COMPUTER-ASSISTED THEMATIC MAPPING WITH A DEDICATED MINICOMPUTER SYSTEM

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INTRODUCTION

The Bundesforschungsanstalt fur Landeskunde und Raumordnung (Federal Research Institute for Applied Geography and Planning) is concerned with spatial research and analysis on the Federal level in Germany. One of the major tasks is the development and maintenance of a spatially oriented information system for data acquisition, analysis and presentation in written, tabular and graphic form. Thematic maps are the best tool to visualize spatial distributions because they combine analytic, synthetic and documentary functions. To take full advantage of fast data retrieval and analysis capabilities, design and drafting of thematic maps have to be integrated into the system.

Several constraints are imposed on the development of the information system in general and the computer-assisted map production specifically:

- Limited resources, mostly in respect to qualified personnel. Due to old-fashioned budget regulations it is easier to get a million marks to buy hardware than fifty thousand to pay a programmer. Other regulations set salary limits at a level not acceptable to qualified EDP personnel.
- Results have to be provided as quickly as possible. The bottlenecks in the well-established cartographic production process at the BfLR have to be circumvented as quickly as possible by computer methods without making obsolete too much existing machinery for reproduction and printing.
- Political pressure to cooperate with other government or government-funded agencies. As everyone in the field knows, cooperation does not save time and money in all cases.

HARDWARE

Data storage, retrieval, analysis and related functions require a medium to large scale data processing system with sufficient primary and secondary memory space and computing power. Such "number crunchers" are available everywhere; their use is common practice as is the use of data management and analysis software.

The production of maps, however, requires special machinery not available at the average computer center -- graphic input: digitizer; high precision output: flatbed plotter; fast output and interaction: graphic CRT display.

The most economical solution to control these devices is a dedicated minicomputer with the necessary peripherals. The configuration, illustrated in Figure 1, consists of:

- DEC PDP-11 minicomputer
  - moving head disk drives (2)
  - fixed head disk drive
  - IBM compatible tape drive
  - dual DECtape drive
  - card reader
  - line printer
  - paper tape reader/punch
  - terminals
- Tektronix 4002A storage display terminal with joystick
- Calcomp 738 flatbed plotter with tape unit and offline-online switch
- d-mac pencil follower (CAMAC-Interface) (Figure 1)

