Analysis of Business Application Problems on IBM 650 Magnetic Drum Data-Processing Machine

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THIS discussion will consider how the John Hancock Mutual Life Insurance Company viewed the problem of how it might use the International Business Machines Corporation (IBM) type *650* machine to fulfill part of a responsibility of considerable magnitude. This responsibility may be stated as follows: Determine each year the amount of dividends, which will be payable in cash or otherwise credited to the policy holders, for each of 4,000,000 ordinary life insurance policies. The type of administrator normally charged with fulfilling this responsibility should be viewed as one who possesses merely a superficial knowledge of electronics and, at most, only a broad general knowledge of the principles concerning the use of modern machine equipment.

When the type *650* machine was announced, the John Hancock Company used a closely integrated system for calculating dividends for a particular class of 1,400,000 policies which were issued under its Monthly Debit Ordinary branch. This system, which is still being used pending further developments, requires extensive manual-checking operations to test the results obtained from the usual array of machines which include sorters, collators, reproducers, tabulators, and type *604* calculators. Checking is required for some 10,000 possible unit-dividend groups which vary with respect to plan of insurance, issue age, and year of issue. Under this system a considerable amount of supervision of the clerical as well as the technical staff is necessary.

In reviewing this problem, the company evolved a system under which dividends for this class of policies may be calculated with a minimum of supervision by making a single pass of the punch-card file through the type *650* machine. Under this system, the policy number order would not be disturbed while the time required with one such machine might be on the order of one fifth of that required under the older system.

For those who are not familiar with the theory of allocating life insurance dividends, the following is a brief description of one of the methods, the so-called Contribution Method, as it is applied by the John Hancock Mutual Company. The three basic dividend elements which arise under the Contribution Method are:

1. A return from excess interest earnings.
2. A return from experiencing a favorably low death rate.
3. A return from experiencing relatively low administrative costs.

The result of this concept may be expressed in a practical dividend formula which in broad terms is as follows:

$$\begin{aligned} {}^{j}{}_{n}F_x{}^{p} &= \text{dividend payable at the end of the } n\text{th policy year} \qquad (1)\\ &= R_i \text{ (reserve of policy)}\\ &\quad + R_m \text{ (amount at risk)}\\ &\quad + \text{(expense margin)} \end{aligned}$$

where

x = age at issue
p superscript denotes a particular plan
j superscript denotes particular scale of benefits
R_i = return rate from interest earnings
R_m = return rate from mortality experience

The terms of equation 1 assume different values for life plans and special plans which have graded benefit scales. When we first approached the challenge to program a dividend-calculation procedure for this class of business, we already had in existence a scale of unit dividends. Accordingly, we decided to see if we could reproduce this pre-existing scale by programming the precise formulas used on desk machines and type *604* calculators. These pre-existing formulas may be expressed generally by the following desk-machine type equation:

$$ {}^{j}{}_{n}F_x{}^{p} = {}^{j}\pi_x{}^{p}\cdot {}_{n}a_x + {}_{n}b_x + {}_{n}e_x{}^{j} - h^{j}{}_{x+n} + \frac{\alpha_1{}^{p}\cdot \overline{N}_w}{\overline{N}_x - \overline{N}_w} \qquad (2)$$

where in terms of elemental functions:

$$ {}^{j}\pi_x{}^{p} = k_1 \frac{\overline{M}_x{}^{j} - \overline{M}_y + \alpha_2{}^{p}\cdot D_y}{\overline{N}_x - \overline{N}_w}$$

$$ n^{a}x = k_2\cdot \overline{N}_x\cdot {}_2f_{x+n-1} + k_3\cdot {}_1f_{x+n-1} - j_n$$

$$ n^{b}x = {}_1f_{x+n-1} - k_4\cdot \overline{M}_x\cdot {}_2f_{x+n-1} + h_x$$

$$ {}_{n}e_x{}^{j} = k_4(\overline{M}_x - \overline{M}_x{}^{j} - \overline{M}_{x+n} + \overline{M}^{j}{}_{x+n})\cdot {}_2f_{x+n-1}$$

y = age at maturity
w = age when premiums cease
$\alpha_i{}^{p}$ is a variable dependent on plan alone
k_i is a constant

