Making a semi-convex Focus area in a Focus+Glue+Context map, considering map visibility and transport access points

Y Hirako¹ D Yamamoto¹ and N Takahashi¹

Department of Computer Science and Engineering, Graduate School, Nagoya Institute of Technology, Japan
E-mail: hirako@moss.elcom.nitech.ac.jp

Abstract. We previously implemented the Focus+Glue+Context map system EMMA that provides local detailed data in Focus, global context data in Context, and connection data between both in the same view. Introducing the Glue area between Focus and Context makes it possible to provide uniform scaling for the two latter areas. This paper enhances EMMA through the implementation of a Focus creation function that considers transportation access points, such as stations and bus stops. The enhanced EMMA searches a route from the current location to the transportation access point, and allows users to identify the spatial relationship between the various locations in a small-scale Context, and view the route from the current location to the transportation access points in a large-scale Focus. However, if Focus is too large because of unnecessary areas used to identify the route, some parts of Context might be hidden by Focus. The proposed system solves this problem by implementing the following functions: (1) it searches stations that are adjacent to the current location and makes a semi-convex Focus that includes the current location and those stations in order for Focus to include really necessary areas. (2) It reduces Focus distortion by setting a fixed point as the center of the Focus area. (3) It smoothens the Focus shape in order to improve visibility in the Glue area. We developed a prototype of the proposed system that implements these functions.

1. Introduction

Most Web map systems, such as Google Maps [1] and Yahoo! Maps [2], allow users to generate maps by changing the location and scale of the area to be displayed with basic map operations, such as scroll, zoom-in, and zoom-out. Users might eventually find their intended area and adequate scale after repetitive execution of these operations by trial-and-error. They might even switch between multiple images when researching different locations, e.g., their current location and intended destinations. As a result, users might experience difficulties when identifying relevant information, such as the route between two locations, and switching between maps could interrupt the users’ thought processes.

For instance, suppose that a user wants to see the route from a global access point (Global AP), such as airports and large terminal stations, to a local access point (Local AP), such as local train stations and bus stops, and the route from the Local AP to a given destination when planning a long trip. In this case, a small-scale or wide-area map is useful because it includes all destinations, Global APs, and Local APs. On the other hand, when the user wants to carefully check the movement between a Local AP and the destination, a large-scale map is more useful because it shows the route in detail. In conventional Web maps, the user has to repeat the operations of switching between detailed and wide-area maps.
In order to solve the aforementioned problem, we previously implemented the Focus+Glue+Context map system EMMA [3,4,5]. EMMA provides a Focus+Glue+Context map that shows a wide area and details in the same view. The map is composed of the Focus, Glue, and Context areas. Focus expands the area of interest and displays it on a large scale. Context displays the area surrounding Focus on a small scale. Glue connects Focus and Context smoothly on variable scales. Introducing Glue between both Focus and Context makes it possible to provide uniform scaling for them. Focus+Glue+Context maps facilitate glancing at the entire map area and grasping details in some portion of the area.

However, the following problems must be solved in order to make Focus+Glue+Context maps really useful.

**Problem 1** When the Focus area increases, the Context area is sharply reduced. Therefore, it is necessary to minimize the Focus size.

**Problem 2** Depending on the Focus shape, Glue might become too large and hide some portions of Context. In addition, the large Glue might make it difficult to discriminate the connections in road networks because such networks are highly distorted in Glue.

**Problem 3** To display Global AP and all Local APs in the same view, we have to determine the Focus shape that includes all Local APs, and calculate the appropriate Context scale.

In this paper, we propose an enhanced EMMA to solve these problems; it considers both map visibility and the location of transportation access points by making a Focus+Glue+Context map with a Focus area in a semi-convex shape [11].

## 2. Related works

In this section, we describe the related works from two perspectives: fisheye view maps and Focus shapes in EMMA.

### 2.1 Fisheye view maps

Fisheye View maps [6,7] are an effective method for displaying wide area and detail maps in the same view by applying deformation similar to a fisheye lens. This method allows users to comprehend the topological relationship of map objects in a wide area and the details of a small area that surround a given destination simultaneously. On the other hand, fisheye view maps suffer from problems in that the entire area of the map is distorted and/or the density of the roads in the corners of the map is large. EMMA provides enhanced Fisheye View maps and Focus+Glue+Context maps where all the distortion is concentrated in Glue in order to realize uniform scaling in Focus and Context [3].

### 2.2 Focus shapes in EMMA

Some types of concave Focuses, or non-semi-convex Focuses, provide erroneous or incoherent map objects in EMMA where the topological relationship between some map objects change from their original relationships by making Focus and Glue areas. The semi-convex Focus creation method makes it possible to create these types of Focuses correctly [8]. Without such a method, EMMA could generate only simple convex shape Focuses, such as circles and rectangles, in order to avoid erroneous and incoherent maps. The literature [8] has clarified that transforming a Focus shape to semi-convex allows the creation of semi-convex Focuses without erroneous or incoherent Glue images. However, this method does not consider the distortion in Glue, and the destination in Glue becomes too large for viewing roads in some cases. In addition, if a Focus shape includes acute angles, the Glue of that point becomes enlarged and hides large portions of Context. This might also decrease map visibility.

