Journal for Geometry and Graphics
Volume 5 (2001), No. 1, 61–69.

A Deformation Algorithm of Railway Maps

Takafumi Noguchi, Yoshio Ohno

Faculty of Science and Technology, Keio University
3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Japan
email: ohno@on.cs.keio.ac.jp

Abstract. Railway maps are often printed or posted in a deformed style for better understanding the topological connections of intersecting lines. In this paper we propose an algorithm for the automatic generation of deformed railway maps. The railway map is represented as an undirected graph; a vertex corresponds to a station and an edge corresponds to a railway between two stations. The data necessary for this algorithm are the position of each station, and a list of stations of each line. The algorithm proceeds as follows:

1. An angle value is assigned to each vertex based on the direction of edges attached to the vertex.
2. Adjacent vertices which are on a same railway line and which share similar angle values are gathered to make a group.
3. Assign a priority to each vertex based on the sizes of groups to which the vertex belongs.
4. Place each edge in the order of priority of its two end vertices.

This algorithm is applied to some railway maps including the very complex one of Tokyo Metropolitan Area, and excellent results are obtained. The obtained deformed maps will be evaluated based on their accuracy and the understandability.

Key Words: Graph drawing, deformation

MSC 2000: 68U05

1. Introduction

Currently a lot of designer's work is needed for the preparation of deformed railway maps. Railway maps can be expressed as a connected graph, but its characteristic is somewhat different from a graph representing a road map (Kajita et al. [4], Horie et al. [3], and Wakaizumi et al. [5]). A railway map has less intersections than a road map, and has many 2° vertices. For the deformation of railway maps, larger move of each vertex is usually allowed because the information on connection is much more important than the shape information.

