Rectangular Cartograms: Construction & Animation

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1 Introduction

Cartograms, which are also referred to as *value-by-area maps*, are a useful and intuitive way to visualize statistical data about a set of regions like countries, states or provinces. The size of a region in a cartogram corresponds to a particular geographic variable [1]. Since the sizes of the regions are not their true sizes they generally cannot keep both their shape and their adjacencies. A good cartogram, however, preserves the recognizability in some way.

Globally speaking, there are three types of cartogram. The standard type (the *contiguous area cartogram*) has deformed regions so that the desired sizes can be obtained and the adjacencies kept. Algorithms for such cartograms are described in [2, 3, 6, 9]. The second type of cartogram is the non-contiguous area cartogram [7]. The regions have the true shape, but are scaled down and generally do not touch anymore. The third type of cartogram is the rectangular cartogram, introduced by Raisz in 1934 [8], where each region is represented by a rectangle. This has the advantage that the sizes (area) of the regions can be estimated much better than with the first two types.

Tobler states in a recent survey, "Thirty-five years of computer cartograms" [10], that none of the existing cartogram algorithms are capable of generating rectangular cartograms. However, even more recently the last two authors of this abstract presented the first algorithms for rectangular cartogram construction [11].

Quality criteria. Whether a rectangular cartogram is good is determined by several factors. One of these is the *cartographic error* [2, 3], which is defined for each region as $|A_c - A_s| / A_s$, where A_c is the area of the region in the cartogram and A_s is the specified area of that region, given by the geographic variable to be shown. The following list summarizes the most important quality criteria:

- Average cartographic error.

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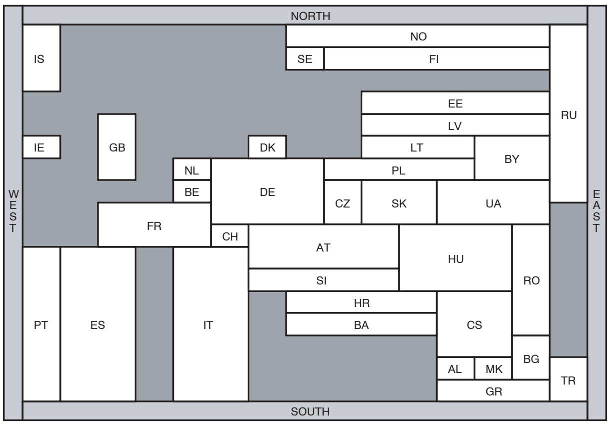

Figure 1: A rectangular layout for Europe.

- Maximum cartographic error.
- Correct adjacencies of the rectangles.
- Maximum aspect ratio.
- Suitable relative positions.

For a purely rectangular cartogram we cannot expect to simultaneously satisfy all criteria well. Recently Heilmann et al. [4] presented rectangular map approximations that have zero cartographic error but do not satisfy the other criteria.

Cartogram construction. Following [11] we first formalize the region adjacencies based on their geographic location and then use this information together with an algorithm by Kant and He [5] to construct a *rectangular layout* (see for example Fig. 1). A rectangular layout is a map where each region (country, state, etc.) is represented by a rectangle and adjacent regions are depicted by adjacent rectangles. We also introduce additional *sea rectangles* that help to preserve the original outline of the regions.

We then use one of three methods to try and give the rectangles their desired sizes. The simplest one of these is the *segment moving heuristic.* The segment moving heuristic loops over all maximal segments in the layout and moves each with a small step in the direction that decreases the maximum error of the adjacent regions. After a number of iterations, one can expect that all maximal segments have moved to a locally optimal position. However, we have no proof that the method reaches the global optimum or that it even converges, although it often gives aesthetically pleasing cartograms with small error.

