AUTOMATIC DERIVATION OF A PEDESTRIAN NETWORK BASED ON EXISTING SPATIAL DATA SETS

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ABSTRACT

Pedestrian navigation service (PNS) needs more sophisticated and complicated network data than car navigation service due to the relatively free and random nature of pedestrian movement. Thus, the existing network data that are developed for the car navigation has many problems to use for PNS. From this fact, it is necessary to construct a new network data that reflects the movement characteristic of pedestrians. Constructing a new network data could be cumbersome and time consuming. It may be the most efficient and economic way to create the new network data using existing and already well-defined base maps, without collecting spatial data directly. In this paper, we proposed a method automatically to generate the new network data for PNS using existing national geospatial data sets that included digital topographic maps and new address base map. For this, first, we defined information that need for pedestrians, and selected layers that are suited for pedestrian network after investigating content of existing spatial data sets. Lastly, we introduced the process of pedestrian network and proposed how to generate the node-link network. We experimented on proposed method at a small set of existing spatial data set from Suwon, urban area to evaluate the method reliability and efficiency.

Key words: pedestrian navigation system, network, existing spatial data sets.

INTRODUCTION

With recent developments in wireless communications such as WiBro (Wireless Broadcasting network), microelectronics, sensors, and portable devices such as PMP, smart phone, and mobile GPS receivers, car navigation services (CNS) are now useful not only in vehicles but also outdoors. Therefore, as the environment in which CNS is applied outdoors develops, there is much interest in navigation systems for pedestrians or travelers. However, CNS has only limited use for pedestrian navigation at present, as pedestrian navigation services (PNS) require more sophisticated and complicated network data compared to CNS due to the relatively free and random nature of pedestrian movement (Corona and Winter, 2001; Elias, 2007; Tang and Pun-Cheng, 2004). In other words, PNS must generate additional information for pedestrians. For example, NAVETQ, the leading global provider of digital map and location data, provides users with a digital map that includes information for pedestrian such as the locations of overpasses, auto-free pedestrian zones, pathways, and parks in North America. The most convenient and efficient means of obtaining relevant information for PNS involves the use of existing and previously well-defined base map features directly without attempting to generate a new supplementary data set for a particular purpose (Tang and Pun-Cheng, 2004). Thus, Tang and Pun-Cheng (2004) developed a specific path-finding application alternatively that is computed based on both the user-defined relevant spatial features (e.g., vehicular roads, walking paths, buildings) in any geometry and their descriptions (e.g., stairs, turning directions) without the concept of using road centerlines from digital maps. Elias (2007) built a semi-automatic pedestrian navigation database customized to the specific needs of pedestrians for PNS using different existing data sets that included topographic database ATKIS, digital cadastral map data (ALK) and indoor plans. A number of problems can arise when construct a pedestrian navigation database, but the relevant information parts for pedestrians are easily extracted using different existing data sets. Huang et al. (2007) proposed a data model of navigable geographic framework data and a method for constructing a road network based on multi-scale fundamental geographic data. Using existing geographic data, the proposed method can reduce the workload of manual editing and promote production efficiency. For this reason, a method that automatically generates a pedestrian network from existing spatial data sets is proposed. The process of the creation of an automatic deriving pedestrian network has three procedures. The task of automatically changing the geometry data type to extract relevant information for pedestrians from existing spatial data sets is a special focus of the proposed method.

ANALYSIS OF DATA FOR THE GENERATION OF A PEDESTRIAN NETWORK

In this study, pedestrians are limited to persons moving by foot among any person who wants to travel by foot, wheelchair or electric scooter, as defined by the Australian Pedestrian Council (2004). The network data of the existing CNS contain geometry data in addition to such information as topology, guidance information, and rotation restrictions; however, in this paper, this is restricted to node-link network data, specifically geometry data for PNS. To generate the pedestrian network data, relevant information for PNS from preceding research was analyzed, and it was determined pertinent information could be obtained from existing spatial data sets. Finally, we extracted the necessary information for pedestrian network and the relevant existing spatial data to generate the pedestrian network.

