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Computer Graphics for Federal Planning in West-Germany

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To satisfy the cartographic requirements for spatial analysis, planning and forecast on the federal level in West Germany the Federal Research Institute for Regional Geography and Regional Planning established a system for computer-assisted production of thematic maps. Development priority was given to choropleth and graduated symbol maps as the most important mapping techniques to display spatial disparities. Other, less frequently used techniques, e. g. network display, surface representation, perspective drawings, etc., have also been implemented to provide additional aids for visualization, and to reduce the bottlenecks in the manual production process.

1. Monitoring spatial disparities in the Federal Republic of Germany

The government of the Federal Republic of Germany has the legal obligation to create equivalent (not equal) conditions of life in all regions of the country (5). The government has a number of instruments at its disposal which directly or indirectly influence regional development: improvement of transportation facilities, taxation, subsidies to private enterprise and local government etc. Before the administration can apply the appropriate instruments it has to know more about state and causes of the disparities in the regional distribution of the quality of life.

Therefore, the Federal Research Institute for Regional Geography and Regional Planning (BfLR), has been put in charge of establishing a computer-assisted system for monitoring the regional disparities in the quality of life. We devised a system of about 300 indicators which are supposed to represent the important aspects of life. The variation of the indicators over time should also reflect the effects of measures taken to improve the situation. The indicator system is supposed to provide better information for all stages of planning, namely the discussion of goals, the design of instruments and their application (8).

The 300 indicators are derived from a data base with appr, 1000 variables. The smallest spatial units are the 327 counties (1980), for a small number of variables also the regions of second order central places (VMS) with appr. 780 polygons, and the appr. 9 000 communities. The variables are updated yearly. For some specific variables monthly (employment) or quarterly updates (migrations) can be obtained.

Besides the indicators other data available at irregular time intervals or on special request are also used, such as, of course, the census data, but also data from samples, e.g. the yearly 0.1 %

sample ("microcensus"), the 1% housing census (1978) etc., and a very small amount of data from other sources.

It is quite obvious that this huge collection of numbers can only be managed, analysed and presented with substantial computer assistance. The tools in form of computer programs fall into four main groups:

- General data base management;
- Descriptive and multivariate statistical methods;
- Modelling and simulation;
- Data presentation: tables, diagrams, maps.

In this context I cannot say very much about the first three groups. Just a few remarks: we think that a general data bank system like IMS or ADABAS is in several aspects too expensive for our applications. For plausibility control, data access, arithmetical transformations and regional aggregation we use our own programs. For more advanced statistical methods own programs and the well-known packages, e.g. the BMDP programs, SPSS, OSIRIS and others are applied.

2. The role of thematic maps

The preparation of reports and tables and the computer-assisted drafting of statistical diagrams is common practice everywhere. Hardware vendors and software houses offer numerous program packages and systems to facilitate the plotting of diagrams. In our case we are using the subroutine libraries provided by Calcomp and Tektronix, supplemented by a few home-made programs.

The most important technique to present spatial data is the thematic map. Therefore our development efforts have been concentrated on the computer-assisted production of thematic maps. Before we go into the details it might be beneficial to look at the main application fields of the Monitoring system and thematic maps. The system and the maps are utilized for

- research projects conducted at the institute,
- reports to prepare political decisions,
- information of the (more or less) general public.

These groups represent quite well the predominant uses and the different "half-life" times of system output, especially maps. In spatial research diagrams and maps are important analytical tools. Theses about the distribution of a specific variable, either in variable space or on the surface of the earth, can be verified or disproved at a glance by looking at the graphic output. A more thourough analysis requires more than just a glance, of course, but generally the life time of a map used during a research project is very short. Normally only one copy of the map is sufficient, sometimes even the quick display on a CRT.

Reports for decision making are usually distributed in 10 to 100 copies. Their life time is longer, from days to a few months. The number of copies and life time of maps for public information may vary considerably, from 500 copies for a specialized journal which will be kept forever in the libraries, to a government brochure with 10 million copies thrown in the wastepaper basket shortly after distribution. The Federal Regional Planning Atlas (Atlas zur Raumentwicklung) is an intermediate stage somewhere between the two extremes. It has been produced with substantial computer assistance (2).

Life time and number of copies determine the economics of map production and, indirectly, the quality of the maps. In pre-computer times the use of the map as an analytical tool was restricted because the production costs (mainly labour costs) could only be justified if the specific map also served as documentation of the results; that is, if the map was published in a reasonable number of copies. The line printer bridged the gap between the economically feasible and the requirements of the map users. Although the graphic quality of line printer output is very much below the modest standards of cartographers, line printer maps are still quite popular at some places.

When producing a map one cannot be sure that it will serve exclusively one of the aforementioned purposes. Some maps used for research may also be published, either as a part of a report, or as documentation of research results in a journal or in an atlas. Even with the help of sophisticated reproduction techniques including color separation, line printer maps never reached the map quality customary for a convential map laboratory, especially for our lab with its long tradition in publishing maps and atlases. Fortunately the line printer maps have been obsoleted by the general availability of plotters and other graphical output devices with reasonable resolution and accuracy.

