

Using Interactive Computer Mapping to Teach Cartographic Concepts at Middlebury College

by Robert R. Churchill and Phillip Frankland

BACKGROUND

Automated cartography has greatly reduced the time and effort required for map production, and has become widely accepted in both the public and private sectors as an effective and efficient means for portraying spatial data. With the increased demand for people with training in computer graphics, many colleges and universities now include instruction in the use of computer cartography in their curricula. Most often, the objective of such instruction is to lead students to the successful execution of mapping programs.¹ Computer mapping, however, need not be regarded only as an instructional goal; the relative ease of procedure, especially with the advent of interactive capabilities, can transform it to a profitable pedagogic tool. More specifically, it can be used to illustrate many basic spatial and cartographic concepts far more emphatically and convincingly than conventional classroom approaches.

This paper describes the use of interactive computer mapping to teach cartographic concepts to undergraduate students at Middlebury College, Middlebury, Vermont. We designed a five-week module to introduce students to some of the most commonly encountered problems in cartographic design and production. The course emphasized the use of interactive mapping programs that permitted the students to discover and evaluate basic concepts on their own.

Middlebury College's computer — a DEC PDP 11/45 — and peripheral equipment proved to be both an advantage and a disadvantage in the implementation of mapping programs for the course. Because limited core precluded the use of many widely available mapping software packages, it was necessary that all programs used in the course be expressly written for a small timesharing system.² On the other hand, timesharing, availability of interactive terminals, and hands-on access to a Houston Instruments DP-3 drum plotter and a DEC lineprinter enhanced the opportunity for students to experiment independently, with almost immediate turnaround.

In describing the mapping programs written for the course and the concepts that they were used to explore, the discus-

¹Unfortunately this approach often neglects fundamental cartographic principles. For more detailed discussion, see G. F. Jenks. "Contemporary Statistical Maps — Evidence of Spatial and Graphic Ignorance." *The American Cartographer* 3:11-19, 1976.

²Program listings and documentation are available from the authors on request.

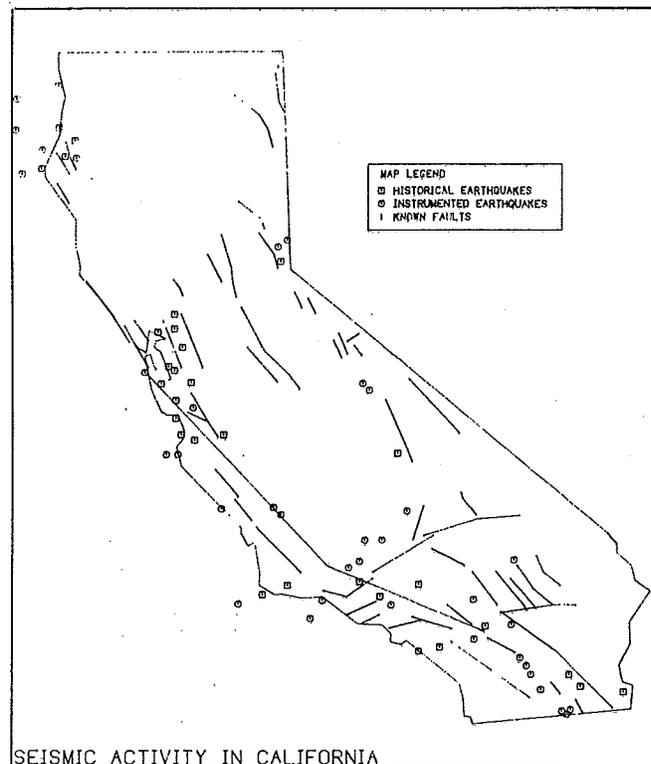


Figure 1. Example of Output from the Interactive SGNMAP Program. (In addition to plotting qualitative point symbols, the program also contains an inline option, which was used here to show locations of known faults. Data from Bruce A. Bolt, *Earthquakes: A Primer*, San Francisco: W. H. Freeman, 1978.

sion essentially parallels the progression of the course itself. Initially, we posed the problem of representing qualitative point data, primarily to introduce principles of managing and communicating spatial information. This was followed by the more difficult problem of representing magnitudes of quantitative point data. Finally, students were introduced to methods of representing areal information and the problems associated with choroplethic and isarithmic mapping; specifically, aggregation of data, derivation of data classes, and interpolation procedures.

