A Label Placement Method for the Context Aware Map Synthesizer

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The Context Aware Map Synthesizer is a map projection technique where users are allowed to apply different scale transformations to different parts of the map according to the user's interest. Using the map synthesizer it is possible to blow up places of higher interest while other places are still in a smaller scale. In the map synthesizer, while map features can be viewed at different scales, some text labels either come too close to each other or overlap other labels in the neighborhood. In either case the labels hide parts of interest of the user. In this paper, we present a new label placement method for the context-aware map synthesizer. The main feature of our method is to compute user's focus areas from the transformation of a given map automatically, and apply the Tabu search and random filtering algorithms to the labels on these areas. By this strategy, our method makes it possible to put more labels without conflicts in a short time. This method improves the visibility of the area of interest of the user. We show by experimental results, the feasibility and the effectiveness of our method.

1. Introduction

There are many map projection techniques that have been proposed over the years. The Context Aware Map Synthesizer [1] is one such technique. What makes this projection technique different from other techniques is that it allows the user to manipulate its scale at run time, allowing the user to view different parts of the map at different scales at the same time.

Nevertheless when allowing dynamic changes to be made on graphical features of the map, same rules that apply for graphical features cannot be applied on the labels that describe the graphical features.

- Any label present on the surface of the map should not overlap any other label on the map.
- The size of the labels should be such that they are easily comprehensible.
- For every label displayed it should be clear which graphical map feature it associates with.

In this paper we present a label placement method for the context aware map synthesizer. The main features of this method is that we make it possible to display more number of labels without conflicts on the map by using the Tabu Search Algorithm followed by the Random Filtering techniques. These methods are applied on a reduced area of the map. i.e., the user's focus area only. Hence the Tabu Search Heuristic does not take up a lot of computation time.

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2. The Context Aware Map Synthesizer

The Context Aware Map Synthesizer is a special kind of map projection technique, where the map frame can be manipulated as if it were an elastic sheet. With its help the user can automatically change the scale of different parts of the map. This would mean that at any point of time, a single frame of the map would be displaying various map features at various scales according to the specifications of the user. The Context Aware Map Synthesizer has been developed keeping in mind web based automated map projection as one of its foremost applications. The Context Aware Map Synthesizer implements a space filter for scale transformations within the map.

The space filter is applied to a particular space on the map so that transformations may be made according to the conditions of the user.

The working of the space filter is described using Figure 1. In the figure solid lines represent map objects and the dotted lines represents the frame over which the map is displayed.

Initially all vertices of all map data within the frame are projected from the map coordinate system to the display frame's coordinate system. (Figure 1(A) → Figure 1(B)). In this case the projection is made as such to the display coordinates. Points P and R become points P' and R' respectively. However point Q does not appear in the display frame because its coordinates lie beyond the scope of the display. Every point that lies within the display frame undergoes similar transformation and is projected to the display coordinates.

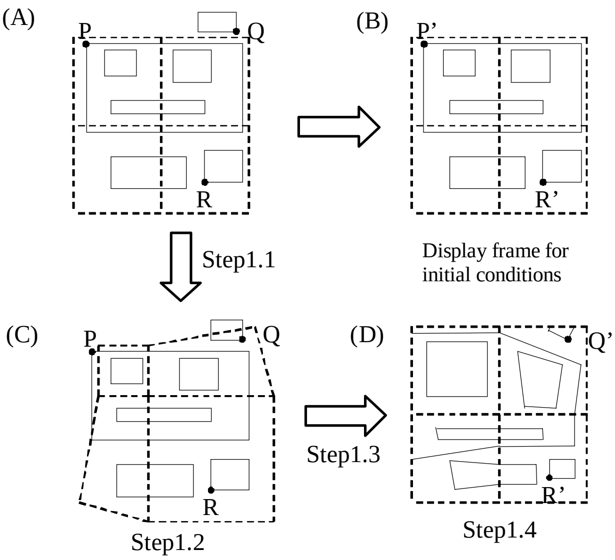


Fig 1. Transformation of map by using Space filter

However when there is a change in the display coordinates according to the proposal of the map synthesizer the transformation is done in the following way.

