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Comment

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Statisticians have traditionally shown a wide range of attitudes to computing, from being deeply involved and enthusiastic to regarding the subject with some distaste, or at least suspicion. In the early days negative attitudes were often strong. As an enthusiastic undergraduate in the early 1960s, I was cautioned by a faculty advisor that, while computers certainly had their uses, actually programming them was not really compatible with a research career.

Current attitudes usually exhibit less outright opposition than feelings of confusion over hardware and software choices, combined with some resentment at the learning and relearning that each new development seems to require. Professional statisticians reasonably want to know how they can benefit from computers in their work. If an overview such as Professor Thisted's paper could clarify this issue, it would do its readers a service. In the present case, I worry that several helpful insights may have been somewhat buried by irrelevant details, shifts in viewpoint and unnecessarily old-fashioned examples. The reader's overall level of confusion may rise rather than fall. Rather than quibbling with the paper, however, it will be more helpful for me to present, briefly, my own view of the topic.

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What *are* the important points about computing environments for data analysis? Here are two, from which most of the relevant conclusions follows:

(1) Computing environments should be judged by their complete, present and future, contribution to their user's effectiveness.

(2) Most of the important improvements in statistical computing environments have come through advances in general computing, not from anything statisticians have done. This will continue to be true for the immediate future.

Point (1) implies that it is not sufficient to ask how easily the user can carry out a specific current data analysis, important as that question may be. Two other questions must also be weighed. How well does the environment carry out the nonstatistical tasks

that might benefit the user? How effective will the environment be in adapting to the user's future, evolving activities?

Like other users, statisticians can make many of their professional and private tasks easier through the information and communication facilities of a good general computing environment. Writing and editing (books, papers, or just letters), personal scheduling, retrieving general information (such as telephone numbers and addresses), and communication with colleagues are examples of such tasks. Closer to the data analytical tasks, but still not necessarily part of a statistical system, are the tasks of data entry and management (including data retrieval from external, commercial databases). Hardware aspects of the environment also need to be looked at broadly; not only raw processing power, memory, and backup storage, but also facilities for good, dynamic graphics and for communication with other machines are important. Currently available workstations and computer systems can serve well for both the scientific and the miscellaneous tasks.

The need to provide for future as well as present activities implies that both the statistical system and the general environment should be open, and should be effective environments for "programming," in the broad sense of creating new software. Providing an effective *quantitative programming environment* for data analysis and similar activities is an active part of our current research (Chambers, 1985). Such an environment should provide intelligent, nonprogramming interfaces for applications or for nonexpert users; for example, through dynamic menus. The environment itself should combine the virtues of "integrated" programming environments with the special features needed for quantitative computing. In such an environment, casual users can evolve into software developers along a natural, productive path.

Current systems can provide some of the advantages of such an environment today. The stimulation for the ideas above, in fact, comes partly from observing the use of *S* in a variety of applications. Purchasers of new computer systems, however, will need to look for an environment with the capacity to grow with their own growing activities. The low end of a more powerful computing environment is likely to provide better for growth than the high end of a relatively weak personal computer environment.

Point (2) is not intended to denigrate the importance of statisticians' contributions, but rather to emphasize that we should always try to get the best statistical environment, for the least effort, usually by starting with the best appropriate general computing environment.

A current example is that there are available, now, powerful workstations that provide a good environment, for data analysis as well as other activities, featuring multiwindow displays, rapid interaction through a mouse or other device, and access to a powerful software environment. These are available from a variety of manufacturers, at prices that start around $5000. Except for special circumstances, most statisticians will find such an environment a better investment than either a combination of mainframe computer plus ordinary terminals or a lower-powered personal computer. Becker et al. (1985) give a discussion of the use of such workstations in data analysis.

These are the issues that data analysts need to keep in mind when thinking about their computing environments. The implications seem, on the whole, consistent with the author's paper. In any case, statisticians can certainly benefit from thorough discussion of what they want and can expect from the use of computers.

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