Intelligent Progressive Model (IPM) for Label Placement of Cartographic Dense Point Features*

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Abstract

An Intelligent Progressive Model (IPM) is given in this paper to solve cartographic point feature label placement, which works very well for the dense point features. IPM imitates cartographer's thinking in cartographic processes. The final places of labels are not completely limited in the given set of typical places of labels. The rules observed in label placement must be formulated. The strategies of the rules application are established to drive the model. The greatest-probability placements are the bases of a following process. The trivial repositioning method of labels is employed, in which the overlapped labels are not necessarily deleted, but transformed according to spatial relations with their neighbors, in order to avoid giving up freely in the current awkward conditions. Therefore, the final label placements of points are not restricted in the finite set. Like selecting the typical placement, the directions of trivial repositioning are ranked according to the preference degrees of relevant placements of this current point label. This process is progressive and repeated.

Keywords: Dense Point Feature, Automated Label Placement, and Spatial Relation, Intelligent Progressive Model (IPM), Rules for Label Placement

1. Introduction

Map label placement is a time consuming work in the manual and automatic map making and the GIS

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output, which is a strongly subjective problem and depends on the experience and aesthetic judgement of the map producer. Automatic annotation of map feature has been a stubborn task in computer aided cartography for a long time. Numerous efforts have been made and many models are given for different purposes. The computational complexity of automatic label placement of point features is NP-hard (Zoraster, 1997), so previous researches are mainly aimed to reduce the processing time, and to optimize the label placement. Even earlier, some researchers have worked to summarize the rules about label placement to facilitate the expert system. However, recently most methods are based on optimization theory, including integer-programming, simulated annealing, etc.

The previous works are mainly based on limited given typical places of a label. Every feature's label placements should be in an infinite-elements set and are appropriate to be used independently. Chinese annotation can be placed in upright manner as well as horizontal manner that differs much from the Latin words.

In this paper, the authors present an intelligent progressive model (IPM) for label placement of point features, this model is convenient to be implemented, and is efficient for dense point features. First, the basic rules and application are discussed. Second, IPM in detail is presented.

2. **Classification and Application of Rules**

2.1 Rules for Label Placement of Point Feature

In map production, there exists a multi-phase with the spatial reasoning in the cartographer's mind when he decides where a label can be placed. The label placement is effected by the individual subjective, which combined exterior alternative factors. Those factors are constrained by cartographer's geographic cognition, aesthetic view and experience in map mapping (Imhof, 1975). It is known that different cartographers will give different results of label placements even on a same map. Here, five rules for point features are employed in the following test.

1). Labels should not overlap any point features.

2). Each label should not overlap any other labels.

3). Visual distance between a point and its label should be longer than the other point features with this label.

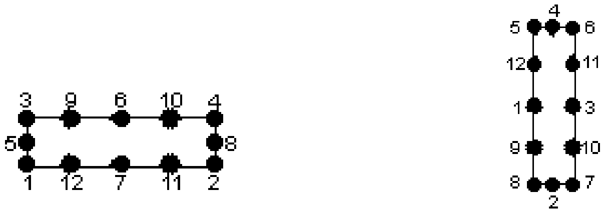
4). If there are conflicts among labels from different ranks, labels with low rank are repositioned firstly.

5). All places of each label are not limited in a finite set, and different placements have different priorities.

The shape of a label can be regarded as a rectangle with its minimal bounding box. The feasible way is based on a heuristic idea. Because the problem is NP-hard, we still take the typical placements as the first given set, and search the other placements around them by means of constraint rules. First, the typical placements and respective weights are determined with the cartographic rules. We can evaluate them, and select the reasonable ones. A succeeding process includes trivial repositioning for label placements, and optimizing of the intermediate results. In this test, the typical placements of a point feature are given (figure1). A label can be represented by a rectangle. The points on the rectangle denote positions of point features, and the rectangle of each placement is relative to the label. The numbers in Fig. 1 are their weights of label positions respectively. Low numbers are prior to other high numbers.