METHODS

SGNMAP, an interactive computer program that produces a map of qualitative point data on the drum plotter (Figure 1), was used to illustrate the recovery and manipulation of spatial data.³ Students were required to digitize the program input manually, including the map outline and data point coordinates. Initially, they were instructed to digitize all inflections in the outline and execute the SGNMAP program using this outline. Subsequently, they were directed to generate additional maps by applying progressively coarser smoothing techniques.⁴ This simple exercise permitted them to discover some of the fundamental issues in management of spatial data, particularly the trade-offs among data preparation time, production costs, and resolution of the final map.

The SGNMAP program was also used to introduce basic symbolization problems. Symbols for the point phenomena to be mapped are selected by the user from a program-supplied catalog that contains both geometric and associative symbols. Nonetheless, some thought was required on the student's part to select symbols that were distinct yet that did not connote ordinality.

After working with the relatively simple SGNMAP program, students were introduced to more complex data representation and symbolization problems through a program called PWRMAP.⁵ Like SGNMAP, PWRMAP is an interactive program that uses the drum plotter to produce maps of point data. PWRMAP, however, involves the representation of quantitative data using graduated symbols, specifically circles, triangles, or squares, at the user's option (Figure 2).

While graduated circles are probably the most widely employed means of symbolizing quantitative point data, they are also problematic in that there tends to be an underestimation of larger circle sizes when the areas of the circles are scaled in direct proportion to the data values.⁶ This perceptual distortion can be compensated for by using an exponential transformation of the data values.⁷ While a given exponential transformation is used by default, the user can alter the value of the exponent. Students were asked experimentally to derive the most representative portrayal of their data and to explain the rationale underlying their solution. Parenthetically, most selected maps with circles scaled using the exponential transformation, although they concluded that the best solution was given by an exponential value larger than that considered optimal by most research on the subject.

³Frankland, P. *User's Guide to SGNMAP Point Symbolic Mapping Program*. Middlebury, VT: Department of Geography, Middlebury College, 1980.

⁴Douglas, D. H., and T. K. Peucker. "Algorithms for the Reduction of the Number of Points Required to Represent a Digitized Line or its Caricature." *The Canadian Cartographer* 10:112-122, 1973.

⁵Frankland, P. *User's Guide to PWRMAP Graduated Symbol Mapping Program*. Middlebury, VT: Department of Geography, Middlebury College, 1980.

⁶While underestimation of larger circle sizes may be the foremost problem with graduated-circle maps, there seem to be additional limitations. The visual context in which the circle appears, for example, may result in viewer distortion according to Gilmartin, P. P. Visual Context as a Source of Perceptual Error in Graduated Circle Maps. Presented at the Annual Meeting of the Association of American Geographers, 1980.

⁷Flannery, J. J. "The Relative Effectiveness of Some Common Graduated Point Symbols in the Presentation of Quantitative Data." *The Canadian Cartographer* 8:96-109, 1971.

Although graduated circles are more commonly used than other symbols, alternatives can minimize, if not eliminate, perceptual problems associated with the circle.⁸ For this reason, students were additionally instructed to produce maps using not only graduated circles but graduated squares and triangles as well, and then to evaluate the results comparatively. Most students, perhaps conditioned by familiarity, considered the graduated circles as visually more effective in data representation than either the square or the triangle.

In experimenting with the PWRMAP program, students also discovered that a large number of data points resulted in maps with differences in symbol sizes that were virtually indistinguishable, particularly when the range of data values was small. This experience provided a basis for a discussion of the use of range-graded symbols, and prompted student use of the PWRMAP program to produce maps with range-graded symbols.

In addition to the more formidable problems of data representation and symbolization, PWRMAP also required some basic cartographic design considerations. Specifically, while the maximum symbol size is set by program default, it is rarely optimal. Students were thus forced to arrive at appropriate symbol size for their particular maps.

While PWRMAP was used to introduce basic problems of data representation and symbolization, even more complex problems are associated with mapping spatially continuous or quasi-continuous, areal data, CMAP⁹ and ISOMAP¹⁰ are interactive programs that produce choropleth and isarithmic maps respectively on the lineprinter. As widely available mapping routines such as SYMAP¹¹ have core requirements that exceed storage available on small systems, both programs use scan-line algorithms that require minimal core, and have the additional advantage of providing almost instantaneous turnaround.¹² Because several maps can be generated in a matter of minutes, students can experiment freely with the various mapping options.

Such experimentation is particularly valuable for choropleth mapping, where a major problem continues to be derivation of an appropriate number of data classes and class intervals (Figure 3).¹³ While the same problem must be reckoned with in isarithmic mapping — and isopleth mapping, in particular — the ISOMAP program additionally requires the user to input both the number of data points to be searched for interpolated

⁸Graduated squares, in particular, may minimize many of the perceptual problems associated with circles according to Robinson A. R. Sale, and J. Morrison. *Elements of Cartography*. New York: John Wiley & Son, 1978.