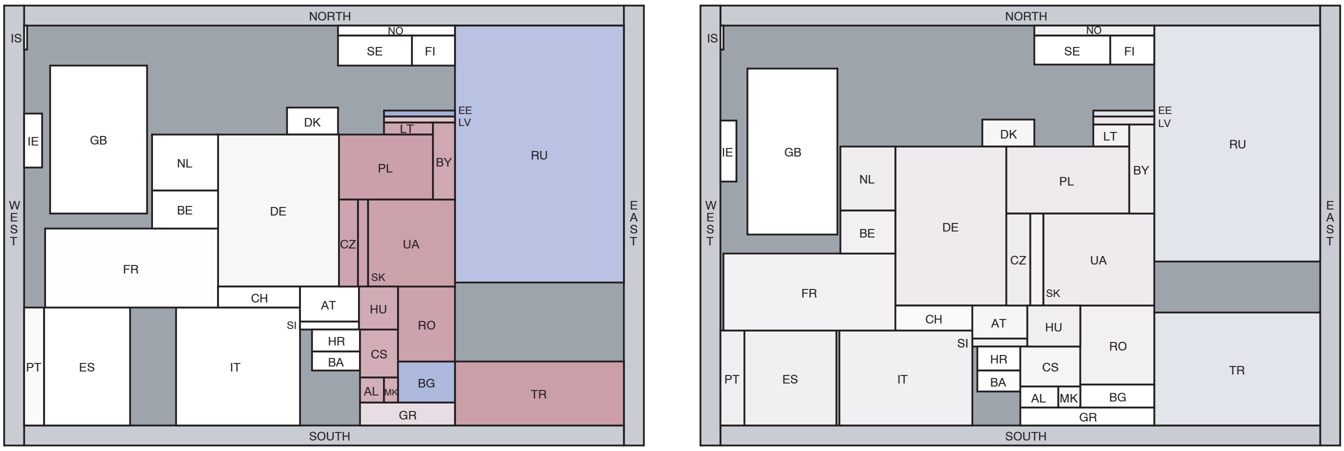

Figure 2: The population of Europe: correct adjacencies (left) and mildly incorrect adjacencies (right).

2 Implementation

We implemented the segment moving heuristic for cartogram construction. Our program allows the user to experiment with different settings for many parameters, for example, the maximum allowed aspect ratio of the rectangles, correct or false adjacencies, the percentage of the whole area that is specified to be covered by sea, or the number of iterations the algorithm goes through.

We use a color coding with shades of red and blue to visualize the cartographic error: Regions with $A_c - A_s < 0$ are red, regions with $A_c - A_s > 0$ are blue, and regions with zero error are white. The segment moving heuristic can also be easily and nicely animated. The animation together with the error visualization allows us to study how the heuristic computes a cartogram from an initial layout and where and why it cannot reduce the cartographic error of a given map any further.

There are several reasons why the segment moving heuristic does not always generate a cartogram with (close to) zero error. Whether the maximal aspect ratio is such a reason can be seen from rectangles that are elongated while they locally have the largest error (darkest shade in the color scheme). A higher aspect ratio generally reduces the cartographic error but the cartogram becomes harder to interpret.

Adjacencies play a role if there are places in the cartogram where several adjacent regions have large error and nearly form a four-corner point. Consider, for example, Figure 2 (left): Turkey, Bulgaria, and Romania all have comparatively high error. If we allow the adjacencies to be mildly incorrect, then (in this case) we can reduce the average error from 0.163 to 0.079 as depicted in Figure 2 (right).

The locality of the segment moving heuristic may also prevent an optimum from being computed. Other reasons, or a combination of the above, can also apply.

Morphing. Morphing between two rectangular cartograms is a striking way to visualize the discrepancy between two variables. Animating the segment moving heuristic between two data sets provides an easy means to create such morphs. Starting with any rectangular layout or cartogram, we simply specify new area values for all regions and then use the segment moving heuristic to compute the new cartogram.

The Demo. We demonstrate a slimmed down version of our implementation that visualizes the construction of rectangular cartograms with the segment moving heuristic. We use error visualization and animation to illustrate the effects of different maximum aspect ratios and true or false adjacency options. The demo also contains two morphs that show the relation between the highway length and the number of cars per state of the USA and between the population and the GDP for the countries of Europe.

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