2.2 The Rules application

In the application of IPM, the above-mentioned cartographic rules are not considered at the same time. When the labels conflict with cartographic features, only the labels are appropriate to be repositioned. Therefore the first rule is comparatively simpler than others, and is applied firstly. While the labels are overlaying other labels, many methods can be used to solve this problem. If the conflict exists in the same rank labels, then the labels are repositioned along the same line. However, if these labels belong to different ranks, then the low label should be repositioned in all directions, even the current optimum situations become worst. In the optimum model, several rules are considered.



(a) Horizontal direction (b) Vertical direction

Fig.1 Typical label placements for point feature

3. **Intelligent Progressive Model**

3.1 Generating a Typical Label Placement Set

Every point feature's label has its own infinite placements (Fig. 1). However, in order to facilitate the computational process, we had determined a seed set with limit typical places of a label. This seed set is as follows.

$Pm: [Pm_1, Pm_2, Pm_3,..., Pm_n]$;

m=1,2,M (the sum of points);

n=1,2,N (the sum of the typical and reasonable label placements of a point)

This set is a true subset of the optimal function's solution set. We call it seed set, because the next step will get more placements from the current elements. Each element in this set is attached a unique weight value, which is determined by 24 typical label placements. However, not all of them are put in the set Pm, because some typical places are not eligible for a point when the first rule is considered.

3.2 Determining Label Placements with the Least-Conflict

From the above-mentioned set Pm, the optimal solution can be determined by means of a following optimum model. This model is a following formula.

Formula, Min (Pm), $Pm_i = W_1 * F_1 + W_2 * F_2$, $i = 1, N$; $W_1 + W_2 = 1.0$

F_1 denotes the function for evaluation about Pm_i's relations with all possible label placements around a point feature; for example, the area of intersected parts of rectangles. F_2 denotes the weight function determined by cartographic rules corresponding with Pm_i, which effects the visual effect. W_1 and W_2 are the weights respectively. Every point can get Pm_k as optimal solution with this model. Now the set Pm: $[Pm_1, Pm_2, Pm_3, ..., Pm_n]$ is turned into $[Pm_k]$.

3.3 Optimizing the Typical Placement

The above-mentioned process is based on the local optimizing and the greatest probability of a label placement. Therefore, a general optimizing model is necessary. This model is same as the above-mentioned formula. But, F_1 denotes the function for evaluation about Pm_i's relations with only the above identified labels in set $[Pm_k]$; F_2 denotes the weight function, which is determined by cartographic rules, that influence the visual effect. The label placements of every point feature are evaluated with these constraints. When a better solution is found, the label placement will be recorded, as well as the value of evaluation and relative conditions. Otherwise, this process is repeated directly until no a better solution is found. Figure2 is the result of selected typical placements, and shows the conflict of rectangles. Figure3 is the result of general optimization.

3.4 Trivial Repositioning of Label Placements

In the previous works about automatic label placements, the label placements are selected from set with limited elements, but the practice of map production is not like this process. In order to placing the label as it is in the practice, we present a trivial reposition idea. When neighbor labels conflict, by repositioning one or two of them the awkward situations can be solved. Thus, the relative positions of the typical placements will not be deleted freely in this process, and should be imported into the solution set. Figure 4 shows one of those situations. If the label of point A transforms to right (or down) or the label of point B transforms to left (or up), the conflict will be solved well.

During repositioning labels, the transformation directions of labels are ranked according to the optimization formula. In figure4, the numbers beside arrows denote transformation orders of labels. If the transformation causes a new conflict, this action stops. Figure 5 is a snapshot during trivial repositioning.

