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A methodology for placement and evaluation of area map labels

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Abstract

In order to speed up the map design process, many attempts to automate the label placement task have been carried out. One of the most challenging issues is the labelling of areas, since the criteria for correctly placing these labels on complex shapes is highly subjective. This article introduces a new measure to assess the fitness of a circular arc (on which the label will lie) with respect to the boundary of the area being labelled. After a summary of the usual cartographic rules on label placement, we describe and justify this new measure. A process for generating candidate placements and selecting the most suitable is then proposed. Results on different kinds of area are then presented. The article concludes with an analysis of the results and suggested further improvements. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Label placement, a major step of the map design process, remains a time-consuming task. Due to the high cost of map labelling, most research to date has focused on the computational complexity of the problem. That has brought about, for instance, some interesting solutions that speed up the placement of horizontal labels (i.e. mainly point labels, cf. next section for references). But a full automation of label placement will not be reached until the cartographic quality of label layout can be determined.

Although horizontal labels often account for 80% of all labels on a map, linear and area features are much more difficult to place on a map, which can severely slow

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down the overall process. This article focuses on area feature labels. It is based on previous work of the author on label placement for point and linear features (Barrault, 1998). It intends to indicate cartographic rules leading to cartographic label placement as well as to explain their necessity for ensuring map legibility. It then describes a global process that generates candidate positions for labelling area features, introduces an evaluation function for selecting the optimal position based on several criteria, and provides a perspective on cartographic evaluation.

2. Cartographic label placement

Through symbols and text, maps offer two powerful ways of conveying spatial information. But the formalisation proposed by Bertin (1967) for map symbols hasn't been carried out in an equally detailed way for text positioning so as to permit the automation of label placement, which will achieve adequate cartographic quality.

2.1. Labels on a map

Traditional cartographers such as Imhof (1975) and Cuenin (1972) have already attempted to formalise the label placement process. They defined general principles and proposed rather detailed rules for the three principal kinds of labels:

1. Punctual labels letter a point symbol or a small region and are characterised by fixed extent and curvature (mostly straight and horizontal except for very small scales where they curve along the parallels of the spherical grid).
2. Linear labels are applied to linear features. Their curvature must be fitted to the section of the features, which they follow and moreover, the label can be repeated for long linear features.
3. Area labels letter larger area features and are extending along circular arcs or horizontal lines.

Analysis of cartographic rules suggests that label placement contributes to the efficiency of a map in several ways (Barrault, 1998). It displays semantic information, provided that labels do not overlap and are clearly discernible. Efficient label dispositions[1] also assist in highlighting the associated features, and, by doing so, emphasise the relationships to other features.

2.2. Avoiding overlaps

One of the general principles is that no label may overlap another one in order to guarantee their legibility. This very issue, which turned out to be a NP-complete

[1] The term *disposition* is preferred to *placement* in order to emphasize the notion of the label shape, since *placement* only induces the notion of location.

problem (Kato & Imai, 1988), attracted most of the research carried out on the automation of label placement. Christensen, Marks and Shieber (1995) then showed that a simulated annealing technique provided the best and fastest results for the problem of point label positioning that consists in:

1. Defining a set of candidate label positions, for each feature to letter with a punctual label.
2. Finding among those a final position for each label that minimises the amount of overlaps between them.

Lecordix, Plazanet, Chirié, Lagrange, Banel and Cras (1994) used this same approach but enriched candidate positions with a quality weight and refined the set of candidates in order to avoid overlapping important geometric features of the map background (e.g. roads or other symbols). They obtained encouraging results (80% of labels placed adequately) by integrating other cartographic rules.

2.3. Cartographic quality

Basically, a label is better placed when it is legible, when it and its feature are easily associated (without any ambiguity), when it doesn't overlap any major information of the background, and when it is homogeneously spread among its neighbouring labels. Unfortunately, cartographic rules often remain global advice or generic constraints that can neither be easily turned into a formal computational process nor used to establish clear priorities between the various factors governing the placement (Barrault, 1998). Nevertheless, for curved labels, their location and even more so their shape (characterised by an extent, a curvature and an orientation) contributes greatly to the association identification with the corresponding feature and often even assists in characterising the shape of the associated feature. Good placement regarding the associated feature, then, is the first inevitable step to satisfactory label arrangement.

Area labels add two major constraints that justify this research. Firstly, their disposition quality has to fit the associated area's shape, whose analysis rapidly becomes a complex and computationally expensive process. Secondly, since area labels must be spread across the area (cf. Section 2) and thus require sufficient free space, implies that they are positioned before any other labels which might definitively consume the space area labels need.

An evaluation of area label disposition quality with respect to their area feature would allow alternative dispositions and thus remove from the label placement process these space-consuming and rigid constraints. Thus, this paper describes the criteria that govern efficient area label disposition. Next it proposes a measure that allows a disposition evaluation with regard to area coverage. It then goes on to present how to integrate this "coverage evaluation" in a more generic measure so as to be able to compare any areal disposition with another label of any kind. The description of a complete chain of candidate dispositions and an analysis of results, as well as possible improvements conclude this paper.

3. Quality of an area label

From the cartographic rules in the literature, we hereafter propose criteria that define a satisfactory disposition.

3.1. Cartographic rules

For an area feature, the main rules, synthesised from several literature references are:

1. The area is labelled only once.
2. The label must fit into the area.
3. There are two suitable kinds of possible arrangements: along a circular arc (with a circular angle $<\pi/3$) or with words placed on one or several horizontal rows, both based on the area shape (cf. Figs. 1 and 2), although the latter solution is preferred if possible.
4. The label should be spread across the area so as to cover most of the feature, though it should not touch the boundaries (several different rules exist regarding the distance to the boundaries).
5. Inter-character, -word and -line spacing (for horizontal positions) may be adjusted to stretch the label, up to a threshold defined with respect to the font size.

