Artificial Neural Networks and Virtual Reality

as a basis for

Research in the New Millennium.[1]

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[1] We are grateful to Nick Stoyanoff and Scott Danielsen of Terra Research & Computing for permission to use proprietary data. CATPAC and GALILEO are trademarks of The Galileo Company. We are also grateful to Scheriber Instruments for the use of the STEREO 3-D display program.

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The Communication Revolution

There is widespread agreement, particularly among students of communication, that we are living through a revolution in communication technologies of a magnitude and importance equivalent to the industrial revolution. Spearheading this development has been scientific and technical advancement in computing and computer networking.

As an indication of the magnitude of this revolution, over a quarter century ago, Sewell, et al (1969), and Woelfel & Haller (1970) published the first substantive uses of path analysis in the sociological literature.[2]The computer that analyzed the data for these studies had 120 times less core memory, ran 578 times slower, and cost 3500 times as much as the computer on which the research reported here was conducted. Moreover, the human-computer interface for that original CDC was hopelessly primitive, requiring punched card or paper tape entry, with printed paper output, usually within a 3 to five day period. This computer, on the other hand, can portray true color high resolution graphics in three dimensions, has stereo sound and can even converse at an elementary level.

Yet it could be argued that the original CDC computer and its saurian relatives revolutionized social science research to a much greater extent than contemporary equipment. For, by and large, *the kinds of data analysis performed by social scientists in the 1990's is virtually the same as that performed in the 1960's.*

Now, as then, the most common analyses performed by quantitative social scientists consist overwhelmingly of frequency counts, tables, t-tests, anovas and regression equations. Non-linear regression models are used by only the smallest elite, as are complex causal models. Every one of these analyses could have been conducted -- and were conducted -- in the 1960's on 1960's computing equipment. None of these elite analyses can be described as "cutting edge" or even "modern" by 1990's standards.

In the period since the 1960's, the human Computer interface has been carefully studied and completely revolutionized, with even greater changes to come. The 1960 computer could not be addressed in real time, and, indeed, could not even recognize lower-case letters. It could not be accessed by telephone, could not display pictorial or graphical information except via plotter, and needed to be addressed with a programming language such as COBOL or FORTRAN. The contemporary computer, on the other had, can be addressed interactively and graphically, is networked worldwide, and can be addressed in many ways, some of them very similar to everyday language. All contemporary computers can easily read and write multilingual text, and, indeed, word processing is probably the most common function of the contemporary PC.

Equally important has been the revolutionary development of analysis algorithms, including perceptual mapping, clustering techniques, pattern recognition, artificial

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[2] A 2SLS path model would not be published in the communication literature until 1974.

intelligence and artificial neural networks. These new analytic tools have revolutionized major aspects of engineering, design and manufacture, as well as research in military, industrial, financial and other areas of research. Yet contemporary communication research has remained curiously immune to the new tools of the communication revolution.

The Need for New Research Technology

Researchers ought to be at the forefront of technological developments, since scientific research shares with applied research at least three goals:

1. Increasing access to data. The more information that can be accessed by the scientist or applied researcher in a given interval of time, and at a given level of expenditure of resources and energy, the better the capacity to describe and understand.

2. Increasing ability to isolate relevant features and identify recurrent patterns in large arrays of data. Whatever philosophical differences may confound advocates of alternative scientific models, most investigators would agree that a major function of science is to separate important, essential or recurrent patterns and features from the otherwise inchoate flow of sensation to which people are exposed. This process of isolating salient and recurrent patterns underlying data is called analysis.

3. Increasing ability to communicate results of data collection and analysis to scientists and others who must understand and make use of the results of scientific data.

The communication revolution speaks quite directly to all these issues, since advances in both the worldwide communication system and the interface between that system and computers has been dramatically enhanced. The baud rate at which it is possible to gather information through the growing worldwide network exceeds capacities of a few decades ago by several orders of magnitude. New pattern-recognition algorithms, particularly self-organizing neural networks, provide ways of identifying salient trends and patterns that were not available to the founders of quantitative social science. And, finally, remarkable advances in computer display capabilities provide dramatically enhanced ways to communicate information to the analyst.