For purposes of programming, equation 2 was expanded to the following 27-term formula:

$$\begin{aligned} {}^{j}{}_{n}F_x{}^{p} = k_1\left[\frac{\overline{M}_x{}^{j} - \overline{M}_y + \alpha_2{}^{p}\cdot D_y}{\overline{N}_x - \overline{N}_w}\right]\times &\\ [k_2\cdot \overline{N}_x\cdot {}_2f_{x+n-1} + k_3\cdot {}_1f_{x+n-1} - j_n] + k_4[\overline{M}_x - \overline{M}_x{}^{j} - &\\ \overline{M}_{x+n} + \overline{M}^{j}{}_{x+n}]_2f_{x+n-1} + &\\ \Big[{}_1f_{x+n-1} - k_4\cdot \overline{M}_x\cdot {}_2f_{x+n-1} + &\\ h_x + \frac{\alpha_1{}^{p}\cdot \overline{N}_w}{\overline{N}_x - \overline{N}_w} - h^{j}{}_{x+n}\Big] & \qquad (3) \end{aligned}$$

where all terms are elemental functions.

Some 550 elemental functions, apart from orders, were stored initially in the type *650* registers.

We found that the programming for equation 3 could be done quite comfortably for the following range of variables with respect to premium-paying plans except the Family Income Plan.

$0 \leq x \leq 75$ for the range of issue ages
$20 \leq y \leq 100$ for the range of maturity ages
$20 \leq w \leq 100$ for the range of ages when premiums cease
$2 \leq n \leq w - x$ for the range of durations from date of issue to dividend due date
9 values of p, the plan code
6 values of j, the graded death-benefit code
2 values of $\alpha_1{}^{p}$ } variables depend upon plan
2 values $\alpha_2{}^{p}$ } code

After using 400 registers for storing the orders required to program equation 3 alone and discovering registers to spare, we next incorporated a search program which would give the dividends for the Family Income Plan. We also incorporated a program to calculate dividends for paid-up policies.

In the course of programming for equation 3 we decided to incorporate the following steps to edit data:

1. Test for improper plan.
2. Test policy number sequence.
3. Test for improper issue age.
4. Test for improper issue date.
5. Test for improper policy year duration.
6. Test for improper class of business.
7. Test for improper dividend account.
8. Test that amount of dividend lies within a specific range.

Discovering that we still had registers to spare, we decided to incorporate a program to provide for checking results for 168 broad plan-issue age-duration groupings for which confidence limits can

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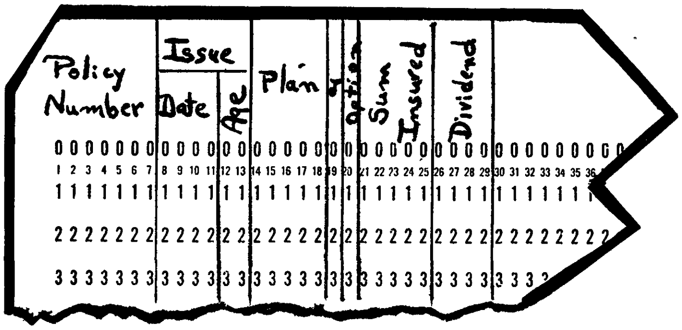

Fig. 1

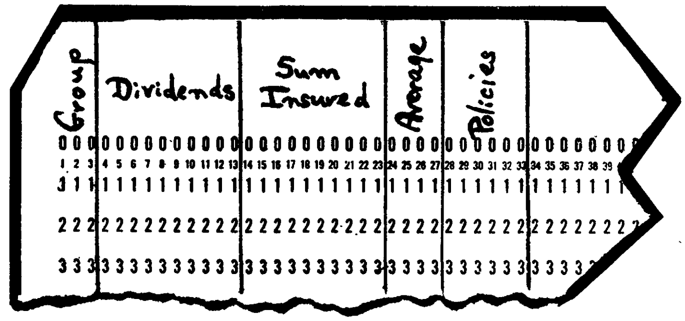

Fig. 2

be established. For each of the 168 check groups, totals were stored for policy count, accumulated sum insured, and accumulated dividend. One of such groups provided for a grand total check. Upon an order to clear these registers, the program provided for obtaining the average dividend per $1,000 sum insured for each group.

In review, the programming concerned the following card types:

1. Answer card for policy data (Fig. 1).
2. Answer card for summary check data (Fig. 2).

The input card for policy data has the same form as card 1, except that dividend field is not required.