ISSN 1433-8157/\$ 2.50

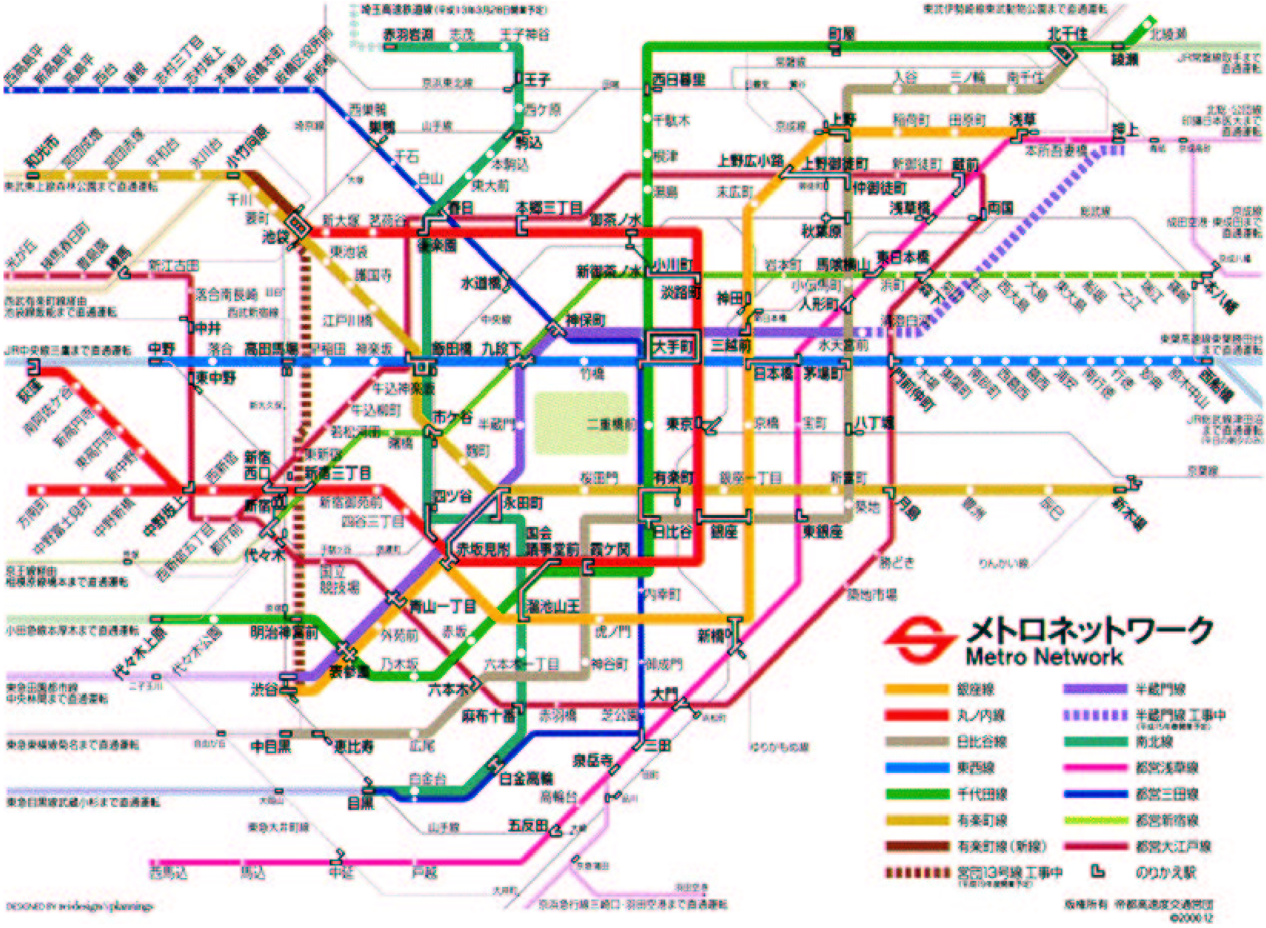

Figure 1: A typical railway map [1]

In this paper we propose an algorithm for the automatic generation of deformed railway maps. In this algorithm, such characteristics of railway maps mentioned above are taken into consideration.

2. The approach

A typical railway map in deformed style is shown in Fig. 1. As can be seen from this figure, deformed railway maps have such characteristics as:

- stations on a same line are positioned on a straight line as far as possible,
- angles of lines are limited, e.g., to multiples of 45°, and
- stations on a same line are positioned at regular intervals.

Our deformation algorithm moves the position of each station so that the lines satisfy these conditions. But we set a limit for the distance that each station can be moved for better recognizing all stations and lines.

3. The algorithm

The only data that are necessary for the algorithm are:

- position and name of each station,

- name of each line, and
- list of stations for each line.

Position data are given by the latitude and longitude. In our current implementation, data "Line type" is also given to each line. This indicates the shape of the line by "Loop", "Fork", or "Normal". Such data are obtained from the station lists, but it is now given explicitly for the ease of implementation.

We adopted the following strategy for the deformation:

1. deform each line separately,
2. assign a priority to each station, then
3. place edges according to the priority of their stations.

We place important lines first. The Importance of a line is determined by the number of connections to the line and the number of stations it contains. This approach is simple and straightforward; it does not backtrack. Nevertheless it turned out that it is effective enough for such complicated railway maps as that of Tokyo Metropolitan Area.

The strategy is implemented in the following algorithm steps:

1. Deformation of each line:
   - 1.1 determination of angle value at each station,
   - 1.2 quantization of the angle values,
   - 1.3 grouping of stations based on the quantized angle values,
   - 1.4 alignment of stations in a group,
2. Determination of priority;
3. Placement of stations:
   - 3.1 quantization of edge lengths,
   - 3.2 selection of edges,
   - 3.3 placement of stations.

3.1. Deformation of a line

For each station in a line the angle value is determined as the average of its two edges. For a terminal station the angle value is defined as the angle of its (only one) edge.

The angle value is quantized to a multiple of some predetermined basic angle. Usually 45°, 60°, or 90° are chosen as the basic angle. This selection is based on such factors as:

- complexity of the railway lines,
- size of space where the map is drawn, and
- aesthetic point of view.

When some contiguous stations share the same quantized line angle, they are treated as a group in the subsequent steps.

