

# Accentuating Focus Maps via Partial Schematization

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## ABSTRACT

We present an algorithm for schematized focus maps. Focus maps integrate a high detailed, enlarged focus region continuously in a given base map. Recent methods integrate both with such low distortion that the focus region becomes hard to identify. We combine focus maps with partial schematization to display distortion of the context and to emphasize the focus region. Schematization visually conveys geographical accuracy, while not increasing map complexity. We extend the focus-map algorithm to incorporate geometric proximity relationships and show how to combine focus maps with schematization in order to cater to different use cases.

**Categories and Subject Descriptors:** H.4 [Information Systems Applications]: *Geographic Information Systems* I.3.5 [Computer Graphics] Computational Geometry and Object Modeling

**General Terms:** Algorithms

**Keywords:** Focus maps, schematization, information visualization

## 1. INTRODUCTION

Focus maps are an integrated alternative to map insets (see Fig. 1(a)). They continuously combine an enlarged and detailed *focus region* with context information on a smaller scale. A standard approach is the fish-eye view which uses a rim of “glue” that is heavily distorted (Fig. 1(b)). It is comparatively easy to identify the focus region in such maps, since the distortions are rather obvious. A recent method by Haunert and Sering [8] significantly reduces the distortion, but it becomes difficult to separate the focus region from the context without additional visual cues (Fig. 1(c)).

**Contributions.** We combine focus maps and cartographic schematization to obtain *schematized focus maps*. Such maps provide high detail within the focus region but schematize the context, hence drawing the attention towards the focus region (Fig. 1(d-e)). We use the geometry of the map to steer the focus of the user; this has multiple advantages.

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First, the schematized geometry visually conveys that the context is not geographically accurate. Second, it does not require additional geometric elements that would otherwise increase the map’s complexity. Third, it allows color to be used more effectively to convey other (thematic) elements.

In Section 2 we extend the focus-map algorithm by Haunert and Sering [8]. Specifically, we show how to augment a given map with edges to control its rigidity and how to increase the distance between any two map objects. In Section 3 we extend the framework by Van Goethem *et al.* [5] to allow for partial schematization. In Section 4, we combine these methods and showcase our results with various use cases.

**Related work.** Fish-eye projections are well-known in cartography and received renewed interest with the advent of cartography on small mobile devices [6, 14]. However, since fish-eye projections usually cause large distortion at the boundary of the focus region, Haunert and Sering [8] introduced an optimization-based graph-layout method that minimizes distortion. This method is related to others that manipulate network maps, for example, to generate route sketches [1, 12], destination maps [9], or metro maps [13].

To emphasize the focus, the level of detail of the context can be reduced [15]. Beyond a reduction of the level of detail, however, schematization enforces a certain design scheme (we use circular arcs in this paper). Various methods exist for straight-line schematization of territorial outlines [2, 3, 10]. The method by Buchin *et al.* [2], which is iterative, could be adapted to support partial schematization.

## 2. FOCUS MAPS

The method of Haunert and Sering [8] distorts a subdivision  $S$ , i.e. a planar straight-line embedding of a graph in  $\mathbb{R}^2$ . It consists of a vertex set  $V$  and an edge set  $E$ . For each  $u \in V$ ,  $X_u$  and  $Y_u$  are the input coordinates and there are three variables: the output coordinates  $x_u, y_u$  and the scale factor  $s_u$  locally valid in  $u$ . Constraints ensure that the bounding box of the input contains the output subdivision and a user-selected focus region is enlarged by a user-set factor. Subject to these constraints, the method minimizes

$$\sum_{u \in V} \sum_{v \in \text{Adj}(u)} \frac{(s_u \cdot X_{u,v} - x_{u,v})^2 + (s_u \cdot Y_{u,v} - y_{u,v})^2}{X_{u,v}^2 + Y_{u,v}^2}, \quad (1)$$

where  $X_{u,v} = X_v - X_u$ ,  $Y_{u,v} = Y_v - Y_u$ ,  $x_{u,v} = x_v - x_u$ ,  $y_{u,v} = y_v - y_u$ , and  $\text{Adj}(u) = \{v \in V \mid \{u, v\} \in E\}$ . Additional constraints avoid edge crossings. We extend this method to control the rigidity of  $S$  (Sect. 2.1) and increase the distance between selected map objects (Sect. 2.2).

