# A Framework for Navigating with Map Signboards on Smartphones Using Basic and Advanced Image Geocoding Methods

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**Abstract.** Map signboards are widely distributed in public places. The map signboards are more concise, thematic, artistic, and diverse than current web maps, but map signboards also have shortages on accessibility and mobility. We propose a framework to integrate map signboards with Location-based Services on smartphones. We provide basic and advanced geocoding methods for different situations. The basic geocoding includes direction alignment and point based referencing, which are easy to operate by ordinary users. The advanced geocoding is based on polyline referencing. It provides more accurate positioning result, but it is relatively difficult to build the referencing polylines. Professional users with background knowledge of GIS and cartography are supposed to make the advanced geocoding, and the results would be shared to ordinary users. Our experiments show that ordinary users can easily make correct basic geocoding; meanwhile, the advanced geocoding offers better positioning result, which could ensure the relative spatial relation between user's location and the roads on the map.

**Keywords.** Map Signboards, Pedestrian navigation, Polyline references

## 1. Introduction

Nowadays, people rely more and more on Location-Based Services (LBS). With smartphones, people can get access to maps, like Google Maps and Apple Maps, almost anytime and anywhere. However, as large companies, such as Google, Apple, Baidu, and so on, have dominated the web maps, the styles of web maps are limited. The web maps that are now usually used as standard tools for spatial searching and navigation are useful but not attractive.

On the other hand, another kind of maps that are widely distributed in public places and used by the public are map signboards. Compared with web maps, map signboards have advantages on their artistic expression and the diversity of styles, which make map signboards attractive and interesting. And compared with illustrated maps on guidebooks, map signboards are easier to find self's position with the help of YOU ARE HERE point. However, map signboards also have shortages: misaligned orientation, scattered distribution and immobility. These disadvantages make map signboards difficult to read and limit the accessibility for people.

If the advantages of map signboards and web maps could be combined on smartphones, it would make way finding easier and more interesting. With this idea, researchers have started explorations on this field when smartphones were not as popular as present. Schöning et al. (2009) proposed the technic to use GPS equipped mobile phones to take, geocode, and display You Are Here (YAH) maps. They proposed two ways of geocoding YAH maps: *two point referencing* and *smart alignment*. These methods are easy to operate but each has limitations. The two point referencing method is available only for northed maps while the smart alignment method asks that the user's trace overlaps with the spatial extend of the photo of the map. These are all critical requirements, and according to the paper, only 81% maps they collected meet the first requirement and less than half (%48) maps meet the second requirement. Morrison et al. (2011) made AR application *MapLens* which could timely overlay location-based media on the paper map image through the camera of mobile phone. It use predetermined map data files to position medias on the right place. This application only works on the predetermined maps, which limits the usability of it. Wang et al. (2012) proposed a three point referencing method to calculate user's location on the image of site maps. The method uses three referencing points, which are weighted by the horizontal accuracy of the GPS positioning, to calculate user's locations on the image. Although the method reduces the error, in some degree, that are brought by the error of GPS positioning, it does not necessarily reduce the error that caused by the reference points on the image and the distortions of the site maps. Thus the improvements of the results are very limited. Lu and Arikawa (2013, 2013 and 2014) studied on integrating illustrated maps on tour guiding books with the mobile devices. They did not only geocode the map part to position user's locations, but also geocode the texts and images to offer multimedia story telling and real time instructions. They also enables user's to make geocoding for spatial references and POIs. However, the editing tools are complex and it is difficult for ordinary users to operate. The related works did contribute a lot but the main shortages come in two aspects: accuracy of positioning and the feasibility of operation for ordinary users.

In this paper, we will introduce our work on embedding Location-based Services (LBS) in map signboards on smartphones. We provide two levels of map geocoding methods: a simple method for ordinary users to make basic geocoding of map signboards for accessing basic LBS like reorienting and positioning; and a relative complex method for GIS specialists and cartographers for more accurate positioning.

