

Article

A Method of Directional Signs Location Selection and Content Generation in Scenic Areas

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Abstract: The Tourist Oriented Directional Signs (TODS) system is an essential and important project in constructing and planning scenic areas. At present, the placement of directional signs generally depends on the personal experience of the tour manager to identify important positions and display the name of critical scenic spots on a signboard. Few studies have focused on how to generate the location and display the content of directional signs automatically. This article proposes a method for directional sign location selection and automatic generation of content in a scenic area based on the tourist spatial behavior theory and network analysis algorithm. Junction nodes of the road in a scenic area are used as the candidate locations of the directional signs to be placed. The main steps of the method in this paper include tourist route simulation, betweenness centrality calculation, location selection, and content generation. The Ming Tomb in Nanjing, China, is selected as the experimental area. The evaluation indexes of the traveled distance and the number of errors were adopted. The random walk algorithm is applied to compare the generated scheme with the existing scheme in the experimental scenic area. The generated scheme is also verified through questionnaires and interviews. The results show that the method proposed in this paper can select relevant and appropriate junction nodes where to deploy directional signs and automatically generate displayed content more prominently. The comparison shows that the generated scheme in this method is significantly better than the actual placement scheme. It can optimize the actual placement scheme in the experimental area, and it also can reduce the traveled distance and number of errors.

Keywords: directional signs; location selection; content generation; tourist behavior; TODS

1. Introduction

Tourism wayfinding and navigation are important topics for tour managers when allocating resources and facilities in a scenic area [1]. For tourists, the Tourist Oriented Directional Signs (TODS) system provides easy route-following instructions for sighted pedestrians, especially when touring in unfamiliar environments. Compared with a paper map and GPS navigation system, the sign system can offer more direct and effective wayfinding instructions [2], and it is the basic infrastructure in scenic area planning. As a critical component of the sign system, directional signs provide the most straightforward wayfinding information with a direction arrow, destination name, graphic, and travel distance (optional) on a signboard, as shown in Figure 1. At present, some standards have put forward relevant requirements for the placement of directional signs, and several landmark location selection

methods have been proposed in the field of pedestrian navigation. However, location selection and content design of directional signs still rely on planners' personal experience in many scenic areas. The improvement of directional sign placement remains an open issue in the research community studying location-based services (LBS).



Figure 1. Examples of directional signs in a scenic area. (a) A directional sign with scenic spot name, representative graphic, and direction arrow; (b) A directional sign with scenic spot name, representative graphic, direction arrow, and travel distance.

In the existing literature, relatively few studies directly examine the placement of tourist directional signs and mainly focus on the setting principles [3–5], content and style design [6,7], individual differences [1,8], and evaluation [9]. The concepts of directional signs and landmarks are similar in some respects to those of the pedestrian navigation application field [10], and their location selection and optimization can be regarded as the same research topic. Some studies have proposed and discussed optimization methods for landmark selection [11–14]. However, several shortcomings are evident from previous research in which landmark selection was directly introduced to determine the placement of directional signs. First, heuristic algorithms, such as Genetic algorithm (GA) and ant colony optimization (ACO), were commonly used, which require manual adjustment. Different test areas require different configuration parameters so that the practical application is limited. Second, the above studies rarely start from the perspective of tourist spatial behavior, which focuses on achieving the minimal number of decision landmarks, and content generation of directional signs has been ignored. Third, the evaluation of existing methods is limited, and little evidence is available to show that existing methods can effectively improve tourism wayfinding.

Related research has shown that the cost of directional signs is not an important aspect for managers to consider. The key is deploying directional signs at places at which tourists need to find their way and displaying the name of their desired destination. Thus, the placement of directional signs can be divided into two aspects: the first is location selection, and the second is the display content generation. When deploying a directional sign at a road junction, the tourist's information that which route to choose and where to go need to be considered. It directly determines whether the location needs to be selected and what content needs to be displayed. Tourists' movement patterns have an important influence on the placement of directional signs. Therefore, the tourist's activity space and route choice behavior should be understood. In recent years, tourist spatial behavior has become a popular research topic in tourism geography, and it has provided significant support for cultural heritage protection, environmental capacity control, public service configuration, and facility layout planning [15,16]. Among these applications, GPS tracking records the movement trajectories of tourists in scenic areas objectively and accurately. Previous studies show that tourist activities are mainly concentrated on the routes among the entrance and scenic spots, and tourists tend only to visit high-grade scenic spots

and lack interest in low-grade sites [17,18]. How travelers choose scenic routes has been thoroughly analyzed in Alivand's research [19]. The scenic route choice behavior of pedestrians in different road intersections has been studied in Japan [20]. The related research on tourist spatial behavior and route choice behavior in the scenic area provides a good foundation for this article.

This article proposes a method for directional sign location selection and automatic content generation in a scenic area based on tourist spatial behavior theory and a network analysis algorithm, which is only used for pedestrian navigation. All road junction nodes extracted from the road network in the scenic area are used as the location candidates for directional signs placement. The middle position of the road is not considered. The Ming Tomb in Nanjing, China, is selected as the experimental area, and the users' task performance (the traveled distance and the number of errors) is selected as the evaluation index. The generated placement scheme and the existing scheme in the experimental area are compared based on the random walk algorithm and tourist questionnaire. The results in the experimental area show that the proposed method meets the tourists' location selection. They can optimize the existing sign system effectively, reduce the traveled distance and the number of errors in wayfinding, and have a better guidance effect for low-grade scenic spots especially. Compared with the existing global optimization methods, this paper's approach emphasizes tourist's decision making, uses few data types, and has no need for adjustment of configuration parameters, resulting in a more universal and applicable method. More importantly, this method automatically generates the display content for each directional sign according to the context information of the route and road junction data. This research provides a practical reference for the planning and designing the tourist signs system in a scenic area.

The remainder of this paper is organized as follows. Section 2 briefly reviews related works on the relevant standards, tourist sign placement, and landmark selection. Section 3 presents the specific method for selecting directional sign location and automatic generation of content in a scenic area. In Section 4, the proposed method is tested in an experimental area, and the results are evaluated by comparison with the random walk algorithm and tourist questionnaire. Section 5 draws conclusions and discusses directions for future research.

2. Related Works

Compared to other subjects within the tourism geography field, the tourist signs system has not been commonly studied to date. The current study's research can be categorized according to three aspects: related standards, tourist sign placement, and landmark selection.

2.1. Related Standards

Several standards have outlined relevant principles and requirements for the construction of the TODS system. The International Organization for Standardization (ISO) 7001:2007 provides a communication tool for public information that can be used at public places (e.g., airport, shopping center, hospital, tourist facilities). It only stipulates common graphic symbols and text and does not replace the need for careful consideration and application of wayfinding and signing schemes. The Idaho Transportation Department of the United States developed the Standards and Procedures for TODS in 2007, which specified highly systematic sign design. In terms of location requirements, it proposes that sign placement shall be determined after a thorough field review conducted by the district office, and TODS placement shall be on the most appropriate state highway at a location nearest the most direct and usable access road to the facility. The Chinese "national standard public information guidance system—setting principles and requirements—Part 9: Tourist attraction" explicitly proposes that the quantity and location of directional signs should be planned overall with consideration of characteristics of tourism activities, and the amount must be consistent with the actual demands in a scenic area. "Manual of uniform traffic control devices, Part 6: Tourist and services signs" and "National Tourist Signing Eligibility Guidelines" in Australia provide information about creating

a tourism signing system that communicates with visitors effectively, meets the needs of tourism operators, and protects the amenity of road reserves.