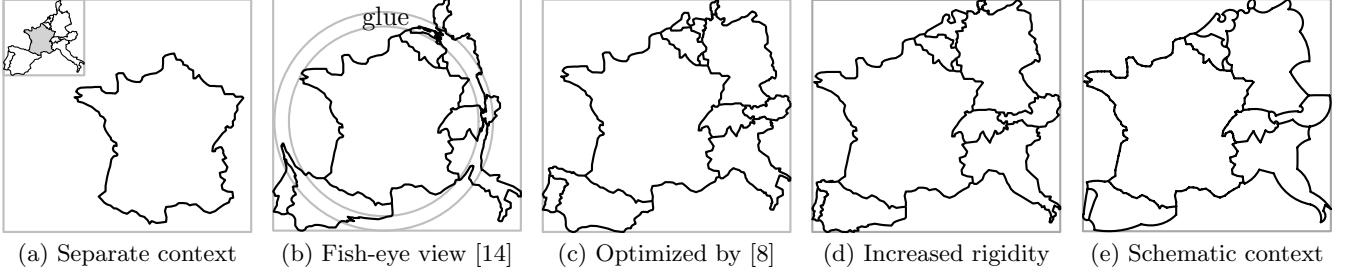


Figure 1: Focus maps for France with various options of visualizing context (continental western Europe, subset of input in Fig. 3(a)). (d-e) Results obtained using the techniques presented in this paper.

## 2.1 Adding bottleneck edges

The method of Haunert and Sering [8] requires a connected subdivision as input. It fails if, e.g., islands are present. We suggest augmenting the input graph with edges to render it connected and, furthermore, to control its rigidity.

Let  $\tau_S(u, v)$  be the stretch factor of a vertex pair  $(u, v)$ , i.e.,  $\tau_S(u, v) = ds(u, v)/d_{\text{Euclid}}(u, v)$ , where  $ds(u, v)$  is the length of the geometrically shortest  $u$ - $v$ -path in  $S$  (or  $\infty$  if no  $u$ - $v$ -path in  $S$  exists) and  $d_{\text{Euclid}}(u, v)$  is the Euclidean distance of  $u$  and  $v$ . We aim to decrease the stretch factor of  $S$ , i.e.,  $\tau(S) = \max_{u, v \in V} \{\tau_S(u, v)\}$ , to at most a user-set value  $t \geq 1$ , by adding a preferably small number of edges.

We use a greedy heuristic that iteratively adds a *bottleneck edge*, i.e., an edge connecting a pair of vertices with maximum stretch factor. This can be computed for a subdivision with  $n$  vertices and  $m$  edges in  $\mathcal{O}(mn + n^2 \log n)$  time by computing shortest paths for all pairs of vertices [4]. We may improve upon this as follows. Only in the first iteration we need to compute shortest paths for all pairs of vertices if we maintain the graph distances in a matrix  $D$ . If we add a bottleneck edge, we can update  $D$  in  $\mathcal{O}(n^2)$  time, which implies that we reduce the runtime of any further iteration to  $\mathcal{O}(n^2)$ . Furthermore, we *contract* (most of the) vertices of degree two (Fig. 2). The reduced subdivision  $S^*$  allows us to compute shortest paths in  $S$  more efficiently. The last improvement, a heuristic, is to test only a small number of candidate pairs to find a pair with the maximum stretch factor  $t_{\max}$ . If  $t_{\max} \geq t$ , we connect the pair, update  $S^*$ , and continue. Else, we stop adding edges and return the subdivision  $S$ . In our implementation, we define a candidate pair for each edge of a constrained Delaunay triangulation (CDT) of  $V$  with a constrained edge for each edge in  $E$ .

When we applied our algorithm to the subdivision EUR in Fig. 3(a) with  $t := 4$ , it added 159 edges and needed 2.9 seconds on a Windows PC with 3.0 GB of RAM and a 3.0 GHz Intel dual-core CPU; with  $t := 3$ , it added 262 edges and needed 8.8 seconds.