The following outline shows the general pattern of the flow of steps which were required:

1. Test type of card.
2. Test for proper dividend option and policy number sequence.
3. Test for proper plan. If Family Income Plan, search for unit dividend and proceed to step 14.
4. Test for proper age range and proper issue date.
5. Store ${}_1f_{x+n-1}$, ${}_2f_{x+n-1}$, w, $\overline{N}_w$. If paid-up plan, compute unit dividend and proceed to step 14.
6. Test for proper duration.
7. Store $\overline{N}_x$, $\overline{M}_x$, $\overline{M}_{x+n}$.
8. Test for graded benefit-type code and store $\overline{M}^j_x$, $\overline{M}^j_{x+n}$ and h^j_{x+n}.
9. Store $(\overline{N}_x-\overline{N}_w)$, j_n and h_x.
10. Compute ${}_na_x$, ${}_nb_x$ and ${}_ne_x^j$. If endowment plan, proceed to step 12.
11. Compute ${}^j\pi_x^p$, $\dfrac{\alpha_1^p\overline{N}_w}{\overline{N}_x-\overline{N}_w}$, ${}^j_nF_x^p$. Proceed to step 14.
12. Store D_w, α_2^p, $\overline{M}_w$.
13. Compute ${}^j\pi_x^p$, ${}^j_nF_x^p$.
14. Test magnitude of ${}^j_nF_x^p$.
15. Compute total dividend $=S\cdot{}^j_nF_x^p$ where S = sum insured.
16. Store results in summary registers. Punch answer cards and return to starting order.

Up to this time, the type *650* machine has not been used to authorize actual payments to policy-holders. Preliminary tests have shown that calculation time is approximately 1 second per policy. A variation of the method being discussed appears to be most promising. Due to a change in requirements recently made in our administrative philosophy, we are reprogramming to obtain a desirable byproduct, namely, the policy cash value. Under this variation which we are testing, it appears that dividend calculations for many more plans may be programmed from elemental functions. Among these plans are the Family Income, Retirement Income, Joint Life, and Return Premium plans.

The program under discussion, however, is applicable only with respect to particular issues associated with a specific class of business. Parallel programming has been performed but not completely tested for other issues. Also, we were perhaps somewhat fortunate to be able to express the dividend scale as voted by the board of directors in terms of formulas which do not require extensive tables of empirical values.

It is gratifying to see a machine of this type in anticipation of the availability of more powerful equipment. For these many years the administrator whose activities have centered in part around punch-card systems has found that he could not possibly devote the time required to understand completely the complex skills which are so necessary to integrate all the phases of work. The introduction of this type of machine can change this picture materially.

The programming for this dividend calculation responsibility for the *650* machine was done without benefit of any formal training. The only aids were an instruction manual and help of an International Business Machines representative who clarified relatively few numbers of questions regarding the response of the machine. The broad scope of the operation was first sketched by the administrator who had only a formal 2 weeks' course in programming. The operation was then entrusted to a mathematically inclined staff member who had never had any formal training in programming and to his assistant who tested the program on paper by carrying through specific problems. When the programming was first tested on the machine, it ran without apparent error. The essential quality which appears to be required by people who are to do programming is the possession of reasoning ability, common sense, and enthusiasm rather than technical ability alone.

A curious and inspired administrator can understand the machine. If he understands the machine, he may possibly become a more effective administrator of an appropriate domain by critically reviewing programming which may be presented to him for approval.

Discussion

E. H. Friend (New York Life Insurance Company): Why did the programming group maintain the file in policy number order rather than valuation order? Does not a seriatim handling require considerable extra processing time?

J. M. Boermeester: In answer to this I would like to say that our company prefers to maintain its registers in policy number order so we can make easy reference to them for questions which may arise, and that in the previous operation the policy number order was disturbed. Under this concept which we have employed today the order of the cards is not disturbed, there is no extra handling, and therefore requires not extra time but time which I believe is on the order of one fifth of that now required.

H. O. Rohde (Minneapolis-Honeywell): Can you estimate how many man-hours of programming were required to put the illustrated problem on the machine?

J. M. Boermeester: This programming was done by one person full time and another person part time over a course of, I would say, 3 months. We didn't take any precise time on it. That was our first venture. I would say that we were probably very, very slow. We were feeling our way along and any figure I give to you now would perhaps have no meaning a year from today.