## 3. Proposed system

In this section, we describe our research goals and provide an overview of the proposed system.

### 3.1 Goal 1: access points-based map
The proposed system realizes access points-based maps as shown in figure 1 using the Focus+Glue+Context map system, EMMA. The Focus center might be a current location or a destination point. Focus displays routes from the center point to Local APs and some areas around the center point on a large scale. Context displays the Global AP and the outside of Focus on a small scale. Glue is a variable scale and connects both Focus and Context smoothly. Through this map a user can simultaneously view the routes from the center point to Local APs, and the topological relationship between the center point and the Global AP.

3.2 Goal 2: creating semi-convex Focus

In EMMA, Focus is created by rearranging each vertex that forms a Focus in the direction opposite to a reference point, called a fixed point, as shown in figure 2. At this juncture, all those polygon points that form the Focus have to be visible from the fixed point. Such polygon is called semi-convex [11]. For instance, the polygons shown in figure 3(a) are semi-convex, but the one shown in figure 3(b) is non-semi-convex. If we create a non-semi-convex shaped Focus, the generated map might sometimes include abnormal portions, such as road interruptions. For this reason, the Focus shape must be semi-convex.

3.3 System overview

As shown in figure 4, the proposed system consists of the following three main functions: Focus creation, Focus transformation, and Context adjustment functions. Given a current location or destination, the Focus creation function acquires the location of those stations located within walking distance from the designated point. Based on this information, the creation function determines a Focus shape. The Focus transformation function reduces the distortion in Glue by setting a fixed point as the center of the Focus area. Moreover, the Focus transformation function improves visibility at the corner of Focus by smoothing the apex angle of Focus. Based on information obtained from the Global AP database, the Context adjustment function adjusts the Context area and scale in order to
include Global AP in the Context of a screen. At the end, the map display system generates the Focus+Glue+Context map and presents it.

4. Implementation methods

In this section, we describe the implementation methods for the three functions mentioned in the previous section.

4.1 Focus creation function

Assume that a user specifies point P as the current position (or destination). Then, the Focus creation function creates the Focus area with P at the center, and includes the vicinity of P and routes from P to Local APs. We use the system parameters r and d to specify the Focus shape, which correspond to the radius of the vicinity area and maximum walking distance, respectively. Parameter r is set to 500 m and d is set to 1500 m in our prototype of the proposed system. The algorithm for determining the Focus shape is as follows:

Step 1: Obtain the locations of the Local APs whose distance from point P are between r and d by searching the Local AP database.

Step 2: Create a circle whose center and radius are P and r, respectively. Then assign the Local APs obtained in Step 1 as the vertexes and draw the circle’s tangential lines from the vertexes, as shown in figure 5(a).

Step 3: If the tangential lines drawn from the adjacent vertexes in Step 2 cross at some point v, as shown in figure 5(b), assign point v as a new vertex.

Step 4: Make a semi-convex polygon by connecting the vertexes or Local APs assigned in Step 2 and the new vertexes assigned in Step 3, as shown in figure 5(c).

The algorithm creates the Focus area centered at the current position (or destination), and includes the center’s surroundings and routes from the center to Local APs.

Figure 4. System overview
4.2 Focus transformation function

This function transforms Focus in order to prevent visibility deterioration. The details of the method are as described in the following subsections.

Setting the fixed point. The distortion in Glue is directly proportional to the distance between the fixed point and vertex of Focus. This function finds a minimum circle that includes all Focus vertices and sets the fixed point to the center of the “minimum inclusion circle.” Consequently, the distortion in Glue is reduced because vertices that are too far from the fixed point are not generated. A minimum inclusion circle means the minimum circle that includes all designated points. Moreover, the radius of this circle is as short as possible. The proposed system uses an algorithm to calculate approximate solutions in order to prevent extensive calculation times. Using this algorithm makes it possible to realize a processing speed that is practicable as a Web map service. The algorithm for calculating the approximate solutions is as follows:

Step 1: Set a temporary center at the center of gravity of the polygon that constitutes the expanding area.
Step 2: Move the temporary center toward the expanding area’s vertex that is farthest from the temporary center.
Step 3: Repeat Steps 1 and 2 repeatedly while gradually reducing the movement distance.
Step 4: Define the last position of the temporary center as the center of the minimum inclusion circle, and define the distance between the center and the farthest vertex as the radius of the minimum inclusion circle.

Setting the fixed point as the center of the minimum inclusion circle using this algorithm makes it possible to create Focus with less distortion.