2.2. Tourist Sign Placement

At present, little direct research on location selection and content generation of tourist signs exists. The placement principles, individual differences, optimization strategy, and evaluation methods are mentioned in the relevant literature. Moosavi [21] emphasized that visibility, readability, and understandability were the major factors for designing an airport tourism signage system. João and Fernando [5] provided principles for the systematic development of wayfinding signage, including necessity, universality, usability, simplicity, uniformity, normativity, and perceptibility. Different individuals have specific differences in wayfinding performance. Chang [2] examined the differences (gender, age, and previous traveling experience) in wayfinding strategy preferences and anxieties among international tourists. In terms of optimization, Tilden [22] pointed out that a high number of signs is not initially required, because they not only cause visual fatigue for tourists but also increase the construction cost of a scenic area. Findlay's [23] analysis of the influence of different spatial layout modes of tourist signs indicated that wayfinding problems were related to the context and location of signs, rather than the materials and details of sign design. Ikuta [24] studied the essential elements of good visitor sign establishment. Basiri [13] used crowd-sourced movement data to make tourist guidance systems more intelligent, adaptive, and personalized. Various studies have evaluated human wayfinding performance based on task performance criteria. These studies have measured the time taken to complete a task [25], the distance traveled to the destination, and the number of errors made during the task [26]. The combination of methodologies used for wayfinding evaluation of interior spaces has been described as space syntax, which is evaluated wayfinding in underground train stations in Belgium and found it effective in analyzing the space [27]. Ruddle and Lessells [28] reviewed the existing literature and summarized as three levels of metrics for evaluating wayfinding, namely, users' task performance (time taken, distance traveled, and the number of errors made), physical behavior (locomotion, looking around, and time and error classification), and decision-making rationale (think aloud, interview and questionnaire), which is suitable for different application scenarios. The most common method of evaluating wayfinding is to measure task performance directly.

2.3. Landmark Selection

In the field of pedestrian navigation, many studies have focused on the location selection of the landmark, which is similar to directional sign selection. Landmarks are significant physical, built, or culturally defined objects that stand out from their surroundings and help in locating the geographic position [29]. Landmark-based pedestrian navigation systems can offer the most explicit cues to enhance wayfinding instructions [30,31]. In general, the landmark selection approach can be classified into three categories [10]. The first approach is to choose landmarks by integrating the influencing factors into a single computational model. For example, Caduff and Timpf [32] computed a linear weighting function by summing the weighted influences of distance, orientation, and salience, and then calculated the optimal route using a weighted shortest-path algorithm. The second approach represents the factors as a landmark graph model and to optimize it using graph theory. For example, Elias and Sester [11] proposed a landmark graph model to represent the weights of factors, including distance, object weights, segment weights, and chunking. The third approach is a hierarchical optimization process. For example, Fang [10] proposed a multi-objective model to generate optimal landmark sequences for pedestrian route instructions using an ant colony optimization algorithm. Zhou [14] proposed an approach for computing routes without complicated decision points in landmark-based pedestrian navigation with GA, which involved the calculation of decision point complexity based on the structure of the pedestrian network and landmark data from panoramic images.

2.4. Summary of Research Works

To summarize the current state of the relevant research, many national and industry standards for TODS have been released with high practical application value. However, these standards mainly outline broad requirements, and details of specific implementation and location selection are not provided. In the tourism geography field, some principles for the placement of directional signs have been proposed, but there are few specific practical methods. The landmark selection method provides related ideas for this paper, but the research of automatic content generation for directional signs is limited.

3. Method

3.1. Basic Ideas

In this paper, road networks, scenic spots, and entrances data are needed. Based on the theory of tourists' spatial behavior, the method uses the node importance measurement algorithm of the complex network analysis field. The specific implementation method includes four main phases, as follows and shown in Figure 2.

Phase1: Tourist Routes Simulation. The Dijkstra algorithm has generated the weighted shortest paths among entrances and scenic spots. The grade of the road was taken into consideration as a weight. The paths are regarded as the simulated tourist routes in a scenic area.

Phase2: Betweenness Centrality Calculation. Based on the simulated tourist routes, a complex network node evaluation index, Betweenness Centrality, is used to calculate the importance of each junction node in the road network. Simultaneously, the destination information of the simulated routes passing through each junction node has been recorded.

Phase3: Location Selection. All road junction nodes are regarded as candidate objects. The final location for directional signs placement is selected based on three proposed rules, which considering the betweenness Centrality value, the grade of the connected roads, and the distance in adjacent junction nodes.

Phase4: Content Generation. Based on the statistics of the destination name and the number of simulated tourist routes in each direction of each junction node, content on directional signs at each junction node was generated based on certain rules and the route contexts.

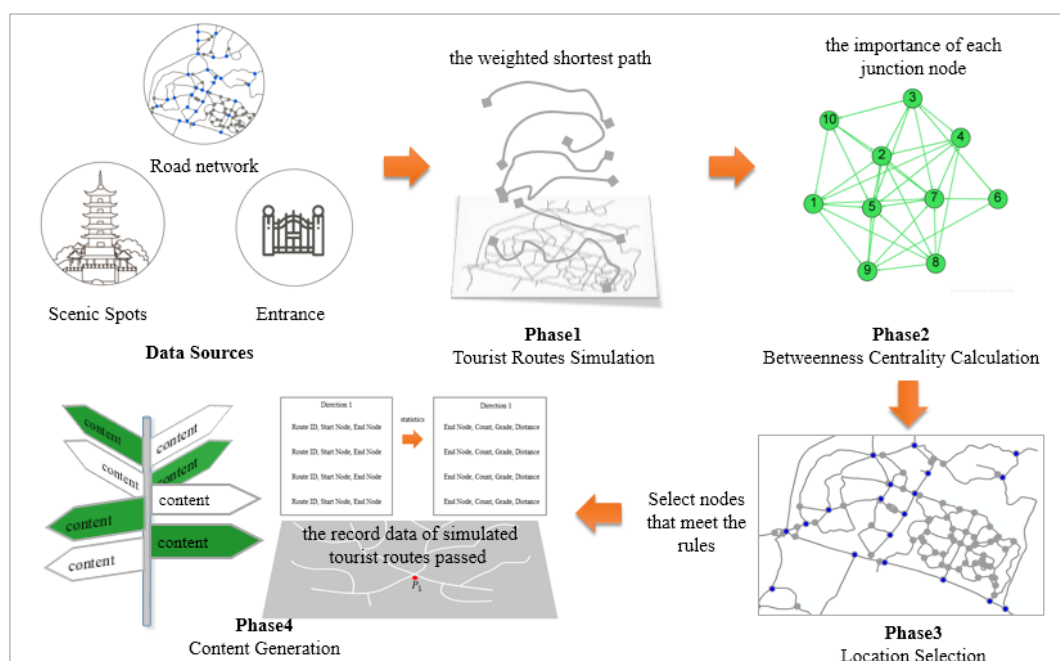


Figure 2. The four main phases of the basic idea in this paper.