3. Cartographic requirements

Before we go into the details of hardware and software let me summarize the requirements for thematic maps and map production at my institution. We need

- low-cost maps produced with short turnaround time, usually one copy, modest quality, typewriter page format;
- medium-quality maps for reports and publications of short life time;
- high-quality maps for publications, three or more colors, various formats;
- provisions to switch from one group to another at marginal additional cost, reproduction and printing costs excepted.

To give an impression of the quantitative requirements: in 1980 about 750 maps have been plotted (unsuccessful tries not counted). About 35 % were printed, 20 % as high quality maps with more than five colors.

The most important part of our map consumers, the decision makers, are characterized by

- having a tight time budget: if a map fails to attract their curiosity within ten seconds the message to be conveyed by the map has not reached the addressee.

- being untrained and seldom accustomed to reading thematic maps.

Therefore, the maps and other graphic representations should conform to the following rules-of-thumb:

- they should catch the eye of the observer immediately:
- they should be self-explanatory and easy to read.

These statements seem to be trivialities and not worth to be mentioned. But superficial browsing through publications and atlases already demonstrates strikingly how often these and other cartographic rules are violated. The growing availability of computer-assisted mapping will make things worse: even graphic illiterates can produce graphic output which does not always deserve the name "map". The software designer cannot do very much to prevent the abuse of his tools. To my mind this problem can only be solved by strict quality control, and continuing education and training of both map designers and map recipients.

4. Hardware

The high demands made on the quality and quantity of graphic output required a specialized computer system consisting of a mini-computer with peripherals and graphic input and output devices. The system grew gradually from a minimum system installed in 1972 to the present configuration (fig. 1). In 1978 the first generation of graphic devices had been replaced by devices with improved capabi-lities and higher throughput to satisfy the increased requirements in quality and quantity. The minicomputer also serves as a remote job entry station for an IBM /370-158 mainframe in a computing cen-ter a few kilometers away.

Following the original concept the minicomputer was supposed to serve solely as a graphics processor, whereas the data base manage-ment, data preparation and statistics should run on the mainframe. But the performance of the minicomputer system and its advantages for the users in terms of accessibility, response time and flexibi-lity in resource and time scheduling had the result that the main-frame is now used only for tasks requiring large memory space, huge data sets, or special software. Consequently the throughput problem of the mini becomes more seriously every day. We hope to solve it by a supermini to be delivered during 1981.

5. Choropleth maps

The most appropriate mapping technique to detect, analyze and document disparities in the regional distribution of variables is the choropleth map. The disparities are measured by relative values, e.g. inhabitants/square km, physicians per inhabitants etc. They are represented visually by filling the regions with quantitative or qualitative symbolism (hachures, characters or dots).

The computer-assisted production of choropleth maps results in considerable economic advantages:

