The Feedback Approach to Cartographic Areal Text Placement

I. Pinto and H. Freeman

CAIP Center, Rutgers University
Piscataway, New Jersey 08855-1390 (USA)

Abstract. For proper labeling of a bounded region in a geographic map, the label (text) should normally be placed (and spread out) so as to conform to the size and shape of the region and be easily perceived. To accomplish this automatically has proved to be a challenging task because of the infinite variations in shape and size that can be encountered and the requirement for avoiding overlap with other text or features. This paper describes a new approach toward solving this problem. Rather than attempting to develop an algorithm for directly accomplishing the task, the method employs a *feedback* approach, wherein an initial placement is made using a general placement algorithm, the result is evaluated according to established placement criteria, and the placement is then progressively modified to reduce deviation from the ideal. The technique has potential application also to other complex, two-dimensional shape-understanding problems.

1 Introduction

One of the most challenging tasks of map production is the labeling of a map's features – the points, lines and areas with which a map conveys spatial information. As a minimum, there must be no overlap with features or other text, each name must be placed so as to achieve unambiguous association with the feature to which it refers, and the text should be easily and quickly perceivable. However, for a high-quality map, the placement of a name should in addition convey information about the size, shape, and importance of the feature as well as about the spatial relationships between the feature and its neighbors [1]. Over centuries cartographers have refined the art of name placement to a high level of sophistication, recognizing that a map, as a medium for conveying spatial information, will be judged by the effectiveness with which it communicates – consciously as well as subconsciously – information to its viewers.

Although map information is today readily stored in the form of large computer files and accessible online via geographic information systems (GISs), the placing of text on a map is still largely a manual task, which, if not literally done by hand using techniques of scribing or pasting, is at least done by a human operator on a graphics workstation. The task is easy enough for an experienced cartographer; however, because of the complex spatial relationships that are involved and the spatial conflicts that must be avoided, its automation by computer has been inordinately difficult. Although there were some early attempts at automating the task [2], progress was slow until more computing power became available and a better understanding of the subtle complexities of the task was gained [3-5]. In the last few years good results have been achieved in certain specialized name placement tasks, such as soil map polygon labeling [6] and point-feature text placement [7].

We shall here address one particularly challenging name placement task, the one of placing a region's name so that it is spread out over the extent of the region and conforms to the shape of the region, as illustrated in Fig. 1. Cartographers consider such shape-conforming placement desirable for high-quality maps because, in addition to providing the reader with the name of the region, it simultaneously (and subconsciously) provides him with a perception of the region's size and shape. Of the various name-placement tasks, the placing of spread-out area-feature text is considered the most demanding. For this reason, when determining the order in which the various types of features are to be labeled, area-feature text is usually given priority over other placements.

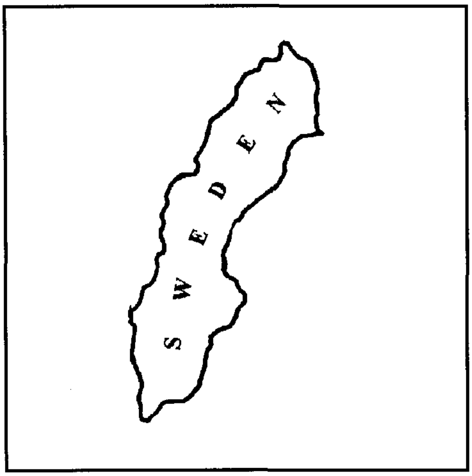

Fig. 1. Spread-out name placement.

The following are the main guidelines for spread-out area-feature name placement [1]:

1) The text should extend over the entire region and convey a sense of the region's size. It should lie entirely within the region, unless the region embraces some areas of water that can be said to belong to (or be associated with) the region.
2) The character size should reflect the size of the region.
3) The text should conform to the dominant shape of the region. There should be a space of at least 1½ times the width of the letter 'H' in the selected font at both ends of the text.
4) Horizontal (east-west) placement is the default placement and is preferred, unless it is clearly in conflict with criterion (3). (Note that "horizontal" means parallel to the constant-latitude lines of the map; for a small-scale map, the latter will likely be curved.)
5) Vertical placement is to be avoided.
6) Placements other than horizontal should always be curved. Circular arcs are preferred. No arc should exceed 60°. There should be no curvature reversal.
7) Text curvature should "harmonize" with the curvature of text in adjacent regions.
8) The text should be easily perceived and readable.