Step1.1: Change in the coordinates of the display frame: The map data is not transformed at this time. The dotted line in figure1[C] illustrates this.

Step1.2: Projection of the points of the map objects with respect to the new display frame. As we see in figure 1[C] points Q and R are projected to the display frame.

Step1.3: Reconstruction of the map: The map is reconstructed inclusive of all changes that were incurred in Step 1.3. For example, considering figure 1[C], the mesh on the bottom right is magnified. In order to bring it back to its original position the size of the object whose vertex is R is reduced to a smaller scale as shown in figure 1[D].

Explaining the use of the Map Synthesizer with an example: Consider a case where the user has to travel from Place A to Place B, both accessible by train though it is necessary to walk from the station. Assuming the user is unfamiliar with both place A and place B, he/she will require a detailed view of Place A and Place B and also the overall view of the train route from Place A to Place B. Under normal conditions the user would end up with three frames each containing a detailed view of Place A, a detailed view of Place B and an overall view of the route from Place A to Place B respectively. In the case of the Context Aware Map Synthesizer all three frames would be integrated into a single frame.

3. The Proposed Label Placement Method

Motivation

In a real time applications such as the map synthesizer one cannot predict the different configurations in which the user would be viewing the map. Since the scale changes in the map are irregular, possibilities of labels conflicting with each other under certain circumstances increases. For this reason it is necessary to have a method by which appropriate label positions may be calculated in real time.

Fig 2 The Context Aware Map Synthesizer introduces new conflicts between the labels when slight scale changes are made

Figure 2 shows the Context Aware Map Synthesizer. Both the figures illustrate the same area of the map. The only difference between the two figures is that while the figure on the left contains all the features in a uniform scale the figure on the right has slight scale changes in the marked area.

From the figures we see that a small change in the scale of the map at certain places may move a few labels around the map and hence may trigger new conflicts among the labels. Hence a need arises for real time selection and display of labels on the map.

The Execution Procedure

The label placement method proposed in this paper is performed by the following procedures. Figure 3 shows the various steps that were followed in the implementation of the label placement method.

Step 1: Scale transformation on the Map Synthesizer

As explained in section 2 the Map Synthesizer allows for non-uniform scale changes on the features of the map.

Step 2: Determination of user's focus area

The Context Aware Map Synthesizer allows the user to select and enlarge preferred areas at run time. Therefore as a requirement it is best to give more importance to the labels that are present within the users interest. The labels on the other areas can be given secondary importance. For this reason it is necessary to calculate the users focus area on the map at run time. The exact process undertaken for the determination of the user's focus area is explained in the next section.

Step 3: Application of Tabu Search

When conflicts occur between labels on the map, in most occasions these conflicts may be corrected by moving the labels to a different place around the point. Since the labels would still be around the point, there will not be any confusion as to which geographical feature it describes. Currently a new location for each label is chosen from nine possible locations around the point.

Step 4: Random Filtering

Even though correction by the Tabu Search algorithm has proved to be useful on many occasions there are certain occasions when Tabu Search fails to correct all the possible conflicts on the map. This happens in cases where the density of labels present in the area is so high that no matter where the labels are moved to they still conflict with other labels in the area. One probable solution to this problem would be to remove certain labels in the area and display the other labels. Currently we have devised a random deletion method that removes either of the conflicting labels at random.