Analysis of the Necessary Information for a Pedestrian Network Data

As mentioned previously, cars move only along the roads while pedestrians, unlike cars, freely move in different types of areas or spaces. Hence, pedestrian network data would contain additional information. Table 1 gives a description of the additional information that comprises pedestrian network data.

Table 1. Analysis of the required information of pedestrian network data; (a) NAVTEQ Discover Cities™ (b) Corona and Winter, 2001 (c) Elias, 2007 (d) Tang and Pun-Cheng, 2004

Features \ Researches	(a)	(b)	(c)	(d)
Sidewalks		O	O	O
Walkways	O	O		
Bicycle paths		O		
Streets		O		O
Squares		O		
Overpasses (Pedestrian bridges)	O	O	O	O
Pedestrian crossings		O		O
Underpasses (Subway entrances)	O	O		O
Parks	O	O		
Building blocks / Paths within multi-story building		O	O	O
Building entrances			O	
Stairses				O
Mountains		O		
Rivers / Lakes		O		
Pedestrian areas or zones	O	O	O	

Sidewalks, walkways, streets, overpasses (pedestrian bridges), pedestrian crossings, underpasses (subway entrance), parks, building blocks and pedestrian areas or zones were commonly proposed in prior research. However, the pedestrian network in this paper is restricted to what exists outdoors, so we omitted information as regards indoor environments of buildings, such as paths within multi-story buildings, from the gathered set of information. Therefore, the required information for a pedestrian network is defined here as sidewalks, walkways, streets, pedestrian bridges, pedestrian crossings, underpasses (subway entrances), parks, and pedestrian areas or zones.

Investigation of Existing Spatial Data Sets

To obtain the previously defined data, existing spatial data sets created by government or public offices were consulted. These included digital topographic maps at a scale of 1:1,000 and 1:5,000 and a new address base map at a scale of 1:1,000. The digital topographic map differentiates seven domains of features, including transportation features, buildings, facilities, vegetation, water features, topography features, and districts. The feature types and attributes in the digital topographic map are updated every five years. The new address base map was created for the maintenance of addresses; it is updated every month. Its content includes buildings, building entrances, address signs, and transportation and other facilities. After all objects and attributes of the existing spatial data sets were analyzed, the required information listed in Table 2 was chosen as a candidate set for the generation of the pedestrian network data. As there are some limits when defining relevant information for PNS from existing spatial data, for example if the definition of a pedestrian area or zone is vague or if a walkway is not in the target existing data sets, information related to sidewalks, streets, overpasses (pedestrian bridges), pedestrian crossings, and underpasses (subway entrances) were extracted from target data sets. In addition, the relevant existing spatial data were defined to generate the pedestrian network data.

Table 2. Extracting the required information and the relevant existing spatial data to generate the pedestrian network data

Required information	Main source	Layer	Data type
Streets	Digital topographic map (1:5,000)	Road centerline (A002)	polyline
Sidewalks	Digital topographic map (1:1,000)	Sidewalk (A003)	polyline
Overpasses (pedestrian bridges)	Digital topographic map (1:5,000)	Overpass (A006)	polygon
		Bridge (A007)	
Pedestrian crossings	Digital topographic map (1:1,000)	Crosswalk (A004)	polygon
Underpasses (Subway entrances)	New address base map	Subway entrance	point
Building entrances	New address base map	Entrance	point
		Connect line	polyline

CONSTRUCTION OF NETWORK DATA FOR PEDESTRIAN NAVIGATION

The Approach for Generating Pedestrian Network Data

To generate a pedestrian network using existing spatial data sets, existing spatial data sets must be conflated in advance. The conflation of spatial data is actively being conducted at present; hence, most systems provide users with conflated spatial data via the internet.

Thus, the process of constructing a pedestrian network, particularly geometry data, using existing spatial data sets used the procedures shown in Figure 1. The first step involves changing the geometry type of the target data in existing spatial data, such as changing polygons to points. The second step involved conflating the changed geometry data and non-changed geometry data that were necessary for a pedestrian network in existing spatial data and then conflating the attributes of the geometry data. The third step involves generating the pedestrian network data.

