Recent Computer Applications in Cultural Anthropology

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This brief summary of developments in computer applications by cultural anthropologists updates a previous review (Burton, 1970), which dealt with multivariate data analysis, particularly multidimensional scaling and cluster analysis. The scope here is linear programming, linear regression, content analysis of text, and simulations. For recent developments in multidimensional scaling and cluster analysis, the reader is referred to Romney, Shepard, and Nerlove's two volumes of papers on multidimensional scaling (1972), and to the review article on mathematical anthropology in the *Annual Review of Anthropology* (1973).

In the past few years recourse to the computer at some point has become common for the practicing cultural anthropologist. Although a large part of that usage takes the form of analyzing data with packaged statistical programs, more and more anthropologists write their own programs for specialized problems which are unique to cultural anthropology. This change in the role of the computer in cultural anthropology is a consequence of two trends: first, an increase in the quantification of field data, and second, an increase in the construction of formal models, which often require the computer for their formulation or computation.

Linear Programming Models of Decision-Making

Since the publication of Goodenough's pioneering article on Trukese residence rules (Goodenough, 1956) anthropologists have increasingly viewed social organization as the result of the aggregation of individual decisions within the constraints of a) cultural rules for decision-making and b) demographic, genealogical, and economic variables. Some consequences of adopting this decision-making view of social organization have been a shift from static, functional analyses to processual analyses, and a shift from a compartmentalization of social and economic studies to an integration of social and economic variables in a single model. To construct such models, the need to adopt some theoretical framework for the study of individual decision-making has led a number of cultural anthropologists to discover the rather large literature on choice behavior and decision-making behavior in psychology and economics, and to consider such questions as whether people maximize or satisfice, whether they make decisions or have decisions made for them by cultural rule systems, and whether the standard economic model for behavior within a market system is applicable to non-Western societies. My previous review predicted that the growing concern with decision models would lead anthropologists to experiment with linear programming models; that

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prediction has been realized in several studies which have grown out of the work of Buchler and Selby at the University of Texas.

A linear programming model is a computational procedure for maximizing one or more variables, or linear combinations of variables, subject to constraints on other variables or linear combinations of variables. In that it computes the best decision for an individual or society to make, given the assumptions of the model, it is normative for decision-making. Comparisons between the numbers computed by the linear program and observed data provide simultaneously a test of whether the individual or society exhibits maximizing behavior and of the appropriateness of the linear programming model as a representation of the actual decision processes which are embodied in the behaviors of the individual or society. Cultural rules and economic or demographic constraints can be represented as constraints in the linear program, a special case of a general mathematical programming model for which relationships among variables can have any polynomial form. Because the linear programming solution, compared to nonlinear programming techniques, is much simpler to compute, nonlinear programming problems are often solved by approximation to linear programs. Even linear programs, although they can be solved with paper and pencil if they involve only a few variables, are generally so complex as to require the use of computers.

A classical problem for a linear programming solution is that of a diet, in which there are n foods to be combined in quantities $Q_1, \ldots Q_n$. Associated with these foods are costs per unit portion, $c_1, \ldots c_n$. There are k nutrients such as calories, the several proteins, vitamins, and minerals which must be provided in minimal amounts, $X_1, \ldots X_k$. A unit portion of each kind of food contains a specified amount of each nutrient. Y_{ij} is the amount of nutrient j in a unit portion of food i. The problem is to minimize the total cost, which is equal to $c_1Q_1 \ldots + c_nQ_n$, subject to the constraints

$$Y_{11}Q_1 \ldots + Y_{n1}Q_n \geq X_1$$
$$\vdots$$
$$Y_{1k}Q_1 \ldots + Y_{nk}Q_n \geq X_k .$$

For problems like this, the linear programming model makes one simplifying assumption which may have deleterious consequences for applications of the model: it makes no provision for variance in the amount of a given nutrient in a unit portion of any food. If the variances in the technical coefficients are high, the model will compute a solution for which the constraints are met only on the average.[1] When anthropologists use linear programming models they must take into account the assumption that the technical coefficients in the model are constant.

Buchler and McKinlay (1969) and White (1972) have developed linear programming models for the Kapauku Papuan economy, based on data from Pospisil's monograph (1963). The problem is to maximize total calorie production by allocating labor among three different kinds of land, subject to limitations on the total amounts of land and labor. Both of the models obtain a good match between predicted allocations of labor to the three kinds of land and the observed allocations of labor to the three kinds of land.

A second linear programming model has been developed by Selby, Stepick, and Hendrix for use with their project on migration decision-making in Oaxaca, Mexico (Selby and Hendrix, n.d.; Stepick and Hendrix, 1973). Unlike the model of Kapauku

[1] I am indebted to Joyce Chen for this observation.

Papuan economy, in which the goal is to describe maximization behavior for a society, the model of Oaxacan decision-making is an attempt to describe maximization behavior for individuals. The problem is to maximize overall personal welfare, subject to linear constraints on how the individual can allocate time. Overall welfare is a linear function of several values, estimated by a linear regression analysis, where the data are judgments by individuals of the positions of other individuals on the values. Like the model of Kapauku Papuan economy, the linear programming model obtains remarkably good matches between predicted time allocations and observed time allocations. The two models taken together provide an encouraging prognosis for the future of linear programming models in anthropological studies of decision-making.