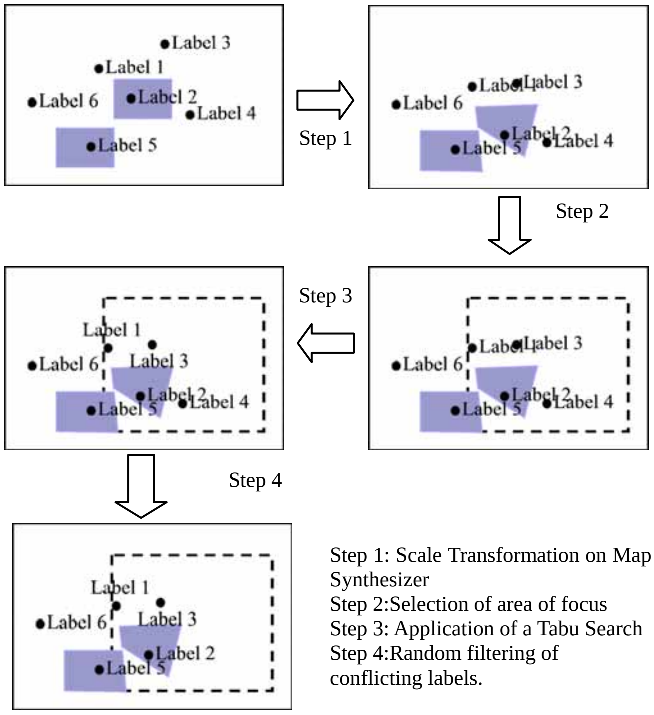


Fig 3. The Proposed Label Placement Method

4. Determination of user's focus area

All features on a vector map are primarily defined by points on the map surface. These points form the basic building blocks for all the lines and polygons that are drawn on the map surface. Irregular scale changes on the map surface result in changes in the position of the points in the area with respect to the other points in the map. Such points that experience a change in their relative positions are calculated. The smallest rectangle that encloses all these points gives the focus area of the user. The steps followed are illustrated in Fig 4 and are explained as follows:

Step 2.1: Fig.4A shows a prototype map. Fig. 4B is the same map shown as line drawing for sake of clarity. All vertex points of the map features in Fig 4B are calculated. Fig. 4C shows all the vertex points. Let the set of points before transformation be given by,

$$P = \{p_1, p_2 \ldots p_n\}$$

For easier understanding Fig 4C' is a simpler version of Fig. 4C. The set of points on Fig 4C' is given by,

$$P = \{A, B, C, D, E\}$$

Step 2.2: When scale transformations are made on the map as shown in Fig. 4D, the points on the map move with respect to each other. The new positions of the points would be given by set,