- manual drafting is time-consuming and error-prone,

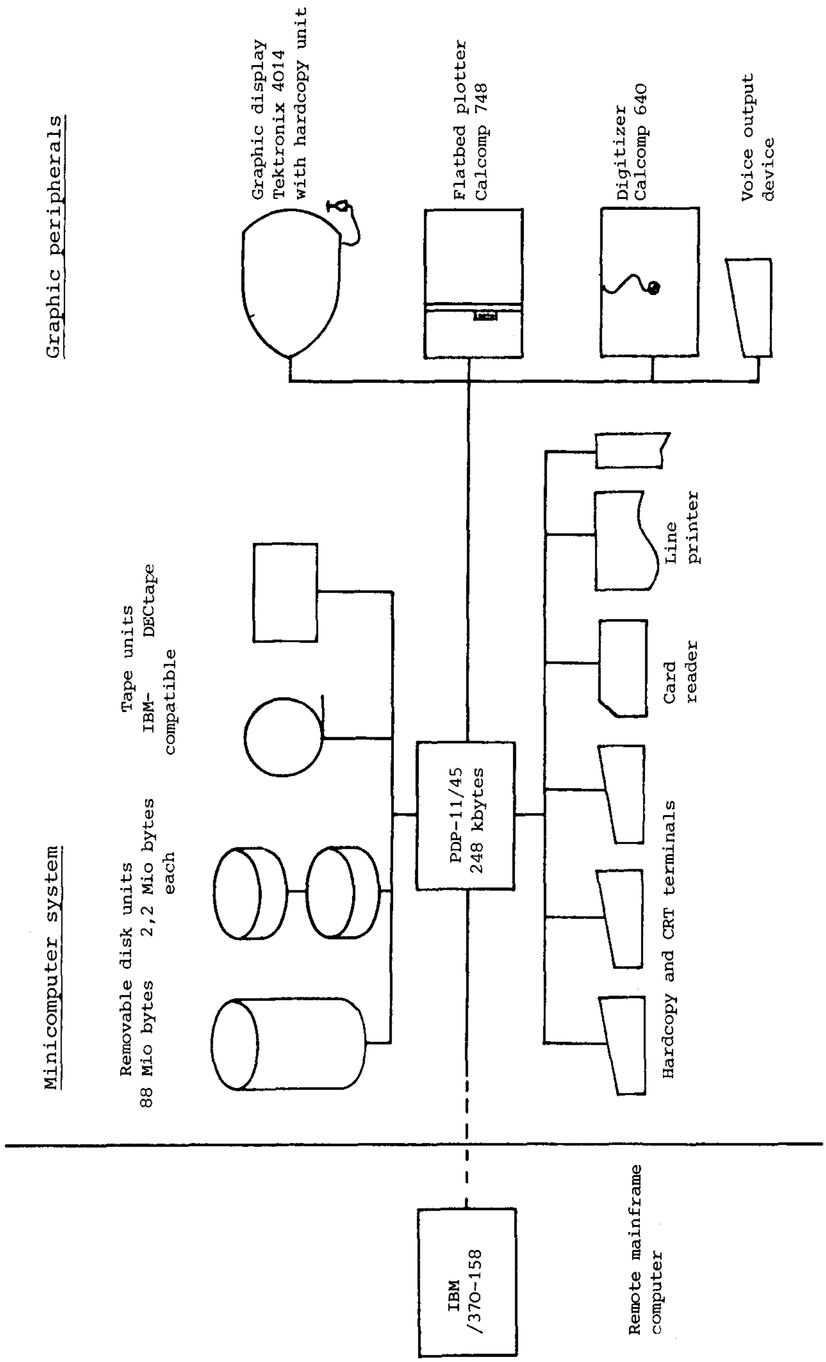

Fig. 1 Hardware configuration

- the algorithms to plot choropleth maps are relatively simple,
- the amount of arithmetic operations is moderate,
- memory requirements can be kept low.

The requirements are well suited to implement the choropleth mapping program on a minicomputer. Because appropriate software was not available in 1971 I developed my own choropleth mapping program (10). The main program options include, among others,

o qualitative symbolism (classes) by polygon painting, hachuring with user-selectable angle, distance and color;
o quantitative symbolism: dot map, continuous shading (4), mesh of circles of proportional size (3);
o placement of legends, histograms, text strings of variable character size and type font, markers, scale and logotype;
o plotting of boundary networks;
o support for color separation and scribing.

Fig. 2 is an example of graphical output produced by the choropleth mapping program.

For digitization of the boundary networks an interactive System has been designed and implemented which generates the necessary coordinate and polygon reference files (16).

The quality of the output depends on the program options and the output device the user chooses. For a quick look a coarse shading and the Tektronix display are sufficient. By pressing a button the user even gets a hard copy off the screen. The same program instructions, with a few parameters changed, also generate the plotter file to scribe the separate color sheets required for high quality multi-color printing. Various intermediate stages are possible, from fast plotting with ballpoint pens, pen-and-inkplots, hachure scribing instead of complete area filling, to the replacement of plotted character strings by typeset ones during reproduction. The latest addition is the possibility to use an inkjet raster plotter (9).

CHOKOS is a batch-type program generating an intermediate device-independent display file. An interactive utility program displays the file on the Tektronix CRT for preview and low-quality hardcopy. Other programs generate the tapes for the vector and raster plotter, with options for additional color separation, tool exchange, operator messages and other service functions. To enhance the flexibility it is possible to edit and to merge display files.

6. Graduated symbol maps

Because the choropleth maps are used most frequently, and caused the major bottlenecks in our production process the programming capacity was concentrated on solving the problems in this field. For other map types computer assistance is not yet as comfortable as for choropleth maps. Nevertheless acceptable results can be obtained. For the plotting of graduated symbol maps a family of subroutines has been provided (12). The user may select graduated symbols proportional in length, area or (pseudo-) volume to the values he wishes to display (fig. 3). A relative variable may be