3.2. Tourist Routes Simulation

The placement of directional signs should refer to the pattern of tourists' space movement and deploy at important positions with frequent tourist activities. But in a scenic area under construction, the data collection of tourist activities is not available. Therefore, the existing research results on the spatial movement pattern and route choice behavior of tourists in scenic spots have been referred to in this article. Through identifying scenic hot spots in GPS tracking data, Huang [33,34] revealed that the paths of tourists' activities in a scenic area mainly concentrated on the routes among the entrance and scenic spots, and the activity density on the routes among core scenic spots is significantly higher. Alivand's [19,35] detailed analysis of scenic route choice behavior and divided the attributes that influence route choice behavior into travel time, distance, road type, or the number of turns, proximity to mountains, water bodies, green areas, or historical buildings. The test results identify several variables of the surrounding environment as significant contributors to route scenery after controlling for road type. However, for tourists who are unfamiliar with the scenic area, fewer tourists plan the route in advance when visiting for the first time, and the route choice is based on the type of road. Hiroshi [20] has done an experiment in Nara Park to study the route choice behavior of pedestrians in different types of road intersections. The results have shown that tourists tend to choose wider or high-grade routes, and more than 56% of pedestrians would choose to go straight when encountering an intersection, and the route with a small angle between the original line is more likely to be selected at a three-way intersection.

Based on past research on route choice behavior, we realize that the road type is the main factor in the route choice for the unfamiliar tourist when first visit a scenic area without the directional signs. Meanwhile, in the process of planning of the scenic area, the main roads built are the recommended routes for tourists, which connect the most scenic spots. Thus, the simulated tourist routes based on tourists' spatial behavior were proposed in this paper. The weighted shortest paths among entrances and scenic spots in the scenic area were generated using the Dijkstra algorithm, as shown in Figure 3. The grade of the road was taken into consideration as a weight. The generated paths were used as simulated tourist routes and represent the frequency of tourists' activities.

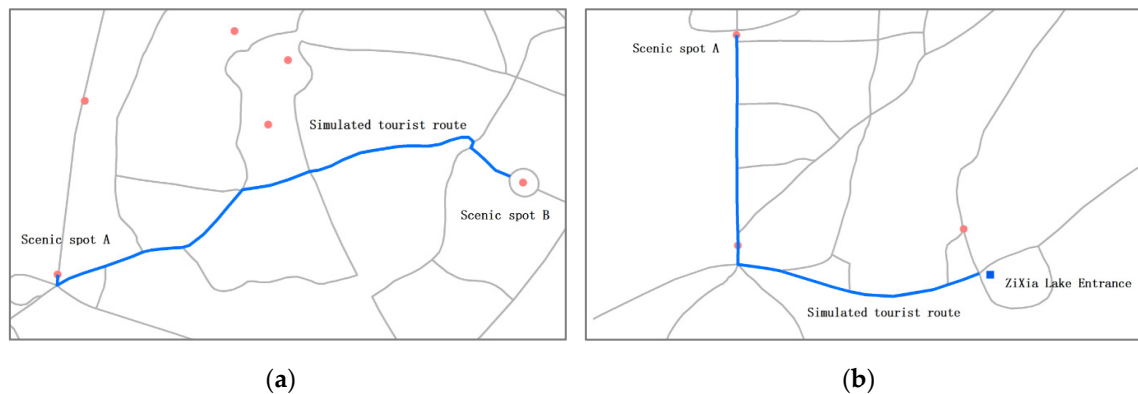


Figure 3. The simulated tourist routes: (a) The weighted shortest paths between each scenic spot, (b) The weighted shortest paths between scenic spots and entrances.

The following assumptions are made first. In a scenic area $S = \{S_1, S_2, \dots, S_i, \dots, S_n\}$, where S_i is a scenic spot, and n is the number of scenic spots. $S_i = \{x_i, y_i, d_i\}$, x_i is the longitude, y_i is the latitude of the scenic spot, and d_i is the grade of the scenic spot. The entrance data in a scenic area $E = \{E_1, E_2, \dots, E_i, \dots, E_m\}$, where E_i is an entrance, and m is the number of entrances. $E_i = \{x_i, y_i, d_i\}$, x_i is the longitude, y_i is the latitude, and d_i is the grade of the entrance.

The simulated tourist routes R are generated from the scenic spot S and the entrance E , which are superimposed on the existing road network in a scenic area. The number of simulated tourist routes

is $n * (n - 1) + n * m$. The routes R are assumed to be $\{R_1, R_2, \dots, R_i, \dots, R_{(n^2+mn-n)}\}$, where the start point of each route R_i is $d_{i,s}$ and the end point is $d_{i,e}$.

3.3. Betweenness Centrality Calculation

In order to ensure the appropriateness of the tourist signs system, the directional sign should be deployed at junction nodes where the tourist frequently passes, which is instead of every junction node. Therefore, the identification of important junction nodes is an essential part of this research. The scenic area can be abstracted into a network structure composed of scenic spots, facilities, entrances, and roads. There are many methods for evaluating the importance of network nodes, including indicators such as degree centrality, closeness centrality, betweenness centrality, and eigenvector centrality. Among them, betweenness centrality can measure the number of shortest paths through the node and select important nodes in the network from a global perspective.

This paper uses weighted betweenness centrality to calculate the importance of each junction node. Assume that all junction nodes, $C = \{C_1, C_2, \dots, C_i, \dots, C_a\}$, have been extracted from the road network, and the number of junction nodes is a . For any junction node C , the calculation formula of the weighted betweenness centrality is as follows:

$$BC = \sum_{i=1}^{n^2+mn-n} \frac{(d_{i,s} + d_{i,e})}{2}$$

where $d_{i,s}$ is the weight of the start node of the simulated tourist route R_i , which intersects with node C , $d_{i,e}$ represents the weight of the end node of R_i . $n^2 + mn - n$ is the number of simulated tourist routes. The calculation process of betweenness centrality for each junction node of the network is presented in Table 1.

Table 1. Betweenness centrality calculation process of each junction nodes.

Input: simulated tourist routes R and junction nodes C
Output: Betweenness Centrality of each nodes bc_array
<pre> double bc_array[] for the junction node $C_i \in C$ do double $BC_i = 0$ for the simulated tourist route $R_j \in R$ do /* function ST_intersects can determine if the node is on the line*/ If ST_intersects (C_i, R_j) then $BC_i = BC_i + (d_{j,s} + d_{j,e})/2$ else $BC_i = BC_i + 0$ end end for bc_array[i] = BC_i end for return bc_array </pre>

Besides, in the calculation process of the betweenness centrality of each junction node, the start and end point information of the simulated tourist routes through each node should be recorded to provide a basis for the content generation of the directional signs in the last phase.

3.4. Location Selection

All junction nodes in the scenic area are used as the candidate location object for selection in this article. After obtaining the betweenness centrality value of all junction nodes, the importance of each node has been calculated. Through consultation with planners in scenic areas, three rules for location selection was proposed as follows:

Rule1: Delete this junction nodes when their BC value is null. The reason is apparent, and no simulated tourist routes pass through such nodes, which indicates tourists rarely pass, and the importance of those nodes in the network is extremely low.

Rule2: Delete this junction nodes for which the grades of all passing road lines are the lowest. These low-grade trails are short and mainly used for viewing, as shown in Figure 4. Delete these junction nodes when there is an intersection with the highest- and lowest-grade road line because tourists tend to choose wider or higher-grade routes, instead of choosing the path with the lowest grade.



Figure 4. The small and simple paths in a scenic area and the fourth-grade red lines are similar to narrow winding trails of a garden or forest.