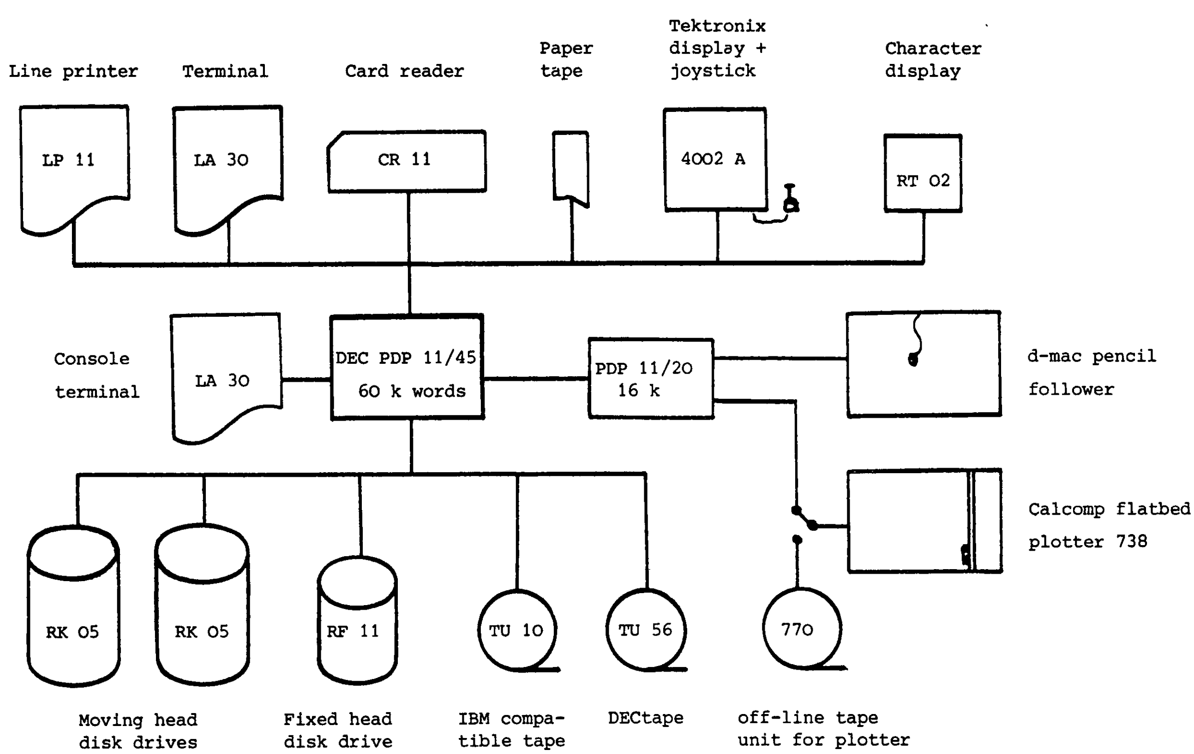

Figure 1. Hardware configuration at the Bundesforschungsanstalt für Landeskunde und Raumordnung

The selection of the devices may not look optimal to everyone. Besides the fact that the system was ordered four years ago, criteria other than technical specifications played an important role, e.g., proven reliability, maintenance service, and availability of basic, functional application software. For example, we decided not to buy a more advanced digitizer because we were not able to get maintenance service for it. Of course we have learned a few things in the meantime. 1/

To improve performance a PDP-11 model 45 with hardware floating point replaced the original 20 a year ago. At the moment we are switching over to a system which allows multi-programming and simultaneous operation of a digitizer and plotter under control of the 20 processor.

APPLICATIONS

Programming efforts have been concentrated on three groups of applications (in order of priority): 1) error-minimizing acquisition of geometric data base, especially boundary networks; 2) medium to high quality production of statistical maps for immediate use in the reproduction and printing process; 3) interactive design of statistical maps, interactive spatial analysis.

The logical sequence would be to develop the design system first and then to produce high quality output. The need for a fast solution to our production problems, however, required us to delay the interactive system. It is undoubtedly easier and faster to write a few plot programs than an interactive display system. That bought us some time for the design and development of the interactive system.

Besides the basic device-dependent software, all programming is done in FORTRAN. Again that might not look like the optimal solution, but we have found that FORTRAN makes a lot of things easier, especially the integration of existing software or the transition to a more advanced operating system.

ACQUISITION OF GEOMETRIC DATA BASE

The base data for thematic mapping can be classified into the usual three-level hierarchy of geometrical coding:

- Point: Reference point or point representation of a reference area
- Line: Flow lines, like streets, energy or communication flows
- Network: Area-oriented: boundaries; Edge-oriented: traffic network

The transformation of points and lines from base maps into computer-readable format imposes no serious problems. The necessary accuracy is moderate. In most cases the base maps are already generalized and curved lines are composed of a small number of straight lines. Orthogonal coordinates are the appropriate encoding and storage mode.

Things become more complicated with the digitization of networks, in our case, boundary networks. To avoid the shortcomings of simple coding schemes, like the representation of an area by a closed polygon, we use a data organization resembling what is known on this side of the Atlantic as "World Data Bank Format."