These rules highlight that analysis of shape and of goodness of fit, two highly subjective processes, are needed to manage area label placement. By fitting to its feature, a label's curvature discriminates its owner's nature. It also participates in delineating its geometry. It speeds up map reading and improves feature identification, thus improving the overall map effectiveness. The better the feature is labelled, the clearer the map becomes.

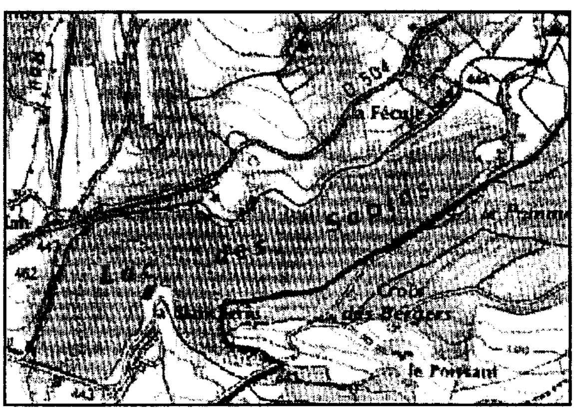

Fig. 1. Areal label following a circle arc (Lac des Sapins) — I.G.N.©.

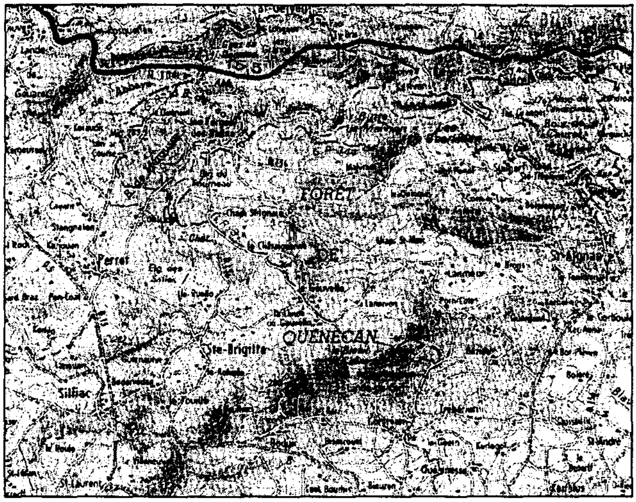

Fig. 2. Horizontal area label along a vertical line (Forêt de Quénécan) — I.G.N.©.

In order to explain our process, we will focus on the circular arc disposition since the horizontal line arrangement will mainly follow the same principles as described below.

Although studies on area feature labelling have been carried out (Pinto & Freeman, 1996), they mainly focus on small-scale features (greatly generalised features leading to simple shapes) and do not take into account neighbourhood effects such as overlapping labels. A more generic, automated process should be able to handle complex shapes, with sinuous and noisy contours, that prove more common in large-scale maps. Moreover, this extension implies that alternative yet still efficient candidate positions of a label may exist so as to adapt the whole arrangement to the constraints of the region, which may be a complex background, with a competing set of labels or icons.

Nevertheless, the criteria defined by Pinto and Freeman (1996) provides an interesting formalisation which can be used to develop optimal placement methods.

3.2. Circular label criteria

Six criteria are likely to influence the label quality. They must be managed in order to reach the best disposition or at least a satisfactory one (cf. Fig. 3a).

We will use the terms *longitudinal* and *latitudinal*, respectively, for any measure or characterisation related to the left and the right parts (or top and bottom parts, respectively) of an area with respect to its label. Due to the complexity of the possible relationships between an area and its label our terms remain fuzzy, although simple shapes of a circular arc and label's extent divide intuitively the area-space into four "quadrants". Although you can focus on the top, bottom left and right parts of the label, the exact boundaries of these quadrants can not be accurately

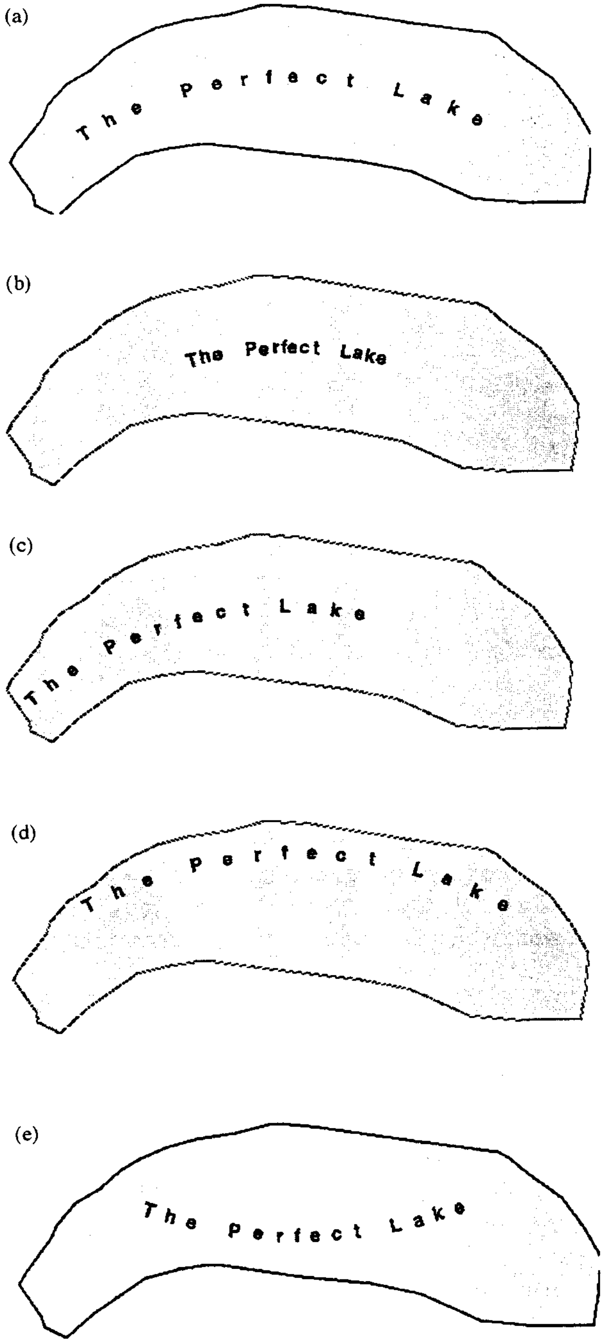

Fig. 3. (a) The best disposition for the most suitable shape. (b) Longitudinal extent is too short. (c) The label is off its longitudinal center. (d) The label is off its latitudinal center. (e) A non-conformant label.

detailed and by so, limit the assessment of how well the label is centred, spread and fitting to the shape.