## 2. Framework of Geocoding for Map Signboards

To embed LBS in map signboards, we build the mapping relation between map signboards (the target maps) and base maps using web maps (like Google Maps and Apple Maps). Unlike topographic maps and photogrammetry images, whose distortions mainly come from map projection and are regular, map signboards sometimes are distorted irregularly for emphasizing themes and for artistic expressions. Such distortions increase the difficulty for mapping positions accurately from base maps to the image of map signboard.

The number of map signboards is too large that it is difficult to geocode all of them for users beforehand. One solution is that users can take photos of map signboards and make geocoding by themselves. Considering the difficulties for ordinary users without special training on Geographic Information Systems (GIS) and cartography to make geocoding, we designed the strategy to offer two geocoding methods for different users and different situations. One is basic geocoding, which use north arrow and reference points to enable the functions of map auto-aligning and location positioning. The other is advanced geocoding based on polyline references, which offers better positioning function. The basic geocoding is simple for ordinary users to operate so that they could get a quick LBS on map signboards; while the advanced geocoding is relatively complex and users with background on GIS and cartography are supposed to make it and share the result with ordinary users.

### 2.1. Basic Geocoding Based on North Arrow and Reference Points

As mentioned above, ordinary users have limited knowledge and skills to make geocoding for maps. One of the most common difficulties that users may meet is to find proper places to add points on the image and to find the corresponding points on base maps. We have designed a basic geocoding method for ordinary users, which includes two steps.

The first step is to align the direction of the map. Usually map signboards show the north arrow, and to make the direction alignment, users need to rotate the map signboard on the screen to make the north arrow on the map signboard upward. By doing so, the system can get the angle from the upward direction of the device to the north of the map image, noted as $\alpha$, as shown in *Figure 1*. Using the compass sensor, the system can get the angle from upward of the device to the real north direction, noted as $\beta$. Then system will calculate the angle from the north arrow on the map image to the real north $\theta = \beta - \alpha$. And by rotating the image with the angle of $\theta$, the map signboard would be aligned with its north arrow being consistent with the real north and its forwarding direction being consistent with the direction the user is facing to.

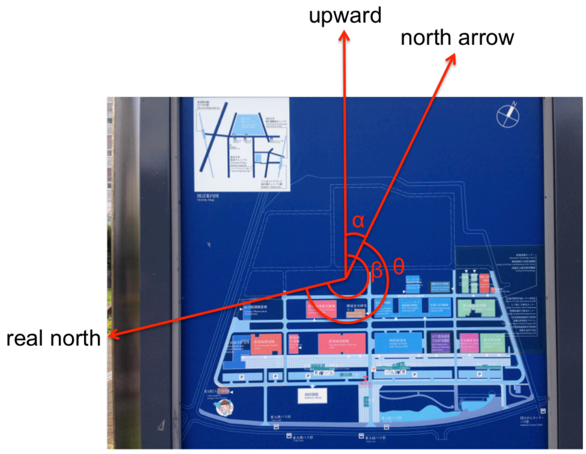



**Figure 1.** Direction alignment

The second step is to add reference points. For the point based referencing, at least two pairs of reference points are needed for positioning user's location on the target map. We provide two ways for making reference points: inputting reference points directly and matching the trajectory of the user's.

For directly adding reference points, a user has to add corresponded points on both the target map and the base maps. Users are suggested to add the first point at the YOU ARE HERE point when they take the picture of the map signboard, and use their GPS locations as the corresponding point on the base maps. And they could walk along the road and add the second pair of reference points at the first roads intersections in the same way. After the direction alignment, the map is automatically aligned. It is relatively easy for users to find their locations on target map with the hint of the first point and the heading direction. We also provide the way to add reference points on the base map manually, so that user can add many reference points without moving.

The second way is to add reference points by matching trajectory. It is designed for the situation that users cannot find their location on the target map. The system will record user's moving trajectory and display it on the screen, then user is supposed to match the trajectory to the corresponding road on the target map. Because of the different map projections and the irregular distortions of the map signboard, the whole trajectory of the user's sometimes could not be well matched with the target map. To solve the problem, we separate the user's trajectory into straight segments, and the user just need to match segment by segment. Once a segment of the trajectory is matched, the corresponding relations between the points of the segment on the target map and the points of the segment on the base map are built.