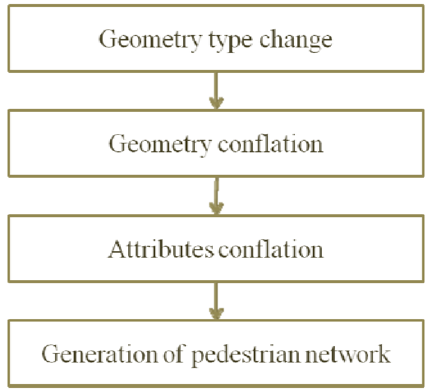


Figure 1. The conceptual framework of the research.

Traditionally, the use of network data, i.e., in vector format, is by far considered as an easily understood means of storing a feature semantically, as it is in GIS. Vector representation has also been the domain of network analysis. A linear network model is normally defined as a graph G, where G = (N, A) consists of (i) a finite set N = {n_1, n_2, … , n_n}, whose elements are termed nodes, and (ii) a subset A of the Cartesian product A × A, the elements of which are termed arcs. These two primitives, nodes and arcs, represent the intersections and segments, respectively, in a continuous and connected linear network (Tang and Pun-Cheng, 2004). Therefore, we generated a pedestrian network for a node-arc data model. We constructed the basic link data of the node-arc(link) model using road centerline information from a digital topographic map at a scale of 1:5,000, and we classified node attributes such as road intersections, road start and end points, and nodes for which road attributes had changed in addition to the necessary information for the pedestrian network. To do this, it was initially necessary to change the polygon data among existing spatial data into points (nodes). Hence, a method of automatically converting polygons into points was formulated, and this method was applied to the target area.

Experiments to Convert Polygons into Points

We experimented with the proposed method using existing spatial data sets in Suwon, South Korea, which was an urban area, and used digital topographic maps at a different scale. There were 4,567 road centerline links, 156 pedestrian crossings, one overpass, and five pedestrian bridges as the only type of bridge a pedestrian is able to walk across in the target area. As shown Table 2, the data types of the pedestrian crossings, an overpass, and pedestrian bridges were all polygons. To construct the pedestrian node-arc network data, it was necessary to change the geometry type from polygons to points.

Pedestrian crossings and an overpass. The polygons of pedestrian crossings and an overpass characteristically intersect with road centerline links with no direction in existing spatial data sets. Therefore, a polygon of a pedestrian crossing and an overpass can be represented as one point on a road centerline link. Most research generally involves calculating the center point of gravity (centroid) for geometry changes from a polygon to a point. However, in this paper, it is meaningless to calculate the centroid for one polygon because changed points must intersect with road centerline links.

Hence, in this paper, geometry type changes from a polygon to a point are classified into two cases, as follows:

Case 1: Two crossing points

For two points intersecting between road centerline links and a target polygon of a pedestrian crossing and an overpass, we generated a central point between the two crossing points between the road centerline link and the target polygon (Figure 2(a)). At this time, if a road centerline link which intersects a target polygon is not a straight line, that is, if a road centerline link includes vertices in a road centerline segment which meet at the target polygon, the previously generated central point can be beyond the road centerline (Figure 2(b)). To solve this problem, we transferred the coordinates of the previously generated central point into the coordinates of a vertex that has a minimum distance from the previously generated central point and vertices, each within the target polygon (Figure 2(c)).