A reference area is defined by a list of numbers. These numbers represent "segments" or "arcs" whose coordinates are stored in a second table or file. The sign of the segment number indicates the direction in which the coordinates are stored in respect to the reference area. 2/

With conventional off-line digitization the sources of error are numerous: manual enumeration of segments, table construction, arc end point coincidence and so on. The elimination of errors from the graphic file is a tedious and costly business. Thus we designed and implemented an interactive digitization program to monitor the acquisition process, to check constantly for error conditions, and to correct errors if possible or at least give warning messages to the operator if a nonrecoverable error occurs. 3/

A small 32-character display, indicator lamps, acoustical alarms and an array of 16 special function buttons, besides the normal keyboard input, facilitate the dialogue between operator and system. The Tektronix display is used to get graphic replay of the digitized coordinates. At the moment we are testing a computer-controlled cassette recorder to assist the character display function; the operator should be able to keep his eye on the map instead of reading the display.

The computer-assisted digitization process has many advantages in comparison to off-line procedures. Nevertheless, we are not completely happy because it still requires a human operator (two are better). At the moment we are looking into the possibilities of fully automatic acquisition of boundary networks. As far as I can see, there are no conceptual but rather a few technical problems to solve.

We have also developed some additional programs for aggregation of the basic network to arbitrary regional divisions, transformation into other representations -- e.g. closed polygons or optical centers, and area, segment and coordinate reduction and generalization.

PRODUCTION OF STATISTICAL MAPS

The need for immediate relief from labor-intensive steps in the map production process, the existing machinery for reproduction and printing, and the limitations in respect to qualified EDP personnel led to some kind of incremental approach to automated cartography. As I mentioned already we decided not to wait for an interactive design system but to provide solutions for our production problems as quickly as possible. These solutions might be preliminary and will become obsolete sometime, but they are working.

Figures 2 and 3 are examples of the preliminary solutions. Manual grouping of data, area shading and coloring are time-consuming and prone to errors, as is the size calculation of proportional symbols and the elimination of hidden lines and areas. Now these steps are done by program which results in considerable savings in labor cost and time. Alternative designs of the same map, e.g. with different class intervals or shading, can be done without additional costs except for computer time. 4/

If a design has been accepted as final draft, the outlines of the areas are scribed on a plotter, separated by colors. The scribed outlines are copied on standard peel foil and peeled by hand. This procedure is still too time-consuming.