Several schemes for solving this particular map name placement problem have been devised in the past [3, 4, 8, 9]. One approach was based on extracting the region's skeleton and then using the dominant branches of the skeleton to form the baseline for the name. This scheme worked well in many cases, but could fail badly if the region was severely concave. Other schemes used the region's convex hull and the areas outside the region but within the convex hull to characterize the region's shape [8]. A number of variations on these ideas have been explored [9]. Almost every new approach was able to achieve good placement in some cases where others failed; however, none could be relied upon to provide satisfactory placement in all the varied and complex region shapes that maps proffer.

2 The Feedback Approach

It was noted that, although, it did not seem possible to devise an algorithm that would place text properly in every instance, there appeared to be no difficulty in *criticizing* a particular placement and pointing out its deficiencies. This suggested an alternative approach: abandon the apparently fruitless attempt at finding an acceptable synthesis algorithm and instead concentrate on developing a sophisticated "evaluation" algorithm, i.e., an algorithm that would *evaluate* a particular spread-out placement and indicate in what ways it was deficient. The information thus gained could then be fed back into a "dumb" placement algorithm that would now be directed to minimize these deficiencies, as shown in Fig. 2. The process could iterate until the actual placement met the desired placement criteria.[1] In a sense, this concept is analogous to the feedback principle used effectively for more than half a century in the design of electronic amplifiers and control systems. It is on this concept that the technique presented here is based [10].

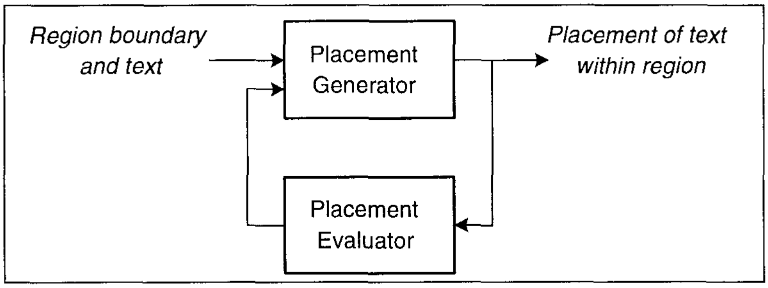

Fig. 2. The feedback placement scheme.

3 The Placement Method

As illustrated in Fig. 2, the feedback placement method involves two major components: a *Placement Generator* and a *Placement Evaluator*. We shall now describe these two components in some detail.

---

[1] The underlying idea is that it is easier to criticize than to create something; e.g., people who themselves are unable to sing may yet have a fine ear for judging the performance of an expert singer.

3.1 The Placement Generator

The Placement Generator consists of a set of software routines which generate a large set of potential text placements for a given region. First the region's bounding x-y extent rectangle is determined and the degree of convexity is computed as the ratio of the region area to the area of this rectangle. (It can reach a maximum of $\pi/4$ for a circular region.) A rectangular array of potential anchor points is then overlaid on the region, with the array resolution varying inversely with the convexity ratio. This is illustrated in Fig. 3.

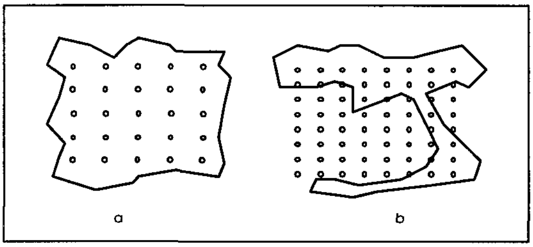

Fig. 3. Two regions and their overlaid anchor-point arrays.

The anchor points are candidates for the start and end points of the text's baseline. Since the entire text must be contained within the region, any anchor points lying outside the region can be immediately eliminated.[2] Further, there is a minimum distance that must exist between the baseline's anchor points which depends on the text's length (number of characters and font size). This very much limits the pairing of anchor points to serve as candidates for a baseline's start and end. Also since the objective initially is merely to localize the search for final text placement, a relatively coarse anchor-point array can be used. Once the search has been localized, a finer-resolution anchor-point array is called upon to obtain precise anchoring of the baseline.

A tabulation of candidate anchor-point pairs is made next. These will be evaluated by the Placement Evaluator module and the 10 best (i.e., highest scoring) pairs selected. In a subsequent iteration, anchor points at finer resolution are chosen in the neighborhoods of these high-scoring anchor-point pairs and the process is repeated, with the 10 best again selected.[3] The process terminates when successive improvements become diminishingly small.