Rule3: Merge the adjacent junction nodes for which distance is less than a certain threshold. When the distance of two adjacent junction nodes is low, as shown in Figure 5, the directional signs would generally be deployed at a more important node or in the middle of two junction nodes. If the distance between each adjacent junction node is less than the distance threshold, the node with lower BC value would be deleted, and the information of the simulated tourist route through the deleted node should be merged with that of the more important node. The distance threshold is generally evaluated by the visible distance of the signs' text in the scenic area.

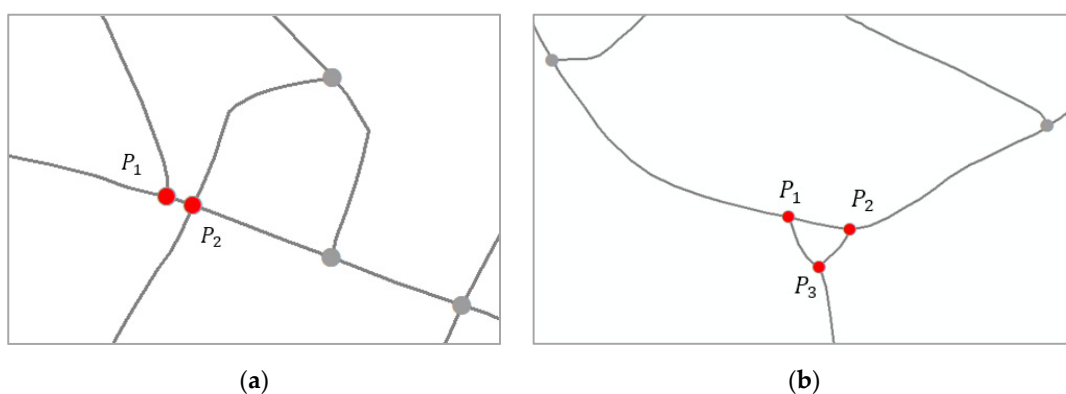


Figure 5. Examples of very close adjacent junction nodes: (a) two junction nodes, (b) three junction nodes.

After completing the filtering of the candidate location using the above three rules, the remaining junction nodes are the final location of the placement of the directional sign. If the number of directional signs needs to decrease due to cost constraints, the remaining junction nodes can be further reduced according to the betweenness centrality value.

3.5. Content Generation

The content generation in each route direction of the signboard at the selected junction node is an important part of this research, which is rarely mentioned in the existing research. At a junction node, the name of important scenic spots and its arrived distance of all directions should be displayed to provide a better wayfinding service. In the calculation process of the betweenness centrality, the information of the simulated tourist routes has been recorded, including the route ID, and start node and end node of each direction. From the recorded data, the most popular scenic spots from a given junction node can be found.

The simulated tourist route information recorded for the selected junction nodes must be processed first, as shown in Figure 6. The information box on the left is the recorded data from direction 1 the node P_1 , which is structured as $\{Route\ ID, Start\ Node, End\ Node\}$. Through the group statistics, each direction of all selected junction nodes are looped, and structured as $\{End\ Node, Count, Grade, Distance\}$ in the right information box. Thus, the count of the scenic spots that tourists visited in each direction is realized based on the simulated tourist routes.

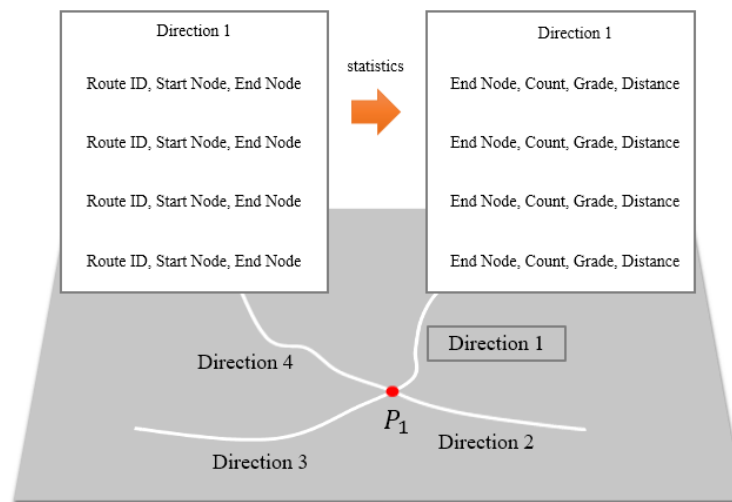


Figure 6. The statistical process of recording simulated route information of a junction node.

In the content design of the directional sign, the rules adopted as follows: at a junction node, two scenic spot names are set in a direction by default, and the content format is “name of the scenic spot, arrived distance”. The most important and nearest scenic spot name in this direction should be displayed in the directional sign. According to the recorded data of each selected junction node and the above rules, the method of automatic content generation of each directional sign includes the following steps:

Step1: Choose one direction of a junction node which is selected for sign placement, and obtain the converted record data $\{End\ Node, Count, Grade, Distance\}$.

Step2: Select the end node with the maximum count*grade value in the record data as the most important scenic spot in this direction.

Step3: Select the end node with minimum distance value as the nearest scenic spot in this direction.

Step4: Check the most important and the nearest scenic spot are the same. If they are equal, the end node with the second-highest count*grade value is selected as the most important scenic spot. The name of the most important and the nearest scenic spot is the display content.

Step5: Complete the content generation in all directions for all selected junction nodes in a loop through Step1, Step2, and Step3.

Step6: Check all scenic spots that have been selected to display. If there are scenic spots that are not shown, find their nearest selected junction nodes, and add the name of the rest scenic spots to the display content.

The calculation process of content generation for each selected junction node is presented in Table 2.

Table 2. Content generation process of each junction node.

<p>Input: the selected junction nodes C and its record data $\{End\ Node, Count, Grade, Distance\}[]$</p> <p>Output: display content of each junction nodes $DisContent$</p>
<pre> Array DisContent [[]] /* scenicSpot[] contains all scenic spots name*/ String scenicSpot[] for the junction node $C_i \in$ selected nodes C do for the direction $D_j \in C_i.direction$ do String visitData[] = node.getRecordData(direction j) /*get the most important scenic spot in this direction*/ String disName1 = visitData.getMax(Count*Grade) /*get the nearest scenic spot in this direction*/ String disName2 = visitData.getMin(Distance) If disName1.equals(disName2) visitData.remove(disName1); disName1 = visitData.getMax(Count*Grade) DisContent[C_i, D_j].add(disName1, disName2) scenicSpot.remove(disName1, disName2) end end for end for /*check all scenic spot has been displayed in the directional sign*/ if scenicSpot.length != 0 For scenic_i in scenicSpot[] DisContent [scenic_i.getNearestNode()].add(scenic_i) end for end return DisContent </pre>

Through the above steps, the generation of the content of the directional signs in each direction of all selected junction nodes could be completed. This method utilizes the information of the simulated routes passing through the junction node and achieves the recognition of the scenic spots that are most popular with tourists.