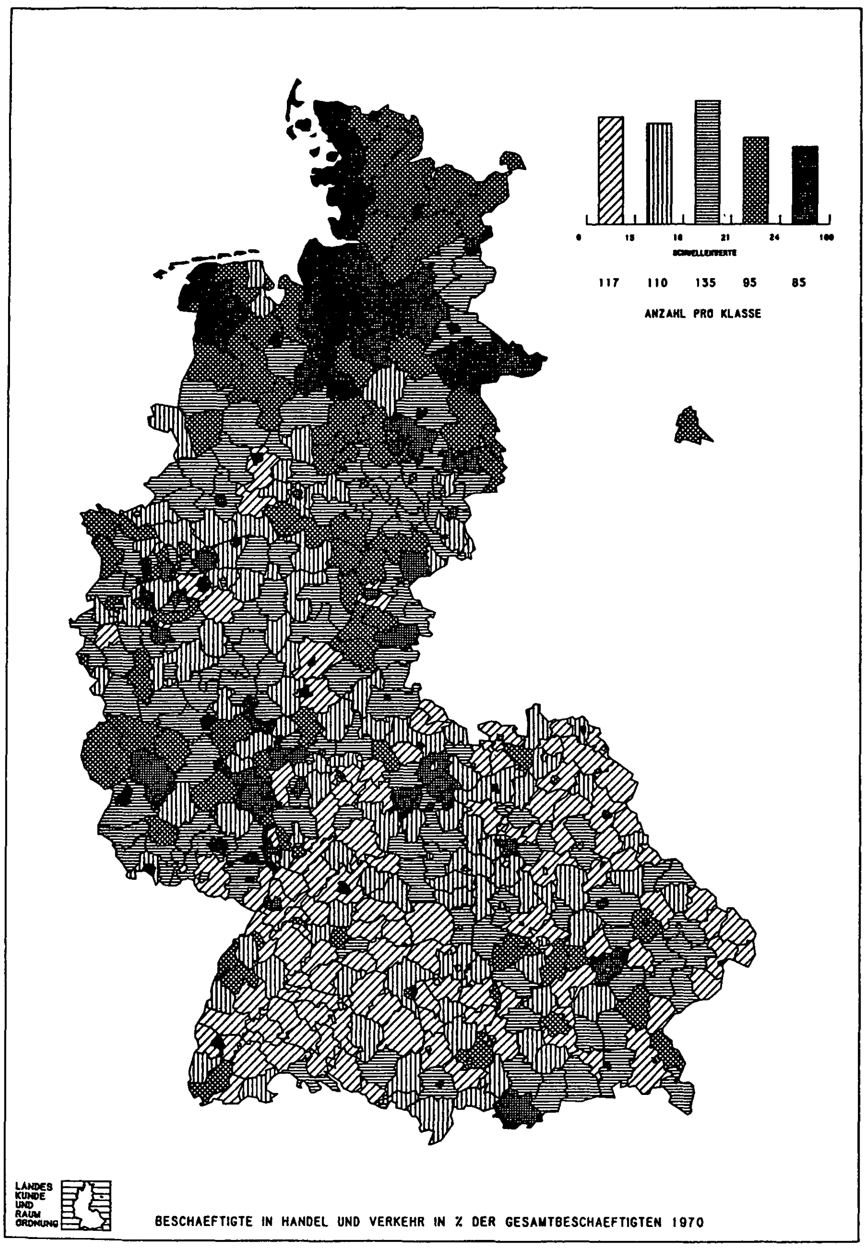

Figure 2. Choropleth map. 542 Counties, Federal Republic of Germany

For less high quality we plan to eliminate full color printing and to use scribed area shading to avoid manual work.

Of course we also use other representation techniques like contour lines, profiles, perspective drawings, etc., which are used at many places around the world.