3.2.1. Longitudinal extent

The more the label extends along a circular arc, the more likely it is to cover the area and by doing so, to indicate the area's extent (Fig. 3b).

3.2.2. Longitudinal centre

The more centred the label is, the more likely its location will reflect the area boundaries' centroid. Moreover, the centroid is an aesthetic criterion the reader is highly sensitive to (Fig. 3c).

3.2.3. Latitudinal centre

The label must be positioned so as to suggest the best separation between the upper and lower parts of the area, in order to indicate the latitudinal centre (Fig. 3d).

3.2.4. The conformity

The circular arc must portray a shape that has maximum similarity with the area (Fig. 3e). Two other criteria can be proposed in order to increase label legibility.

3.2.5. Orientation

The more horizontal the label arrangement, the better. Horizontal labels can be read faster.

3.2.6. Curvature

The less curved the label arrangement the better. Straight labels are easier to read. These last two criteria are easy to measure and should only intervene in the final quality function that will translate the cartographer's preferences: the label legibility (a small curvature and a horizontal orientation makes the label faster to be identified) versus the area shape characterisation (right curvature, orientation and location highlight the area shape's main characteristics).

The four first criteria, yield necessary conditions (good latitudinal and longitudinal coverage) to produce a disposition that fits the area's shape, but their efficiency relies on their measurement since the extent of the label within a complex area may easily lead to biased results. Unfortunately, most cartographic area features don't look like bananas or potatoes.

The measures proposed by Pinto and Freeman (1996) are sufficient for their own purpose (a process that leads to the best disposition for simple shapes) but are less easily adapted to more arbitrarily complex shapes. They rely on simple measures that compare minimal distances, from the circular arc to the feature boundaries, to the bounding rectangle parameters and references, which become less and less significant as soon as shapes become more complex.

We propose an alternative approach, based on one coverage assessment that integrates conformity to the shape, latitudinal and longitudinal fitness, as well as shape simplification. This approach should allow:

1. an efficient disposition to be found within the area, if possible;
2. a satisfactory labelling to be achieved when the inner area is constrained by obstructing features; and
3. to simplify the initial areas, so as to ease the shape analysis underlying the coverage measure.

3.3. Coverage assessment

We base our measure on three assumptions:

1. Each letter and circle centre defines a spatial reference that gives a latitudinal centre quality and coverage. They are based on the upper distance l_u (resp. lower distance l_d) from the letter to the *closest* upper (resp. lower) point of the area boundary *along the direction* defined by the centre of the letter and the centre of the circular arc (cf. Fig. 4).
2. The closer the letter to the boundary, the worse the real latitudinal coverage is perceived.
3. The circular arc from which the baseline is extracted can be extended until it meets the area boundaries.

We can then develop a set of measures that are going to help us to find interesting label positions. Let us denote La(sl, sw) the extent of a label to dispose within an area. It is defined with respect to the fixed font size, the content of the label (the text) and moreover, variable inter-letter (sl) and inter-word (sw) spacings. We assume that whatever the continuous baseline the label will be using, the final label disposition should retain the same extent with respect to the curvilinear abscissa. For our

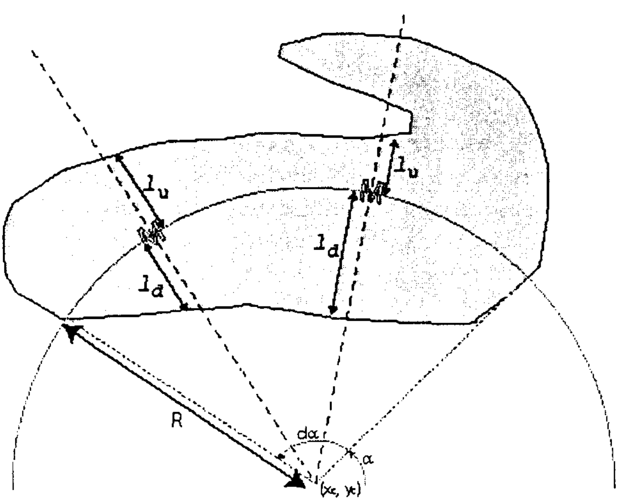

Fig. 4. Support line parameters and two instances of latitudinal coverage parameters of a letter disposed on the support line.

concern, we will fix the font size as well as the label content (we don't make use of label abbreviations) but we keep the spacings variable. SL(xc, yc, R, α, dα) the support line from where the label baseline is extracted: a circular arc with a centre $(x_c,y_c)\in R^2$, a radius $R\in R$, a starting angle $\alpha \in [0, 2\pi]$, and a variation angle $\mathrm{d}\alpha \in [0, 2\pi]$ (the endpoint is then $\alpha+\mathrm{d}\alpha$). α and dα are defined so that $\forall\, s \in[\alpha,\alpha+\mathrm{d}\alpha]$ $(x_c+R.\cos(s), y_c+R.\sin(s))$ lies within the area to label, which ensures the existence of l_u and l_d.