4. Experiment and Result

4.1. Experimental Area and Data Preparation

To evaluate the method proposed in this research, we selected the Ming Tomb as the experimental area, which is a famous scenic area located in Nanjing, Jiangsu Province, China. The Ming Tomb is the mausoleum of Zhu Yuanzhang, the founding emperor of the Ming Dynasty, built in 1405 and included in the World Heritage List in 2003. In the experimental area, data for 39 scenic spots, 6 entrances, emplaced directional signs (location and content), and the road network has been collected and processed in ArcGIS Desktop. A total of 141 junction nodes were extracted from the road network. According to the size and daily passenger flow of scenic spots and entrances, the level of scenic spots and entrances has been divided into four grades.

4.2. Result

Based on the collected data of scenic spots, entrances, and the road network, the location selection and display content generation methods were realized. A total of 1716 simulated tourist routes were generated. The betweenness centrality of each extracted junction node was calculated, which is shown in Figure 7a. The darker the color and the larger the size of the circle, the higher the importance of the

junction node. Among the 141 junction nodes, 25 nodes with blue circles do not have any simulated tourist route passed through, and their betweenness centrality value is zero. The junction nodes with higher betweenness centrality value mainly concentrated around high-grade scenic spots and entrances. After the location selection process, among 141 junction nodes, 41 nodes are selected as the recommended deployment location, and the result is shown in Figure 7b.

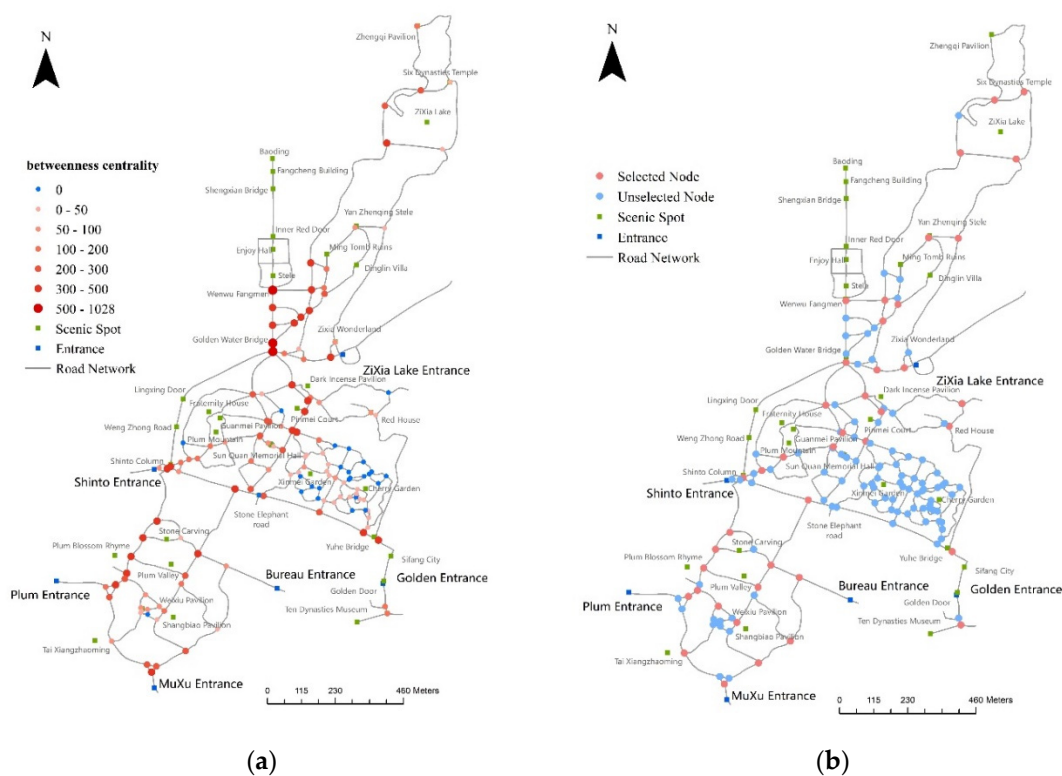


Figure 7. The generated result in the experimental area. (a) The betweenness centrality of each extracted junction nodes with a red circle in a different size; (b) the selected junction nodes for directional sign placement with a blue circle.

At the same time, the display content of the directional signs in each direction of all selected junction nodes was generated. Three representative results for display content are chosen to introduce in this paper.

In the first type, the content of the selected directional sign in a junction node is generated by obtaining the most important scenic spot and the nearest scenic spot directly in its record information. The representative example is shown in Figure 8. Although the red node is the intersection of six roads, its display content generation is relatively simple and clear.

In the second type, the content generation in a junction node is come from the record information in multiple nodes after merging some adjacent junction nodes. The representative example is shown in Figure 9a, and the red junction node merges the two adjacent unselected gray nodes.

In the third type, the content generation in a junction node is edited after the check process. The representative example is shown in Figure 9b, “Baoding” as the most important and “Stele” as the nearest scenic spot has been selected, “Fangcheng Minglou”, “Shengxian Bridge”, “Inner Red Door” and “Enjoy Hall” are not chosen to display by any selected nodes. Therefore, their name has been added to the display content of the nearest selected junction nodes.

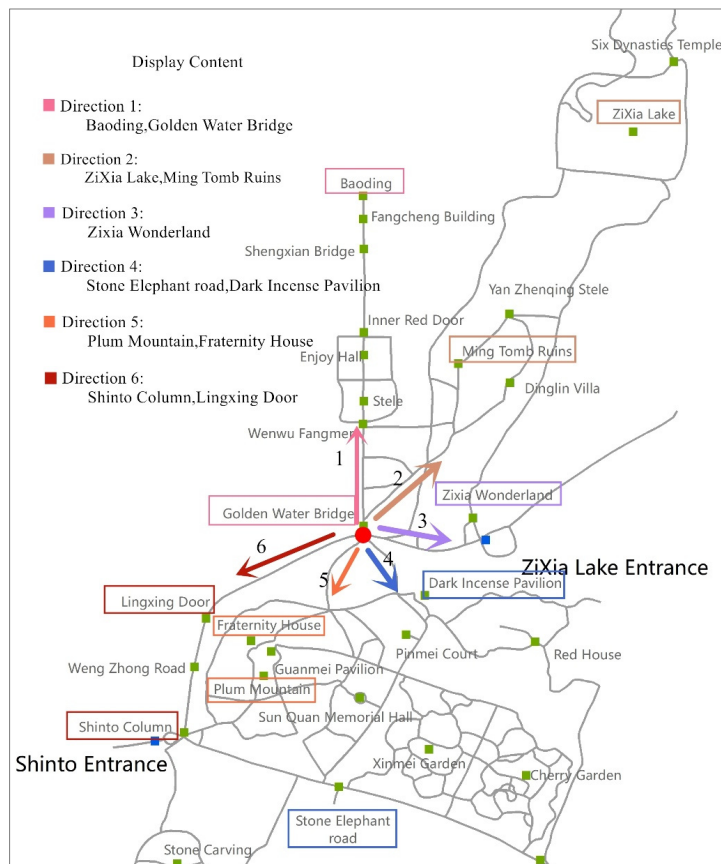


Figure 8. The representative example of display content in the first type, the content displayed in each direction is shown in a different color of arrow and box.