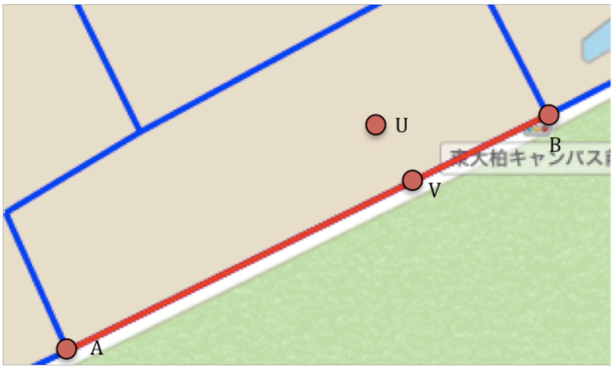
As long as there are two or more pairs of reference points, the application could position user's location on the image of the map signboard. For the detail of the algorithm of two-point referencing, we have taken the results of Schöning et al. (2009) and Lu (2013) as references.

### 2.2. Advanced Geocoding Based on Polylines

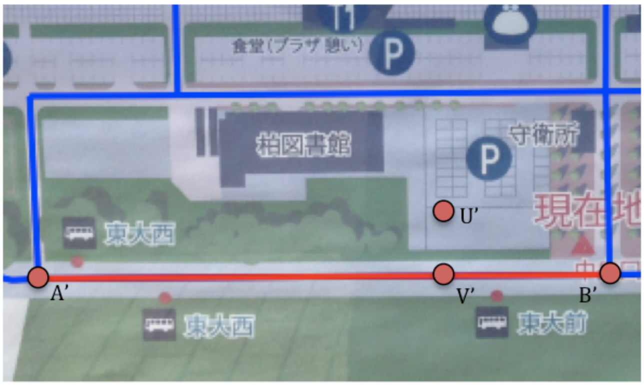
According to Lynch (1960), roads are important spatial references for navigating people. Wrong spatial relations between user's location and the roads will easily mislead the user. Because of the irregular distortions of map signboards, the positioning function based on point referencing does not ensure the correctness of relative spatial relations between user's location and the roads.

To solve the problem, we propose a mapping algorithm based on polyline referencing. It contains the following four steps:

- Digitalizing the target map: users need to depict the roads on the image of map signboard. Usually, roads are depicted by segments. The two nodes of the road are the intersections and should be located accurately. And the order of the start node and the end node on the both target map and the base map should keep consistent.
- Matching roads on target map and roads on base maps. For each road that has depicted on the target map, its corresponding road on the base maps can be picked out to build the mapping relation of the roads on the target map and the roads on the base maps.
- Mapping user's location from base maps to the target map. As shown in *Figure 2*, we can find the nearest road $AB$ from the user's location $U$ on the base maps, and calculate the nearest point $V$ on polyline $AB$ from user's location $U$. Then we pick up the corresponding road $A'B'$ on the target map, and calculate the point $V'$ on polyline $A'B'$ so that $\frac{AV}{VB} = \frac{A'V'}{V'B'}$. Then we calculate user's location on the target map by making vertical segment from point $V'$, so that $\frac{AV}{VU} = \frac{A'V'}{V'U'}$.
- Check and adjust. By the above three steps, we have got the user's location on the target map. It keeps the correct left and right relation with the road that used as the reference. However, as the distortion of the map signboards may be irregular, some other spatial relation may become incorrect. For example, when the map is asymmetrically scaled, the user's location calculated from the nearest road may be displayed more close to another road on the target map. We need to check the result and make adjustment. As shown in *Figure 3*, the left is the base map while the right is the target map. $U$ is the user's location on the base map, $AB$ and $CD$ are the nearest and the second nearest roads to the user's location $U$, and the distances are noted as $d_1$ and $d_2$. $A'B'$ and $C'D'$ are the corresponding roads on the target map to $AB$ and $CD$. $U'$ is the user's location on the target map calculated using $AB$ and $A'B'$. $d'_1$ and $d'_2$ are the distances from $U'$ to $A'B'$ and to $C'D'$. If $d'_2 \geq d'_1$, we do not need to make adjustment. Else if $d'_2 < d'_1$, we calculate user's location on the target map by the relation that $\frac{d_1}{d_2} = \frac{d'_1}{d'_2}$.