Smoothing the apex angles of Focus. When a Focus shape has acute angles, the area surrounding Glue becomes too large. As a result, the visibility of a given road and railway connection is reduced. This function smoothes the Focus shape in order to prevent Glue from becoming large. Moreover, it expands the Focus shape simultaneously in order to prevent loss of the Focus edge area. The algorithm for smoothing the apex angle of Focus is as follows:

Step 1: Vertex points V1, V2, and V3 that form a corner of Focus move a certain distance α in the opposite direction from the fixed point. Define the vertex points after moving them as V1’, V2’, and V3’.
Step 2: An interior point that divides V1’ and V2’ into V1’V4:V4V2’ = 2:8 is labeled V4. An interior point that divides V1’ and V3’ similarly is labeled V5.
Step 3: Delete V1’ and connect V4 and V5.

By applying this algorithm to all apex angles, the generated Focus includes the Focus before the transformation. Moreover, all apex angles change to an obtuse angle.
4.3 Context adjustment function
This function adjusts the Context area and scales it in order to include Global APs within the Context area. First, the function connects the Global AP database and acquires the location of the nearest Global AP from the current location (or destination). If the acquired Global AP is located outside the map displayed at present, the function expands the Context area and reduces its scale to include the Global AP within the Context.

5. Prototype system
We implemented all the functions of the proposed system through Java. The prototype system uses PostgreSQL as the database, and uses PostGIS to manage Local AP and Global AP data. PostGIS is a spatial database extender for the PostgreSQL object-relational database that adds support for geographic objects, thus allowing location queries to run in SQL [9]. We used raster and vector map data obtained from Yahoo Japan Corporation, and railway station data from the Station Database [10].

The prototype system generates the Focus+Glue+Context map that includes the location of transportation access points, as shown in figures 7 and 8. In figure 7, there is one Local AP within walking distance from the location designated by a user. Focus includes routes from the designated point to the Local AP. In addition, the Nagoya station that is the Global AP nearest to the designated point is displayed in Glue.

Figure 6. Smoothing apex angles

Figure 7. Example map generated by prototype system: Convex Focus
The map shown in figure 8 is another example generated by the prototype, where the destination point is farther than the Nagoya station. In this map, there are three Local APs within walking distance from the designated point. Therefore, the Focus shape becomes a concave and semi-convex polygon, as shown in figure 8. The closest Global AP from the designated point is the Nagoya station, similar to the map in figure 7. In this map, however, the distance is too long to display Focus and Global AP in the same view. The prototype system reduces the scale of Context in order to display Focus and Global AP in the same view.

Figure 8. Example map generated by prototype system: concave and semi-convex Focus

6. Conclusion
In this paper, we proposed a Focus+Glue+Context map system that considers the location of transportation access points, and described methods for its implementation. Such methods search Local APs located within walking distance from a designated point, and make a semi-convex Focus that only includes the destination point and route to Local APs so that Focus includes really necessary areas. Consequently, users can simultaneously see the routes from the destination point to Local APs, and the topological relationship between the Focus area and Global AP.

In addition, we implemented a prototype system and attempted to generate many maps for various destination points using the system. As a result, we confirmed that the system can create a map that includes Local APs in Focus and Global APs in Context; moreover, it can reduce Focus distortion and smoothe the Focus shape to improve visibility in the Glue area.

For the future, we plan to evaluate the effectiveness of the proposed system using it in the real world. In addition, we plan to implement functions to search and draw some types of map objects on the map generated by the proposed system, e.g., transportation access points such as bus stops and highway entrance/exit points, and shops such as restaurants and convenience stores. These functions allow for compact and useful maps that can adjust to different situations and uses of many map users.

Acknowledgments
We would like to thank Yahoo Japan Corporation for supporting us in the development of our prototype system. This work was also supported by JSPS KAKENHI 26330136 and 25700009, and the Core Research for Evolutional Science and Technology (CREST).
References

[1] Google Maps, http://maps.google.co.jp
[2] Yahoo! Maps, http://map.yahoo.co.jp
[3] Takahashi, N An elastic map system with cognitive map-based operations. International Perspectives on Maps and the Internet. Springer Berlin Heidelberg, 73-87, 2008.
[4] Hiroya M, Daisuke Y, Naohisa T, A Fusion of Multiple Focuses on a Focus+Glue+Context Map, Intelligent Interactive Multimedia Systems and Services (IIMSS 2012), pp. 11-21, 2012.
[5] Daisuke Y, Shotaro O, Naohisa T, Generalization Method of Fisheye View Maps Based on Following Path Algorithm, IEICE Transactions on Information and Systems, 2010 (in Japanese).
[6] Furnas G, Generalized Fisheye Views, CHI 1986 Conference Proceedings, 16-23, 1986.
[7] Manojit S, Brown M, Graphical Fisheye Views of Graphs, CHI 1992 Conference Proceedings, 83-91, 1992.
[8] Fumiya K. Daisuke Y, Naohisa T, Implementation of Focus Creating System in Consideration of Map Object Shape, DEIM Forum 2014 E9-1, 2014 (in Japanese).
[9] PostGIS, http://postgis.net/.
[10] Station Database, http://www.ekidata.jp/.
[11] Michael W, Matt D, ‘Fundamental Spatial Concepts,’ Chapter 3 in Worboys, M and Duckham M eds. GIS: a Computing Perspective. CRC press, 2004.