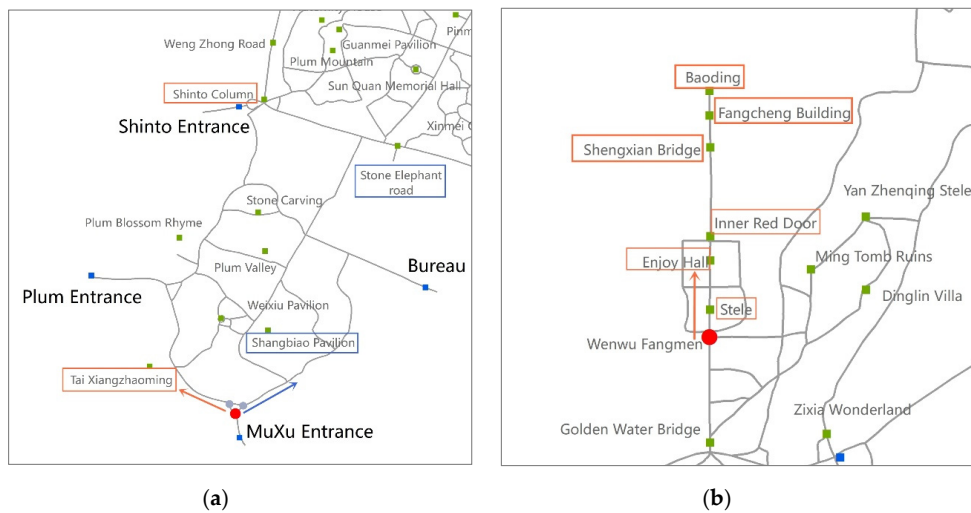


Figure 9. The representative example of display content in second and third type: (a) The result comes from multiple nodes; (b) the result is the edit after the check process.

4.3. Comparative Evaluation

4.3.1. Qualitative Comparison

The results generated in this paper are compared with the actual placement scheme of the directional signs in the experimental area, which is shown in Figure 10. It contains three types of selected location: the location with the red circle is selected both in two schemes, the location with

the blue circle is selected in the proposed method but unplaced actually, and the location with the gray circle is actually placed but not selected in the proposed method. After the data collection in the Ming Tomb, 26 junction nodes have been deployed the directional signs, but 41 junction nodes are selected as the recommended deployment location in this paper. The coincidence rate is 58.53%. Among the above 26 junction nodes, 24 nodes were also chosen in the proposed method, and the other two unselected nodes were abandoned because they are in the lowest-grade road lines.

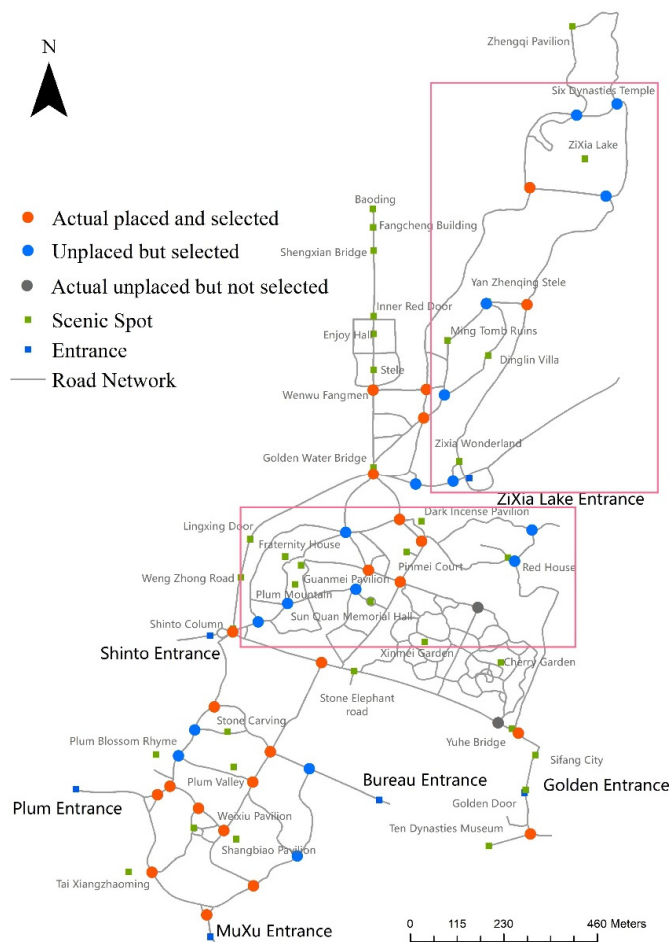


Figure 10. The comparison of the actual placement scheme and the result in this paper.

The main differences between the two placement schemes are concentrated in the “ZiXia Lake” and “Plum Mountain” areas, as shown in Figure 10 inside the two red rectangular boxes. “ZiXia Lake” is an important tourist attraction in the experimental area, and “Plum Mountain” is one of the most important plum viewing bases in China. However, no directional signs are currently deployed in these two areas, which is not conducive to tourists’ wayfinding and constitutes a relatively significant flaw in constructing the signs system.

From the display content in the directional signs, this paper achieves the full coverage of all scenic spot names. At the same time, the actual placement scheme only guides 17 high-grade scenic spots, accounting for a proportion of only 43.6%. Compared to the content displayed on the 24 junction nodes selected by two schemes, the overlap rate of content in each node is shown in Figure 11, and the overall average overlap rate is 85.63%.

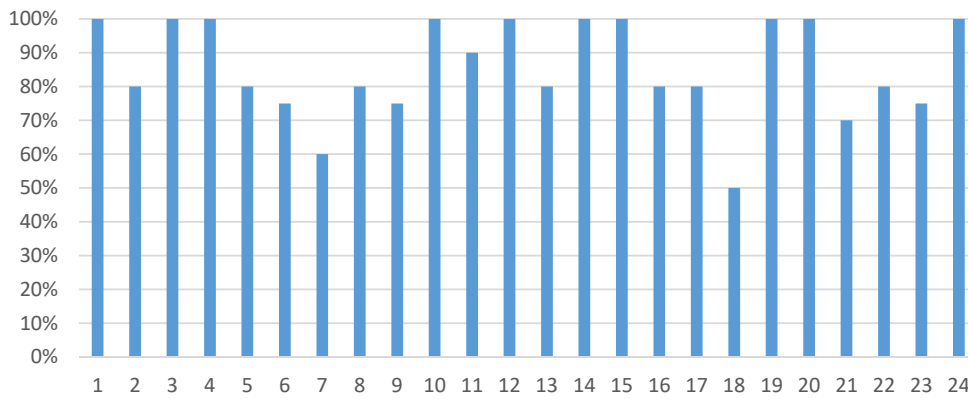


Figure 11. The overlap of display content in each junction nodes selected by two schemes.

The number of selected junction nodes for directional signs placement far exceeds the current number deployed in a scenic area. This article limits the number of results generated to 26, which are further selected from the generated results according to the sorted betweenness centrality values. The comparison between two placement schemes when the number of selected junction nodes is limited to 26 is shown in Figure 12. The similarity of location selection is 73.08%. Among 26 nodes, 19 nodes near the entrance and core attractions are selected by two placement schemes. However, the generated scheme covers a larger range of scenic spots and major tourist areas, “ZiXia Lake” instead of the actual placement scheme has a higher coverage in “Plum Mountain”.