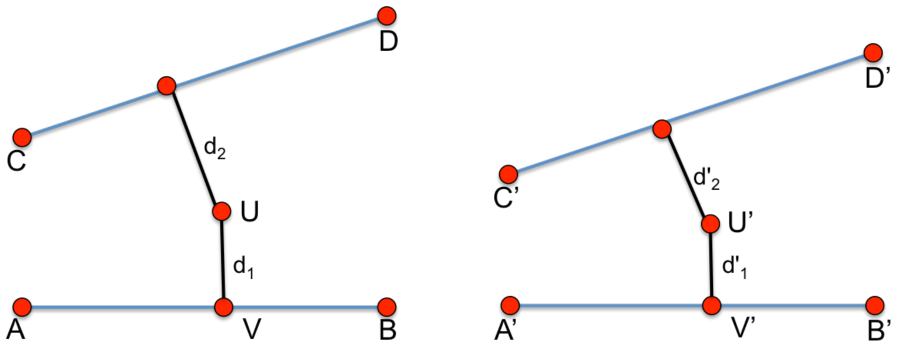



**(a)** Road $AB$, user's location $U$, and the nearest point $V$ from the user's location to the road on base maps.




**(b)** The corresponding road $A'B'$, mapped user's location $U'$, and the nearest point $V'$ from the user to the road on target map.

**Figure 2.** Calculation of user's location on target map with roads references




**(a)** Base map **(b)** Target map

**Figure 3.** Adjust of user's location in the case that the target map is asymmetrically scaled

In this section, we introduced the framework to geocode the image of map signboard and to reorient map direction and positioning user's location on the map signboard. We considered the users' abilities to make geocoding of map signboards are different, and proposed two levels of geocoding method: point geocoding for ordinary users and line geocoding for professional users. Users can get quick LBS but rough positioning results using point geocoded maps, while get relatively accurate positioning results if they have downloaded the line geocoded maps.

## 3. Implementation of Prototype

We have developed a prototype application for geocoding map signboards on smartphones. *Figure 4* is the main interface for basic geocoding, and the map is a photo taken from the map signboard in the Kashiwa Campus of the University of Tokyo. There are three buttons for geocoding: *North Arrow*, *Ref. Points*, and *Trajectory*.


**Figure 4.** Main Interface for basic geocoding

The *North Arrow* is for direction coding. As *Figure 5* shows, users need to rotate (and scale and pan if necessary) the image of the map signboard to make the north arrow up.

The *Ref. Points* is for adding reference points. *Figure 6* shows the interfaces for inputting reference points. The user will at first insert a point on the image of map signboard, and then insert the corresponding point on the base map. The user can use the *Auto-Matching* button to add reference point of his/her current location on the base map automatically according to the GPS location; also, the user can use the *Manual-Matching* button to turn to the base map and input the reference point manually.

The *Trajectory* is another way to input reference points. As *Figure 7* shows, we separate the user's trajectory into straight segments by user's turns. And user is supposed to match the red segment of the trajectory (the segment before the last turn) with the corresponding road segment on the image of map signboard by moving, zooming and rotating the image. Then the connections between the trajectory points on the target map image and the corresponding points on the base maps are built, and the two end nodes of the segment would be used as reference points.

The advanced geocoding needs to edit polylines, which is not easy to operate by ordinary users. We have made a prototype of an editing tool separately and have built the test reference data of the map signboard of *Map of Distributions of Buildings of the University of Tokyo Kashiwa Campus*. The reference polylines are shown in *Figure 8*.