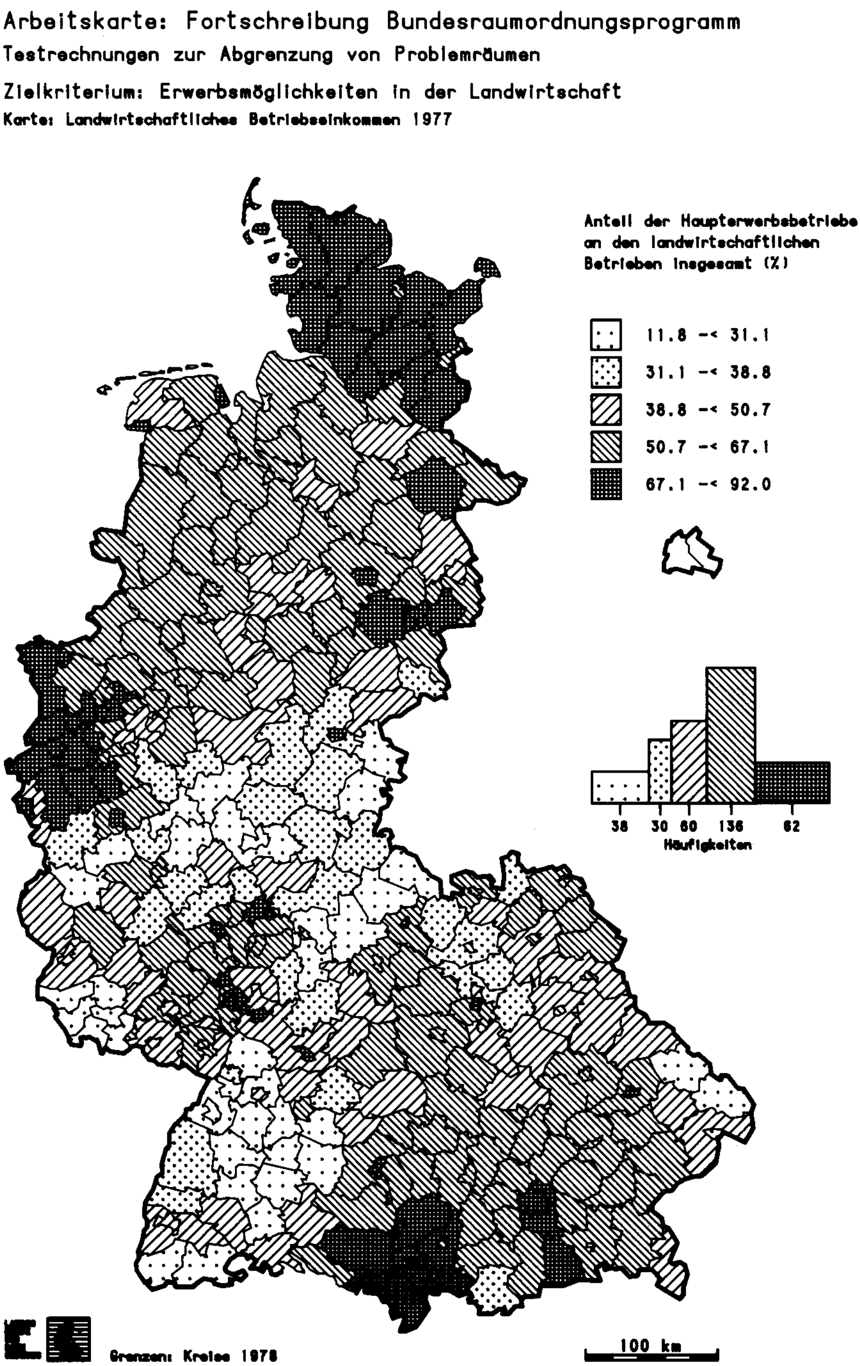

Fig. 2 Typical choropleth map

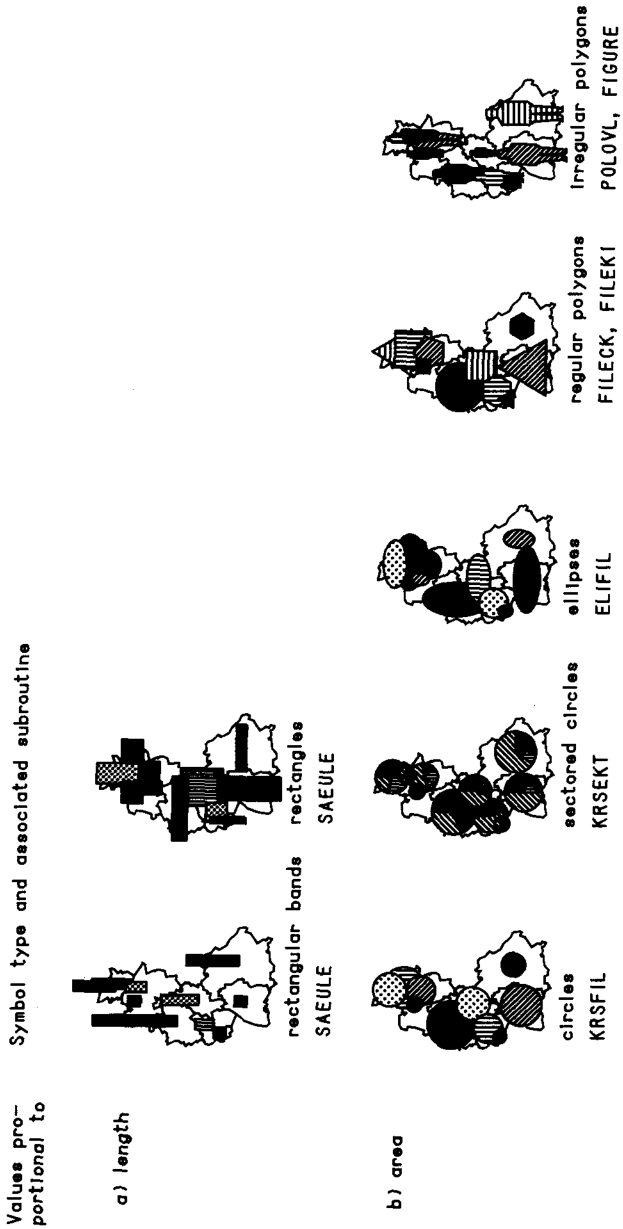

Fig. 3 Graduated symbols

displayed as well by filling the symbol with hachures of arbitrary angle, distance and color. The form of the symbol may also be used to represent a variable. In fig. 4 the ratio of major to minor axis in the ellipses is equal to the ratio of the average farm income below and above a certain level. The distribution of the ellipses revealed a distinct spatial pattern previously not recognized with other map types.