Figure 3(b) shows the result of enlarging Britain after augmenting the input subdivision EUR using  $t := 4$ . Germany and France get distorted severely. Using all edges of a

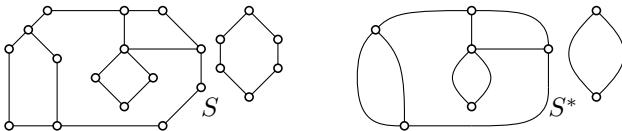


Figure 2: Contraction of degree-two vertices.

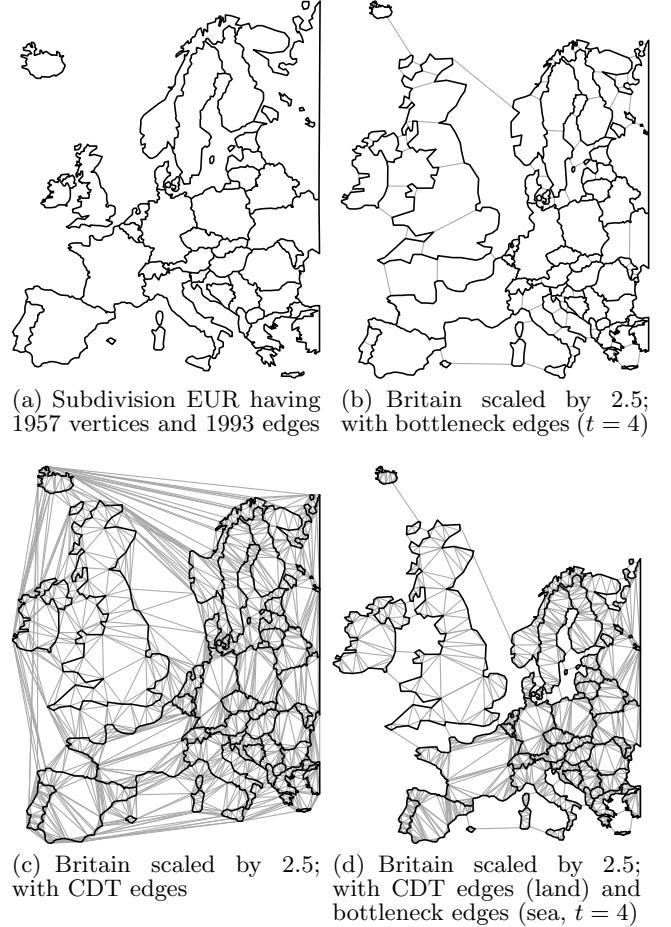


Figure 3: Focus maps generated using different methods of graph augmentation. We only forbid crossings among the original edges (black), as we assume that the additional edges (gray) will not be shown to the user.

CDT, however, we still observe severe distortions in France (Fig. 3(c)). To keep the characteristic shapes of countries, we suggest using two different thresholds,  $t_{\text{in}}$  and  $t_{\text{out}}$ , for the inner faces of the input subdivision and its outer face, respectively. We used  $t_{\text{in}} := 1.0$  and  $t_{\text{out}} := 4.0$ , meaning that, after adding edges to  $S$  to ensure  $\tau(S) \leq 4.0$ , we add all edges of a CDT to the inner faces to preserve the shapes of countries. This allows us to enlarge Britain with only a small distortion of other countries (Fig. 3(d)).

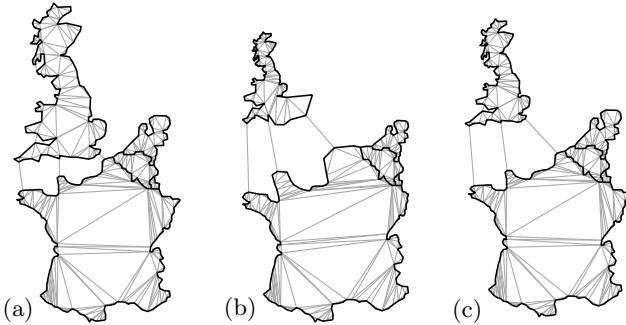


Figure 4: Widening the English Channel.

