PROGRAM ABSTRACTS/ALGORITHMS

A PDP-11 assembly language program for digitizing, sorting, and averaging evoked brain potentials

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Investigators of evoked brain potentials (EPs) are often faced with the problem of developing software to average the single-trial EPs and perform subsequent data manipulation and analysis (Donchin, 1969; John, Ruchkin, & Vidal, 1978). The software to average the EPs involves digitizing the EEG, sorting each point of the digitized EEG according to input channel, sorting each EP according to experimental condition, and averaging the single trials to improve the signal-to-noise ratio. When experiments involve many EPs corresponding to different experimental conditions and electrode placements, this software has taken the form of separate programs or modules. For example, the EEG is digitized and placed on secondary storage; next, the data are sorted and finally averaged (Buschbaum & Coppola, 1974). The major disadvantage of this approach is the time involved in processing the same data three or more times. This is especially troublesome when digitizing takes place off-line.

The program, AVG, described in this paper eliminates the need to process the data more than once. By taking advantage of the powerful addressing modes available with the MACRO-11 language [Digital Equipment Corporation (DEC), 1982a, 1982b; Echouse & Morris, 1979], this program is capable of digitizing, sorting, and summing the single-trial EPs within a few MACRO-11 assembly language instructions. The algorithm implemented by AVG enables each digitized value from all the input channels to be correctly sorted and summed within 1 msec. This is much faster than is possible if the algorithm is implemented in a high-level language or involves the data acquisition and manipulation routines available from DEC (1982a, 1982b). A final advantage of this program is that the digitizing, sorting, and summing occur during the digitization epoch. This frees the time during the interstimulus interval for additional processing, such as artifact rejection.

Algorithm. The algorithm to collect and sum the data basically involves two steps. First, vectors of addresses

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Figure 1. Initial configuration of pointers.

are initialized. Two vectors correspond to conditions (C) and electrode placement (E). Each entry in C corresponds to each experimental condition. Therefore, if there are six different conditions, there are six entries in C. The entries in C are pointers or addresses that point to E. Vector E is divided into segments; each segment consists of entries corresponding to each electrode position. The number of segments is equal to the number of conditions. The pointers are arranged such that the first entry in C points to the beginning of the first segment of E, the second entry in C points to the beginning of the second segment of E, and so on. The entries in E point to a block of memory that will contain the digitized data. This block of data is equal in length to the number of points digitized per EP. The initial configuration of pointers is presented in Figure 1.

The second step of the algorithm consists of associating the current trial with the correct condition and following the pointers to the block of data that will contain the EP. For example, if Register R contains the address of a location in E, then, using register-deferred addressing, the digitized value from the analog-to-digital converter buffer is added to the location pointed to by the address in Register R. The location pointed to by R is then incremented so that it now points to the next location in the data block (i.e., the next point), and Register R is incremented so that R points to the next location in E (i.e., the next input channel). These additions can take place with one instruction using auto-increment addressing. After all channels are sampled, R is loaded with a pointer to the beginning of the appropriate segment in E or the first channel, which in turn points to the location where the next point is to be added. This process continues until all the points are digitized. Between digitizations, E is restored to its previous contents and the process is repeated for the next sweep. A flowchart of this process is presented in Figure 2.

Figure 2. Digitizing, sorting, and summing process.

When all the data are digitized and summed, AVG calculates the averages, converts the data to ASCII to facilitate subsequent processing with FORTRAN routines, and writes the data to disk.

Limitations. AVG averages data from experiments involving a number of different conditions and a maximum of 14 electrode locations or input channels. The

limiting factor on the number of conditions, electrode sites, and points digitized per epoch is the 15,000-word block of memory allocated for data. The program is capable of digitizing the EEG at 1-msec intervals.

Transportability. AVG is currently running on a PDP-11/34 computer with the RT-11 operating system. Hardware requirements for the program include 32K words of memory, the AR-11 real-time subsystem, and a secondary storage device. The entire program is written in MACRO-11.

Availability. A listing of the program can be obtained free of charge from Albert L. Schmidt, Division of Neurosurgery, University of Texas Medical Branch, Galveston, Texas 77550.

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