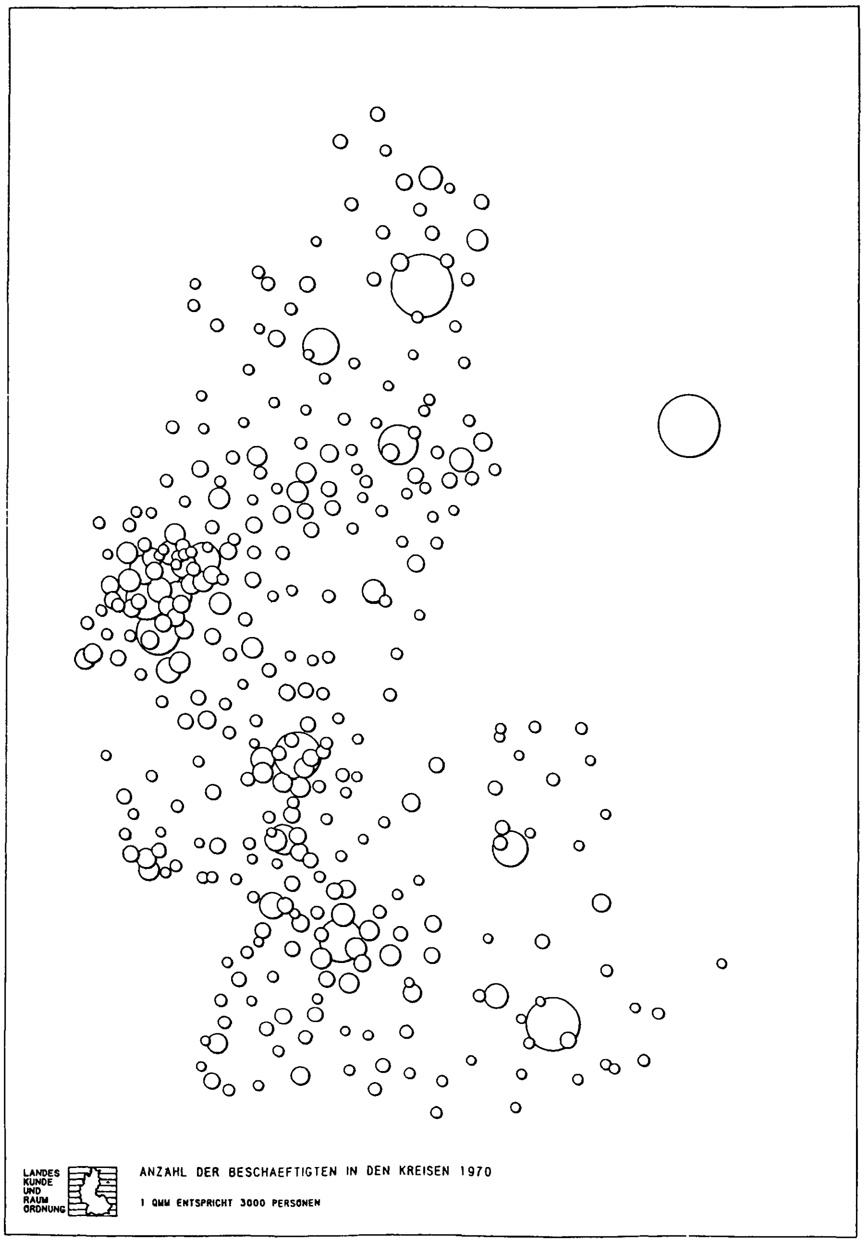

Figure 3. Proportional symbols. Hidden lines removed by program.

INTERACTIVE MAP DESIGN

To find the best alternative for a specific map, the current trial and error approach is cumbersome and time-consuming because mechanical plotters are very slow devices. If computer assistance is to be extended to more complex steps like placing of legends, diagrams, and lettering on the map sheets or minimizing overlapping areas by moving proportional symbols, the use of CRT displays and interactive graphic manipulation becomes inevitable.

Our system, called CAMS for Computer Augmented Mapping System, is built around the Tektronix storage display terminal under control of TCS (terminal control system by Tektronix, a set of FORTRAN subroutines exercising basic display and interaction functions). I do not intend to go into CAMS in detail. A short description of the capabilities and the design philosophy should be sufficient in this context.

With the help of CAMS the user, namely the cartographer or the researcher, should be able to do the following design steps interactively:

- Define and read in a specific geometric base file
- Select, if necessary, a subset from the GBF
- Define and read in a file with statistical figures for the areal units
- Do arithmetic transformations, e.g. calculations of percent values, combined with logical decisions on the statistical figures
- Group the data into classes; find the optimum by changing the thresholds or an optimizing algorithm
- Choose the appropriate mapping technique and the transformation parameters, e.g. area shading, size of proportional symbols, etc.
- Place the legends and statistical diagrams on the map
- Place textual information in different size, font and type on the map
- Make hard copy on the plotter
- Store the map in a library
- Retrieve a stored map
- Manipulate a retrieved map, e.g. change the place and orientation of proportional symbols, text and diagrams
- Print out lists of original and transformed data, directories, etc. and provide other aids

The system is designed to give as much help to the user as possible. Besides typing in the keywords and parameters the user can pick the command words from a menu by positioning the crosshair. The parameters are defaulted; one of the next steps will be the implementation of predefined procedures: frequently used command sequences stored in a file and called by a simple name. 5/

The bottleneck in the system is the display unit; the lack of selective erasure forces a complete replay if only one vector is changed. The display speed is relatively slow; one vector interpolation takes 2.5 msecs. One of the possible solutions would be to use two displays -- one for the menu, one for graphics; or one storage tube for overview, and a refresh display for menus and manipulations.

One of the most important facts in designing and implementing CAMS was the experience that an interactive system is a quantum jump compared with batch programs. It is certainly not sufficient to add dialogue to existent cartographic programs. To ensure both fast access and user friendliness, much attention has to be paid to an appropriate data and file organization, which again requires a lot of programming effort.

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