

## CARTOGRAPHIC VISUALIZATION FOR SPATIAL ANALYSIS

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### Abstract

Characteristics of Visualization in Scientific Computing which are relevant to two dimensional spatial data are identified. An approach which implements them in a single environment for dynamic computer cartography is then outlined. The method takes advantage of the graphical and interactive capabilities of an X11 graphical user interface (GUI) toolkit. Examples of the cartographic visualization techniques that are available through this approach towards analysing spatial data are provided with illustration.

### 1 Visualization and cartography

Visualization in Scientific Computing (ViSC, [8]) represents a trend across the sciences for handling and analysing digital information. It involves computer systems which render graphic representations of data and permit real-time, interactive analysis. Spatial scientists have an interest in the nature of distributions and processes in time and space. Two dimensional representations of spatial information have an established and important role in spatial disciplines and so geographers and others may consider 'visualization' of their data as nothing new. Yet this legacy means that their methods of mapping often remain close to the tradition, and they have been relatively slow in applying many of the techniques used in ViSC to their data. ViSC systems have a number of definitive features, several of which can be applied to maps. These include interrogation of images on the screen, interaction with and control over representations, expressing and re-expressing the data in various different ways, the ability to produce multiple alternative views of the data, and facilities for linking them dynamically.

These techniques are available, but currently each requires its own software, and data must be imported and exported in what MacEachren et al. [6] describe as 'boot laces and sticky-tape' visualization. Spatial analysis requires an integrated environment for real time visualization.

### 2 A new focus for mapping

Maps have traditionally been used both to store geographic information, and as a means of analysing spatial distributions and processes. The effort required to create a complex map manually has meant that single representations have been used for both objectives. Considerable research effort has gone into producing cartographic products from which value can be read, and patterns detected for numerous different variables. Many of the excellent design principles developed for static maps are not applicable when scientists wish to analyse large and complex data sets by using ViSC techniques in their own private realm, with control over which data are displayed through *dynamic graphics*, and how. Even with the advent of digital spatial information and huge data sets which embody massive amounts of complex temporal and spatial behaviour much endeavour has gone into the production of algorithms which replicate or objectify traditional manual cartography. A new analytical focus can be established for computer cartography if cartographers can embrace the features of ViSC, incorporate them into their dynamic representations of spatial data, and embellish them with

their techniques. An effective means of handling and analysing spatial data may then be developed which places cartography at the crux of spatial data analysis.

### 3 Visualization in computer cartography

Software that incorporates features of ViSC in a cartographic environment is demonstrated here. The software uses a structure which replicates the traditional map in that geographic entities are represented by geometric symbols. It takes advantage of an X11 user interface building toolkit known as Tcl/Tk [9]. The Tcl/Tk toolkit provides familiar interface widgets such as buttons, labels and slide bars which link with each other and run processes. Each has characteristics such as colour, size, text and a command to run. The toolkit also contains a canvas widget class which allows structured graphical items to be located and plotted. Many graphical items are available including ovals, lines, polygons, and curves. These have properties such as width, height, colour, and bitmap fill (texture), which relate closely to the visual variables described by Bertin [1], MacEachren [7] and others, with which cartographers have developed great expertise in representing numerous attributes in space. Mapping is possible as digital spatial information can be used to locate canvas items and add their symbolism. Characteristics of ViSC are achievable as an interface builder requires that widget properties can be changed instantly by other widgets. Graphic symbols can thus be located, and allocated shape, colour and other visual characteristics which can be altered instantaneously by the screen cursor or other interface objects. The result is a cartographic data structure which takes advantage of object oriented computer graphics technology to permit full interactive cartographic visualization in a single environment (see Dykes [3] for further details).

For example, a slide bar could be used to specify time with a circle item representing an attribute for a time-space data set. As the time slide bar is moved, the value for the attribute, at the current time, can be used to re-configure the radius, colour or other visual characteristic of the symbol. Several symbols changing concurrently constitute a time series map. Items can also be 'tagged' with data values, so certain items can be selected for display or reconfiguration, and figures retrieved through interrogation. The widget naming convention and variable substitution facilities of Tcl/Tk mean that an item chosen in any canvas widget can highlight items in others. This permits the linking of multiple alternative views of data, meaning that outliers in a scatter plot or clustered symbols on a map can be reconfigured and can issue commands to highlight corresponding symbols in another view or map. Linking geographical, statistical and abstract computed spaces adds provides considerable analytical potential.

Explanations and examples of each of the ViSC techniques, that are applicable to computer cartography, are demonstrated below where 'cdv' a cartographic data visualizer written in the Tcl/Tk scripting language is used to map two complex data sets. One involves enumerated population data for Leicestershire, from the UK census of 1981 (see Figure 1), where 100 variables taken from census tables 4 and 10 are read into the software and can be visualized by applying colour and texture to polygons. Another comprises of attributes collected for individual tourists located in time and space in the Schwalm-Nette park in Germany (Figure 2).

#### 3.1 Interrogation

Interacting with map symbols can produce information for the associated feature. Symbols may change colour as the cursor falls over them, and variable values can be displayed on the map.

Interrogation is not restricted to single data values, as neighbourhood statistics or graphics such as local bar charts or variograms may be returned by moving a cursor over the map.