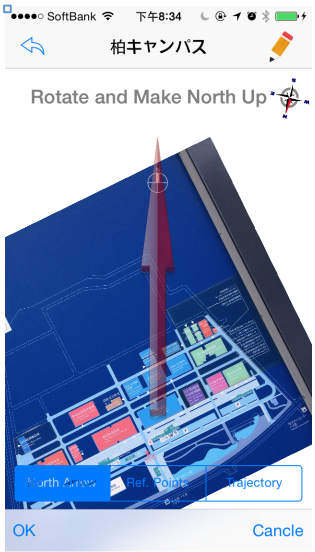



**Figure 5.** Interface for direction alignment

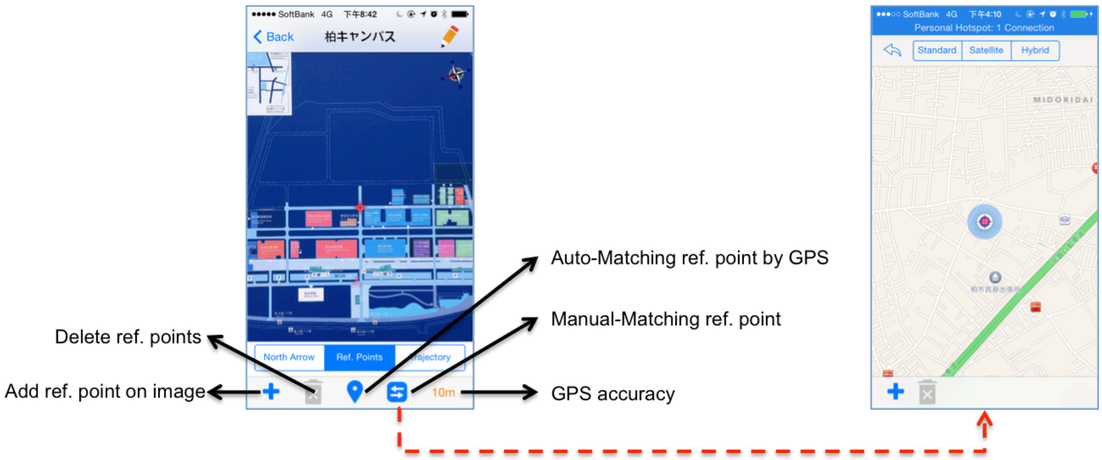
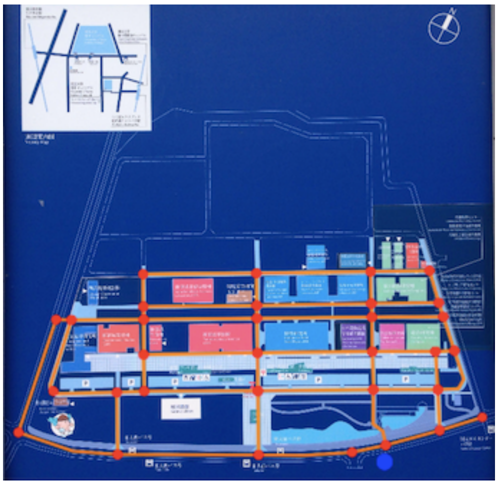



**Figure 6.** Interface for inputting reference points


**Figure 7.** Interface for trajectory matching



● Referencing points

▪ Referencing polylines

**Figure 8.** Editing referencing points and polylines on the map signboard of map of distributions of buildings of the University of Tokyo Kashiwa Campus

## 4. Experiments and Results

We have done experiments to test the feasibility of the basic geocoding methods for ordinary users, and tested the positioning results calculated by point referencing and polyline referencing.

Twelve volunteers have participated in the experiment. They were at first given a short training on the usage of the application and the editing tools. Then they were led to walk around the University of Tokyo, Kashiwa Campus and instructed to geocode the campus map. After the experiment, users were asked to answer questionnaires to judge the easiness of the process to geocode map signboards by four levels: very easy, easy, hard, and very hard. The results are shown in *Table 1*.

| | Very easy | Easy | Hard | Very hard |
|---|---|---|---|---|
| Geocode map signboards (generally) | 7 | 4 | 1 | 0 |
| Make the direction alignment | 6 | 4 | 2 | 0 |
| Add reference points (use GPS to add users' locations on base maps automatically) | 7 | 4 | 1 | 0 |
| Add reference points (add corresponding reference points on base maps manually) | 2 | 5 | 5 | 0 |
| Match the trajectory with the map image | 3 | 7 | 1 | 1 |

**Table 1.** Users' impressions on making map geocoding

According to the results, we can find that generally, most users (91.7%) feel it easy (or very easy) to geocode map signboards. Most of the geocoding tool functions are regarded to be easy to operate. To indicate corresponding reference points on base maps is the most difficult task for users. There are five users (41.7%) voted it hard to achieve this task. However, there is one user prefers this task because the user thinks it more efficient and convenient to add enough reference points one time at the beginning of the trip. Another user thinks all the operations are hard except for direction alignment. The user declared not good at reading maps and expected the application could provide directing and positioning functions without any operations. In conclusion, the basic map geocoding is not hard for ordinary users to achieve, and the different methods to add reference points that we provided could meet the preferences of different user groups.