[3]In spite of these advantages, social research has remained virtually immune to these new developments, and continues to implement a half-century old research paradigm using algorithms developed somewhere between 1900 and 1960.

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[3]The first cluster analysis algorithms date from about 1903. Factor analysis was developed around 1928. The path analysis algorithm was first published in 1929, and perceptual mapping-multidimensional scaling first appeared in 1938; the non-metric algorithm appeared in 1966, about the same time as the

The goal of this paper:

In this paper, we try to show how a contemporary study might use state-of the -art technology to conduct a typical attitude survey. One of the most common studies in market research is the standard "positioning" study, in which a manufacturer attempts to measure the "position" its product holds in a market place. In a typical study, focus groups or in-depth interviews are used to generate a list of potential "attributes" which distinguish the product or service from its Then a paper-and pencil questionnaire is constructed and administered to a larger probability sample. The results are keypunched, and one or more "perceptual maps" are constructed.

In this study, we use new artificial neural network technologies (CATPAC) which do not require numerical data, but can produce perceptual maps directly from text, and project those graphs in a 3-dimensional "virtual reality" display which allows the user to "enter" the perceptual space directly.

Methods

Perhaps one of the most significant changes brought on by the communication revolution is the shift from numeric data to text and graphics. For that reason, all data in this study were completely textual. Six interviews based on a convenience sample were conducted by telephone in the 607 telephone area code (Ithaca, NY and environs) Saturday, October 12, 1993. Since the calls were made solely for demonstration purposes, no selection criteria were used, and numbers were taken at random from the Ithaca and vicinity telephone directory. Readers are cautioned that the results of this analysis are based on a tiny sample that reflects no particular market or market segment, and should be taken only as a demonstration of the way the procedures work.

The interviews were focused in-depth interviews, which means that no specific questions are asked, but rather the interviewer focuses on finding the answers to four general questions using whatever language and wordings seem appropriate in each instance The interview protocol used was as follows:

1.) If you were planning to buy a new car within the next 30 days or so, what cars would you consider buying?

2.) Please discuss the differences among these cars. Be as specific as you can.

BIPLOT or Correspondence Analysis algorithm. The Fisherian statistical model, along with the Popper-Hempel-Openheim deductive-hypothetical model was developed in the first half of the 20th Century. The Thurstone Scale appeared in the late 1920's, and the Likert Scale in 1933. Arguably, the standard research repertoire of the communication scientist contains nothing developed later than 1966.

3.) What kind of person would you expect to buy each of these cars? Please be as specific as you can.

4.) Given what you've said about these hypothetical people, what kind of a person are you? How does the kind of person you are affect the kind of car you might choose to buy?

Analysis

All text from the interviews was red by CATPAC, an interactive activation and competition artificial neural network optimized to read text. CATPAC runs a moving window of variable size through a text, and activates neurons corresponding to the words in the windows whenever those corresponding words are in the window. According the to Hebb Rule, connections among neurons whose activation values are similar are enhanced, while all others are diminished. Ultimately, the artificial neural network in CATPAC forms a pattern of connections which resembles the patterns in the text.

This pattern of connections is always a square matrix of numbers which can easily be input into other multivariate analytic techniques. CATPAC routinely defaults to a diameter-method cluster analysis and a GALILEO(TM) perceptual map. The Gaileo perceptual map, in turn, can be presented either as a color graphic display on a CRT, or as a stereographic anagyph which can be projected onto a screen of arbitrary size.

Results

Although many forms of analysis are possible, only three kinds of output are presented here:

- verbatim transcripts,
- cluster analyses, and
- 3-dimensional, stereographic (anaglyphic) perceptual maps.

Each of these will be discussed briefly here.

Transcripts

Data from the audio tapes was transcribed verbatim onto computer disk; grammar has not been corrected and mistakes have been unedited, except that the data have been spell-checked. Interviewer remarks have been omitted except when required to make sense of the respondent's answers.