An example is shown in Fig. 2: Fig. 2(a) is the given positions of the stations on a line. (b) shows their angle values. (c) is the result of quantization and the grouping.

Stations in a group are positioned on a straight line. When the distance of movement for the alignment exceeds the predetermined tolerance, that group is subdivided into smaller groups (Fig. 3).

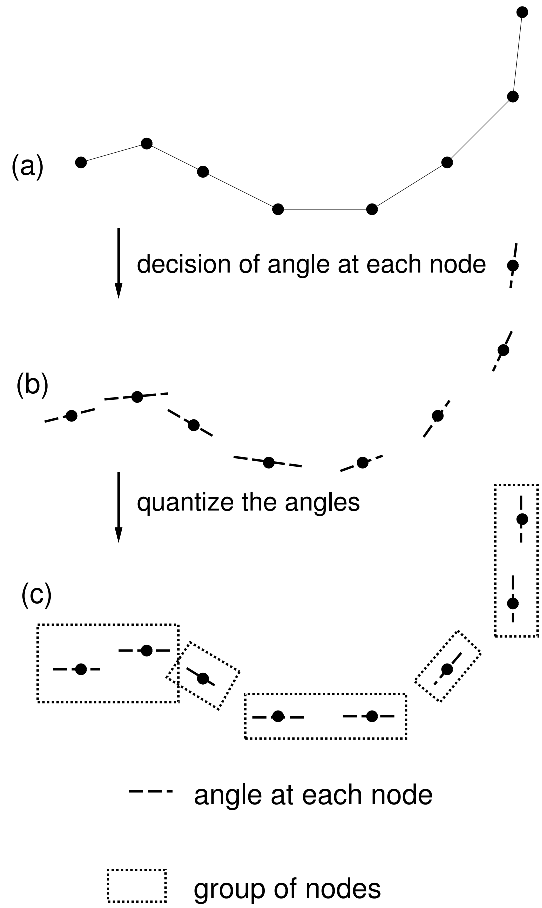

Figure 2: Grouping of stations by the line angles.

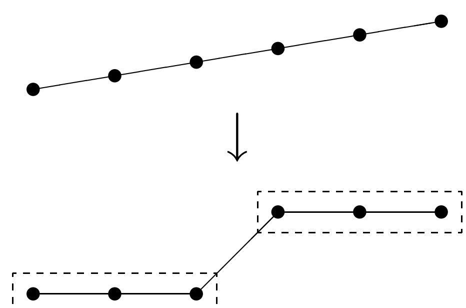

Figure 3: Subdivision of a group.

3.2. Determination of priority

In our algorithm, stations are placed by the order of their priority, as the important stations are more influent to the placement of other stations.

The procedure to determine the priority is as follows:

1. count the number n_i of stations in each group i;
2. give the priority n_i to the stations which belong to the group i;
3. when a station is a junction, its priority is the sum of priorities given by each group.

The line A in Fig. 4 is divided into two groups, $\{1, 2, 3\}$ and $\{4, 5, 6, 7\}$ based on their angle