By extracting any sub-circle arc (β,dβ) from a support line, we can compute the area A_{SL} whose boundaries are closest to the circular arc, regarding the orientation defined on each point by the radius (cf. Fig. 5, the area shape is described by the bold lines). We have:

$$A_{SL}(\beta,\mathrm{d}\beta)=\int_{\beta}^{\beta+\mathrm{d}\beta}(l_u(s)+l_d(s))\mathrm{d}s$$

B(SL,β, dβ(sl, sw)) the baseline of a label, a sub-circle arc extracted from the support line (i.e. $\beta>\alpha$ & $(\beta+\mathrm{d}\beta)<(\alpha+\mathrm{d}\alpha)$). Of course, since the baseline is a circular arc, we have: $\mathrm{d}\beta=\mathrm{La(sl, sw)}/R$.

We propose then a perceived latitudinal coverage measure of the label's baseline PC(B) as the continuous sum of the smallest distance of each point to the closest boundary of the area, regarding the orientation from the circle centre, pc(s).

Let's be more accurate. For a given area A we want to label, we denote its frontier Fr(A). For a given support line SL(x_c, y_c, R, αi, dα), where αi and dα are defined so as the entire arc lies within A, we define:

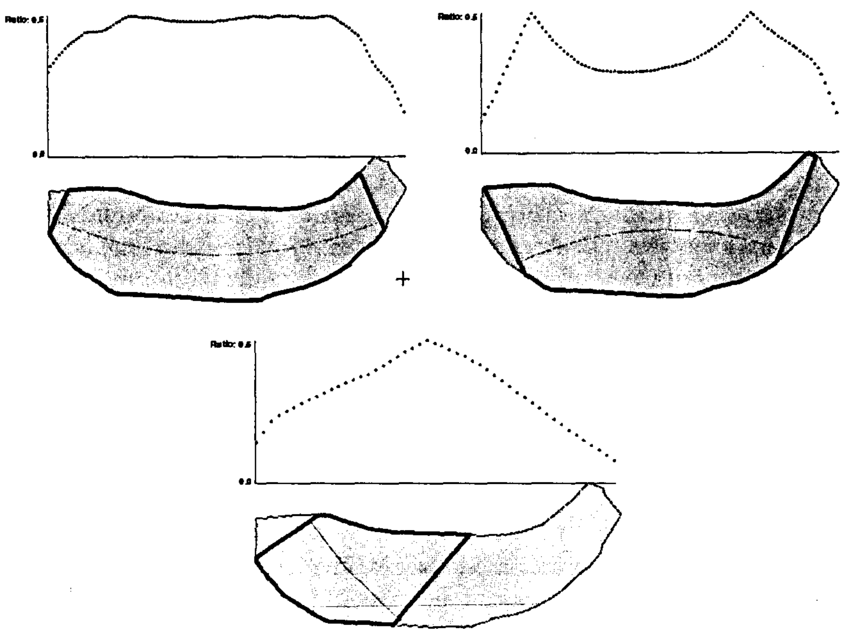

Fig. 5. Latitudinal center along a circular arc within the area.

1. SL(s), for $s \in [\alpha, \alpha + \mathrm{d}\alpha]$ as the point $(x_c + R.\cos(s),\ y_c + R.\sin(s))$
2. $D^+_{\mathrm{SL}}(s)$ as the half line: $(x_c + k.\cos(s),\ y_c + k.\sin(s))\forall\ s\ \in [R, +\infty]$
3. $D^-_{SL}(s)$ as the segment: $(x_c + k.\cos(s),\ y_c + k.\sin(s))\forall\ s\ \in [0,\ R]$
4. $l_u(s)$ and $l_d(s)$ as the functions:

$$l_u : [\alpha, \alpha + \mathrm{d}\alpha] \rightarrow \Re^+ \quad s \mapsto \underset{x \in D^+_{\mathrm{SL}} \cap \mathrm{Fr(A)}}{\mathrm{Min}} (\|x - \mathrm{SL}(s)\|)$$

$$l_d : [\alpha, \alpha + \mathrm{d}\alpha] \rightarrow [0, R] \quad s \mapsto \underset{x \in D^-_{\mathrm{SL}} \cap \mathrm{Fr(A)}}{\mathrm{Min}} (\|x - \mathrm{SL}(s)\|)$$

We can thus define pc(s) as, with respect to s, the minimum value between l_u and l_d:

$$\mathrm{pc} : [\alpha, \mathrm{d}\alpha] \rightarrow \Re^+ \quad s \mapsto \mathrm{Min}(l_u(s), l_d(s))$$

In order to clarify our approach, the following figures (cf. Fig. 5) illustrate the function pc along three different baselines. The curve above each example is normalised (the point density implies the length of each circular arc since the important information remains the behaviour of the curve with respect to the goodness-of-fit of the circular arc). The value displayed is the normalised minimum: $\mathrm{pc(s)}/(l_u(s) + l_d(s))$ and ranges from 0 to 0.5. The x-axis is the location along the corresponding arc drawn underneath, from the starting angle to the final angle. Since we apply the usual trigonometric direction, for the figure in the middle, the first point of the arc (on the right side) corresponds to the first point of the displayed function on the left-hand side. These three examples highlight how the latitudinal coverage may be related to a conformant label disposition. Although the displayed function may seem relevant, the experiments showed that it was not accurate enough. This is why we finally focus on the "perceived covered-area" and propose the measure PC instead of dealing with the ratio defined above.