## 2.2 Widening bottlenecks

Usually, two objects in a topographic map must have at least a certain minimum distance; this can be ensured by *displacement* [7]. In thematic maps, we may want to increase the distance between two objects to make space for additional content, e.g., a label or the flow lines in a flow map.

Consider the map in Fig. 4(a), which displays the countries adjoining the English Channel, and assume that we want to widen the channel to represent vessel traffic with a fat line. This can be achieved by defining a lower bound on the scale factors  $s_u$  and  $s_v$  for each edge  $\{u, v\} \in E$  connecting Britain with France; see Fig. 4(b). The channel has been widened, but, as an undesirable side effect, also the southeast of Britain (Kent) has been vastly enlarged.

To avoid this effect, we choose a different approach. We introduce a variable  $s_e \geq s_{\min}(e)$  for each edge  $e = \{u, v\}$  that we want to enlarge, where  $s_{\min}(e)$  is the minimally required scale factor. Then, to control  $e$  with  $s_e$ , we add

$$((s_e \cdot X_{u,v} - x_{u,v})^2 + (s_e \cdot Y_{u,v} - y_{u,v})^2) / (X_{u,v}^2 + Y_{u,v}^2)$$

to our objective function. The scale factors  $s_u$  or  $s_v$  should not control  $e$ , thus when measuring the distortion with Equation (1) we do not consider  $v$  and  $u$  to be neighbors. However, we add the constraint  $s_u = s_v$ . Thereby the scale is propagated over the network. As a result, both France and Britain are only marginally distorted, see Fig. 4(c).

## 3. SCHEMATIZATION

Van Goethem *et al.* [5] introduced a framework for curved schematization. When applying their framework with area-preserving arcs and the Fréchet distance, a vertex-restricted algorithm entails. This algorithm schematizes the input up to a given error bound. It assumes as input a subdivision, e.g., an output of the focus-map algorithm. The algorithm produces a *topologically equivalent* subdivision that uses circular arcs instead of straight lines. Thus, regions correspond one-to-one; each region has the same neighbors; and there are no intersections between the arcs of the output (assuming the input has none). Each circular arc has a *Fréchet distance* [11] of at most  $\varepsilon$  to the input polyline it represents (a *chain* in the terminology of [5]). The framework produces a subdivision that has a minimal number of circular arcs. Below, we describe how we extend this algorithm to support partial schematization.

**Weights.** We assume that each vertex has been given a weight to indicate its importance: this importance depends on the use case as described in Section 4. The weight is at

least one and may be infinite. A vertex of infinite weight is always required to be in the output.

To obtain a partial schematization, we need to locally define different values of the error margin  $\varepsilon$ . Vertices with a high weight should be less schematized and, hence, have a lower error margin. We observe that in the described framework [5] an arc can only replace a chain if its score (Fréchet distance) is at most  $\varepsilon$ . Instead of locally decreasing  $\varepsilon$ , we can increase the score of a replacement arc according to the local weight. To do so, we multiply the score by the average weight of the vertices in the chain.

The area-preserving circular arc of a single edge (a chain of 2 vertices) is the edge itself; the Fréchet distance is exactly zero. Hence, the original framework is guaranteed to yield a solution. When vertices can have an infinite weight this property no longer holds, as even arcs fitted to edges can have an infinite score. To solve this issue we define the product of zero and infinity to be zero. This ensures that the edges connecting consecutive vertices can always be used for any  $\varepsilon$  value. As a consequence the framework always has a solution regardless of the weighting scheme.

## 4. SCHEMATIZED FOCUS MAPS

Schematization and focus maps should be combined differently depending on the purpose of the final map. In this section, we discuss various combinations based on use cases.

**Context for location.** When users are not familiar with the shape of an area it is useful to include context to guide them in recognizing and localizing a map. Examples of these types of maps are often found in tourist brochures. We draw attention to the focus region by schematizing the context, weighting all vertices with weight 1 except those in the focus region which have weight infinity. Fig. 5 gives an example for country outlines. By enlarging the focus region we remove the need for a map inset and lower the visual clutter introduced in the map. The context helps locate the focus region while its schematization emphasizes the focus region.