Cluster Analysis

Since the sample drawn is so small, and represents no meaningful market segment, no effort has been made to draw meaningful results from the analysis. Rather we've tried to show just how sensitive CATPAC analysis can be.

Three analyses, titled *Frequencies and Cluster Analysis* are provided:: The first is for the first individual interviewed, (Case 1, a fairly extensive interview) the second is for the second respondent (Case 2, a more limited interview). The third analysis is for all six cases combined.

These analyses can best be used by comparing the conceptual structure revealed by the dendograms to the actual texts of the interviews. A fair reading will reveal that the dendograms are a very accurate and complete rendering of the sense of the interviews they represent.

Perceptual Maps[4]

Figures 1-4 represent perceptual maps made from the raw interview text by CATPAC. Figure 1 shows the large scale view of the first respondent (Case 1). This perceptual map (which, it is worth noting, was made from the *raw text of a single interview*) is a remarkably accurate depiction of the views expressed by the first respondent. The car he would buy if price were no option (sic) would be a Lexus, which appears at the right of the plot. Next to Lexus' position are the terms "price" and "option." The respondent also mentioned safety as a factor, and "Volvo" and "safest" (he considered Volvo to be the safest car) appear at the top left. He also owned a Volkswagen camper, which he mentioned was based on the Vanagon chassis, and discussed its safety in terms of crash protection and deaths per hundred million vehicle miles. These terms appear clustered together just under the "Volvo-safest" cluster.

[4] Note that while the maps presented in this paper are two-dimensional because of the black-and-white paper format, in live demonstration they are presented as stereographic anaglyphs. There can be viewed either from the computer screen, in which case they project a 3-dimensional virtual stage of a few cubic feet in front of the viewer, or projected on a large screen giving the illusion of perceptual maps which fill a large proportion of the viewing area.

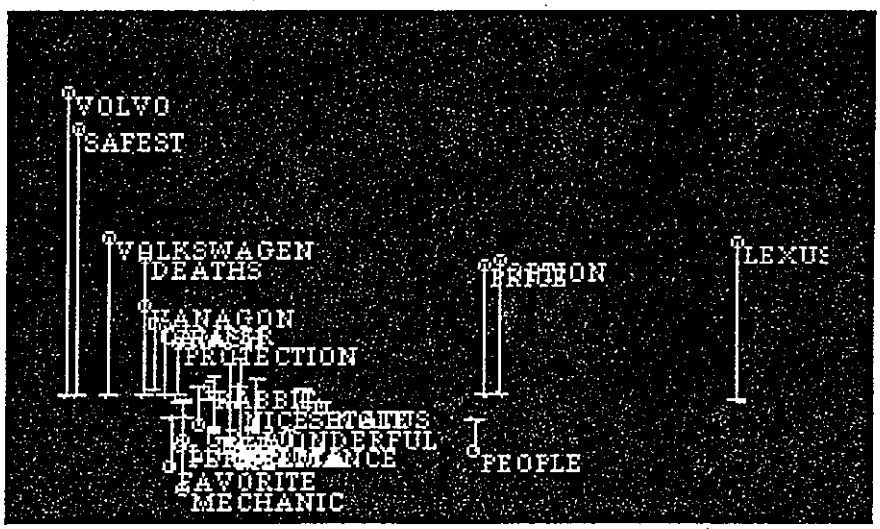


Figure 1 also shows a tight cluster of terms too crowded to read easily; these are blown up in Figure 2 to reveal the wonderful red Toyota Celica that he loved. (He had been a mechanic, and the term "mechanic" appears here. The terms "great", "performance" and "nice" also appear near this car, which he regrets having sold. The term "single" also appears here, since he said mostly single people would by a Toyota Celica. The term "rabbit" appears between the Celica and the Vanagon, because the respondent favored a Rabbit when he was a driver for an import auto shop in Colorado.

By any standards, this is a remarkably accurate rendition of this respondent's views!

