ARTIFICIAL INTELLIGENCE
IN STATISTICS

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The title of this paper refers to what is commonly called “more intelligent” statistical software: in other words, statistical software which embodies features developed in the realm of Artificial Intelligence, most notably the expert system. The title should not be confused with “Statistics in Artificial Intelligence” which has to do with the problem of handling so-called “uncertain knowledge” in all kinds of expert systems. Both topics get equal time in Gale (1986), but only one will be discussed here.

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[the] all-too-automatic reaction by many statisticians and data analysts, the reaction that automating... is a threat to their professional position... is a serious misconception.

3 Paradigms

What kind of intelligence should statistical software have, and where should this intelligence come from? Here are two quite different approaches, the first essentially due to Huber, the second to Gale, among others.
3.1 The Lab Assistant

As Figure 3.1 suggests, a scientist has come to a real-live data analyst for help, which is being provided in real-time! This allows for interaction between them. Either one can suggest approaches and react and adapt to the results. This is, of course, vastly superior to the old-fashioned batch mode approach. But, for it to actually be feasible requires software that is more than merely "interactive." As Huber suggests, it should be responsive to the System Experts wishes in much the same way as a graduate lab assistant would be (but much faster!).

"Check the correctness of these model assumptions [perhaps by doing some simulations]," we should be able to say to our software. Or "repeat the analysis we just did with this modified data," or "modify the analysis with the same data, as follows...." Needless to say, the software would do our bidding unobtrusively, allowing us to simultaneously pursue other tasks, and politely prompt us when it's ready to show off its results. Meanwhile, our electronic lab assistant would be keeping a diary of our session—but not a passive, recording device type of diary such as currently exists in some statistical packages. This diary is to be a lot like a lab assistant's notebook. For example, the users might see on the screen a message like: "excuse me, but would you like to comment on the fit?" and the comments would become diary annotations. The diary might also contain things which are done in the background, without the users' explicit knowledge, but which the software "thinks" will be needed later.

It may be too much to ask this Lab Assistant software to actually write the final report, but the diary it produces ought to provide at least an approximation to a first draft. Furthermore, the diary should itself be "executable;" that is, we should be able to replay the session, at least the useful parts of it. (Actually this is not new; the diary command in "S" produces an executable file, which the user can edit before re-running it.)

Now what do you call an executable diary produced from a comprehensive data analysis session involving a system expert and a domain expert? Is it...could it be...an Expert System in Statistics? In other words, could it, with a little bit of tinkering, perhaps, perform some other similar analysis for some other, or the same, scientist, automatically without the intervention of either the live Data Analyst or the Lab Assistant software? This vision of an expert system almost literally creating itself has been a tantalizing one. Many a diary has been created with the hope of such a metamorphosis. But the results (circa 1988) have been frustrating (see the STUDENT example in the next section). To bridge the gap between executable diaries and a genuine (usually "rule-based") expert system, enter an AI guy called a Knowledge Engineer.

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As Figure 3.2 shows, the Data Analyst now switches seats and plays a role analogous to the Scientist in the previous paradigm, providing expertise about his own specialty, Statistics. An example of this collaboration occurred at Bell Labs where Bill Gale played the role of
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WORK STATION

DATA ANALYST
SYSTEM EXPERT

SCIENTIST
DOMAIN EXPERT

Fig. 3.1
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But notice that Tukey spoke not only of improving but also of understanding data-analytic systems. So while we are striving to automate data analysis by building expert systems, we need to be keenly aware of the need for some kind of a theory to help us understand what is really “significant” among the multitude of things which computing power allows us to see. It is interesting to note that both of these goals require us to formalize the process of data analysis, or as some have said, to try to “capture statistical strategy.”

4 Prototypes

Most of the examples to follow were presented at Compstat VIII, a Symposium held in Copenhagen in August, 1988 under the auspices of the International Association for Statistical Computing. Almost without exception, the word “prototypes” is much too optimistic; most never have and never will be put into production, or even be seriously used by anyone other than their developers.

REX Regression EXpert. Developed by Gale and Pregibon at AT&T Bell Labs. The goal was to encode enough expert knowledge to enable a novice user to do a simple linear regression “safely.” See Figures 4.1 and 4.2 for illustrations of the multi-window environment it provides the user.

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TESS (Tree-based Environment for Statistical Strategies) Here Gale and Pregibon abandoned trying to model a human analyst, in part because they became convinced that only a human can supply enough of the context. Alternatively they now seek context-free results (note the plural). Their inspiration is the classic book of Daniel and Wood (1971, 1980), who said

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The next stage of the analysis is linearity checking. The test used finds a mild nonlinearity, so REX pauses to ask if the user wants to call the problem ok. A plot is offered, which we accept. The plot show a scatter plot of the transformed variable and a smoothing curve. The curve shows a small bump in the middle. We would suggest calling this “ok.” In fact, REX does not have a means of fixing this problem.
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There is currently considerable debate centering on questions such as

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- WHAT should it do? Should it do several kinds of data analysis, or just one kind; or should it be oriented toward a particular kind of application rather than toward a particular kind of Statistical technique.

- WHY do we need it?

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WITH APPLICATIONS TO
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This is a working paper. Comments are invited and should be directed to the author at the address listed below. Please do not reproduce in any way without the author's permission.

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We are considering whether we can regress brain.y on brain.x. But first, the distribution of y is unduly skew. skewness of y is quite large.
Using the rule:
If
then
The distribution of y is unduly skew
and the rule
If
then
sign of y is positive
assert that logarithms of the response variable y should be used
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We suggest the fix that logarithms of the response variable y should be used
(Type 'c' to continue)

<table>
<thead>
<tr>
<th>'INTERP. OF TESTS</th>
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<td>TRACE INFO</td>
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The vertical scale shows the number of points in the interval of values shown on the horizontal scale. The histogram of the transformed variable should be more evenly distributed.

Before and After Histograms

**Histogram of y**

**Histogram of log(y)**

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