Two techniques commonly used in cartography and computer graphics are implemented to improve the visual perception of the graduated symbols. According to cartographic practice the smaller symbols cover the larger ones: the overlapped segments of the larger symbols are omitted. The elimination of the hidden areas is simplified due to the following reasons:

- The symbols have zero thickness: projective transformations are not necessary.
- The size of the symbols alone determines the sequence of placement in the direction of the z - axis. The depth-priority problems arising in the more general cases of 3-Dmodeling are avoided.
- The restriction to a vector output device reduces the hidden-area problem to a hidden-line problem which is geometrically more tractible.

The algorithm may be considered a relative of the segment-polygon-algorithm for hachuring polygons (4).

The second feature to improve visual appearance is the possibility to select a halo effect. A small gap between the symbols and the boundary network generates a shadow-like effect which enhances the impression of depth (1). For the simple symbols (circle, ellipse, regular polygons) it is sufficient to increase the size temporarily during the area-filling step. The irregular polygons, however, require a line parallel to the symbol outline. The specific problems of parallel line generation, e.g. small angles resulting in long spikes, loops and points with equivalent coordinates, have to be observed and solved.

The execution time is rather moderate, especially with the most frequently used symbol, the circle. Although the subroutines have been designed for low memory requirements, the 16 bit address space of the minicomputer restricts the size of data sets and the complexity of symbols. Therefore, the planned interactive system for plotting graduated symbol maps has has been deferred until the supermini with virtual addressing becomes available. At the moment the production requirements are fulfilled by dedicated main programs using the graduated symbol subroutine library.

7. Other cartographic techniques

The predominant provision of computer assistance for choropleth and graduated symbol maps was dictated by user requirements and the bottlenecks in the existing production process. The implementation of other cartographic techniques is partly an urgent need, partly an offer to the users. Most of these techniques are economically unfeasible if they are realized by manual drafting. They require either