**(a)** Trajectory on base maps

**(b)** Trajectory calculated by point referencing

**(c)** Trajectory calculated by polyline referencing

**Figure 9.** Comparison of point referencing and polyline referencing positioning results

To test the positioning results of advanced geocoding, we geocoded the campus signboard map based on the main roads, and we also built points referencing using the intersections of the roads. The referencing polylines and points are shown in *Figure 8*. We walked around the campus and recorded the trajectory, and mapped the trajectory to the map signboard by both point referencing and polyline referencing. The results are shown in *Figure 9*: *Figure 9(a)* is the base maps (Apple Maps) that shows the trajectory we have recorded; *Figure 9(b)* is the mapped trajectory using point referencing; *Figure 9(c)* is the mapped trajectory using polyline referencing. We can see that the trajectory mapped by polyline referencing is much stable than the trajectory mapped by point referencing.

## 5. Conclusion

This paper proposed a framework to navigate users with photos of map signboards on smartphones. The framework considered the capabilities of different users and offered easy point geocoding method for ordinary users and relatively complex polyline geocoding method for professional users. The results of the experiments have shown that point geocoding is easy for ordinary users to operate to get basic directing and positioning functions, while line based geocoding method could offer better positioning results.

However, in the experiments, many users expected not only directing and positioning functions, but also searching functions; and they hope that they could get helps and instructions when making the geocoding; also some users hope the interface would be more aesthetic. In the future, we will make improvements on these aspects, to make the system supporting POI searching, adding operating instructions, and make the interface more user-friendly.

For the advanced geocoding, sometimes the map signboards are more detailed than web maps, and some roads on the target maps are not shown on the base maps. These roads cannot be geocoded and the correct relative spatial relation between user's location and these non-geocoded roads cannot be ensured. And polyline geocoding is a time consuming task, which needs patience and skills to deal with inconsistencies of corresponding roads on target maps and based maps. These inconsistencies usually come from the generalization or exaggeration of the target maps. And finally, the polyline geocoding does not ensure the relative spatial relation between user's location and point objects, like buildings. In the future, we are going to improve the geocoding methods to make it easier and to keep the correct relative spatial relation between user's location and both line and point objects.

## References

J Schöning; K Cheverst; M Löchtefeld et al. (2009) Photomap: Using Spontaneously taken Images of Public Maps for Pedestrian Navigation Tasks on Mobile Devices. Proceedings of the 11th Conference on Human-Computer Interaction with Mobile Devices and Services, Mobile HCI 2009, September 15 – 18, Bonn, Germany

A Morrison, A Mulloni, S Lemmela et al. (2011) Collaborative use of mobile augmented reality with paper maps. Computers & Graphics 35: 789–799

YR Wang, CY Tsai, YC Chang et al. (2012) Ubiquitous Navigation based on Physical Maps and GPS. 2012 International Symposium on Computer, Consumer and Control

M Lu and M Arikawa (2013) Map-Based Storytelling Tool for Real-World Walking Tour. Progress in Location-Based Services, Lecture Notes in Geoinformation and Cartography, DOI: 10.1007/978-3-642-34203-5_24.

M Lu and M Arikawa (2013) Location-Based Illustration Mapping Applications and Editing Tools. Cartographica 48(2): 100–112

M Lu and M Arikawa (2014) Walking on a Guidebook with GPS: a Framework Geo-enabling Pages with Illustrated Maps in LBS. Principle and Application Progress in Location-Based Services Lecture Notes in Geoinformation and Cartography 2014: 243-264

K Lynch (1960) The image of the city. MIT Press, 1960