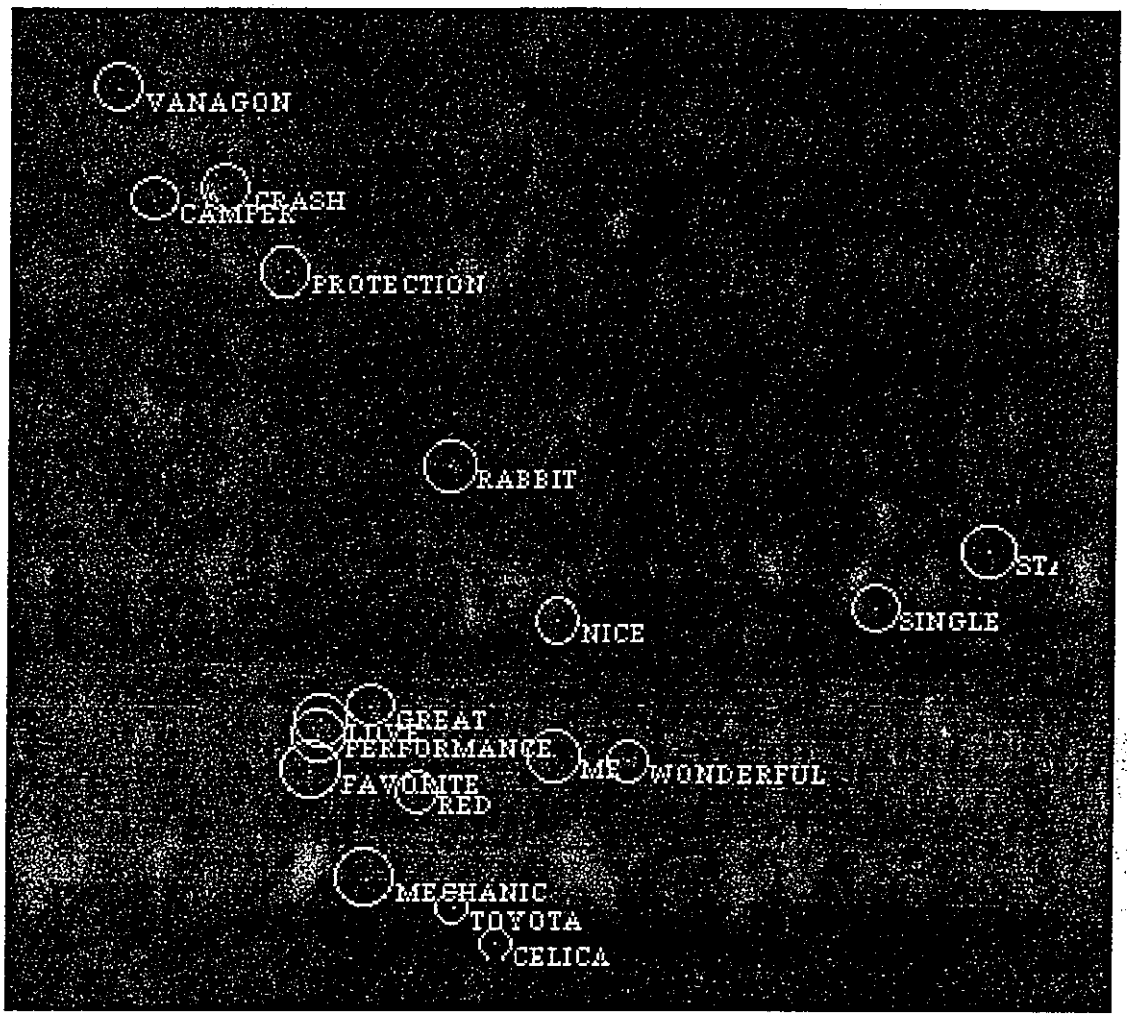
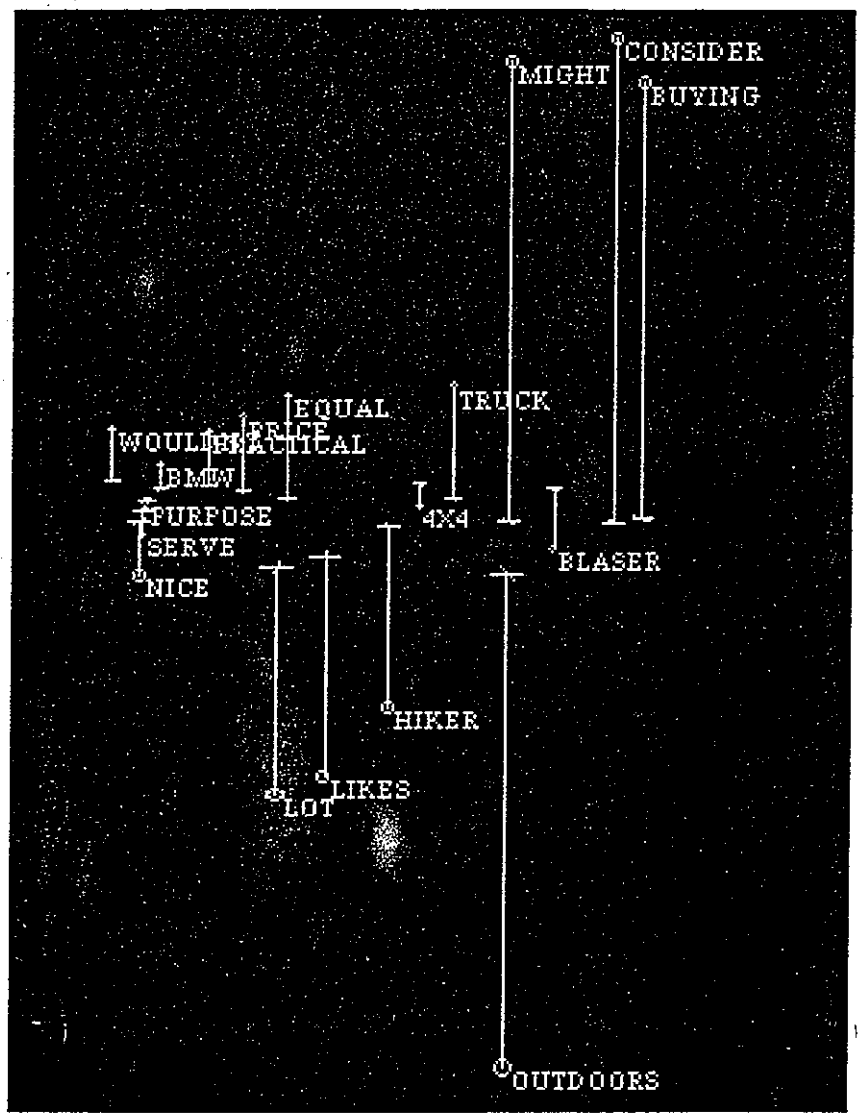
