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THE ROLE OF COMPUTERS IN PROCESSING SCANNING DATA*

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The technical discussion that was originally included in the paper given at this point in the program has been incorporated into another article; this version of the presentation will be limited to some general remarks about computers and their role in medical research.

Homer Smith (1) once remarked that, "The simplest equation has the fearsome power of completely dispelling the comprehension of an audience, at least in fields of medicine." At another level, Pavlov (2) complained that, "Mathematically-inclined physiologists usually glory in abstruse equations, and figure chiefly because of an inability to express things in a simple way."

Evidently the younger generation possesses the virtue of being more mathematically oriented than were their elders, as evidenced in part by the proceedings of this symposium. Even so, there seems to be a degree of apprehension when computers are involved. At the other extreme it is sometimes assumed that a result must be correct because that's what the computer said.

For those who have an unwarranted awe of the power of large computers, it may be well to remember that you, not they, are still the masters. Even the largest modern digital computers are basically stupid devices that can only do what you tell them to, and if they seem to be getting out of control, you can always pull the plug.

The success of modern computers stems from their basic ability to be able to distinguish zero from one and to be able to add one and one or one and zero, to do sequences of these operations at fabulous speeds, counted in millions per second, and to have nearly perfect, large memories.

All logical distinctions, the assignment of + or - signs, arithmetic operations and everything else the computer does is ultimately traceable to the recognition or manipulation of bits of information recorded as one or zero. In most of the modern machines the memory is usually an electromagnetic device such that 1 is represented by the presence of a one magnetic state and 0 by the opposite state. Alternatively, electrostatic charges are used in some machines. Such machines may be described as working in binary arithmetic. However, through the use of built-in programs, it is possible to communicate with the computers in ordinary decimal notation.

Similarly, the instructions may be given in a variety of "languages" that approach English to various degrees, without concern for the fact that within the machine these are all eventually reduced to binary notation. Among the more famous of the languages is FORTRAN, which was developed for use with IBM computers, but which is accepted by several others as well. Communication with the machine is achieved through a code or program consisting of a list of instructions. One of the program instructions included in FORTRAN is the arithmetic statement, in which a value to be computed is represented symbolically on the left of an equation and a formula for computing it, in essentially the form that would be used in ordinary algebra, is the right member. Built-in or library programs take care of details such as arranging the sequence of operations needed to make the desired computation, computing trigonometric functions, exponentials, square roots or etc. where called for, and so on. Another type of instruction provides a branching so that if a certain condition is met, one procedure follows, otherwise another sequence of program steps is used. Another very important provision is

that any given sequence can be recycled, usually with some parameter value stepped along as a function of the cycle number. Combinations of these instructions are used to achieve the most complicated calculations. There are, of course, also the necessary input and output instructions for reading in data and printing out or displaying the answers.

Without being concerned any further with how computers operate, we may consider them as black boxes that obey certain instructions and essentially never make mistakes. We may turn to the question of what can they do for us in data processing?

Any data processing procedure, whether or not computers are involved, should only rearrange the information. Sometimes it is desirable to discard data, as is discussed in some of the other presentations in this symposium, but a valid procedure should not actually add information. In the positron scanning problem (Bozzo, Robertson and Milazzo, this volume), for example, the problem is to rearrange the information contained in the counting data to provide a mapping of the sources of radioactivity. The point is that the information has to be there all the time, and the data processing procedures serve to separate the signal from the noise and to present the signal in a more meaningful format. These principles hold for all of the scanning procedures discussed at this symposium. No amount of data processing can generate high resolution or improve the modulation transfer function if the detection system itself has intrinsically poor qualities.

The process of rearrangement of the data may be regarded as an extension of the perhaps more familiar processes of ordinary algebra. For example, if you have the equation for two lines that cross, the

coordinates of the meeting point or points are usually not obvious by inspection of the equations, but when the equations are combined, they yield the desired information. The point is that the information was present in the equations, and the processing merely brought it out, rather than creating it. The matrix method provides similar solutions for a large number of equations and a correspondingly large number of unknowns. In principle, matrix solutions can be obtained by hand, but with those of high order the number of steps required is prohibitive by any except machine methods.

The computer, then, has no magic properties. It is another tool that may be used at all steps of data-handling: data acquisition, data processing, and presentation. How it is to be used is to a degree limited only by the imagination of those who use it, but it must also be kept in mind that the quality of the output is directly dependent upon the quality of the input, and any process that "improves" the data or adds information is committing an error.

Returning to the problem of processing scanning data, the computer can help in arranging and presenting the data in a more readily understood form, but the final result is necessarily limited by the quality of the input information. We have heard of several examples of computer applications in processing scanning data at this symposium, and there is every reason to expect that computer usage will continue to become more widespread.

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