficients entered in the usual fashion with signs as indicated by equation (2).

Some difficulty has been encountered in getting mixed-integer problems to converge without exceeding the capacity of the machine. The number of additional restraints that have to be formed apparently depends on the criteria for selection of the row for which the restraint is to be formed. No one criteria is known by this writer which would be most efficient for every problem. Two programs are provided.

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*I am deeply indebted to Dr. T. E. Tramel for many suggestions and for his assistance in the development of this program.

Program I chooses the integer variable with the largest non-integer portion. Program II chooses the variable for forming the added restraints chronologically according to the integer list. Ineffective added restraints are replaced, thus reducing the number of added rows required for the problem.

Preselection of activities to be brought into the basis is provided.

This program was written in FORTRAN for the IBM 1620 II with 60K memory, automatic floating point hardware, and the 1443 printer. If a printer is not available, a provision is made for card output of the final basis and shadow prices but not for the matrix.

B. Scaling - Although floating point arithmetic is used in all calculations, scaling difficulties may be encountered. However, no difficulties have been experienced to date with very poorly scaled problems that have been run. If excessive rounding in the final basis should be encountered, scaling of the input matrix should reduce the rounding error.

C. Input

1. Header card.

   a. Identification = XXXX in columns 1-4. The problem identification to be specified by the user.

   b. m (the number of rows) = XXXX in columns 5-8. The cost or net revenue row is included in m and must be the first row.

   c. n (the number of columns) = XXXX in columns 9-12. The requirements column is included in n and must be the first column. The starting basis is not included in n.

d. d (the number of activities required to be integers if in the basis) = XXXX in columns 13-16. (Leave blank for non-integer problems.)

e. r (the number of additional rows to be reserved) = XXXX in columns 17-20. In general r should be made as large as possible without exceeding the storage capacity, i.e., $(m + r) \leq 45$, $n \leq 45$. (Leave blank for non-integer problems.)

f. Prchk (the control for specifying card and/or printer output of the solution) = XXXX in columns 21-24.

(1) Leave blank if card output only is desired.

(2) Enter (0001) for printer output.

(3) Enter (0002) for both card and printer output.

2. Integer list - entered as four digit numbers beginning in column 1, up to 12 items per card. Up to 24 numbers (two cards) may be entered. (Omit if no integers are required.)

3. Data cards - Data must be entered one element to the card.

a. Identification = XXXX in columns 1-4.

b. i = XXXX in columns 5-8 - the row number of the item of data.

c. j = XXXX in columns 9-12 - the column number of the item of data.

d. a_{ij} is entered as F30.15 in columns 13-42. Zero elements need not be entered except (1) a_{mn} must be entered even if zero, and (2) a_{il}, the restraints column elements, must be entered even if zero. Data cards may be entered in any order except the element a_{mn} must be last.

e. c_i, the costs associated with elements of the starting basis (the disposal activity for the particular restraint) are

entered as F30.15 in columns 43-72. This item is entered only on data cards containing an element of the restraint column and need not be entered if zero.

4. Preselection control cards - one card for each activity to be brought into the basis arranged in the order in which activities are to be brought in. A blank card must follow the last preselection control card. (Omit these cards if no preselection is desired.)

   a. Identification = XXXX in columns 1-4.

   b. k = XXXX in columns 5-8 - the column number of the activity to be brought into the basis.

5. Price change and resource change cards - one card for each price or resource being changed. Each set of price and resource change cards must be followed by a card containing the identification in columns 1-4, m in columns 5-8, and n in columns 9-12.

   a. Price change cards. (None entered if no prices are to be changed.)

      (1) Identification = XXXX in columns 1-4 - the identification of the problem. May be different from the identification used on control, data, and preselection cards if the user wishes.

      (2) i = XXXX in columns 5-8 - the row identification of the cost row which is always 0001.

      (3) j = XXXX in columns 9-12 - the column number of the activity for which the price is being varied.

      (4) New price entered as F30.15 in columns 13-42.

b. Resource change cards. (None entered if no resources are to be changed.)

(1) Identification = XXXX in columns 1-4. May differ from identification used on control, data, and preselection cards if the user wishes.

(2) i = XXXX in columns 5-8 - the row number of the resource (restraint) being varied.

(3) j = XXXX in columns 9-12 - the column number of the resource being varied. This number is always 0001.

(4) Rchg - entered as F30.15 in columns 13-42. The incremental change to be added to the resource being varied. This amount may be either positive or negative.