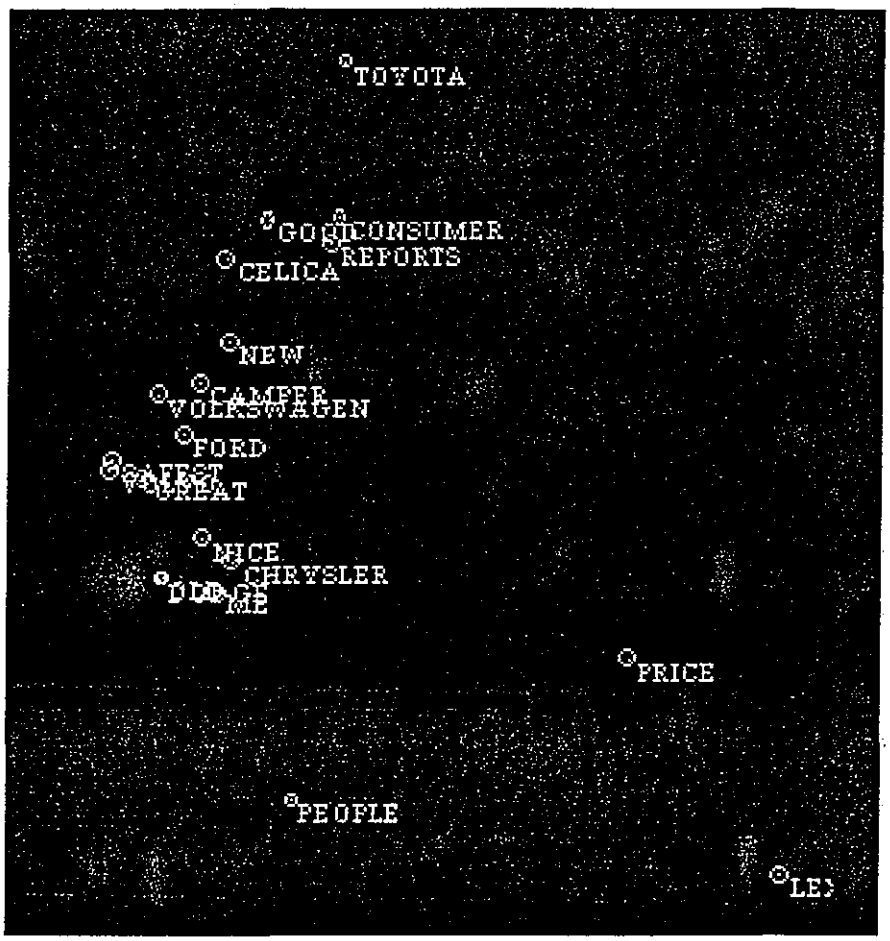


