Pedestrian Path Findings using Multi-Factors Affected Walking

Sooho Kim, YongJin.Joo, SooHong.Park

Abstract

Previous route guidance researches are mainly focused on route guidances for vehicles. However, due to the recent spread of personal computing devices such as PDA, PMP and smart phone, route guidance for pedestrians is increasingly in demand. The pedestrian route guidance is different from vehicle route guidance because pedestrians are affected more surrounding environment than vehicles. So pedestrian path finding needs considerations of factors affecting walking. This is purpose of this paper that extract factors affecting walking and charting the factors for application factors affecting walking to pedestrian path finding. In this paper, we find various factors about environment of road for pedestrian and extract the factors affecting walking. Factors affecting walking consist of 4 categories - traffic, sidewalk, network, safety facility. We calculate weights about each factors using analytic hierarchy process (AHP). Based on weights we calculate scores about each factor's attributes. The weight is maximum score of factor. These scores of factor are used to optimal pedestrian path finding as path finding cost with distance, accessibility.

1. Introduction

Since 1990s, the vehicle navigation market has been grown continuously. Such a growth of market has led to an advancement of related technologies. Technologies related to vehicle navigations may be divided into a hardware part such as terminals, storage media etc., data part such as road networks, background, POI, and a software part to utilize data stored. Among them, the software part responsible for a functional part is basically developed for vehicles so that data used by it has been also developed in a field related to a vehicle drive. Examining the path finding which is a typical function, technologies have been emerged beginning with the shorted path finding...
considering an initial distance, the fastest path finding considering speed limits and classes of roads, the free road path finding considering a toll, and the optimum path finding with the real-time traffic information of TPEG (Transport Protocol Experts Group.)

Recently, demands to not only functions to guide roads for vehicles but also services to guide roads for pedestrians are increasing due to the popularization of portable mobile devices such as smartphones, PDA, PMP.

The portable mobile devices could provide a location based service (LBS) through a GPS receiver and a variety of application programs. Map services based on road data is the most typical LBS and companies having navigation map data for vehicles provide applications developed themselves to use in the mobile devices by converting navigation data for vehicles. The navigation system for vehicles, however, is difficult to reflect properties of pedestrians using mobile devices. Therefore, it is required data and application programs specialized for pedestrian services.

This study analyzes factors having an influence on walking for data of road network constructing up to alleys where vehicles could pass through, and selects factors to be used for finding costs. Then, weights are assigned to the selected factors through the AHP (Analytic Hierarchy Process) method, and a path finding score is calculated using
them. The path finding score is used to calculate a final path finding score for pedestrians through operations with a distance which is the existing finding cost.

Chapter 2 derives factors having an influence on walking through an analysis on the existing studies. Chapter 3 calculates finding costs for pedestrians by assigning weights and scores for the derived factors, and Chapter 4 carries out an experiment for some areas. Finally, Chapter 5 discusses about conclusions and the future study subjects.

2. Extract Factors Affecting Walking

The walking factors are divided into physical environmental elements and human subjective elements. The physical environmental elements are the ones for walking facilities, which are used as indexes for evaluating the walking environment, and the human subjective elements are ones that could be differently represented depending on individual preferences and walking purposes etc. Handy S. (1996) proved that the physical environment was an influence factor of walking by conducting a survey targeting pedestrians in different areas after classifying the walking purposes into leisure and movement means, and Moudon A. V. (2003) analyzed on an influence factor of walking and cycling with evaluation indexes used in each field. And Lee C. (2006) derived the importance of elements evaluating the walking affinity through a statistical analysis. Seo. H. L. (2006) classified elements having an influence on walking into street environment, network environment, and regional environment to analyze them, and Park S. H. (2008) carried out a study to make them as indexes. Hieronymus C. Borst (2009) classified elements having an influence on walking of the elderly and infirm into 25 items to make them as indexes and used them in path finding, Lee J. E. (2008) classified the walking influence elements into physical environmental elements, changes of direction, visual field and accessibility to use for path finding through arbitrary weights.

Through these existing studies, this study carries out classification for traffic, sidewalk, network, and safety facilities etc. as physical environmental elements having an influence on walking, and finally derived factors are as follows.
Table 1. Factors having influences on walking

<table>
<thead>
<tr>
<th>Division</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>velocity, traffic lights, traffic calming facilities,</td>
</tr>
<tr>
<td></td>
<td>crosswalk, traffic density</td>
</tr>
<tr>
<td>Sidewalk</td>
<td>width, impediment, curve, vehicle entry into sidewalk,</td>
</tr>
<tr>
<td></td>
<td>Street trees, garden, seat, hate facilities, slope</td>
</tr>
<tr>
<td>Network</td>
<td>Accessibility</td>
</tr>
<tr>
<td>Safety facilities</td>
<td>Light, CCTV, construction area, buffer facilities</td>
</tr>
</tbody>
</table>

2-1 Traffic environment

Traffic environment is a factor for driveways adjacent to a footpath. The fact that is adjacent to a driveway may affect pedestrian’s safety. A speed limit is a factor giving the most significant influence to the extent of pedestrian’s injuries in the event of a traffic accident with them, and traffic lights, crosswalk, traffic tranquilization facilities could call a driver’s attention to increase safety for pedestrians. The traffic density is a traffic volume comparing to the road capacity, which pedestrian’s signal wait time may be changed according to the extent of traffic volume, and it may affect the emission extent of exhaust gases.