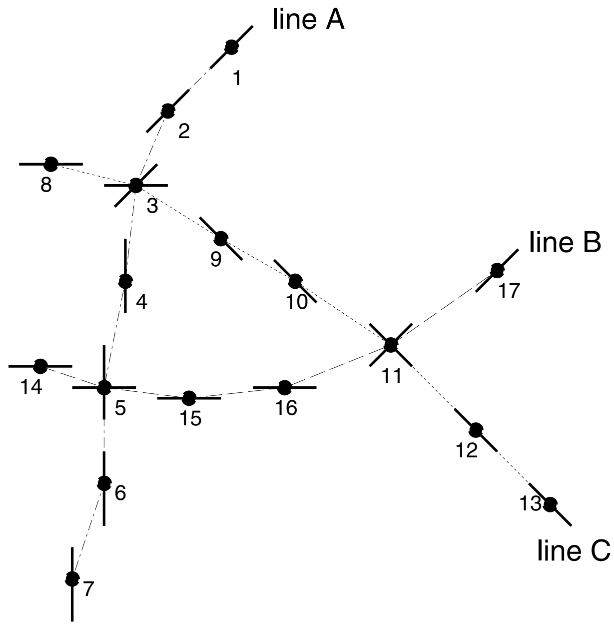

Figure 4: Determination of priority

values. This grouping gives priority 3 to Stations 1, 2 and 3; priority 4 to Stations 4 through 7. The line C is also divided into two groups, $\{8, 3\}$ and $\{9, 10, 11, 12, 13\}$. This grouping gives priority 2 to Stations 8 and 3, and priority 5 to Stations 9 through 13. Therefore priority $5 = 3 + 2$ is given to Station 3. By this procedure, the priority of each station is determined as shown in Tables 1 and 2.

Table 1: Grouping for Fig. 4

Group	Line	Angle	Stations	Num.
a	A	$\swarrow$	1,2,3	3
b	A	$\downarrow$	4,5,6,7	4
c	C	$\rightarrow$	8,3	2
d	C	$\searrow$	9,10,11,12,13	5
e	B	$\rightarrow$	14,5,15,16	4
f	B	$\nearrow$	11,17	2

3.3. Placement of stations

The station that is not placed yet and whose priority is the largest is determined, and pick up the groups that the station belongs to. The stations that belong to these groups are placed. Stations of a group are located on a straight line whose angle is determined by the angle values. This process is repeated until all stations are placed.

For the map in Fig. 4 Station 5 has the largest priority. Therefore the groups b and e are picked up first and the stations are placed on two straight lines. Then groups d and f are placed as Station 11 has next largest priority. Groups e and f are connected between Stations 16 and 11. At this stage, positions of stations are adjusted, if necessary, with a group as a unit.

Table 2: Priority of stations

Station	Groups	Priority
1	a	3
2	a	3
3	a, c	$5 = 3 + 2$
4	b	4
5	b, e	$8 = 4 + 4$
6	b	4
7	b	4
8	c	2
9	d	5
10	d	5
11	d, f	$7 = 5 + 2$
12	d	5
13	d	5
14	e	4
15	e	4
16	e	4
17	f	2

3.4. Examples

The map in Fig. 5 shows the subways operated by Teito Rapid Transit Authority and a JR line in Tokyo Metropolitan Area. The deformation algorithm generated the map of Fig. 6. This result is satisfactory because we can recognize each line in this map very easily.

Fig. 7 shows JR lines and subways in Tokyo. The generated deformed map is shown in Fig. 8. These maps are very complicated especially at the central part. An enlarged map of that and its deformed version are shown in Fig. 9. As can be seen from these figures, our algorithm is able to deal with such complicated situation.

3.5. Discussion and conclusion

As mentioned in the previous section, our algorithm works well for the very complicated railway maps. The authors could not find other algorithms for the same purpose, and could not compare the obtained maps. In our current algorithm, only the placement of stations and lines are considered. For the complete deformation, label placement also must be considered (Christensen et al. [2]). We are making some experiments on this topic.

3.6. Acknowledgment

This research is partially supported by The Japan Society for the Promotion of Science "Research for the Future" Program No. JSPS-RFTF97100103.