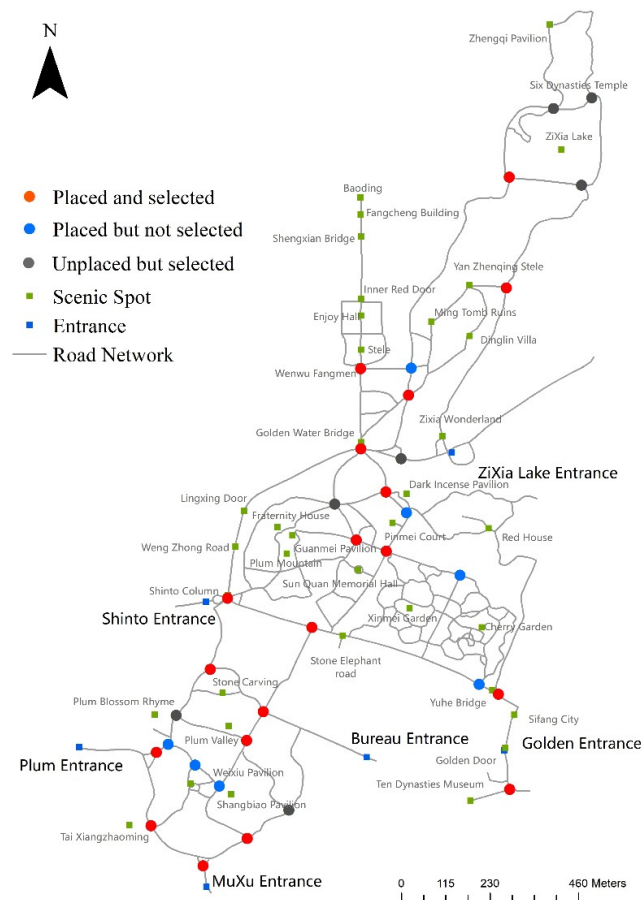


Figure 12. Comparison of two placement schemes when the number of selected nodes limited to 26.

4.3.2. Evaluate in Random Walk Algorithm

In order to evaluate and compare the method more quantitatively, the most common evaluation index in the research of wayfinding behavior was used, which includes the traveled distance and the number of errors made. Based on a particular rule of a random walk algorithm, the tourist movement process in the scenic area is simulated, and it referred to tourists' spatial behavior in a scenic area that tourists would choose high-grade scenic spots to visit and choose high-grade routes to walk. The specific random walk algorithm proceeds according to the location and display content on the directional sign at each junction node. The detailed step of the random walk algorithm is as follows:

Step1: Randomly select a start point from six entrances in the experimental area and list the names of scenic spots required to reach.

Step2: Enter the scenic area from the start point, follow the connected route until reaching a junction node. Judge there are scenic spots in the list on the connected route or not. If yes, mark these scenic spots as visited.

Step3: Check the reached junction node. If a directional sign is deployed, select the route directly with the highest grade of the scenic spot from the display name in the list randomly. If the names of the scenic spots in the list are not in the display name of the directional sign, the route direction with a higher grade of the scenic spot is selected randomly. If there is no directional sign at the junction nodes, randomly select the route direction with higher road grade.

Step4: The reached junction node in Step3 is as the start point, follow the route direction selected in Step 3, and get the next connected route, repeat steps 2, 3, and check whether there are scenic spots around the connected routes.

Step5: Continue the above tour process until all scenic spots in the list are marked as visited. Then stop the random walk process.

After the random walk route is completed, a route is generated among a random entrance and the scenic spots that are required to be visited. The distance of the generated route is the traveled distance, and the number of errors made is the number that the route between adjacent scenic spots is not the weighted shortest path, which indicates it go by a roundabout route. Finally, the traveled distance and the number of errors made are output as an evaluation index.

In this article, the scenic spots have been divided into four grades according to the popularity and scale. The higher number of the grade, the more important of a scenic spot. Then, there are 10,000 random walk routes generated for the comparison in each grade, and the result of traveled distance is stable under the above number of simulated routes. Comparing the placement scheme with 41 directional signs, the placement scheme with 26 directional signs, and the actual placement scheme in the experimental area, a result is shown in Table 3. Tourists have completed different grades of scenic spots based on the random walk algorithm. The traveled distance and errors in Table 3 are the average value of 10,000 test results.

As shown in Table 3, the generated scheme with 41 directional signs is significantly better than the actual placement scheme. When all scenic spots are traveled, compared with the actual placement scheme, the average traveled distance and the average number of errors are reduced by 49.3% and 76.9%, respectively, in the placement scheme with 41 directional signs. When the number of selected nodes is limited to 26, the average traveled distance and the numbers of errors are reduced by 31.1% and 53.8%, respectively. However, when only visit the high-grade scenic spots, the improvement of traveled distance and the number of errors in the three schemes is not apparent.

Based on the data in the generated scheme and the actual placement scheme, the statistical significance test is presented, and the *t*-test ($\alpha < 0.05$) is adopted. The result is shown in Table 4. The significance of different grades is less than 0.05, which indicates that the difference between the generated scheme and the actual placement scheme is extremely significant.

Table 3. The comparison of three schemes in the random walk algorithm.

Scenic Spots	Result Type	Traveled Distance (km)	Errors (Num)
Grade ≥ 4	Scheme with 41	3.5	0
	Scheme with 26	3.8	0
	Actual scheme	4.1	2
Grade ≥ 3	Scheme with 41	4.4	1
	Scheme with 26	5.1	3
	Actual scheme	5.6	8
Grade ≥ 2	Scheme with 41	7.6	4
	Scheme with 26	9.2	6
	Actual scheme	10.6	19
Grade ≥ 1	Scheme with 41	10.2	6
	Scheme with 26	13.8	12
	Actual scheme	20.1	26

Table 4. The statistical significance test after *t*-test.

Scenic Spots	<i>p</i> Value in Traveled Distance	<i>p</i> Value in Errors
Grade ≥ 4	4.18×10^{-6}	2.05×10^{-30}
Grade ≥ 3	2.01×10^{-5}	1.15×10^{-36}
Grade ≥ 2	7.85×10^{-17}	2.05×10^{-16}
Grade ≥ 1	1.45×10^{-17}	1.93×10^{-16}

4.3.3. Evaluate in Questionnaires

Besides, the generated results are verified by tourists through questionnaires in the experimental area. A total of 42 tourists participated in the questionnaire, and most of them are visit the experimental area for the first time. As a tourist who is unfamiliar with the scenic area, they do not know what content should be displayed on the directional signs. This article counts each junction nodes, whether it should be deployed a directional sign in the tourists' opinions. The result is shown in Figure 13. There is a total of 54 nodes that need to be deployed. The probability of selected nodes is shown in the annotation of the map, which is the number of visitors who think the nodes should be selected divided by the total number of survey visitors. The gray circle is not selected by any tourists, and the probability is 0.

According to the results of the questionnaires, 95.2% of tourists believe that the current number of directional signs in the actual placement scheme is insufficient. The 41 nodes selected by the method proposed and the 26 nodes deployed actually are all within the 54 junction nodes that surveyed tourists consider the directional signs should be deployed. Among 54 junction nodes, there are 11 nodes with a probability of 100%, which are also selected by two schemes. There are 34 nodes with a fixed probability of over 80% and 43 nodes with a specified probability of over 50%.

In addition to the 26 nodes deployed in the actual placement scheme, there are 15 nodes with a probability of more than 80% not selected, and 21 nodes with a probability of more than 50% were not selected. These unselected nodes are the location where tourists put forward to add directional signs. There is a big gap between the number in the actual placement scheme and the number in the expectation of tourists, which fully illustrates the current shortage of directional signs in the experimental area.