The displayed functions above show that although each point carries a significant weight, the holistic behaviour along the baseline is the characteristic that must be controlled. We thus can define, for any baseline B(β,dβ) extracted from any valid support line SL of A, the measure PC(B(β,dβ)) $\in$ [0, $A_{\mathrm{SL}}(\beta,\ \mathrm{d}\beta)$]:

$$\mathrm{PC(B)} = 2\int_{\beta}^{\beta+\mathrm{d}\beta} \mathrm{pc}(s)\mathrm{d}s = 2\int_{\beta}^{\beta+\mathrm{d}\beta} \mathrm{Min}(l_u(s), l_d(s))\mathrm{d}s$$

With pc, the function integrates the latitudinal behaviour of each point. With the integration, it integrates all the points and should inform about the conformity of the circular arc to the part of the area it belongs to. But we still need to also integrate the longitudinal behaviour (including longitudinal extent and centre).

3.4. Integration of longitudinal assessment

The start-point of a label on a support line, β, and the label length, sl and sw, must also be taken into account. Several definitions may be found about how the baseline must extend along the area. The rule from Cuenin (1972) has been used which requires the extent to be $e=2/3$ times the area's width (given by the baseline's main direction), which can be interpreted as the extension of the baseline deduced by the map reader from the label. The real perceived extent is then: $((1-e)^*\mathrm{d}\beta+\mathrm{d}\beta)$, with the added part shared equally on both sides of the label.

But in order to avoid dispositions that are too extended (i.e. too close to the boundaries), a cost is added, which removes the perceived area of the extreme ends with respect to the magnitude of violation.

$$\begin{aligned}\mathrm{PC}_{\mathrm{SL}(\alpha,\mathrm{d}\alpha)}(\mathrm{B}(\beta,\mathrm{d}\beta)) = & \int_{\mathrm{Max}(\alpha,\beta-\mathrm{d}\beta^*(1-e)/2)}^{\mathrm{Min}(\alpha+\mathrm{d}\alpha,\beta+\mathrm{d}\beta+\mathrm{d}\beta^*(1-e)/2)} \mathrm{pc}(s)\mathrm{d}s \\ & - \int_{\alpha}^{\alpha-\mathrm{Min}(0,\alpha-\beta-\mathrm{d}\beta^*(1-e)/2)} \mathrm{pc}(s)\mathrm{d}s \\ & - \int_{\alpha+\mathrm{d}\alpha+\mathrm{Min}(0,\alpha+\mathrm{d}\alpha-(\beta+\mathrm{d}\beta+\mathrm{d}\beta^*(1-e)/2))}^{\alpha+\mathrm{d}\alpha} \mathrm{pc}(s)\mathrm{d}s\end{aligned}$$

Fig. 6 illustrates the final perceived area (the clear background) for three different dispositions along the same circular arc. In order to simplify the implementation, circular arcs have been sampled. l_u and l_d computations as well as final perceived covered areas are thus approximated. In order to keep close to exact results, we use a dense sampling interval, which of course, slows down our processes.

3.5. Shape simplification

Mathematical morphology (Schmitt & Mattioli, 1993) offers very powerful operators, which simplify the complexity of shapes without deteriorating the characteristics needed for labelling. Applying a morphological erosion operator proportional to the font size removes excessive detail of the area boundaries (Fig. 7). More complex morphological operations can be applied in order to reduce very complex areas to simpler ones (Barrault, 1998). Based on this coverage measure and the morphological operators, we now propose a process to label an area.

4. Labelling areas

An area to be labelled is defined by a closed polyline, a text to position, a fixed font and its parameters except the inter-letter and inter-word spacings, which are commonly controlled by cartographic rules with respect to the font parameters. Finally, an area label relies on six variables (xc, yc, R, α, sl and sw).

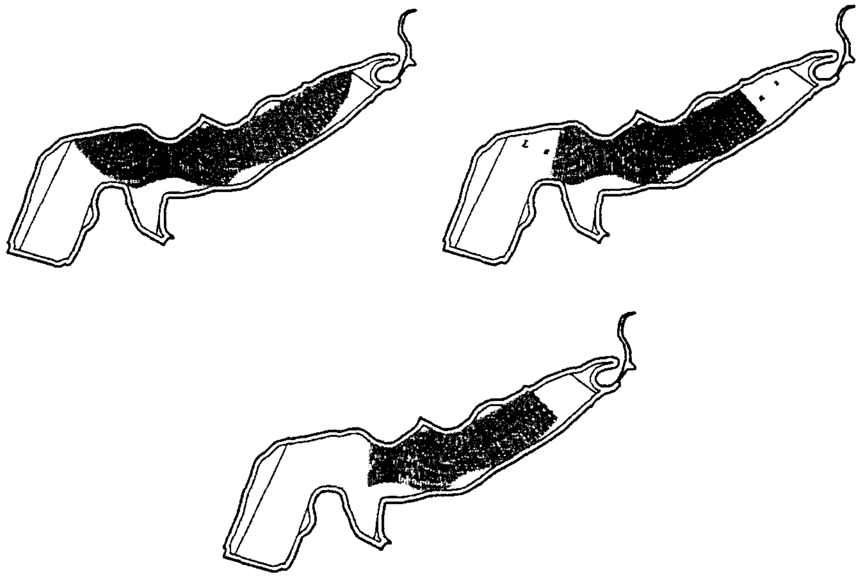

Fig. 6. The simulated perceived coverage. The best disposition covers the entire circular arc. A disposition that is too long prunes its extreme ends while one that is too short does not cover the entire arc.

Fig. 7. Morphological erosion on an area feature (black line). The most important part is extracted.

4.1. The process

The flexibility of spacing between words and letters of area labels drastically increases the amount of possible positions and thus impedes a realistic accounting of the solution domain. This domain can be pruned by selecting the best support lines

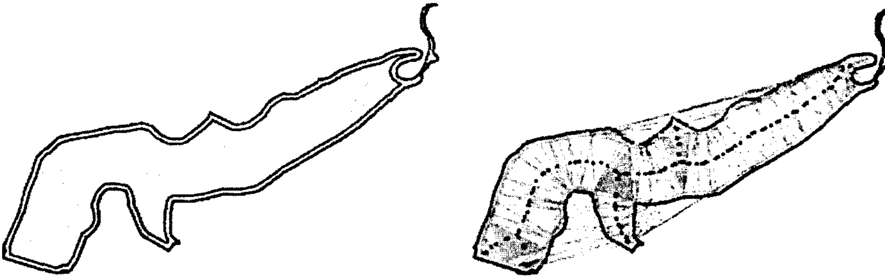

Fig. 8. Eroded area and its filtered skeleton.