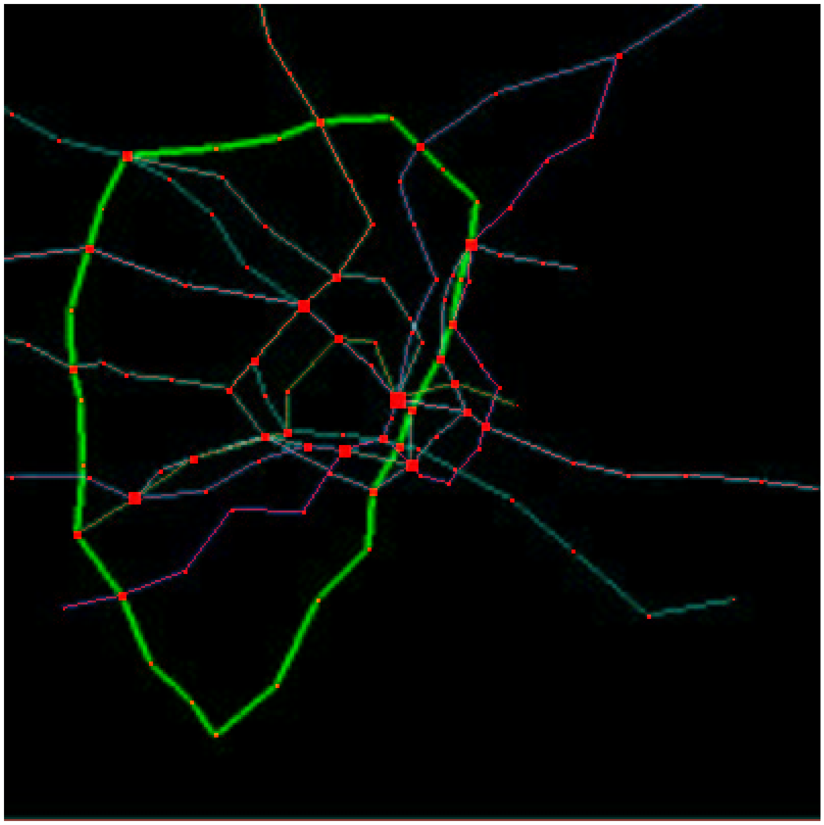

Figure 5: Map of subway lines and a JR line in Tokyo.

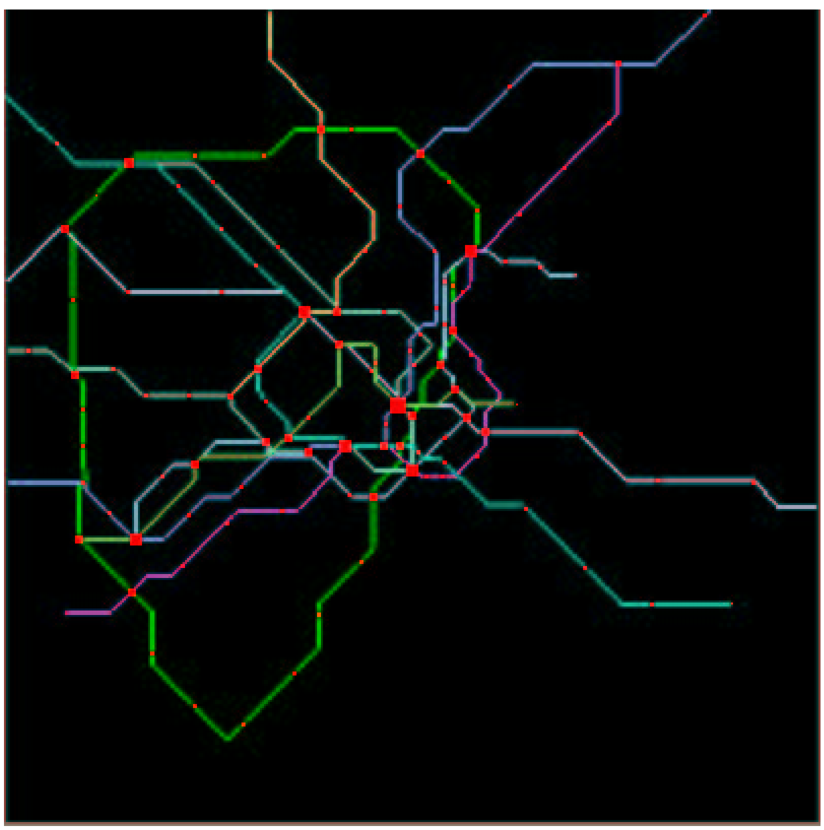

Figure 6: Deformed map obtained from Fig. 5.

