Algorithms for cartographic visualization

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The research focused on developing algorithms for the automated creation of maps, mostly thematic maps. Thematic maps are designed to show a particular theme connected with a specific geographic area. We developed several methods to visualize data that is related to geographic regions or locations.

First we studied the problem of drawing schematic maps. Schematic maps are a well-known cartographic tool; they visualize a set of nodes and edges (for example, highway or metro networks) in simplified form to communicate connectivity information as effectively as possible. Many schematic maps deviate substantially from the underlying geography since edges and vertices of the original network are moved in the simplification process. This can be a problem if we want to integrate the schematized network with a geographic map. In this scenario the schematized network has to be drawn with few orientations and links, while critical features (cities, lakes, etc.) of the base map are not obscured and retain their correct topological position with respect to the network. We developed an efficient algorithm to compute a collection of non-crossing paths with fixed orientations using as few links as possible. This algorithm approximates the optimal solution to within a factor that depends only on the number of allowed orientations. We can also draw the roads with different thicknesses, allowing us to visualize additional data related to the roads such as traffic volume.

Next we studied methods to visualize quantitative data related to geographic regions. We first considered rectangular cartograms. Rectangular cartograms represent regions by rectangles; the positioning and adjacencies of these rectangles are chosen to suggest their geographic locations to the viewer, while their areas are chosen to represent the numeric values being communicated by the cartogram. One drawback of rectangular cartograms is that not every rectangular layout can be used to visualize all possible area assignments. Rectangular layouts that do have this property are called area-universal. We show that area-universal layouts are always one-sided, and we present algorithms to find one-sided layouts given a set of adjacencies.

Rectangular cartograms often provide a nice visualization of quantitative data, but cartograms deform the underlying regions according to the data, which can make the map virtually unrecognizable if the data value differs greatly from the original area of a region or if data is not available at all for a particular region. A more direct method to visualize the data is to place circular symbols directly on the corresponding region, where the areas of the symbols correspond to the data. However, these maps can appear very cluttered with many overlapping symbols if large data values are associated with small regions. We proposed a novel type of quantitative thematic map, called necklace map, which overcomes these limitations. Instead of placing the symbols directly on a region, we place the symbols on a closed curve, the necklace, which surrounds the map. The location of a symbol on the necklace should be chosen in such a way that the relation between symbol and region is as clear as possible. Necklace maps appear clear and uncluttered and allow for comparatively large symbol sizes. We developed algorithms to compute necklace maps and demonstrated our method with experiments using various data sets and maps.

Finally we studied the automated creation of flow maps. Flow maps are thematic maps that visualize the movement of objects, such as people or goods, between geographic regions. One or more sources are connected to several targets by lines whose thickness corresponds to the amount of flow between a source and a target. Good flow maps reduce visual clutter by merging (bundling) lines smoothly and by avoiding self-intersections. We developed a new algorithm for drawing flow trees, flow maps with a single source. Unlike existing methods, our method merges lines smoothly and avoids self-intersections. Our method is based on spiral trees, a new type of Steiner trees that we introduced. Spiral trees have an angle restriction which makes them appear smooth and hence suitable for drawing flow maps. We study the properties of spiral trees and give an approximation algorithm to compute them. We also show how to compute flow trees from spiral trees and we demonstrate our approach with extensive experiments.