Among the 41 nodes generated in this paper, 34 nodes have a probability of over 80%, and all selected nodes have a probability of over 50%, which is meet with a total of 43 nodes have a probability of over 50% in the surveyed tourists' opinion. Compared with the nodes selected by tourists, there are 13 nodes unselected in this paper, and the average probability of these nodes is 43%. Therefore, it is reasonable to give up the 13 nodes. In general, through the above comparative analysis, the result

generated in the proposed method is highly similar to the result in the questionnaires, which is met with the needs of tourists.

In addition, two scenic guiders were interviewed to evaluate the result generated in this paper, which is to stand at the important junction road, guide tourists, maintain order and answer wayfinding questions in the experimental area. They believe that the results generated are reasonable, important nodes in the scenic area have been selected, the display content is in line with frequent wayfinding questions, which can make up for the shortcomings of the current TODS. However, in terms of the display content, it is a basic requirement that the most important and nearest scenic spot name in this direction should be displayed in the directional sign. At some important junction, the number of display content in a route direction maybe 3, 4 or more, and it needs to be flexibly adjusted. In some nodes, it is not only should deploy a directional sign, but also place a global navigation map. The optimization content proposed by the scenic guider would be the research future work.

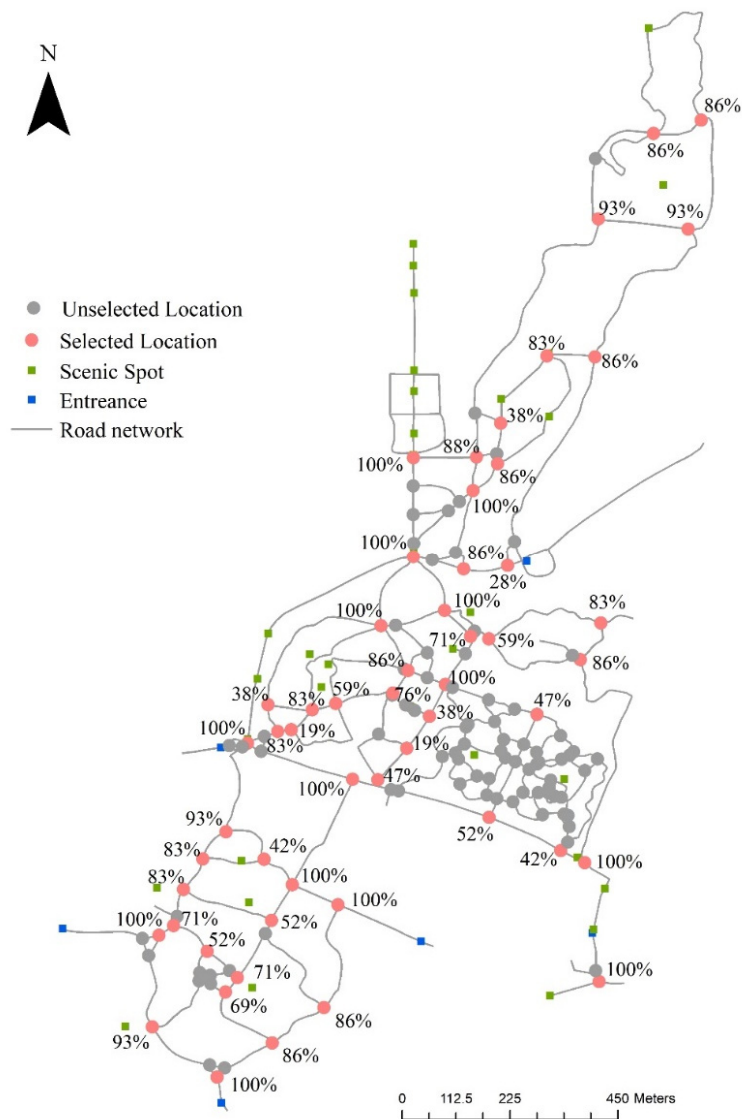


Figure 13. The probability that tourists believe that the location should be selected, the red circle is the selected, and annotation is the probability.

4.4. Conclusions

This article proposes a method for directional sign location selection and automatic content generation in a scenic area. Based on the related data of the experimental area, the results generated were compared with the actual placement scheme in qualitative, quantitative and questionnaire evaluation. Through the above analysis, we can know that:

- (1) The method proposed can extract the important junction nodes for directional signs placement in a scenic area, and it can generate the display content of each direction based on the context information of the passing route automatically.
- (2) In the Ming Tomb, there are 41 junction nodes selected as the recommended deployment location in this paper, while the actual placement scheme only has 26 nodes. Among the above 26 junction nodes, 24 nodes were also selected in the proposed method, and the coincidence rate is 58.53%. When the number of selected junction nodes is limited to 26 in the scheme generated, the similarity of location selection is 73.08%. Compared to the content displayed on the 24 junction nodes selected by two schemes, the overall average overlap rate is 85.63%.
- (3) Through the comparison in the random walk algorithm, the method in the experimental area can effectively reduce the traveled distance and the number of errors. With the gradual decrease in the grade of scenic spots traveled, the improved effect of the scheme generated in this paper is more obvious. The result of the comparison is significant.
- (4) After the questionnaire and interview, there is a big gap between the number in the actual placement scheme, and the number in the expectation of tourists, 21 nodes with a probability of more than 50% were not selected in the actual scheme. The 41 nodes generated in this paper meet with a total of 43 nodes that have a probability of over 50% in the surveyed tourists' opinions. In two scenic guiders' feedback, the results generated are reasonable, important nodes in the scenic area have been selected, the display content is in line with frequent wayfinding questions, which can find the shortcomings of the current TODS.

5. Summary and Future Work

TODS is a basic and important project in the construction and planning of scenic areas. At present, the placement of directional signs generally depends on personal experience to identify important positions and mark important scenic spots. In this paper, a method of directional sign location selection and content generation was proposed. The Ming Tomb in China was selected as the experimental area, and the evaluation index of traveled distance and the number of errors was adopted. The random walk algorithm is used to compare the placement scheme generated with the actual scheme in the scenic area. Through the questionnaire survey, the opinions of tourists on the location selection were obtained. The results show that the method proposed is feasible, which can extract the important junction nodes for directional signs placement and generate suitable display content automatically. The coincidence rate of location selection in the generated scheme and actual scheme in the experimental area is 58.53%, and the overlap rate of display content is 85.63%. Based on the tourist questionnaire and random walk algorithm analysis, the generated scheme is significantly better than the actual placement scheme, and it can optimize the actual placement scheme in the experimental area, and reduce the traveled distance and the number of errors.

Compared with global optimization methods, such as the GA and ACO used in the existing landmark location research, which utilizes a minimal number of decision landmarks, the proposed method is more universal and applicable, and it starts from the placement rules of directional signs and has no need to adjust relevant parameters according to the test area. More importantly, this article focused on the automatic generation of the content of directional signs based on the contextual information of the simulated tourist routes, which provides a certain practical reference for the design of TODS.

However, research on the placement of tourist signs is a practical and complex application problem, which needs to be further researched from the perspective of wayfinding behavior, pedestrian navigation, spatial cognition, and group differences. In addition to considering spatial location selection and content design, it should also involve various other problems relating to height, orientation, visibility, carrier form, service object, etc. This article simply selects the junction node as the location object for sign placement and carries out location selection and content generation. Location selection, including the middle nodes of long road lines, service-oriented design, and the global optimization problem, could be future work based on this article.

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