Figure 3 shows the perceptual map for the second respondent, a man who might consider buying a Blaser 4X4 truck, since he is a hiker who likes the outdoors a lot; he also considers (but rejects) a BMW, which he believes to be about equal in price. Although it would be "nice", it would serve no purpose, he says. Again, even thought his is a single interview and not very extensive, the perceptual map made from the raw text is remarkably accurate.



The last Figure shows the perceptual map made from the entire six interviews. Included in this plot are all the cars considered or owned by the six respondents (Toyota Celica, Volkswagen Camper, Ford, Volvo, Chrysler, Dodge, Lexus, along with several of their attributes (good, consumer reports, new, safest, great, old, nice, price,) and a self point "me."



Recall that these six accidental sample members' opinions of the auto market are of little consequence. But Figure 4 is interesting, because it shows clearly that, even with only six respondents, none of whom are actively in the auto market, a perceptual map indicating the position of the brands relative to each other, their attributes and respondents, is beginning to emerge. This map is based on only the 1535 words recorded in these six interviews, but a full 1000 case sample of the same quality as these six interviews would yield over a quarter of a million words. (since respondents in the main sample would be active in the auto market, they ought to be expected to have more to say than these six respondents.)

Conclusions

In spite of its small scope, this preliminary analysis shows clearly that

- in-depth interviews sufficiently rich for meaningful qualitative analysis can be taken over the phone. In fact, *data are sufficiently rich so that perceptual maps and cluster analyses can be conducted for individual cases.*

- results of CATPAC analysis are compatible with older methodologies, and, in fact, are able to produce perceptual maps of the same type as formerly required elaborate quantitative procedures. In fact, once again, *CATPAC analysis is sufficiently precise to produce perceptual maps for a single individual.*

- CATPAC analysis of in-depth interview data provides data in a format that is particularly amenable to strategic positioning. In fact, although not implemented on this simple half dozen interviews, CATPAC provides on-board algorithms which make it possible to test possible repositioning strategies on a "what-if" basis.

Conclusions

The complete study presented here, from initial interviews to completed data analysis, took less than one day Although the sample is too small to be meaningful in a substantive sense, it nonetheless is sufficient to show that modern artificial neural network technology is sufficiently precise and sensitive to produce fine-grained, detailed patterns of meaninfgul information from very limited data in a very, very short time frame. These results can be presented in a particularly effective virtual-reality framework. Altogether, modern communication technologies offer advanced methods of scientific study which ought to take their place alongside the 1960's technologies which now make up the bulk of our "advanced" scientific toolkit.