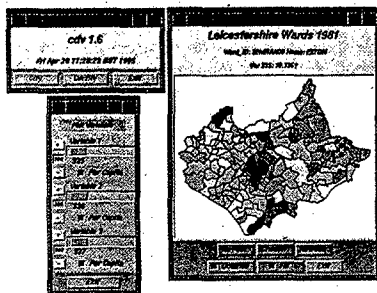


Figure 1: Interrogating variable values by moving the cursor across a dynamic map.

### 3.2 Re-Expression

If spatial scientists are to detect patterns and elicit trends, mapped data need to be expressed in a number of ways immediately. Figure 2 shows how *cdv* maps the Schwalm-Nette time-space data. Counts of individuals in areas, and on transportation routes, are symbolised through lines and circles of different width or radius and grey shading. The data can be re-expressed by using the interface objects to the right of the figure to restrict the selection of individuals to those with certain personal characteristics. For example, males and then females can be mapped by clicking a single button, or a series of counts for each age group viewed by moving a slide bar.

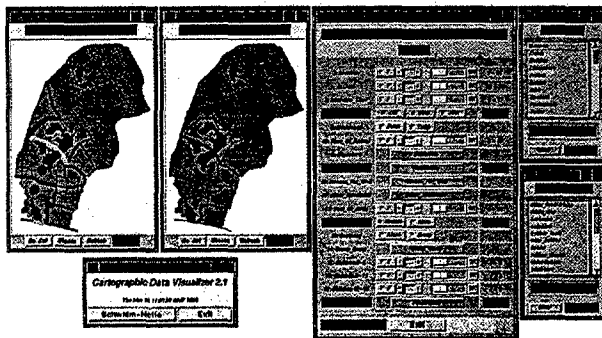


Figure 2: Re-Expression, selected cases are re-mapped. Here the left map shows the distribution of all individuals in at a certain time. The map to the right shows the numbers of female Germans who are using cars or bicycles, as selected through the interface.

### 3.3 Multiple Alternative Views

Cartographic visualization requires that various representations can be created from any variable immediately and altered interactively. In Figure 3 proportional circle maps and scatter plots are shown for variables chosen by the slide bars. Dorlings [2] cartogram algorithm has also been implemented to provide a social view. The cartography can be changed: for example choropleth classes can be altered, scaling factors for proportional circle maps varied, and the number or type of visual variables applied to cartographic symbols changed. A Red-Green-Blue colour composite of three variables has been applied to the maps in Figure 3, whilst an intensity shading scheme depicting a single variable provides the colour for the scatter plots.

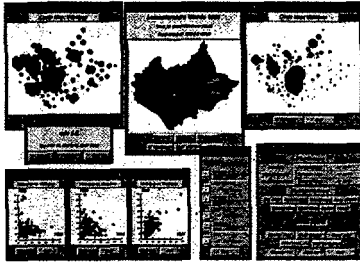


Figure 3: Multiple views of data: Choropleth maps, proportional circle maps and scatter plots are shaded to represent multiple variables.

### 3.4 Dynamically Linked Views

The ability to select symbols and highlight corresponding items in other views is essential in a multi-view environment for spatial analysis. This adds familiarity to unfamiliar views. For example, cartograms can be traversed with a cursor and the current zones highlighted in a conventional map. Linking also allows significant groupings to be detected as items in scatter plots, bar charts, proportionate circle maps or other views can be linked to map items. In Figure 4 (left) outliers from a single scatter plot are highlighted in all other views. The origins of tourists, selected by their attributes, are plotted on a national map in Figure 4 (right). Equally national locations could be selected and the distribution of regional tourists plotted in the park.



Figure 4: Linking views of data: Left - changing the texture of symbols selected in one view, and related symbols in all other views. Right - selecting a cluster of individuals on one map and displaying them on a map of a different scale.

### 3.5 Animation

The temporal dynamism of maps and other representations underlies all of these techniques. Immediate update is essential for visual analysis. Lines and circles are used to map population counts on paths and in areas of the park in Figure 5. The slide bar (left) allows the user to move quickly backwards and forwards through time. Time and attribute series can be combined by using the attribute widget (see Figure 2) to select groups of the population with specific characteristics and see how they behave in time and space. An alternative technique would be to map individuals as moving items which display personal attributes through visual variables.

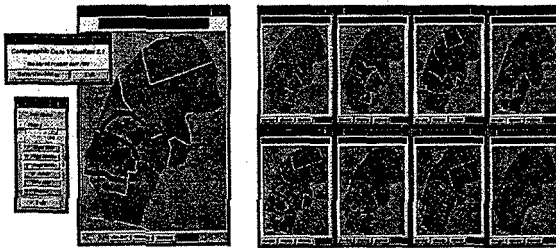


Figure 5: Animation - widgets can be used for time or attribute image series. Here a slide bar is used to move the map through time (left). The full time series is shown on the right.

## 4 Conclusion

Geographic Information Systems implement some of these features in a slow and cumbersome manner, using an import/export means of visualizing Scott [10]. Statistical visualization packages such as REGARD [4] and Polygon Explorer [5] are limited in their cartographic capabilities. Such software does not yet utilise the map as a real-time tool for analysing data, in the way that natural scientists use images from ViSC systems for analysis. Combinations of ViSC features and cartography in real-time interactive maps show that the Tcl/Tk model for visualization in computer cartography [3]. The model provides a powerful environment for handling and investigating geographic data which emphasises the effectiveness of a visual interface for analysing complex spatial data sets and places cartography at the crux of spatial data analysis.

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provided with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown and the Post Office."

For more information see <http://www.geog.le.ac.uk/argus/index.html>

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