Annals of Economic and Social Measurement, 2/3, 1973

IOPE: INPUT/OUTPUT PROGRAM FOR ECONOMISTS

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IOPE is a matrix operations package program designed especially for input/output work. Among the operations available in IOPE are matrix addition, subtraction, multiplication and division; column and row multiplication and division; matrix summation; transposition; matrix inversion; and row vector, column vector, matrix section and matrix element operations. Among the features of this program are flexible data storage and data transmission; extensive facility for documentation; a two-stage job division between error scansion and execution; and free form input. A second version of IOPE also is available which includes, in addition to the operations listed above, a table print-out for publication use, a ranking command that lists the elements of a matrix in order of size and a command that distributes a set of control totals over the elements of a matrix.

The program is written in FORTRAN and BAL (IBM 360 Assembly Language) for the IBM 360/370 OS/MVT system. The minimum core requirement is 140K bytes. A CDC 6600 version of the program also is available. Because of the large volume of data input and printed output, typically encountered in input-output work, IOPE is designed primarily for batch processing. It also can be set up on time-sharing, however, using a system editor.

I. HISTORY

Input/output work is characterized by the large volume of data handling it requires, by frequent revisions and updating, and by complex sets of matrix transformations for analytical purposes. With these needs in mind one of the earliest input/output packages, PASSION, was developed at the Harvard Economic Research Project in 1966. It was designed for the IBM 7094, had two fixed matrix regions, stored intermediate results on a scratch file, and used coded input commands. Later 7094 versions of this program include MAMMOTH and SUPERPASSION. In 1969 an IBM 360 input/output package was designed at the Harvard Economic Research Project to take advantage of the IBM 360's increased flexibility in data handling and internal storage. The program, MOTHER, became operational in the fall of 1970. In the fall of 1972, an improved version of MOTHER—IOPE—became fully operational.

II. FEATURES

(A) *Two-Phase Job.* The system is divided into two phases, which can be run in the same or in separate jobs. The first phase is the "compilation" phase. It requires a region size of 130K. It reads in a set of command cards, checks for syntactical and algebraic errors, and produces an intermediate deck, which is

read into the second phase if no errors are detected. In addition, it computes the region size required for the second phase.

The second phase is the "execution" phase. It executes the operations designated in the command deck. If an error occurs in the first phase, the execution phase halts immediately. The region size of this phase is variable, depending on the run's-storage requirements. The minimum core requirement is 110K.

(B) *Conversational Language.* The command language is in conversational form. For example, "PRINT A" will cause matrix A to be printed; "ADD A = B + C" will set matrix A equal to B plus C. Command abbreviations are provided to reduce key-punching. The input is free-form, and each command is terminated by a semi-colon. Default options also are provided in order to reduce keypunching.

(C) *Flexible Internal Storage.* Dynamic storage allocation is provided by the system. The user can allocate storage areas for matrices, codes, row and column headings and notes at any point in the program. Storage areas can be deleted (using an ERASE command), and the memory re-allocated for other uses.

Up to 25 matrix regions, called A through Z, with the exclusion of I, can be allocated. (I is reserved for the identity matrix.) The region dimensions are specified by the user, as, for example: REAL A(30,25), B(27,42). Region dimensions may vary from region to region but may not exceed 2,000. A matrix region may be either single or double precision. Matrix regions may contain not only full matrices but also row and column sums, row and column vectors and matrix sections.

(D) *Operations.* The following operations are available in IOPE: summation, generating row and column sums and a grand total; addition; subtraction, including B ∞ I − A; term by term division; term by term multiplication; matrix multiplication; relative differences; row and column multiplication; row and column division, the latter used for generating coefficient matrices; transposition; inversion, using the Gauss–Jordan algorithm; scalar multiplication, division, addition and subtraction; logarithms and anti-logarithms; absolute value; a command that sets negative elements to zero, one that sets positive elements to zero, and one that sets elements whose absolute value falls below a specified value to zero; a ranking command that lists the elements of a matrix in order of size; and a command that distributes a set of control totals over the elements of a matrix. Single precision and double precision matrices both may appear in the same operation.

(E) *Data Types.* In most operations the following data types can be operated on: (1) A full matrix, referenced as A or B, for example. (2) A single element, referenced as, for example, A(2, 3). (3) A column vector, referenced like A(*, 5) or A(3–9, 7). (4) A row vector, referenced like A(3, *) or A(4, 2–7). (5) A matrix section, referenced as A(4–13, 2–10), for example. (6) A matrix diagonal, referenced as A(DIAG).

(F) *Data Transmission.* Flexible data transmission is provided by IOPE.

(1) Data can be read or written in "card format": row number, column number, element value. Reading is done through an INCARDS command; writing through an OUTCARDS command. Data can be either formatted (that is,

EBCDIC) or unformatted (that is, binary.) If formatted data are used, the user can designate the appropriate FORTRAN format. Normally, data are read from or written onto cards. However, data in card format also may be read from or written onto tape or disk. Row and column codes may be substituted for row and column numbers. In this case a "codebook" must be provided by the user, equating row codes and column codes with their appropriate row number and column number. Codes may also be used in place of row and column numbers in matrix specifications in algebraic commands. They may also be used in printing, as row and column labels. Normally, a matrix title is transmitted with matrix data, and a special endcode is designated to terminate data transmission. Additional options, however, allow the title to be suppressed and an End of File mark to be substituted for an endcode. One additional option is provided in OUTCARDS, which allows matrix sums to be transmitted alone or with its matrix values.

(2) Data can also be read or written in "IOPE" format: $\text{element}_{(1,1)}$, $\text{element}_{(1,2)}$, ... Reading is done through a READ command; writing through a WRITE command. Two binary records are transmitted in each READ or WRITE operation. The first is a label, containing such information as matrix dimensions, matrix code, precision, title, time and date of creation, and person's name. The second record contains the matrix data, written by rows. More than one matrix may be stored on a dataset. Matrices on a dataset can, however, be randomly accessed by the user.

(3) Data may be read from or written onto as many as 15 different datasets. This allows great flexibility for receiving data from different sources. A DATASET card is used for defining the data set internally. This allows internal file protection. Scratch files may be treated for temporary data storage. This allows the user a trade-off between extra core cost for additional matrix storage areas on the added cost of I/O events.

(4) A special INCARDS STREAM command is available for reading EBCDIC data in free format. Numbers in I, E or F format all are acceptable.

(5) Whole matrices or matrix sections may be printed at any point in the program. Row and column sums also may be printed, as may row and column codes. The number of decimal places may be selected by the user. In addition, a special table print-out routine is provided, geared especially for publication use, with such options as page size, number of rows and columns per page, centering of row and column headings, and centering of title lines.

(G) *Documentation.* Because of the frequency of updates, special documentation facilities are provided. (1) New matrix titles can be specified each time data are transformed. (2) Matrix labels are provided for matrices stored in IOPE format on tape or disk datasets. (3) "Notebooks" may be created, describing data sources and data transformations. Matrix titles may be stored as notes, and thus a running account of a matrix's "history" can be provided. Notes may be stored in matrix labels of matrices written in IOPE format.

(H) *Additional features.* Facilities for program patches, messages at the end of a run, and command "loops" during the cimpilation phase also are available.

III. Availability

A copy of the programming system in load module form and a copy of the user's manual can be obtained from:

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The manual is available at $4.00; the programming system is available at $200.

received: December 20, 1972
revised: April 15, 1973