⁹Churchill, R. *User's Guide to CMAP Choropleth Mapping Program*. Middlebury, VT: Department of Geography, Middlebury College, 1980.

¹⁰Churchill, R. *User's Guide to ISOMAP Isarithmic Mapping Program*. Middlebury, VT: Department of Geography, Middlebury College, 1980.

¹¹Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University.

¹²The scan-line routine used by the CMAP program was modified from Scriptor, M. W. "Choropleth Maps on Small Digital Computers." *Proceedings of the Association of American Geographers* 1:133-135, 1969.

¹³Mackay, J. R. "An Analysis of Isopleth and Choropleth Class Intervals." *Economic Geography* 31:71-81, 1955; also see Jenks, G. F. and F. C. Caspall. "Error in Choropleth Maps." *Annals of the Association of American Geographers* 61:217-244, 1961.

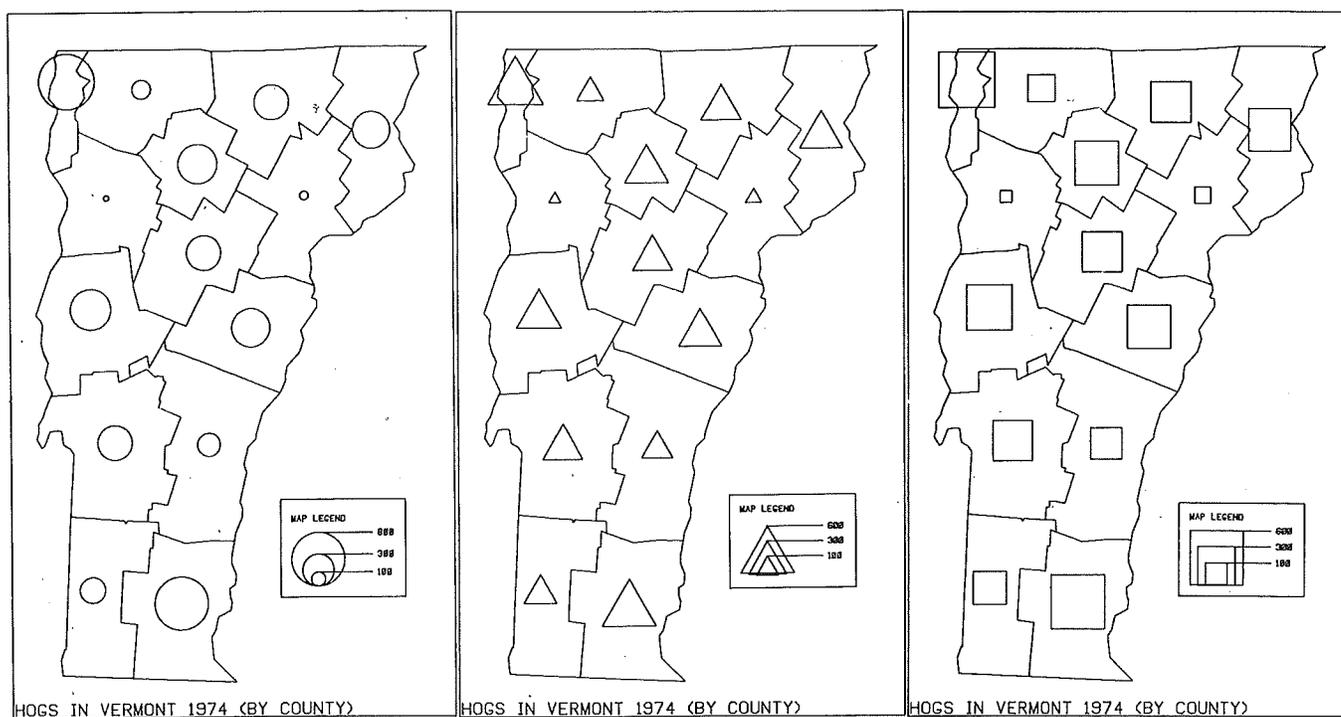


Figure 2. Maps generated by the PWRMAP Program. (The graduated symbol to be used — circle, triangle, or square — as well as symbol size, are specified by the user at the time of execution. Like SGNMAP, the PWRMAP program contains an optional inline plot routine used here to construct county boundaries.)

tion,¹⁴ and the interpolation procedure to be used. The user must select from three program-supplied interpolation procedures: weighted linear distance, weighted distance squared, or a third algorithm that disproportionately weights the nearest control point.¹⁵ The effect of varying the number of search points used for interpolation is demonstrated in Figure 4, and Figure 5 illustrates the effects of varying the interpolation procedure while holding the number of search points constant.