D. Switches

1. Switch #1 On - the activities specified by the preselection cards are brought into the basis. Preselection of activities can be accomplished only before prices (costs) and resource (restraint) levels are varied. If no activities are to be preselected, then switch #1 should be Off. Switch #1 may be turned off anytime after reading the blank card from the preselection group but must be turned off prior to reading price and resource change cards.

2. Switch #2 On for problems for which prices and/or resources are to be changed. If switch #2 is Off regular linear programming problems may be run.

3. Switch #3 On to print the matrix at the end of each iteration. Otherwise Switch #3 should be Off. No provision is made for card output of the matrix at the end of each iteration. Switch

#3 may be turned on at any time during the solution of the problem after reading the header card. When Switch #3 is turned on the matrix and the prices (costs) are printed. At the completion of printing, the program continues with the problem. To print out the matrix after a stop for an unbounded function or after completion of a problem, turn Switch #3 On, enter 4941642 on the typewriter and press release-start.* See discussion on output for format of matrix print out.

4. Switch #4 On to type (1) iteration count, (2) identification of activity being replaced, (3) identification of activity entering basis, and (4) value of the functional at that iteration. Switch #4 Off to suppress typing.

E. Operating instructions

1. Zero core storage.
2. Press computer reset.
3. Load program.
4. Press computer start after program is entered.
5. Enter in order.
   a. Header card.
   b. Integer list (if to be used).
   c. Data cards.
   d. Preselection cards (if to be used).
   e. Price change cards (if no prices are to be varied these cards are omitted).
   f. Resource change cards (if no resources are to be varied these cards are omitted).

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*For Program II, enter 4941662.

6. Processing a series of problems for which prices and/or resources are to be changed for the same basic input matrix.

   The basic input matrix, including the original prices and resources are entered in the above order a - d. The first group of price and/or resource change cards followed by a card containing the identification in columns 1-4, m in columns 5-8, and n in columns 9-12 follows the basic input matrix, etc. Hence a series of price and/or resource changes may be processed for the basic input matrix.

7. To process a series of problems where the matrices (data cards) differ.

   a. For general linear programming, the problems may be stacked one behind the other, i.e., the program is automatically conditioned to accept a new problem.

   b. For variable price and/or variable resource programming, each new matrix must be preceded by a blank card.

F. Other

1. Dimensions of the processed program are $(m + r) \leq 45$, and $n \leq 45$. The problem dimensions can be changed by changing the program cards containing the dimension statements.

2. Artificial costs must be entered as negative numbers. To preserve precision in computations, these costs should be no larger than necessary to insure the activities being excluded from the final basis.

3. Net revenues are entered as positive amounts, costs as negative amounts.

4. The calculation technique followed is that of maximizing the objective function (Z). For minimization problems, maximize -1(Z).

5. If a column is preselected which is not restricted as to the level at which it can be brought into the basis, this preselect instruction is ignored.

G. Output - one element per line

1. Basis - presented as card or printer output for the optimum solution in a general or mixed-integer problem and for each optimal solution for the varied levels of price or resource with the problem identification in columns 1-4, the variable identification in columns 10-13, and the value as F30.15 in columns 19-48. Activities in the original starting basis are identified as 300 plus the row number of the restraint. The first card of the basis identified by the unit digit in column 13 is the value of the objective function. In addition, the unit digit is punched in column 62 for sorting out the bases for use with a program similar to the SPS program, Weighting and/or Naming Linear Programming Solutions*, which is expected to be available in the near future.

2. $z_j - c_j$ - also presented for each optimal solution in the same format as for the basis.

3. Matrix print out.

   a. The first page(s) contain the row identification of elements in the basis in the first word. The costs (revenues)

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*Tramel, T. E., Weighting and/or Naming Linear Programming Solutions, AEc. Tech. Pub. No. 5, Mississippi Agricultural Experiment Station, June, 1964.

associated with these elements are in the second word as F20.10.

b. Following the elements listed in (a) above, the column identification, costs (revenues), and matrix elements are printed five elements per line. The first line will contain column identification; the second, the costs (revenues); and, successive lines, the a_{ij}'s beginning with row 1 $(z_j - c_j)$ through row m. Then the next eight elements for j = 6-10 are printed in the same order beginning on a new page, etc., until the entire matrix is printed. Costs (revenues) and the matrix elements are in the F20.10 format.