Case 2: Two or more crossing points

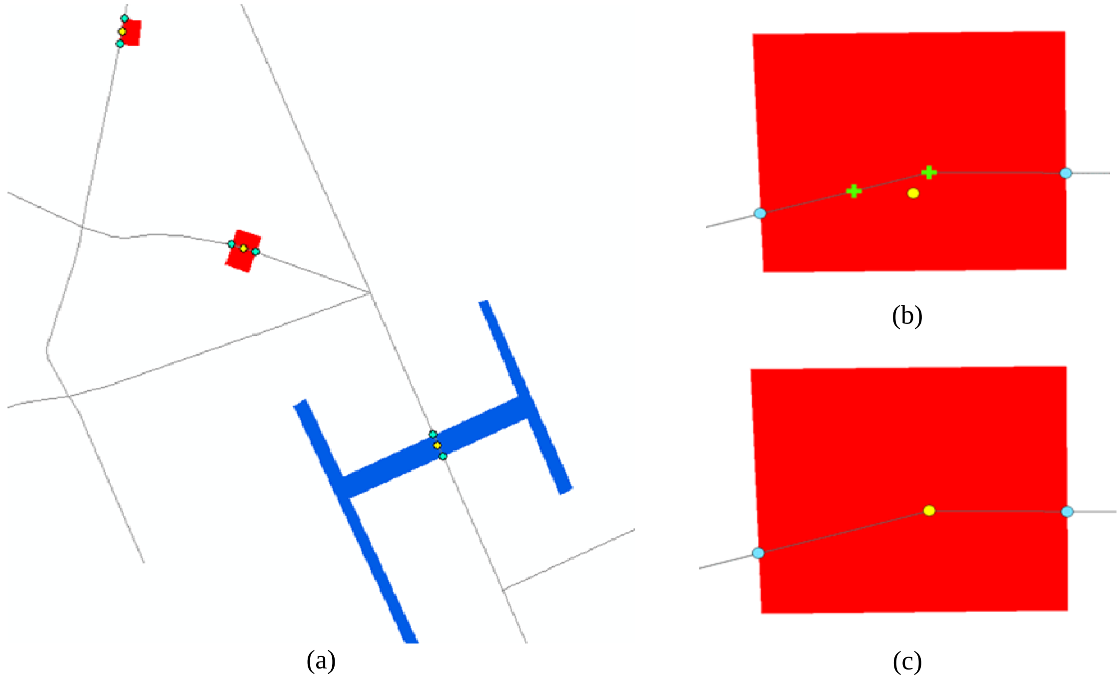
For two or more crossing points between a road centerline link and a target polygon, we extracted a crossing point between the road centerline segments that intersect with the target polygon (Figure 3).

Pedestrian bridges. In existing spatial target data, bridges were constructed in the same direction as the road centerlines. In other words, unlike pedestrian crossings and overpasses, bridges can be defined as the start and end point that intersect with road centerline links. For this, it was initially determined whether a pedestrian would be able to walk on a target bridge according to the attributes of the bridge. Next, we generated pedestrian bridge points that intersect with road centerline links (Figure 4).

Figure 5 shows points (nodes) which were changed from polygons of pedestrian crossings, an overpass and pedestrian bridges by applying the proposed method in the target area.

Result Analysis

We automatically generated points (nodes) for the pedestrian network by changing the geometry type from polygons to points in the target area using topographic digital maps of a different scale. As a result, we extracted the crossing nodes for pedestrian network data such as overpass nodes (central points) and pedestrian bridge nodes (start and end points) in the target area. However, in some cases, invalid nodes were extracted. Examples are those in which a road centerline overshoots a target polygon despite the lack of an intersection between the road centerline link and the target polygon. In other words, the quality of the generated nodes is relative to the accuracy of existing spatial data sets. In order to accomplish the construction of pedestrian network data using existing spatial data sets, the existing spatial data features must be organized systematically with clear definitions.



(a) (b) (c)

Figure 2. Changing from polygons of pedestrian crossings (red) and an overpass (blue) to a point (yellow) (Case 1) : (a) the central point (yellow) between crossing points (light blue) by an intersecting polygon and a road centerline (grey), (b) a mismatch between the previously generated central point and the road centerline, (c) the coordination of the previously generated central point is transferred to the coordination of a crossing point which is a minimum distance from the previously generated central point and vertices (light green cross), each in target polygon.