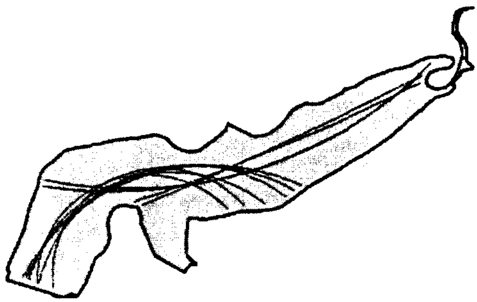

Fig. 9. A set of circular arcs (in white) and the best-selected candidates (in black).

and selecting possible positions by fine-tuning the starting-point as well as inter-letter and inter-word parameters along each support line.

The process first computes a set of circular support lines. The best ones are retained. It then tests all the candidate positions (with respect to their initial position, and the inter-letter and inter-word spacings) along each of the best support lines and finally selects the one that achieves the best area coverage with respect to the measure proposed above.

In order to simplify the coverage computation, the integral measurement has been discretised. A circular arc is then represented by a set of points spaced in a regular angle increment.

4.1.1. Support line extraction

The extraction of a set of support lines should follow three steps:

1. In order to reduce noise and to extract the most significant parts of the feature without distorting the global shape, morphological erosion is applied on the initial polygon (Fig. 8, left).
2. The polygon skeleton is approximated (based on the Delaunay triangulation of the eroded polygon; McAllister & Snoeyink, 2000) and filtered as shown on the right of Fig. 8 (although the erosion supplies a first efficient filtering, the smallest extreme edges of the graph are removed). The graph structure of the skeleton provides best paths (Freeman, 1995).

3. The 50 longest paths are retained. Each of them is approximated by a circular arc (Landau, 1987), centred on the largest suitable part of the skeleton. This provides a set of 50 circular arcs used as support lines.

4.1.2. Support line selection

A sub-set of previously constructed circular arcs is then extracted with regard to their perceived coverage. The coverage measure we proposed above is applied to the circular arcs but with a minimal longitudinal perceived extent (i.e. $e=1$). The 10 circular arcs with the best coverage values are retained. An example is illustrated in Fig. 9.

4.1.3. Generation of candidate dispositions

An important assumption is that font parameters remain fixed. A disposition is then defined by a starting point, an inter-word spacing and an inter-letter spacing. Since we intend to test each possible position so as to evaluate their coverage quality along each best circular arc, it implies four loops, which of course slows down the process. Defining the inter-word spacing as 1.1 times the inter-letter spacing has accelerated the process. Additionally, as will be shown in the last section this computationally heavy process can easily be improved.

4.1.4. Final disposition selection

The coverage of each candidate disposition is then evaluated with the previously proposed function. Since label placements in the absence of competing other labels (e.g. point labels) are likely to be highly satisfactory (see below), we added further spatial constraints to assess the behaviour of our measure for more difficult cases. Instead of placing first the area labels, they are positioned after punctual labels, although the final aim is obviously a mixed approach (that should negotiate between existing candidate positions of each label). Each disposition that has one of its words overlapping with a punctual label is removed from the set of final candidates. The best non-overlapping disposition is finally displayed.

4.2. Results

The whole process has been implemented in Lull, the interpreted language of the LAMPS2 software by Laser-Scan Ltd., Cambridge UK. Although this implementation obviously slows down the process (especially the path approximation with a circular arc), it provides a very good basis for rapid prototyping and does offer efficient geometric tools for simulating the morphological operators and computing the coverage distances. Test areas were extracted from the French BDTopo® database and from boundary data for some of the communes in the Canton of Zurich, Switzerland.

A cost value is defined, on [0,1], for each label disposition characterised by a baseline $B(\beta, d\beta)$ extracted from a support line $SL(\alpha, d\alpha)$:

$$C(B(\beta, d\beta)) = \sqrt{\frac{PC_{SL}(B(\beta, d\beta))}{S}}$$

S is the area of the eroded polygon. The square root is increasing the variations between best proposals, so as to emphasise the coverage attribute when further quality constraints are added (i.e. orientation and curvature). The best value for C is 0, the worst is 1 (note that it is a cost not a quality measure).

A first set of tests has been carried out on areas without any obstructing labels. They provided very satisfactory final dispositions as shown below for an artificial highly complex area (Fig. 10b) and for a French lake (Fig. 10a) as well as for Swiss areas (Fig. 11).

The next two results, for very long labels and areas (Fig. 12), show the problem of making the inter-word space proportional to the inter-letter space. Since the best extent is not reached (the inter-word spacing is too short), the end of the label is privileged because its perceived extent covers a larger area than the beginning of the label. These off-centre labels would not be selected with a better coverage of the inter-word spacing.