2-2 Sidewalk environment

The sidewalk environment is a factor for geometrical structures and facilities on the road where pedestrians are personally walking. The walking obstacles and the vehicle entry into a sidewalk affect pedestrian’s safety and convenience, and the footpath width, street trees, benches, flower beds, unpleasant facilities etc. affect the comfort of walking. Curves of sidewalk interfere with pedestrian’s securing a clear view, and the slopes have a significant influence on pedestrian’s view and walking fatigue degree.

2-3 Network environments

The network environment is a factor for accessibility of roads. This study would like to use local integration’s numerical values of the Space Syntax theory. The Space Syntax is a methodology to quantitatively calculate the extent of each space’s accessibility into
other space by analyzing a mutual structure between spaces. This theory has been used for studies to mainly calculate the accessibility of buildings or roads and represent it visually, and is recently applied also to a study analyzing correlation between accessibility and actual traffic volume. According to results of the study, it is proved that the local integration of the Space Syntax theory has a positive correlation with actual traffic volume (Jiang 2007, 2009.)

2-4 Safety facilities

The safety facility is a factor for safety accidents or crime occurrences that could be arisen when pedestrians are walking. Lighting prevents pedestrians from safety accidents by securing a clear view when walking in the night times, and CCTV could prevent from crimes. The construction area is a factor threatening pedestrian’s safety, and the buffer facilities could protect pedestrians from unexpected threats of vehicles.

3. Calculate path finding cost at each links using AHP method

3-1 Calculation of weights for each element

Every factor derived above has a qualitative property. In order to approach as the GIS methodology when utilizing them in path finding, however, a quantitative analysis is needed. This study uses the AHP method for such a quantitative analysis.

The AHP is a method that Thomas L. Satty devised in 1980, which is a multi-criteria decision making technique to select the optimum alternative by understanding the evaluation criteria and the alternative as a hierarchical structure. This AHP was developed based on the fact that the brain uses gradual or hierarchical analysis process when human beings make decision. According to results of the study, it is said that human beings follow three rules (setting of a hierarchical structure, setting of relative importance, maintenance of logical consistency) when they solve a problem. The following is a procedure to assign weights for each element according to three rules above.
(1) Setting of a hierarchical structure

Factors having an influence on walking are derived in the section 2. Representing them hierarchically, they are as follows.

![Hierarchical representation of walking factors](image)

Fig. 2 Hierarchical representation of walking factors

(2) Setting of relative importance

Weights for each hierarchy are calculated through the dual comparison matrix for each factor proposed by the AHP. This study uses the Expert Choice tool. Weights for each factor calculated through the AHP method are as follows.
(3) Maintenance of logical consistency

The AHP derives a non-consistency index in the integration process of 1:1 comparison results utilizing the main eigenvector of comparison matrix, and logical consistency of the decision-maker could be judged using it. It is an important advantage of the AHP method, which could increase rationality and logicality of decision making. The consistency indexes for weight selection of walking factors are 0.07, 0.06, 0.09, 0.07, and they are numerical values less than 0.1 that is the reference of logical consistency, which it could be found that the logical consistency is maintained.

3-2 Assigning scores for each attribute of factors

The previous stage calculates weights for each factor through the AHP method, and the result being logically right is obtained because weights determined through the non-consistency analysis keeps the logical consistency. At this time, total sum of weights for
each factor is 1. But each factor does not always keep the optimum condition in actual road situations. For example, driving speeds of vehicles exist differently from 10 to 110, and these values are needed to be distinguished. Therefore, this study assigns scores based on the weights for each attribute of each factor. The maximum value of scores for each attribute becomes the calculated weight, and it means that total sum of road scores becomes 1 when the road becomes the optimum condition for pedestrians.

3-3 Calculation of a finding cost

The finding cost considered first was the distance for the vehicle navigation. In other words, it was based on an assumption that a path with the shortest moving path is most rapidly arrived. However, actual road situation is very different from it. The required time basically becomes different depending on the speed limit, and actual required time may become different depending on the number of lanes, curved section, bottleneck state etc. In addition, recently, the optimum path finding techniques have been emerged considering a traffic volume etc. In order to find the optimum path considering factors having an influence on walking like this, a variety of factors were defined earlier, and weights for each factor and scores for each attribute were assigned. The finding cost finally utilized for walking path finding is calculated as the product with the distance which is the most fundamental finding cost. At this time, since the score for each attribute is advantageous for walking as its value becomes larger but the distance is disadvantageous for walking as its value becomes larger, it is calculated with the distance after taking an inverse number of the score for the reference is adjusted.
4. Case Study

The finding cost for walking path finding described earlier is applied to actual road network. The target region is a road around the Sadang station where the No.2 subway line crosses the No.4 line in Seoul, Korea. This region is the downtown area and busy street intersected by two sections of subway, where is the place with large pedestrian volume of people using surrounding facilities and willing to use public transportation.