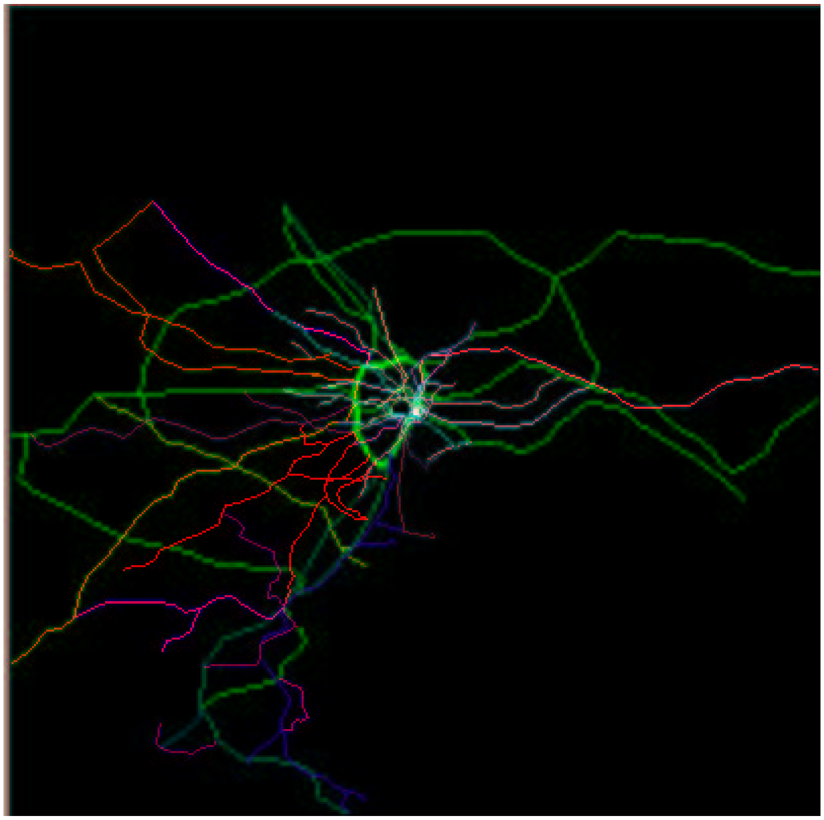

Figure 7: Map of railways in Tokyo .

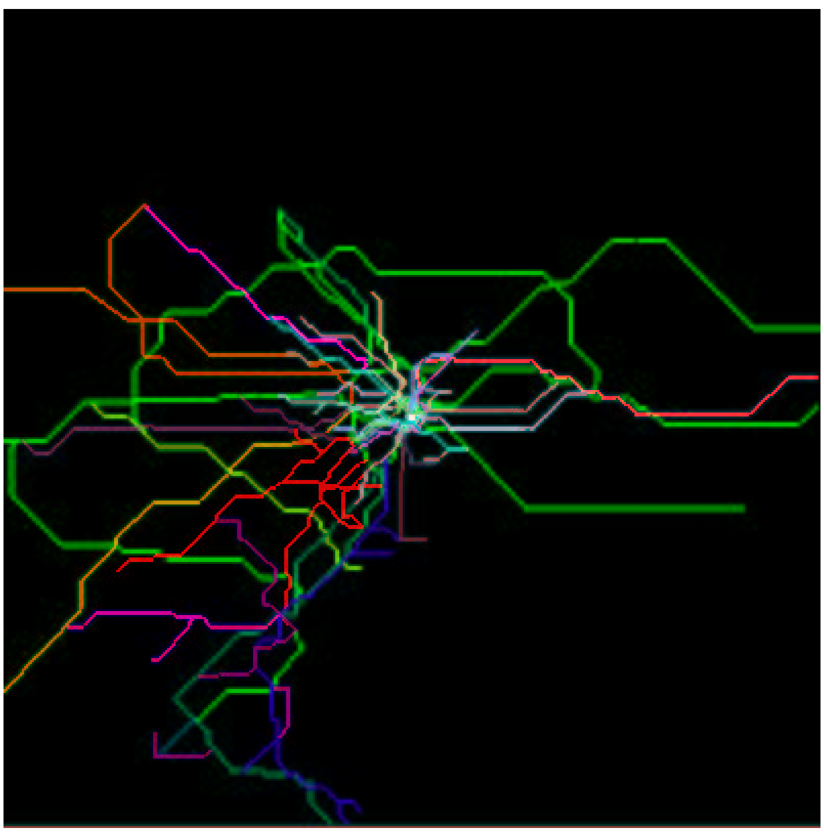

Figure 8: Deformed map of Fig. 7.