Next, obstructing labels have been added. For the French lake (Fig. 13), results remain very satisfactory even though the cost value increases since the label no

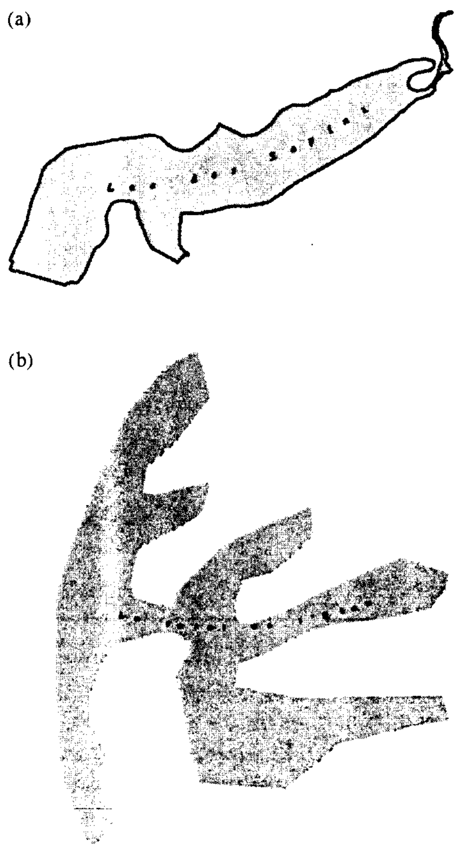

Fig. 10. (a) A labelled French lake. (b) An artificial complex area to label.

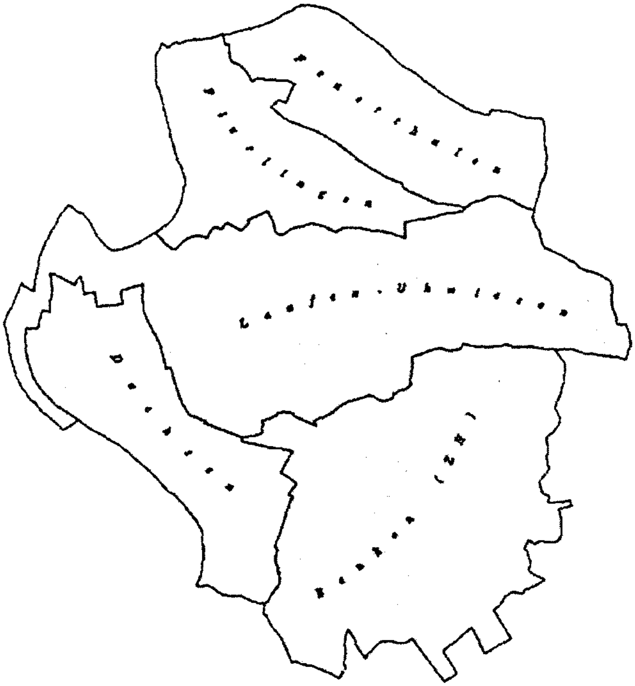

Fig. 11. Labelled Swiss areas.

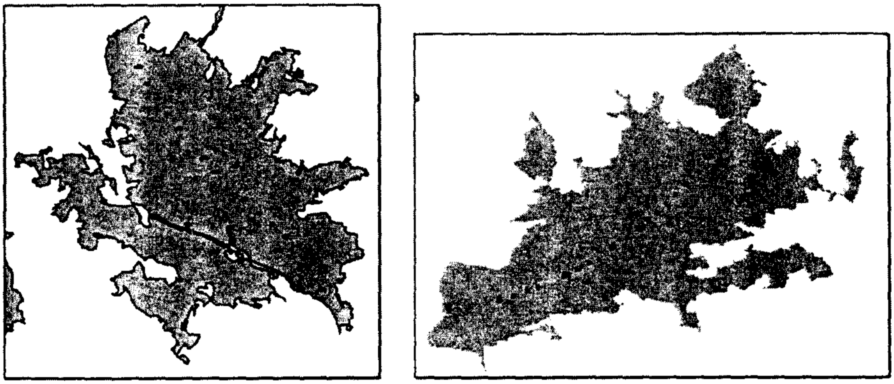

Fig. 12. Side effects of proportional inter-word spacing.

longer covers the right-hand part of the lake. The artificial polygon provides an interesting result that highlights the "non-uniqueness" of the solutions that are still satisfactory. Another, horizontal placement could lie in the lower left part of the feature, for instance. The question here is whether to display a legible label or a label that indicates the largest extent of the polygon.

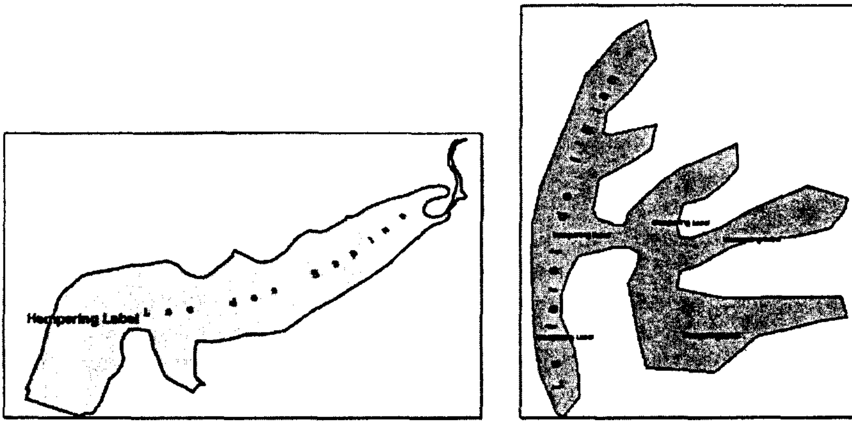

Fig. 13. Results with obstructing labels.

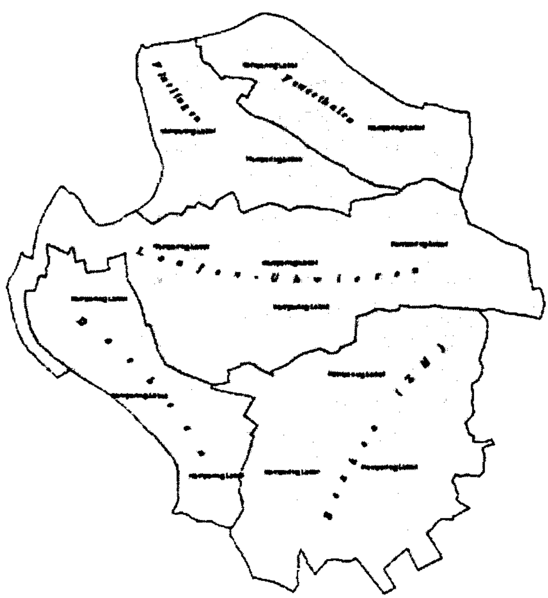

Fig. 14. Proposed dispositions with obstructing labels added. The lack of alternative support lines generates poor dispositions for the two areas at the top.