3.2 The Placement Evaluator

The Placement Evaluator is the central component of the system. Its task is to examine a particular placement presented by the Placement Generator and to assign it a score. The score will be a measure of the placement quality, and will be based on a weighted combination of measures derived from generally accepted standards for manual text placement. In the implementation described here each placement was evaluated according to five criteria.

---

[2] If the region has an associated exterior body of water that can be considered to belong to it, such as a bay or gulf, that body's area should be included within the region prior to commencing text placement. A similar rule would have to be followed for placing the text for an archipelago.

[3] The number 10 is arbitrary. A larger number may enhance the chance of ferreting out a superior placement, though, at the cost of increased computation time.

The total score for a particular placement S_T is given by the product:

$$S_T = \prod_{i=1}^{n} F_i(M_i) \quad (1)$$

where M_i is the i^{th} criterion score and the $F_i(M_i)$ are the associated nonlinear criteria weighting functions. The 5 criteria used are as follows: [4]

Length: In general, a longer, spread-out placement is preferred over a shorter, compressed one. The maximum length can approach the length of the major diagonal of the bounding rectangle. The length measure M_{LEN} is defined as:

$$M_{LEN} = L_p / L_d \quad (2)$$

where L_p is the Euclidean length of the placement and L_d is the length of the bounding rectangle's major diagonal.

Clearance from boundaries: A minimal clearance from the boundary is essential. A clearance somewhat larger than minimum is generally preferred. The maximum clearance is taken as 1/2 of the width of the bounding rectangle.

A smaller clearance can be permitted in areas where less space is available for placing a name. A good measure of the available space is the ratio between the area of the region and that of the bounding rectangle, denoted the *area ratio*. For a region with an area ratio of 0.8, the clearance measure is defined as the ratio between the minimal distance from the boundaries and 1/2 the width of the bounding rectangle. This measure is modified according to the actual area ratio to have a larger value if the area ratio is smaller then 0.8 and a smaller value if the area ratio is larger then 0.8. The clearance measure M_{CLR} is given by

$$M_{CLR} = (.8/R)^{.25}\, d/(0.5\, W) \quad (3)$$

where d is the smallest distance from the placement to a boundary, W is the width of the bounding rectangle, and R is the ratio between the area size and the bounding rectangle. The parameters were determined empirically.

Symmetry: Symmetric (or centered) positioning of the name is preferred, if possible. The symmetry is in terms of the ratio between the left and right distances between the ends of the baseline and the corresponding boundaries. The symmetry measure M_{SYM} is defined by:

$$M_{SYM} = d_l / d_r \quad (4)$$

where d_l is the distance between the left edge of the placement and the boundaries, and d_r is the distance between the right edge of the placement and the boundaries. If the symmetry value is greater than 1, it is inverted to place it in the range [0,1]. A perfectly symmetric placement will have a symmetry value of 1.

---

[4] Additional criteria can be used to enhance quality or to embed constraints for specialized maps.

Horizontal placement: Where applicable, it is preferred to position the name horizontally. The horizontal placement measure M_{HOR} is given by

$$M_{HOR} = H_p / L_p \tag{5}$$

where H_p is the height of the placement given by $abs(Y_{max}-Y_{min})$, and L_p is the Euclidean length of the placement. (See Fig. 4.)