![Fig. 3 Aerial photo and road network of target region](image)

The target links are 993, and the vehicle density, traffic lights, crosswalks, slopes, CCTV are excluded from constructed items. Results of assigning scores for the target road show 0.48~0.69 of values of a range, and these are added with the distance to calculate the final finding cost. It is considered that the range of score values narrowly represented is because scores of items excluded from constructed items are not applied.

As a result of carrying out the shorted path finding using only distance for arbitrary two locations and the optimum path finding using the finding cost calculated from this study, different paths are represented for some paths.
Fig. 5 Cartography of result score

Fig. 6 Result of path finding
Table 2 Cost value of case study

<table>
<thead>
<tr>
<th>Path</th>
<th>Length</th>
<th>Cost</th>
<th>Length</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortest path</td>
<td>2.254km</td>
<td>3.744</td>
<td>0.827km</td>
<td>1.436</td>
</tr>
<tr>
<td>Optimum path</td>
<td>2.257km</td>
<td>3.745</td>
<td>0.841km</td>
<td>1.373</td>
</tr>
</tbody>
</table>

5. Results & Future work

This study extracted a variety of factors having an influence on walking in order to present a path finding method suitable to pedestrian path guidance which is recently issued. In addition, weights were calculated using the AHP to calculate the importance between the extracted factors, and these weight were used to assign scores of factors for each score. The logical validity was also proved using the consistency index when calculating weights for each factor through the AHP method. Finally, the finding cost was calculated for the pedestrian path finding by calculating these scores with distance values of the road network. The calculated finding cost applied to the road network in downtown’s busy street with large pedestrian volume, as a result, it was represented the result different from the path finding through a simple distance. It is analyzed because more suitable walking path was presented considering a variety of factors having an influence on walking.

However, a quantified verification for this is needed because it is only subjective view. In addition, a detailed study is needed for the criteria to distinguish attributes and the assigned scores also in the score assigning process.

The main cause affecting pedestrians in walking has many subjective elements. In other words, some people want a path having poor walking environment but faster way, on the other hand, some people want a walking path with longer way around but comfortable environment. Children and women want a walking path having safety facilities, lighting, or crime prevention facilities. The AHP method presented in this
paper could be utilized for such personalized services. The AHP for decision making of public purposes should gather the major opinion, but for personal purpose such as walking, it is because weights could be calculated according to a personal preference. Therefore, it could be utilized for personalized services through personal computing devices.

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Sooho Kim
2008 Dept. of GeoInformatic Engineering, In-ha University
Graduation (Bachelor of engineering)
2009~Present Dept. of GeoInformatic Engineering, In-ha University
Graduate school attending (Master’s course)
[Mailing Address] 253 Yonghyundong, Namgu, Incheon, Republic of Korea 402-751 [Tel] +82-32-867-7605
[Email] kshoo1@nate.com.
[Mobile] +82-10-4444-9028 [Research Interest] Telematics, Spatial Datamining

YongJin Joo
2001 Dept. of GeoInformatic Engineering, In-ha University
Graduation (Bachelor of engineering)
2003 Dept. of GeoInformatic Engineering, In-ha University
Graduation (Master of Engineering)
2009. Dept. of GeoInformatic Engineering, In-ha University
Graduation (Ph D. GeoInformatic Engineering)
2003.1-2003.12 Software Developer, MobilCom
2004.1~2005.2 Researcher, Korea Transport Database, Korea Transport Institute(KOTI)
2009.11~Present Research Professor, Institute of Urban Sciences, University of Seoul
SooHong Park

1989. Seoul National University geography graduation (bachelo of Geography)
1991. Seoul National University geography graduation (master of Geography)
1996. Univ. of South Carolina at Columbia Graduation (Ph D. geography)

1996.07~1997.08 Indiana University/ Research Associate
1997.09~1997.12 Seoul National University/researcher research study
1998.01~2000.02 Seoul Development Institute, Research committee
2000~Present Dept. of GeoInformatic Engineering, In-ha University, Associate Professor


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Title of the paper : Pedestrian Path Findings using Multi-Factors Affected Walking

Name of the Presenter : SOOHO KIM

Author (s) Affiliation : Inha University

Mailing Address : 4-423 253 Yonghyun-dong, Nam-gu, Inchon, 402-751, Korea
Email Address : kshoo1@nate.com

Telephone number (s) : 032-867-7605

Fax number (s) : 032-863-1506

Author(s) Photograph:

Brief Biography (100 words):

2008 – Bachelor of Engineering

  - Department of Geo Informatic Engineering, Inha University, South Korea

2009 ~ present – Master Candidate

  - Department of Geo Informatic Engineering, Inha University, South Korea