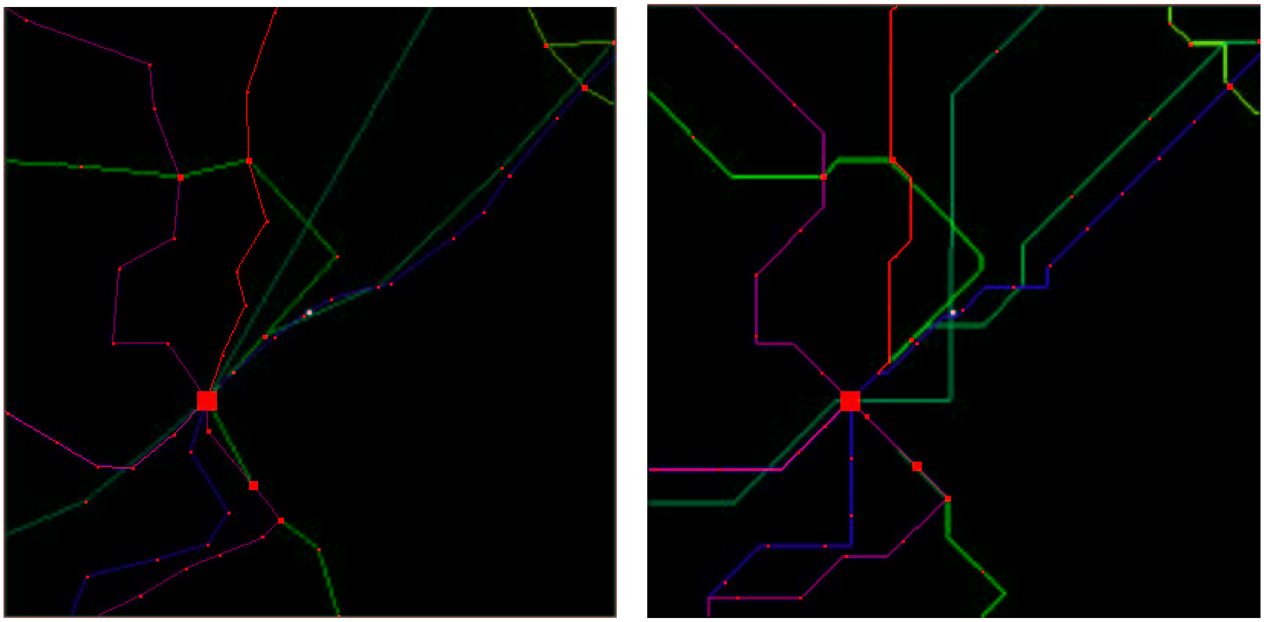

Figure 9: Enlarged maps of Figs. 7 and 8.

References

[1] Quoted from `http://www.tokyometro.go.jp` with permission of Teito Rapid Transit Authority.

[2] J. Christensen, J. Marks, S. Shieber: *An Empirical Study of Algorithms for Point-Feature Label Placement.* ACM Trans. Graphics **14**, 203–232 (1995).

[3] M. Horie, T. Ueda, S. Dan, N. Babaguchi, T. Kitahashi: *A Method of Generating a Road-Network from Vectorized Image of Maps.* Technical Report of IEICE **PRU 94-134**, 31–38 (1995) [in Japanese].

[4] K. Kajita, K. Yamamori, J. Hasegawa: *Development of an Automatic Generation System of Deformed Maps.* J. IPSJ **37**, 1736–1744 (1996) [in Japanese].

[5] K. Wakaizumi, Y. Ohno: *A Deformation Algorithm of Road Maps.* Proc. 9th ICGG, Johannesburg 2000, pp. 143–147.

Received August 1, 2000; final form January 29, 2001