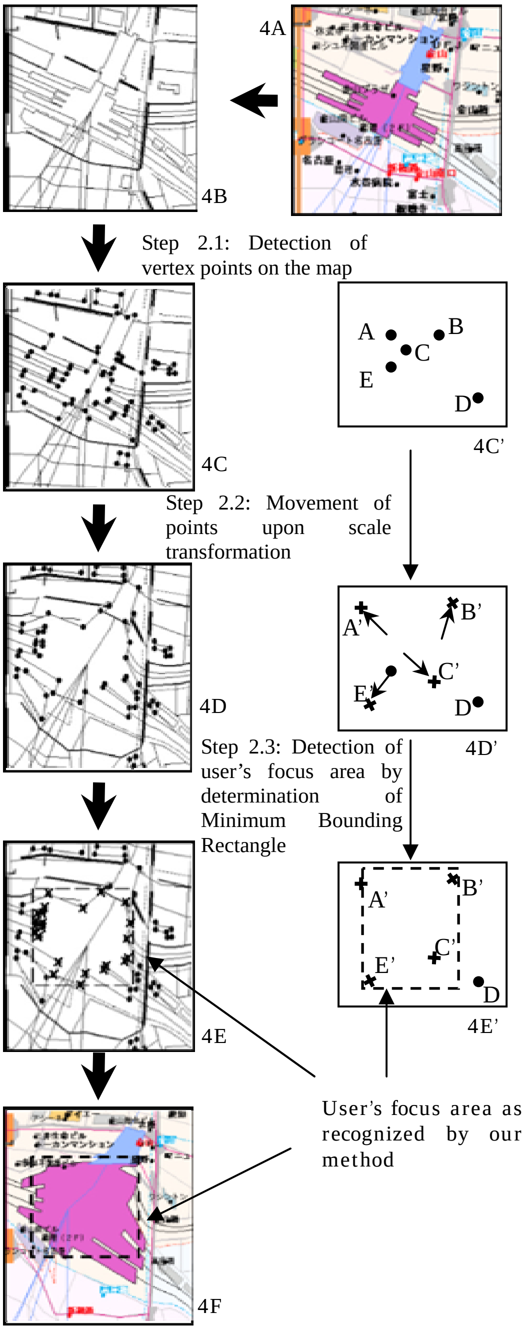


Fig 4. Determination of user's focus area

$$P' = \{p_1', p_2' \ldots p_n'\}$$

Fig 4D' shows the actual movement of the points. The set of points on Fig 4D' is given by,

$$P' = \{A', B', C', D', E'\}$$

Step 2.3: P" is a set of points from set P' such that the individual points change in their relative positions. On doing a one to one comparison of each of the elements in set P and P', the set of points P" can be determined. In our example the set P" would be given by,

$$P'' = \{A', B', C', D'\}$$

The Minimum Bounding Rectangle that encloses all the points belonging to set P" gives the focus area of the user. Fig 4E' shows the rectangle enclosing all points given by P". Fig 4E shows the focus area in the map. Fig 4F shows the original map.

5. Experimental Evaluation

Table 1: Experimental Results.

Placement Method	Magnification of features within the frame.			Pulling in features from beyond the frame		
	Time (secs)	No. of Labels	No. of Conflicts	Time (secs)	No. of Labels	No. of Conflicts
Method 1 [Proposed Method]	0.401	28	0	1.332	62	0
Method 2	2.293	31	7	7.781	90	32
Method 3	3.966	18	0	4.106	35	0
Method 4	5.689	28	0	9.974	62	0
Method 5	0.321	31	26	0.631	90	77

We have performed an experiment to clarify the feasibility of our label placement method.

Experimental method

The Context Aware Map Synthesizer offers two characteristic transformations.

a) Magnification of scale of features within the frame.
b) Pulling in features from beyond the frame.

In each case we have evaluated and compared the number of conflicting labels in the focus area of the user and the execution time in each case.

Method 1: [The Proposed Method]

In this method we have used a combination of the Tabu Search and the Random Filtering Techniques within the focus area only.

Method 2:

Here the Tabu Search Algorithm is applied throughout the frame. The table shows the number of labels in the focus area and their conflict numbers.

Method 3:

In this method conflicts have been brought down to zero by removing either of the conflicting labels at random. The table shows the number of labels that remain displayed in the focus area.

Method 4: In this method the combination of Tabu Search and Random Filtering techniques is applied just as in method 1, but to the whole frame without isolating the focus area. When compared to Method 1 the execution time is phenomenally high.

Method 5: This is the conventional version of the Context Aware Map Synthesizer. Table shows the number of labels in the focus area and the conflicts that arise within them.