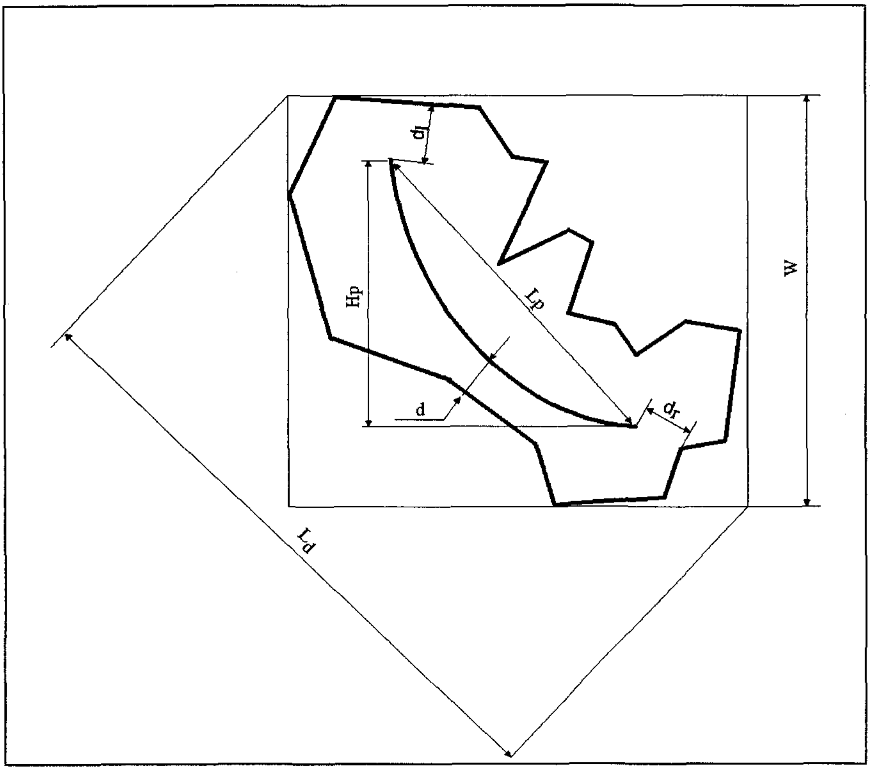

Fig. 4. Parameters for evaluating a placement.

Conformity: Good conformity of the placement to the shape of the region is particularly desirable. We arrive at the conformity measure by dilating the placement curve (i.e., expanding it uniformly in all directions) until it covers 85% of the region area. At this point we note by how much the dilated area spans beyond the region area. For illustration consider the two placements shown in Fig. 5. From a quality point of view they are equal with respect to all the other criteria. Both are centered on the region and are of equal length. However, we observe that to cover 85% of the region, the curve in (a) needs to be expanded less than the curve in (b), indicating the better conformity of the former.

The conformity measure M_{CON} is defined as

$$M_{CON} = A_c / A_e \tag{6}$$

where A_c is the area of the original area image that is covered, and A_e is the area of the corresponding expanded arc.

3.3 Obtaining the score functions

In order to arrive at a composite "score" for a particular placement, we use non-linear score functions to place the different criteria scores on a comparable basis, prior to multiplying them as per eq. (1). A set of 5 score functions is needed, one for each of the criteria scores. The score functions were determined empirically by generating a large number of name placements, evaluating these visually, and then adjusting the individual scoring functions so that they would yield the desired result. The process was repeated a number of times until all the placements for a large variety of different-shaped

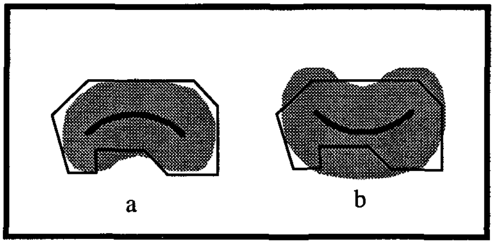

Fig. 5. Obtaining the conformity measure. Expansion of curve (a) is smaller than that of (b), signaling that curve (a) conforms better than (b).

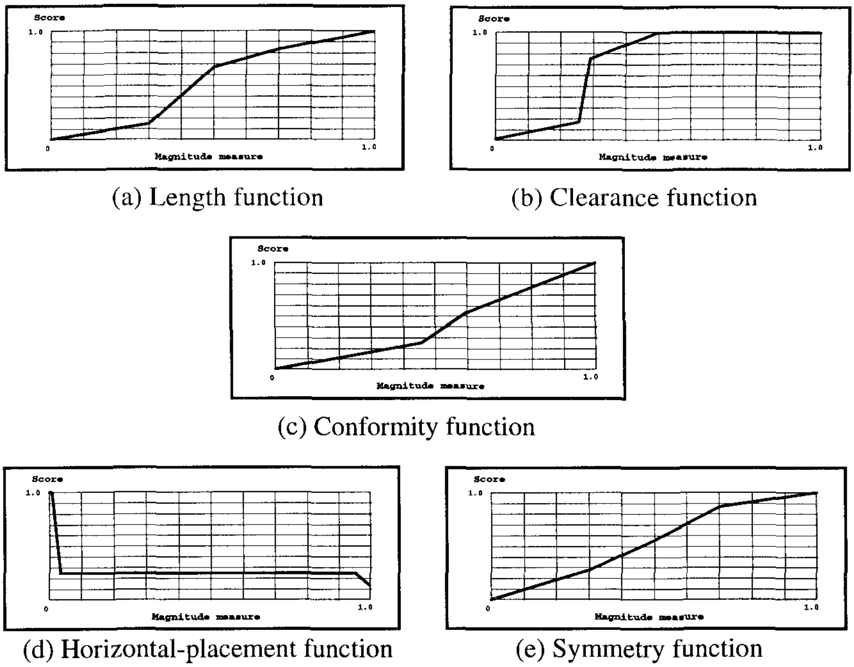

Fig. 6. The 5 criteria weighting functions.

regions were satisfactory.[5] The particular score functions that were obtained as a result of the above process are shown in Fig. 6.