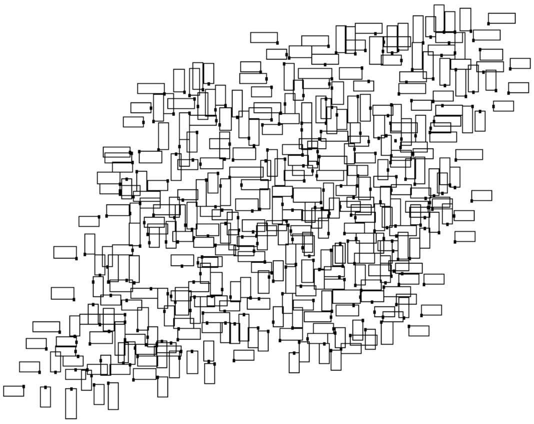


Fig.2 The conflict of rectangles

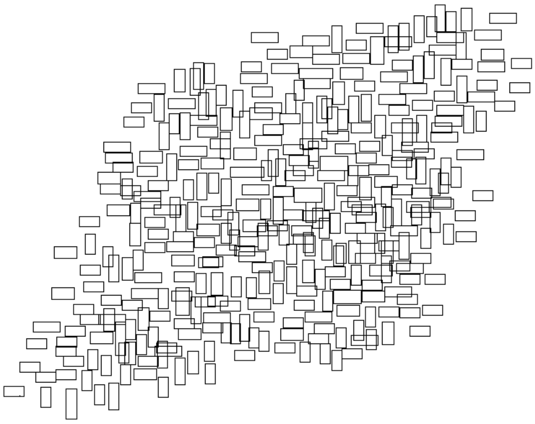
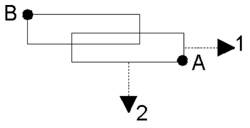


Fig.3 The general optimization of typical placements



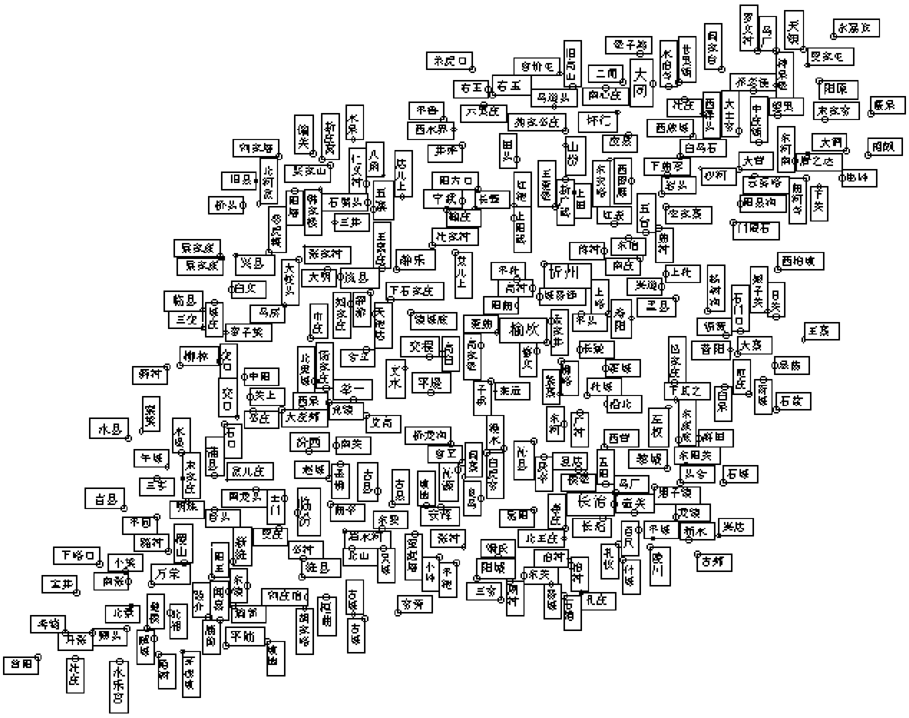


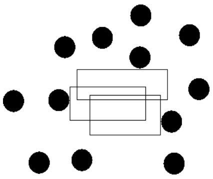
Fig.4 Fine revising principle

Fig.5 A snapshot during fine revising

3.5 Progressive Method of Label Placements

The label placement of every point uses the equivalent rules. However, these point features are handled one by one, so the order of the data handling effects the result of label placements. That is to say, the point feature with a later new label will maybe effect the earlier solution set of all point features. The earlier ones maybe have even more choices, when the later ones get their places. At this time, the label placements can be still optimized. This process is also repeated. In fact, every step in our test, including selection of typical placements, optimization of typical placements and trivial reposition, is all under this idea. Whether the iteration stops is determined by the change of evaluation function.