Results for the Swiss polygons with obstructing labels (Fig. 14) underline the importance of also retaining other circular arcs that may a priori be less adequate but could provide alternative positions, perhaps less satisfactory with respect to circle fitting but avoiding obstructing features (labels or cartographic symbols). The two areas at the top are poorly labelled since all the support lines selected overlap with punctual labels that the fixed inter-letter spacing cannot avoid. The available room below is not exploited since none of the retained support lines makes use of it.

4.3. Analysis of results

Our results are encouraging. Apart from generating sets of valid baselines, it seems our measures match the (highly subjective) human assessment and propose relevant label dispositions. But directions for further improvements are still warranted.

4.3.1. Latitudinal evaluation

It must be noted that the font size is only taken into account in the morphological erosion. The coverage measure could be improved so as to highlight the worst latitudinal ratios (lu/ld) with respect to the full latitudinal length (lu + ld). The longer the full length, the less small variations between lu and ld are perceived by the reader, and the more only extremely unbalanced placements will strike the map reader. The evaluation function may then be improved so as to increase the cost of poor ratios proportionally to the full latitudinal length.

Actually, preliminary tests showed that a slight smoothing of the ratios (by smoothing the shape with a Gaussian function) should cushion ratio jumps caused by narrow bends in the polygon outline, which the reader does not really notice but which bias the evaluation measure. The main drawback of such an approach is that although the measure fit to the human assessment, it can only assess proposed candidates, and can't on its own propose "the" best disposition. It means the support lines as well as the generation of candidate dispositions must meet the expected best disposition or at least one that comes close.

4.3.2. Generation of candidate dispositions

For a polygon that is not obstructed, the best disposition can be easily computed. A start-point al at 1/6 of the best support line is chosen as well as a pair (sl, sw) among the possible inter-letter and inter-word spacing combinations that bring the endpoint $d\beta + \beta$ to 5/6 of the support line.

For crowded areas, the obstructions are projected on the circular arcs: sections of the circular arc where a hampering label is lying are detected. They will define forbidden sub-sets within the angle variation of the circular arc that no letter may overlap. Since any letter position can be computed as a function of the start-point, the inter-letter, and the inter-word spacings, we obtain a set of linear constraints on sl, sw and β. $PC_{SL}(B(\beta, sl, sw))$ must then be optimised subject to these constraints.

4.3.3. Extraction of support lines

The construction as well as the selection of support lines must be improved since it tends to retain sets of closely clustered circular arcs, which should all be forbidden when spatial constraints are added. Alternative circular arcs must then be evaluated and retained based on other criteria than good area coverage alone.

It should be noted that the task of support line evaluation offers an interesting area of improvement for the field of automated label placement as a whole as it will allow the search for optimal placements to rely no longer exclusively on the algorithm that provides the candidate positions. Our procedure offers an a posteriori evaluation of proposed locations, needed as soon as further spatial constraints occur that the placement generation algorithm does not handle.

4.3.4. A more global issue

Finally, legibility constraints can be added so as to select between close candidates. Although the main orientation is a criterion (θ is the orientation of the segment defined by the two extremities of the circular arc), it should be taken into account with respect to the curvature, since the more curved a label becomes, the less the orientation is meaningful as a legibility measure. We propose to use, as an appropriate measure $O(L)$ of the orientation quality of a candidate position L, $O(L) = (2\theta/\pi)^{\mathrm{Rmin}/R}$ where Rmin must be fine-tuned but should be related to the minimal extent (i.e. its size with respect to the spacings) the label may have.

A final quality function $Q(L)$, supplying a real value for any candidate position L, will then be defined as: $Q(L) = a.\mathrm{PC}(L) + b.O(L)$ where a and b are weights that will control the expected purpose (just displaying an feature's attribute, or highlighting the shape's characteristics) of the area label. The final selection should be the best position proposed for an individual area feature with respect to this function. But other cartographic rules may influence the final placement. Avoiding overlaps is the main constraint but since constraints that improve the placement between neighbouring labels are brought into the process, the best location with respect to the feature may no longer be the best one with respect to map legibility. The existing frameworks, with different goals, could be extended in several ways. On the one hand, the process could be fine-tuned for specific mapping tasks depending on the desired speed and cartographic quality, for instance, to quickly compute label positions or to assist a cartographer in a semi-automated system. On the other hand, the area labelling procedure could also be integrated in a global process for automated label placement, such as the one described by Barrault (1998) or by Lecordix et al. (1994).

5. Conclusion

This paper demonstrates an original process to generate and evaluate efficient label dispositions for an area feature. Based on two commonly known tools (a morphological operator and skeletonisation) and a novel quality function characterising the perceived coverage that a circular label arrangement implies, automated placement operations necessary to supply legible and aesthetically pleasing area labels are proposed.

This study takes place in the broader context of research that intends to automate the label placement with respect to cartographic requirements. By defining a quality measure for area labelling, it provides a way of selecting a posteriori, among a set of candidate dispositions, the best placement. But moreover, this should provide a more "objective" assessment that allows a global process to compare labels of any kind but of same importance (defined by the map requirements). This measure thus provides a new step in the direction of selecting the best arrangement between labels that offer a compromise between the legibility of individual labels, the identification of individual features, and legibility and clarity criteria for the maps as a whole (Barrault, 1998).

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