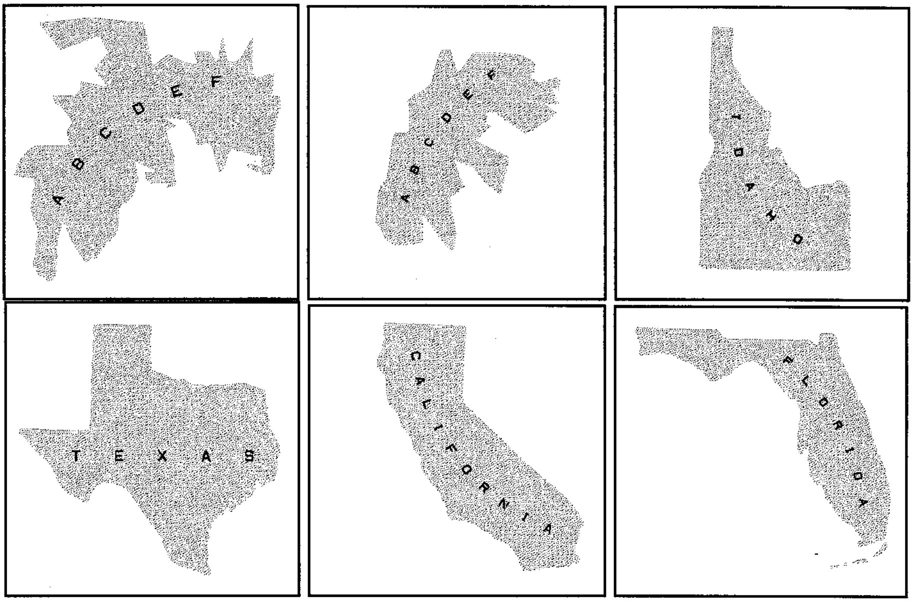

Fig. 7. Some examples of regions with automatically-placed, spread-out names. The two examples in the upper left represent synthetic regions; the rest are actual map regions.

The inputs to the score functions are the various criteria measures as described in Section 3.2. The outputs from the score functions are normalized to fall in the range [0,1]. In all cases the maximum value is set to 1; however, the minimum value is not necessarily set to 0.

4 Results and Conclusions

The foregoing technique was applied to a variety of different-shaped regions. Although previous schemes were able to obtain equally good results in some (or even many) of the cases, none of them were able to obtain good results in *all* the cases. It is this universal power of the new technique that makes it so attractive. A selection of some spread-out text placements produced by this technique is shown in Fig's. 7 and 8. All these name placements were performed fully automatically, without any human intervention whatsoever.

One drawback of the method described here is that it tends to be time-consuming; however, the amount of time required increases roughly proportionally to the desired quality of placement, a tradeoff that is generally acceptable. Further development of

---

[5] The actual "training" process is fairly complex; the details are beyond the scope of this paper.

the method is planned to incorporate additional evaluation criteria (which could be optionally invoked when particularly high placement quality is desired) and to explore ways of speeding convergence.

The reader may have noticed that we completely ignored the question of conflict with other features or other text, which is normally the dominant concern when considering automatic name placement [5, 7]. The rationale for this was that since the placement of spread-out area-feature names is such a demanding task, it should be carried out first, before any other text is placed, and without regard to potential overlap with other features [4]. Once the placement has been accomplished, it must be inspected for overlap with point features. If instances of such overlap are found, then usually only very small shifts in the placement are required to resolve the conflict. If the font is of a large size and the characters are widely spaced, an alternate approach is to make very small lateral shifts in individual characters. By giving