Because of some awkward situations, some labels can not be placed. Figure six shows that the trivial reposition is not applicable. If the label of a point feature intertwines with more than two labels, this label



will be deleted (Fig. 6). Figure 7 is the result of the test with IPM.

Fig.6 An awkward situation

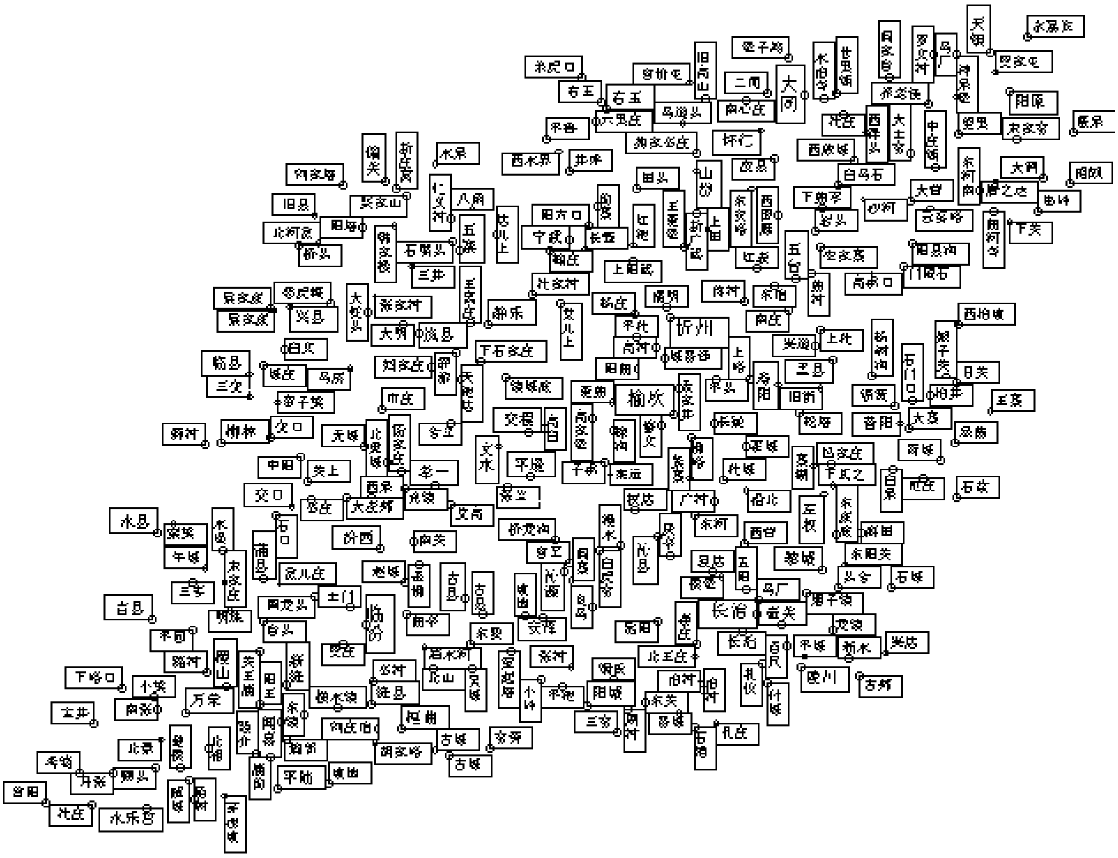


Fig.7 The result of label placements with IPM

4. Discussion

In order to facilitating the measure of spatial relations between a current label and its neighbors, it is reasonable to cluster the point features, because the labels or related point features only in a certain cluster influence each other.

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