As the type characters used in overprinting must be specified by the user in both the CMAP and ISOMAP programs, students were forced to experiment with various tonal contrasts. Although the number and quality of readily distinguishable tones that can be generated on the lineprinter are more constrained than those that can be produced by conventional cartographic techniques, this exercise nonetheless provides a convincing way to illustrate the limits on visual recognition of tonal contrasts.¹⁶

After students became conversant with the CMAP and ISOMAP programs, they were asked to produce the best map interpretation possible for a given set of data, and thoroughly to explain their solution to the problem. This provided a culminat-

ing experience that forced the students to consider a wide range of cartographic problems with emphasis not so much on error-free output as on arriving at a cartographically valid map.

CONCLUSIONS

The approach employed in our computer graphics course provides students with a vivid demonstration of the problems encountered in representation of spatial data. In addition, the approach encompassed both theory and application. While the focus was on providing an appreciation and better understanding of the problems that can be encountered, students first had to acquire knowledge on how to prepare and execute the mapping programs. Prior to experimenting with aspects of cartographic design, representation, and symbolization, it was necessary for them to master the steps of data collection, representation of locational information, data entry, and program execution.

The general approach is easily transferable to other institutions, and with the small core requirements, mapping programs should be operational on any timesharing system having FORTRAN and BASIC compilers. The programs are simple enough, however, that a person with a modicum of programming experience could easily convert them to other compatible languages. In addition, the programs are not hardware-dependent; they will operate on any system with hard copy plotting capability.

¹⁴An overview of interpolation problems is given by Mackay, J. R. "Some Problems and Techniques in Isopleth Mapping." *Economic Geography* 27:1-9, 1951.

¹⁵Adapted from E. B. McDougall, *Computer Mapping for Spatial Problems*. London: Edward Arnold, 1976.

¹⁶Recognition of tonal contrasts appears to be constrained by perceptual limitations of the viewer according to Robinson et al., op. cit., footnote 8; also see A. John Kimberling, "A Cartographic Study of Equal Value Gray Scales for Use with Screened Gray Areas," *The American Cartographer* 2:119-127, 1975.

1975 MEDIAN FAMILY INCOME BY STATE



Figure 3. Choropleth Maps Produced Using the CMAP Program. (Because of rapid turnaround and interactive capabilities, CMAP can be used to experiment with a variety of cartographic concepts including data-class specification problems. The maps here, for example, were generated using two different class-interval specification procedures: parameters of the frequency distribution [upper] and quintiles [lower].)

MEAN ANNUAL PRECIPITATION FOR VERMONT



Figure 4. Examples of Output from the Isarithmic Mapping Program ISOMAP. (The value assigned to each print position on the map is derived by: searching a number of control points, the number being specified by the user; weighting control-point values according to some function of distance; and averaging the weighted values. For all maps shown here, linear distance was used in the weightings, but the number of control points employed in the search was varied, with maps exhibiting greater "smoothing" and less localized influence as the number of search points increases.)