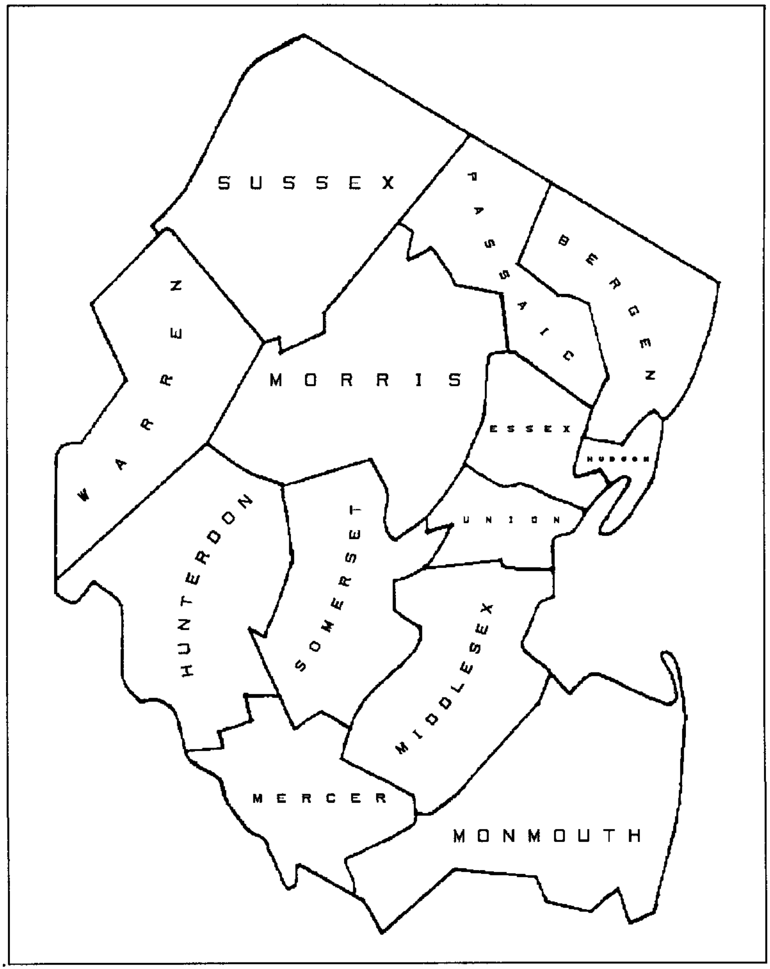

Fig. 8. Automatically placed area-feature names.

priority to the placement of area-feature names, we pass the burden of avoiding conflict with point- or line-feature names to the latter. This is advantageous, both because the degree of freedom for placement is greater for them, as well as because numerous effective techniques for overlap-free placement for them now exist.

References

1. Imhof, E., "Die Anordnung der Namen in der Karte," *Annuaire International de Cartographie II,* Orell-Füssli Verlag, Zürich, 93-129, 1962.
2. Yoeli, P., "The logic of automated map lettering," *The Cartographic Journal, 9* (2), 1972, 99-108.
3. Ahn, J. and Freeman, H., "A program for automatic name placement," *Proc. AUTO-CARTO 6,* Ottawa, 1983. 444-455.
4. Freeman, H. and Ahn, J., "On the problem of placing names in a geographic map," *Int'l. Jour. of Pattern Recognition and Artificial Intelligence, 1,* (1), May 1987, 121-140. 4.
5. Doerschler, J. and Freeman, H., "A rule-based system for automated name placement," *Commun. ACM, 35* (1), 1992, 68-79.
6. Freeman, H., "On the automated labeling of maps," in *Shape, Structure and Pattern Recognition,* D. Dori and F. Bruckstein, eds., World Scientific, Singapore, 1995, 432-42.
7. Christensen, J., Marks, J. and Shieber, S., "An empirical study of algorithms for point-feature label placement," *ACM Trans. Graphics, 14,* (1), 1995, 203-232.
8. Lacroix, V., "An improved area-feature name placement," Tech. Rept. IPL-TR-064, Image Processing Lab., ECSE Dept., Rensselaer Polytechnic Institute, Troy, NY 12181, 1984.
9. Nastelin, J., "Optimization of baseline determination for area map annotation, Tech. Rept. IPL-TR-078, Image Processing Lab., ECSE Dept., Rensselaer Polytechnic Institute, Troy, NY 12181, 1985
10. Pinto, I., "Area name placement for automated cartography," Tech. Rept. CE-104, Dept. of Electrical and Computer Eng'g., Rutgers University, Piscataway, NJ 08855-0909, April 1994