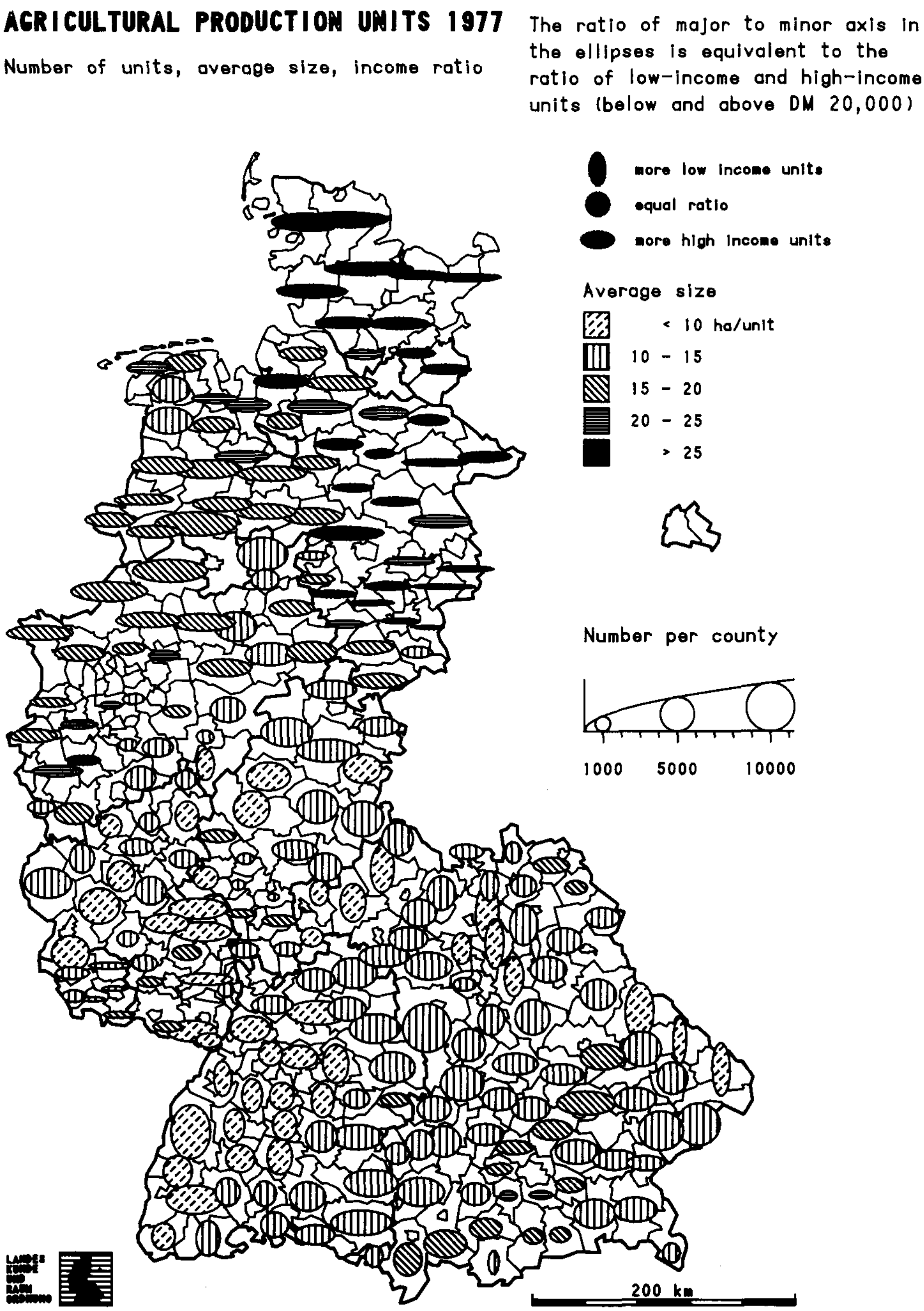

Fig.4 Graduated symbol map using ellipses

- voluminous input data sets not manageable by manual methods, or
- complex algebraic or geometric transformations, or both.

Fig. 5 is an example of the first group. Compared with the graduated symbols the algorithm complexity is rather low. But the size of the data set (appr. 27,000 nodes, 18,500 edges, 15 variables per edge) is prohibiting for manual processing. Computer-assisted techniques not only allow economic graphic display of the network data, but easy selection, generalization and classification. Most important for spatial analysis and planning is the possibility to link the geometric data to analytical procedures and simulation, and to transform it into other spatial reference systems for correlation with demographic and socioeconomic variables.

Although three-dimensional perspective drawings of surfaces, histograms and choropleths have been used for a long time in cartography the extent of their realization was restricted for the above reasons. Computer-aided methods open a wide field of new applications here. Perspective representations have a few shortcomings, for example problems with scale, or the partially hidden picture. Thus they are meant as a complement, not a replacement of the usual planimetric maps. The basic problems of 3-D modeling, e. g. projectional transformations, surface shading, hidden line and area removal, have been solved some time ago. But, as in other fields, the pace of progress moves faster than the users (more the map designers than the map consumers) are willing to accept. This is valid to an even greater degree for a group of cartographic techniques known as cartograms (15). Though intended to be a joke, fig. 6 tries to picture a real situation, namely how the states of the Federal Republic see themselves and the rest of Germany (of course in the eyes of the Federal Government). The message of the map is understood intuitively by everybody familiar with the political background. But cartograms are a provocation of the system of Euclidean space implanted in our minds by generations of highschool teachers, and reinforced by convention both in cartography and everyday life. This is the main obstacle to the widespread use of these "impossible maps", although our natural spatial reference system is non-Euclidean.

8. Experiences with interactive map design

A few years ago we were very enthusiastic about the interactive design of thematic maps and map sheets. After the development of an experimental interactive design system (7) we are not as enthusiastic as before. We found that fully interactive systems are not necessarily better solutions than the mix of batch and interactive programs we are using now. Besides the fact that the term "interactive" has a wide range of meanings (see also (10)) fully interactive systems are problematic in several aspects. We learned a few lessons:

- The number of cases where interactive graphic editing facilitates the task considerably is smaller than we thought. The placement of legends and text strings of choropleth maps can be done interactively. But most maps in our institute are designed with a standard layout where the legends and text strings are always placed at the same spots. Especially for the novice user it is