William Miehle (Burroughs Corporation): In the abstract of the paper in the program, it says, "Analysis. . . .illustrates the percentage use of various basic functions of arithmetic and logical decisions." Please explain this.

J. M. Boermeester: Dr. Petrie, maybe you know something about this.

G. W. Petrie, III: Originally it was hoped that in the presentation we would have a very comprehensive system of evaluation as to the percentage breakdowns on the arithmetic instructions and logical decisions and more statistical data. This paper is in the process but has not been completed. Instead of presenting partial results we felt that all of you would be much happier to hear of one actual case in complete detail such as the one that has just been presented to you.

M. Saslow (Airborne Instruments): What are the estimated dollar savings to be gained by this installation of the *650?*

J. M. Boermeester: This is a question on which of course nobody expects a precise answer from me. However, I would say that there are other elements in here, questions of administration which have not been analyzed and the question of speedup in time on which we have not made any precise estimate.

L. Flynn (Curtis Publishing Company): The calculation time of 1 second per dividend, does this mean 1,000,000 seconds for 1,000,000 policyholders?

J. M. Boermeester: When I went to school $1 \times 10^6 = 10^6$, yes. This time is apart from emergency breakdowns; it does not include time for downtime.

Small Digital Computers and Automatic Optical Design

N. A. FINKELSTEIN

THE photograph reproduced in Fig. 1 is an example of good optical imagery. The picture is crisp and considerable detail is resolved all over the area, even at the extreme edges and corners. Fig. 2 is a poor picture. The reasons are obvious. While the central region is still sharp and full of detail, the rest of the area is fuzzy and ill-defined. The quality definitely deteriorates as we move further and further out from the center. These two photographs were taken with the same camera, at the same exposure, under the same subject conditions with two different lenses of the same focal length. Fig. 3 shows the lenses in schematic form, essentially a section through the lens along the axis. The poor picture was taken with the upper lens, a simple biconvex element. The good picture was taken with the lower lens, a very-well-known design called a Tessar, containing four elements, two of which are cemented together. The difference between the two pictures shown obviously is related to the difference between the two lenses which took them. The techniques which lead us from poor picture to good picture, from simple biconvex lens to multielement Tessar, form the province of optical lens design.

The problem of the lens designer is to combine elements of different curvature, thickness, and refractive index in such a manner as to approach perfect imagery of the class of objects to be placed before the lens. In perfect imagery each point in the object is transformed into a corresponding point in the image without distortion or blurring; of course this condition can only be approached.

Probably the most important tool in lens design is geometrical ray tracing, a technique in which the paths of light rays emanating from a point in the object are traced through the several lens elements following the laws of geometrical optics to ascertain the manner in which these rays recombine in the image. In the ideal lens all the rays from each point of the object would recombine at corresponding points in the image as shown in Fig. 4. In general, the rays will not recombine as

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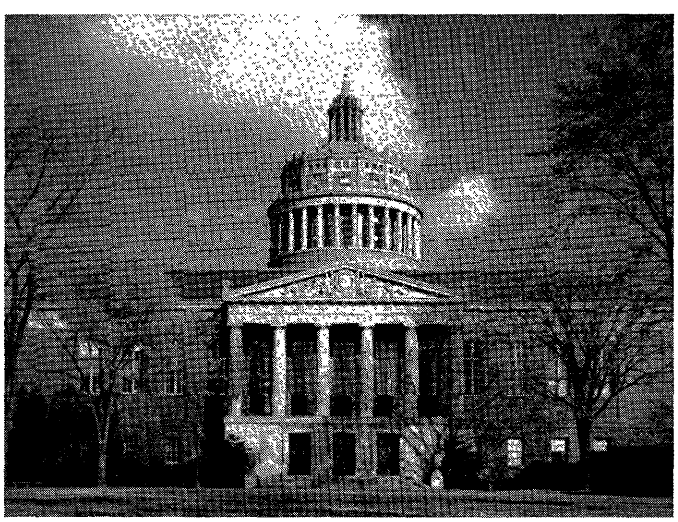

Fig. 1. Photograph taken with Tessar lens of 190-mm focal length at f/4.5

Fig. 2. Photograph taken with simple biconvex lens of 190-mm foca length at f/4.5