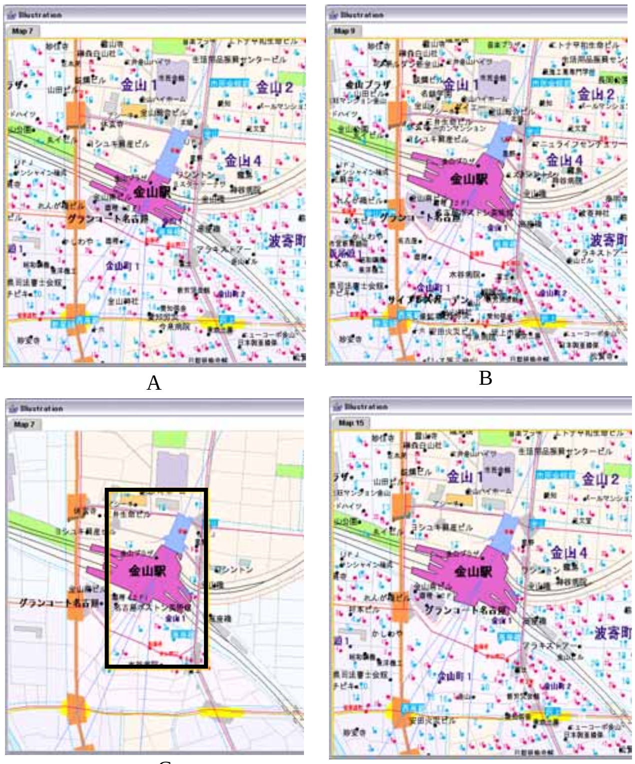
Experimental results and consideration

The results shown in Table 1 indicate that the proposed method moves and corrects conflicts among labels and removes them in the least possible time.

By the usage of method 1 more labels are placed on the map without conflicts than method 3, where either of the conflicting labels are removed at random without possible replacement. While by methods 2 and 5 it is possible to display maximum number of labels within the focus area they also allow for conflicts among labels. Method 1 nulls all conflicts among labels.

On comparing the execution time of the various methods we see that by the determination of focus area and restricting the label placement algorithm to the labels only within the focus area, the execution time can be considerably reduced. Method 4 has an execution time of 5.689 seconds when the user's focus area is not considered, while the proposed method has an execution time of only 0.401 seconds. Similarly in the second transformation namely pulling in features from beyond the frame, method 4 has an execution time of 9.974 seconds, while the proposed method takes only 1.332 seconds to complete. Figure 5 shows the experimental results.

The result of method 2 shows that it is not always possible to correct label conflicts by using the Tabu Search Algorithm alone. Tabu Search fails when the density of labels in the area is very high and there are better places for the labels to move around. Apart from this other failures like though conflicts are zero the labels are very close to each other and cannot be distinguished, when long labels are moved they tend to describe other map features rather than the ones they initially describe may arise.



A B C D

Fig 5. Experimental results

A. Original map
B. Map on scale transformation
C. Tabu Search and Random filtering applied on focus area
D. Tabu Search and Random Filtering applied on the whole map.

One of the main objectives of the Context Aware Map Synthesizer is that it should be usable in a web-based environment. For a successful web application the execution time plays a very important role. By experimental results we show that the method proposed in this paper solves the problem of label placement within minimum time. The experimental results have demonstrated the feasibility of the proposed method.

6. Related work

The Point Feature Labeling Problem is considered NP Hard because a single change locally in the position of a label may globally affect the positions of many other labels

Several algorithms have been proposed so far to solve the PFLP problem [2,3]. While these methods have their own advantages and disadvantages there are instances where these algorithms have failed to reduce conflicts between labels.

The Tabu Search Heuristic was proposed by Fred Glover [4,5]. Similar to other heuristics used to solve the PFLP problem, the Tabu search heuristic does not reduce conflict values among labels to zero under all circumstances. Nevertheless it is by far better than the other heuristics as shown in [6,7].

7. Conclusions and Future Work

By the experimental results we see that the proposed method where labels within the user's focus area are given primary importance and conflicts arising among them corrected, is a very feasible method for label placement. Using this method maximum number of labels displayed within the focus area without conflicts with very little compromise in the execution time.

The random filtering method used to reduce conflicts shows that with a minimum number of labels removed, conflicts that could not be corrected can be corrected. Nevertheless it is not a very plausible solution to the label placement problem. Hence a better method wherein the labels that are removed from the map are selected by the user's context should be used. Future work will be based on the above-mentioned problem and also in determining accurate focus area of the user.

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