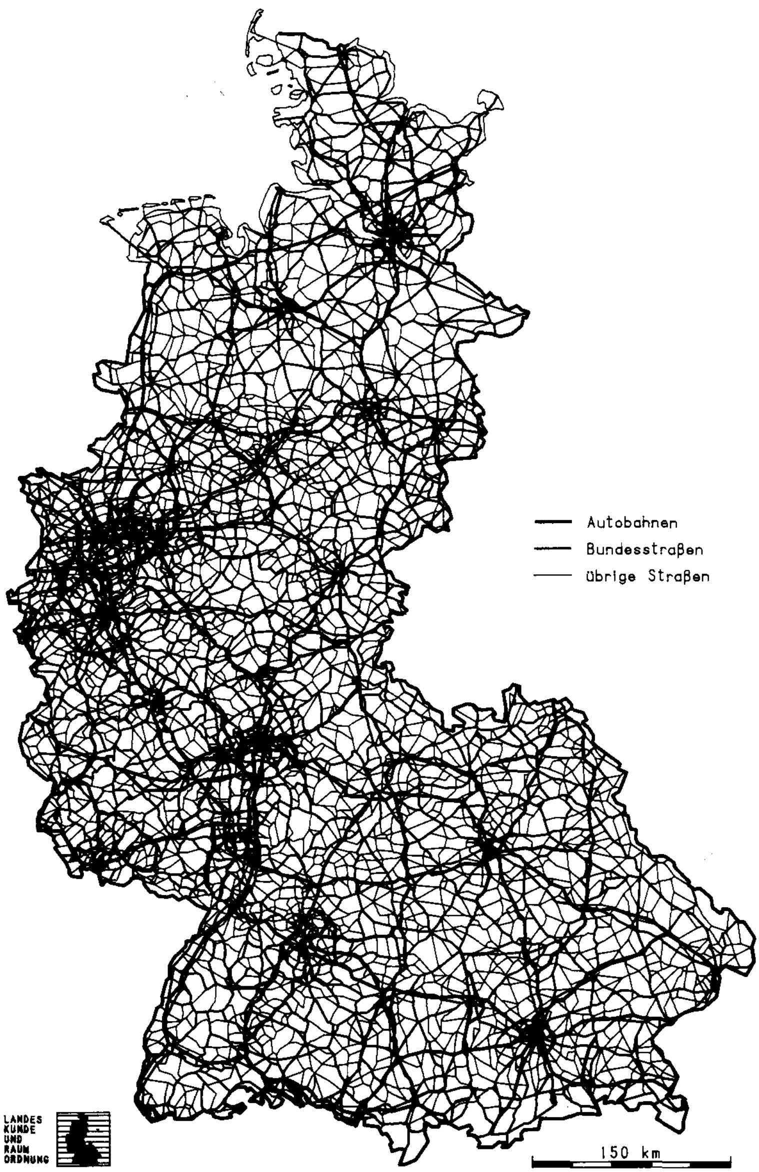

Fig.5 Projected road network for 1985

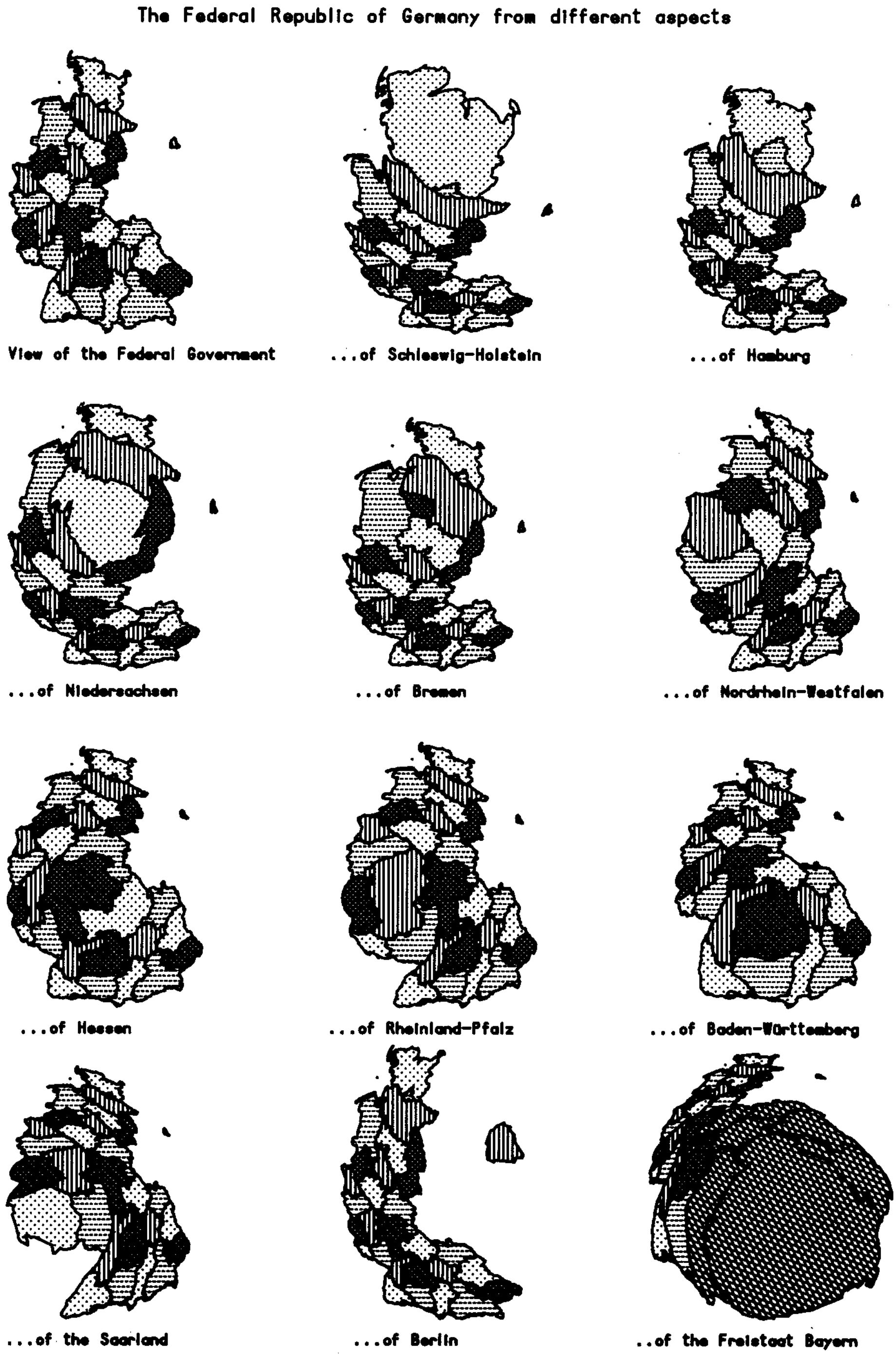

Fig. 6 Cartograms

easier to modify a card deck or data set by repunching or editing the text strings instead of fiddling around with a costly system. Selecting hachures at the graphic terminal is not a great help because line drawings on the display differ too much from the plotter output to allow a safe prediction of the visual appearance after plotting.

- Certain steps during an interactive session take a relatively long time, for example data access and transformation, area shading, hidden line elimination. The user is forced to thwirl his thumbs instead of being able to do something useful, as it is possible during a batch-type run.

- An interactive program requires more system resources (memory, disk space, terminals) for a longer time. To get the same throughput as with our existing programs at least the number of graphic terminals would have to be increased fourfold, with a proportional increase in disk space and other system resources.

- Design, implementation and, especially important in our case, modification and maintenance of a dialog system is expensive. When the original designer/programmer left the system was running, but not stable enough for public release. Important cartographical features already available in the batch programs were not implemented.

- The ambitious system certainly reached, if not surpassed, the limits of the minicomputer system in terms of address and disk space and throughput.

- Interactive systems are not portable in most cases. Even with the same display software but a newer version we never got the system running for our new Tektronix 4014. There is hope that the GKS (6) and the SIGGRAPH proposal (13), respectively, are supported as soon as possible by software packages available for most computers, operating systems and graphic devices at no cost.

As usual the truth lies somewhere in the middle between fully interactive and plain batch systems. Our experiences indicate that the most promising line for future development is the intelligent marriage of batch and interactive capabilities. The user should be able to select a mode suited optimally to his own needs, either in respect to ease of handling, or low response time, or minimal producation costs, or any adequate combination.