Linear Regression Analyses

Although widely used in the other social sciences for many years, multiple linear regression analysis has until recently been ignored by cultural anthropologists. That it has a wide variety of potential uses for them is demonstrated by three recent applications by cultural anthropologists. Graves and Lave (1972) developed a regression model to predict the starting salary of Navajo Indian migrants to Denver. Hammel (1970), concerned with comparing several different models for explaining the prestige-ranking of occupations in Belgrade, compared a) the pattern of correlations of individual prestige-rankings with the group-consensus rank-ordering against b) the pattern of correlations of several "foreign" models with the same group-consensus rank-ordering. The foreign models were based on the ethnographer's ratings of occupations on culture-free characteristics. Multiple regression of the group-consensus orderings onto the culture-free characteristics had explanatory power comparable to that of the individual rank-orderings. Kronenfeld and Kronenfeld (1971), in order to predict informants' judgments concerning the appropriateness of several behaviors towards different kintypes for the Fanti of Ghana, constructed a set of independent variables for kintypes which corresponded roughly to such concepts as "respect," "seniority," "closeness," and "lineage membership." Their dependent variables were percentages of informants who judged behaviors to be appropriate to kintypes. Again, the regressions had good explanatory power, as measured by the R^2 statistic.

Given these encouraging results, however, of its application to anthropological data and its productive use in economics, linear regression analysis seems likely soon to become a standard tool in economic anthropology. Surprisingly, in anthropology, the first applications of regression analysis have been in areas outside the traditional domain of economic anthropology.

Content Analysis of Text

For several years, B. N. Colby has been working on computerized systems for the content analysis of text, particularly folktales. His earlier work, using the General Inquirer system, is reported in Paul Kay's volume on Mathematical Anthropology (1971). Colby has now developed a more general interactional system for the eidochronic analysis of text called SAGE (Colby, Nordrum, and Knauss, 1973). The SAGE system is currently being tested on such varied kinds of textual material as Irish folktales, Ixil Maya Myths, Classical Nahuatl text, and field notes on primate behavior.

The SAGE system, written in the LISP language for the PDP-10 computer, is intended to permit automated analysis of text. It searches for eidons (types of events in narratives), locating them in the text by searching for eidon tags (groups of words which are semantically related to the type of event which defines the eidon). In addition to doing frequency tabulations of words in text, the SAGE program will locate sentences containing any concatenation of the words which define the eidon tags. The goal of this analysis is the construction of a grammar of narratives through

the study of sequential ordering of tags. The SAGE program is able to work with several levels of hierarchical organization by defining super-tags made up of tags, or parts of tags, using the logical relations union, intersection and exclusive *or*. In contrast with most work in cognitive anthropology, the SAGE system is an attempt to study meaning in the context of narratives.

Computer Simulations

A simulation is a kind of dynamic model. Like all models, it mimics reality by making simplifying assumptions about structures and processes, but computer simulations have the advantage over conventional mathematical models that they can handle a relatively large amount of complexity. Not surprisingly, they are popular in those disciplines, like cultural anthropology, which attempt to study naturally occurring systems. By varying the parameters in the simulation, the investigator can perform experiments on the computer. A major problem with simulations, though, is that they can easily become so complex as to add little in understanding of the observed phenomena other than the recognition that it is possible to program a set of processes which accurately mimic them. A second problem is that of uniqueness, for there could be several, or even an infinite number of simulated programs which would produce the same output. A good simulation should incorporate processes which are relatively simple, are intuitively satisfying, and correspond to commonly accepted theories of social science. Thus, the well-known "world model" (Meadows, et al., 1972) incorporates relationships among variables which are derived from conventional econometric analyses.

Because computer simulation is ideally suited to the diachronic study of social organization, it can easily represent marriage rules, demographic processes, economic exchanges, genealogical relations, and other social phenomena. It is somewhat surprising, therefore, that the pioneering study by Gilbert and Hammel (1966) remains an isolated instance of simulation of social organization in anthropology. For the most part, recent simulations have concentrated on spatial relationships and/or on population growth processes. For example, Jordan (1971) deals with the diffusion of innovations over space, while Zubrow's work (1973) deals with population growth and the spread of settlements over space.

A program to simulate the processes in the development and distribution of languages is Kirk and Epling's study of the history of Polynesian (1972), which simulates the spread of these languages from a common origin. It takes into account the distribution of island sizes, uses an exponential function for population growth but ignores distances among islands. It allows for migration to islands which are already populated, and for merger of the language of the migrants with the language of the previous residents. When migrants leave an island, the similarity of their language to that of the island which they left decays according to an exponential function derived from glottochronology. Kirk and Epling ran the program for a 1900-year time period and computed theoretical cognate similarity figures for 43 societies. They then correlated the theoretical cognate similarity matrix to an actual cognate similarity matrix for the same 43 societies. Despite the fact that the program does not take into account the geographic distances between islands, they obtained a sufficiently high correlation between the two matrices to be able to argue that the simulation had captured part of the historical processes in the evolution of the Polynesian languages.

The interest of anthropologists in decision process and the widespread use of computer simulations for artificial intelligence studies should naturally win the computer a place in the simulation of cultural decision processes. Nevertheless, when Gladwin took the lead in the simulation of decision processes in his computer simulation of decisions by Fanti fish sellers about where to sell their fish (Gladwin,

1971), he later found (Gladwin and Gladwin, 1972) that a simple hierarchial decision model made better predictions than the computer simulation. A more recent simulation by Gladwin (personal communication) aggregates data from individual decision processes based on a hierarchial model and compares the results to an additive model of choice behavior. B. N. Colby has recently developed a program in the LISP language which simulates decisions by Ixil Mayan diviners (Colby, personal communication, 1973). In addition to such simulation of decision processes, computer simulations of other cognitive systems such as cultural belief systems should eventually find their place in anthropological research.

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