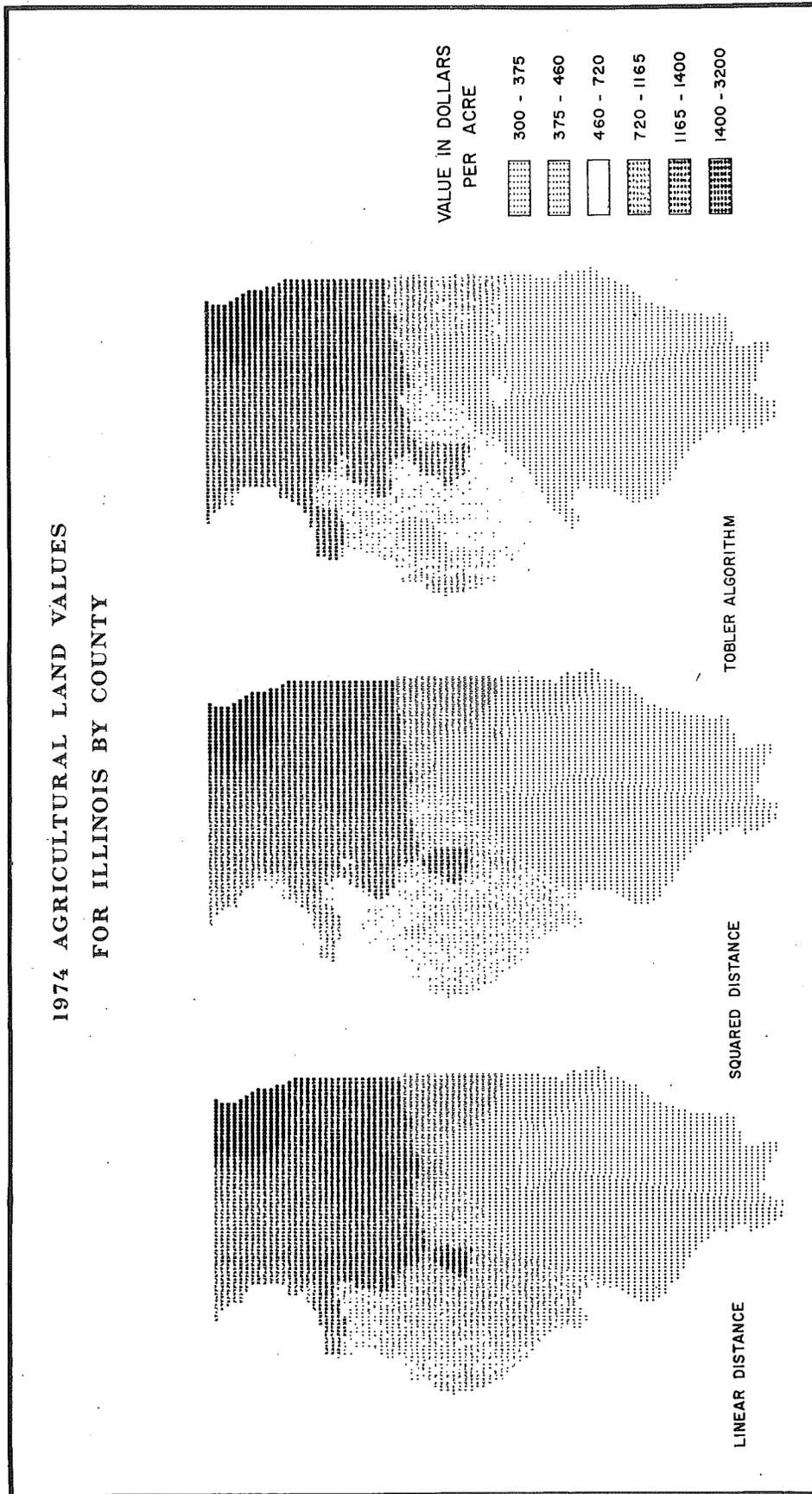


Figure 5. Maps generated by ISOMAP Holding the Number of Search Points Constant, but Varying the Actual Interpolation Procedure. (In the map at left, values of control points were weighted by linear distance; in the center map, weighting was by distance-squared; and for the map at right, assigned values were determined by averaging the value of the closest control point and the value derived according to interpolation by weighted distance-squared, a procedure outlined by W. R. Tobler, Selected Computer Programs, Ann Arbor: University of Michigan, 1970. Note that the local influence increases progressively from left to right.)

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The approach is not without its problems; as with most courses, certain logistic problems must be considered. As the work is cumulative, it is important that instructions be clear and detailed to reduce future problems compounded by past mistakes. In addition, students with little or no computer experience must be closely monitored until they are comfortable with a computing environment, and until early problems are resolved.

A second problem is the considerable amount of time-consuming work for both instructors and students. For the former, the approach requires less in-class time, but out-of-class time is substantial, ranging from debugging problems to discussions with students over the results of their experimentation. The amount of student time required could be considerably reduced with the availability of a digitizer for coordinate measurement. Student time and frustration could be further reduced by supplying the data to be mapped. This, of course, involves trade-offs, between supplying the data to reduce preparation time and maintaining student initiative and interest. Based on our experience, we feel that allowing students the freedom to select their own data ensures a higher level of motivation and interest, and outweighs the dangers of excessive time demands.

Problems such as these notwithstanding, we believe the use of interactive mapping programs to teach cartographic concepts to be both innovative and productive. Furthermore, our experiences as described briefly have prompted us to make further revisions in the programs, and incorporate the general approach in our formal, introductory course.

The most important point to be made, however, is not that interactive mapping programs can be used to demonstrate mapping problems and concepts; rather, the opportunity for students to discover these problems on their own and to experiment with possible solutions results in a more comprehensive understanding and appreciation of spatial concepts than that acquired through conventional classroom approaches.

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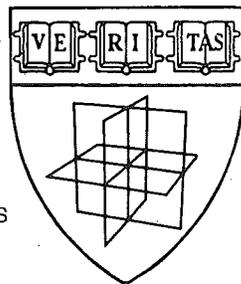
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