$y_{.x}$ scattered against x where y = rows and x = columns, b) partial residual scatters, with $y_{.\mathrm{REST}}$ (where REST is all but y and x) scattered against x and c) full residual scatters, with $y_{.\mathrm{ALL}}$ (where ALL is all but y) scattered against x.

16. SUMMARY

The paper of Becker, Cleveland and Wilks has gone a long way from graphic archeology ("you can see it, if you know how to look!") toward graphic impact ("you can't miss it"). But we need to go further (Points 1, 2, 7, 11 and 15). The proposed styles of graphic presentation could have been improved in a few other cases (Points 3, 5, 6, 13 and 14). There are a variety of points where the text could have been clarified (Points 4, 8, 9, 10, 13 and 14). In general, however, one can only praise the paper of Becker, Cleveland and Wilks.

ACKNOWLEDGMENT

This research was supported by the Army Research Office under Contract DAAL03-86-K-0073.

Comment

Peter J. Huber

The authors deserve to be congratulated for a competent overview of an area of statistics that is becoming more important (and accessible) every year.

They try hard to give a sober, no-nonsense account of the current state of the art. There is a core of simple-minded, extremely useful techniques—foremost among them methods for identification and labeling. But there is also a halo of experimental techniques, and the cautious statement: "Far more experimentation is needed with these advanced strategies" (Section 2.6) ought to be translated into plain English as: "We could not make sense out of those strategies, but perhaps somebody else will." The lunatic fringe techniques are useful to hatch new ideas, but only few of them will survive.

I believe that newcomers to high interaction graphics—the buzzword "dynamic" is semantically inaccurate, by the way—are still attracted mostly for the wrong reasons, namely by the video game glamor of fancy techniques. Reflection on the intrinsic, practical value of a technique comes only afterward, when the glamor has rubbed off. For example, when we gained direct, hands-on access to decent computer graphics in 1978, Stuetzle and I began to experiment first with the most exotic techniques—like interactively controlled sharpening (see Tukey and Tukey, 1981), combined with kinematic graphics in three dimensions. It took a long while for me to realize that I never would be able to interpret the curious shapes I saw in those sharpened scatterplots.

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The following are comments on points where I either disagree with the authors or would put the emphasis differently.

It is important to avoid gimmicks. Built-in side effects can become extremely annoying when a technique is used in a context not anticipated by its designer. For this reason rescaling after a deletion ought not be automatic (Section 2.2), but should require a separate user request.

In Section 2.4, I suspect that the authors' judgment has been colored by accidental features of their implementations (cf. the remarks of Huber, 1987, Section 4). I fail to understand why roping in a region by drawing a line around it should be intrinsically slower than, and inferior to, brushing the interior of that region. Roping is relatively elastic with regard to timing considerations, while the response to brushing can become unacceptably slow in the case of very large scatterplots.

Undeleting is trickier than the authors make it appear (end of Section 2.4). The problem is to *selectively* undelete a few points. It is aggravating if you have to undelete everything and then to start the deletion process from scratch. A more convenient solution, using alternagraphics, is due to Thoma: alternate with a view showing the deleted points only. If you delete a point in the alternative view, it gets visible in the original view, and vice versa. Incidentally, this is one of many examples where alternagraphic switching is better done by the user hitting a button, rather than by an automatic timer.

In Section 2.6, the authors say that "it is entirely reasonable to implement all three ... rotation-control methods ...." I would substitute "feasible" for "reasonable." The point to be made here is that each alternative eats up some menu space and potentially confuses the user by mode trapping (you never are in the mode you think you are). I am not aware of *any* data analytic problem where the first or third of the modes offers a substantial advantage over the second. What sometimes is required in addition is a *variant* of the first method, for moving one object (point cloud) as a rigid body relative to some other. In order to do this, one would have to control all six degrees of freedom of rigid body motion simultaneously (for which, incidentally, the mouse is a woefully inadequate interaction device).

As the authors stress, scatterplot matrices are nice because they provide a single integrated view of the data (Section 2.6). But I believe they understate the resolution problems, and that for all but the very smallest values of p an alternagraphic solution is preferable. For example, show only two scatterplots at one time, keeping one fixed, and use the other space to flip through all the plots in one row or column of the scatterplot matrix.

Some shorter comments.

End of Section 3.1. The distributed processor model is not only at a design disadvantage, but it also creates a software maintenance nightmare.

Section 3.3: *Integer Arithmetic.* I believe these considerations are no longer relevant after the advent of coprocessors (8087, 68881, etc.).

Section 3.4. These sad comments on graphics standards, unfortunately, are even true for semistatic graphics (where the only interaction is the all important identification of labeled observations).

Section 3.5. Windows are great if there is enough screen resolution (800 by 1000 or better) and we immediately got hooked on them with our first Apollo in 1982. But just like the proverbial *goto* in programming, extensive use of windows may actually be harmful in data analysis. Data analysis is an experimental science, and a "laboratory journal" metaphor is more appropriate than a messy "desktop," especially since the electronic version can be messed up much more thoroughly than a real one, and in much less time!

Of course, no survey can cover everything in depth. Still, because of their importance, I believe the following topics would have deserved a more thorough treatment: techniques for identifying and isolating clusters (the letter I of the original PRIM-9) and the role and use of colors.

ADDITIONAL REFERENCES

HUBER, P. J. (1987). Experiences with three-dimensional scatterplots. *J. Amer. Statist. Assoc.* **82** 448–453.

TUKEY, P. A. and TUKEY, J. W. (1981). Graphical display of data in three and higher dimensions. In *Interpreting Multivariate Data* (V. Barnett, ed.). Wiley, New York.

Comment

William F. Eddy

The authors are to be thanked for their thorough review of the current state of interactive graphics (although I think I detected a certain bias in favor of methods they and their colleagues have developed). As I started careful reading of this paper I found myself repeatedly asking: What if Option 2 instead of Option 1? It seems obvious that there is considerable work yet to be done in deciding which choices should be made. I will resist the temptation to produce a long list of such questions but rather point in other directions.

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1. STATISTICAL ROOTS

Graphical techniques have always been a part of statistics. Nevertheless, I was very struck on reading this paper that graphical statistics is currently in very much the same state that mathematical statistics was about 100 years ago. In fact I went back and reread parts of some of Karl Pearson's long series of papers on the mathematical theory of evolution that was published in the *Philosophical Transactions of the Royal Society of London* between 1894 and 1916. In the very first paper, Pearson gives a graphical method for calculating the first five moments of a probability density function.