**Interaction with context.** Information may also be displayed that is related to the immediate vicinity, e.g. a thematic map depicting country export. By gradually increasing the schematization further away from the focus region, we actively draw the attention of the user to the focus region. In contrast to the previous approach this purposefully maintains the relationship with the surroundings. We assign a weight to each vertex depending on the distance to

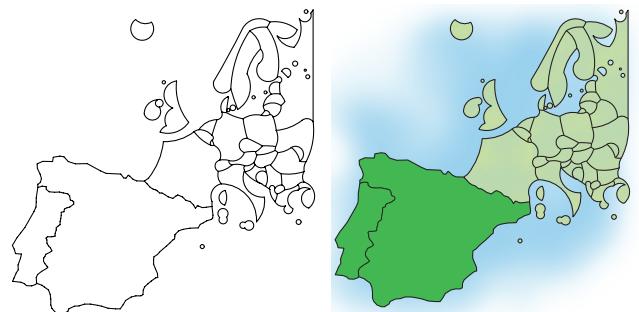
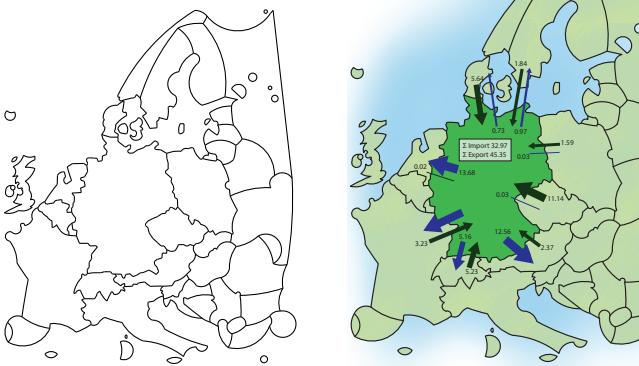


Figure 5: Focus map of the Iberian peninsula using a scale-factor of 2. Context helps to locate the map; schematization emphasizes the focus region.



**Figure 6:** Focus map of Germany using a scale-factor of 2, and Euclidean distance for schematization. Interaction with context is visually reinforced by not fully schematizing near the focus region.

the focus region. Fig. 6 shows the result of our algorithm and an example thematic map<sup>1</sup>. To maintain the relation with neighboring countries while reinforcing the importance of the focus region we gradually increase schematization further away from Germany. As a consequence the visual focus region extends to include the neighboring countries.

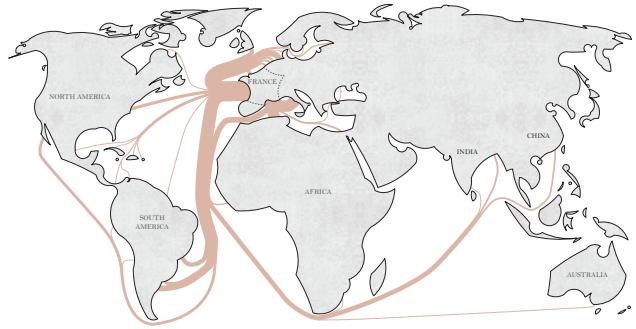
**Focus on thematic information.** This use case concerns thematic maps. No specific region requires focus, but our method still proves useful. By widening the bottleneck edges we make space for the thematic information. This reduces overlap, increasing the clarity of the final map. To emphasize the main content, we schematize the entire map uniformly. Fig. 7 shows a result mimicking the map on wine-export by Minard<sup>2</sup>. To allow the thematic information to be displayed, France has been enlarged and the English Channel, Strait of Gibraltar, and Strait of Malacca have been widened.

## 5. DISCUSSION

Schematizing focus maps creates clear and concise maps. However, we did make the following observations. Enlarging the focus region inherently reduces its visual complexity; it may appear to be simplified already. Thus, the level of detail in the input map should fit the enlarged focus scale; not the input scale. Secondly, the effect of schematization may be bound by different factors including expectations, cultural background, or familiarity with the region. If the user is expecting jagged lines, breaking this expectation by schematization has a big impact. Schematizations, as maps, should be tailored to the target audience.

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**Figure 7:** Use of focus maps to make space for thematic information. Schematization removes unnecessary detail. Roughly based on Minard's map.

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