9. References

1. Appel, A., Rohlf, F. J., Stein, J. A., The haloed line effect for hidden line elimination. Computer Graphics, Vol. 13, No. 2, August 1979, pp. 151 - 157.

2. Atlas zur Raumentwicklung. Hrgs.: Bundesforschungsanstalt fur Landeskunde und Raumordnung. Bonn 1977 - 1980.

3. Bertin, J., Semiologie qraphique. Paris 1967.

4. Brassel, K. E., Utano, J. J., Design strategies for continuous-tone area mapping. The American Cartographer, Vol. 6, No. 1, 1979, pp. 39 - 50

5. Bundesraumordnungsgesetz vom 8. April 1965. Bundesgesetzblatt, Teil 1, Bonn (1965), No. 16, pp. 30b - 310.

6. Encarnacao et al., The workstation concept of GKS and the resulting conceptual differences to the GSPC core system. Computer Graphics, Vol. 14, No. 3, July 1980, pp. 226 - 230

7. Hessdorfer, R. W., An interactive geographical information system for the exploration and display of demographic data utilizing the thematic map as its medium. Internal report, Bundesforschungsanstalt fur Landeskunde und Raumordnung, May 1976.

8. Information zur Raumentwicklung, Themenheft Laufende Raumbeobachtung, Heft 7/8, 1978, Bundesforschungsanstalt fur Landeskunde und Raumordnung, Bonn.

9. Kaster, T., Neue Entwicklungstrends in der automatisierten thematischen Kartographie. Kartographische Nachrichten, 29. Jahrgang, Heft 1, Februar 1979, pp. 4 - 8

10. Ling, R. F., General considerations on the design of an interactive system for data analysis. CACM, Vol. 23, No. 3, March 1980, pp. 147 - 154.

11. Rase, W. D., CHOROS V1.8, Benutzerhandbuch. EDV-Report 1/1979, Bundesforschungsanstalt fur Landeskunde und Raumordnung, Bonn.

12. Rase, W. D., A family of subroutines for plotting graduated symbol maps. Geo-processing, Vol. 1, No. 3, 1980

13. Status report of the graphic standards planning committee. Computer Graphics, Vol. 13, No. 3, August 1979.

14. Sutherland, I. E., Sproull, R. F., Schumacker, R. A., A characterization of ten hidden-surface algorithms. Computer Surveys, Vol. 6, No. 1, March 1974, pp. 1 - 55

15. Tobler, W. R., Cartogram programs. Cartographic Laboratory Report No. 3. Department of Geography, University of Michigan, Ann Arbour.

16. Türke, K., A system for interactive acquisition and administration of geometric data for thematic map production. Computer Graphics, Vol. 10, No. 2, August 1976, pp. 154 - 162.