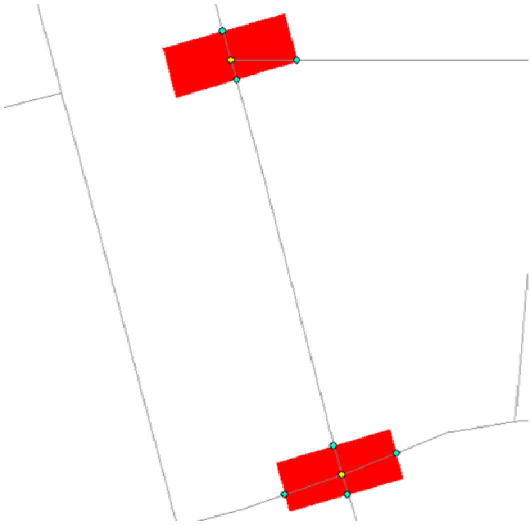


Figure 3. Changing from polygons of pedestrian crossings and an overpass to a point (Case 2).

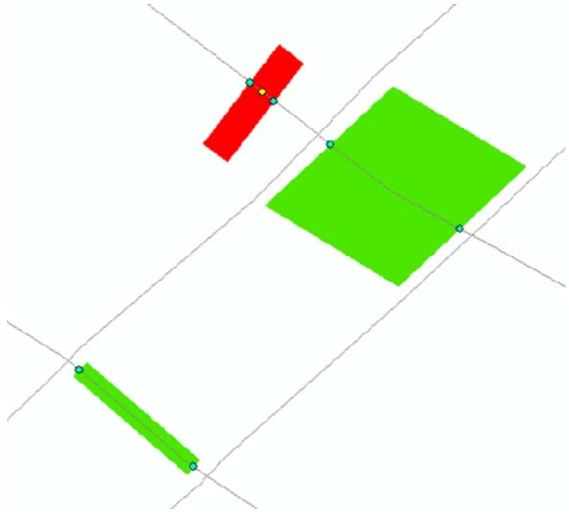


Figure 4. Changing from polygons of pedestrian bridges (light green) to start and end points (light blue).

Figure 5. Converting a polygon into a point or points (yellow) in a target area.

CONCLUSION AND FUTURE WORK

In this paper, to construct network data, particularly geometry data, for pedestrians using existing spatial data sets, we analyzed the required information for PNS and defined this relevant spatial data with existing spatial data sets. This process was then introduced to construct a pedestrian network from existing spatial data sets and a method for the first procedure, essentially involving changes of the geometry data, was proposed. As a result of applying the proposed method in a target area, it was possible to change pedestrian crossings, an overpass and pedestrian bridges in a target area to center points or crossing points automatically. However, to construct pedestrian network data using existing spatial data sets depends on the accuracy and sophistication of existing spatial data sets. To accomplish this, it is necessary for the existing spatial data features to be clearly defined and systematically organized.

To generalize the method proposed in this paper, the proposed method must be applied in various areas and with many existing spatial data sets. A subsequently step is to study other procedures among the many processes that are necessary to generate pedestrian network data, such as those related to geometry and attribute conflation.

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REFERENCES

Australian Pedestrian Council, 2004. The pedestrian council: Pedestrian Council Home. http://www.walk.com.au/wtw/page.asp?PageID=207 [accessed by 3 September 2009]

Corona, B., and S. Winter, 2001. Datasets for pedestrian navigation services, in *Proceeding from Angewandte Geographische Informationsverarbeitung, Proc. of the AGIT Symposium*, J. Strobl, T. Blaschke, G. Griesebner, Eds.,Salzburg, Austria, pp. 84-89.

Elias, B., 2007. Pedestrian navigation — Creating a tailored geodatabase for routing, in *Proceeding from 4th Workshop on Positioning, Navigation and Communication 2007 (WPNC'07)*, March 22, 2007. http://www.wpnc.net/wpnc07.html.

Huang, W., L. Liu, Y. Zhao, and G. Wang, 2007. Modeling and implementation of navigable geographic framework data — Construction of road network based on fundamental geographic data, in *Proceeding from ISPRS Workshop on Updating Geo-spatial Databases with Imagery & The 5th ISPRS Workshop on DMGISs*, August 28-29, 2007. http://www.commission4.isprs.org/urumchi/start.htm.

NAVTEQ Discover Cities™, http://corporate.navteq.com/advanced_discover_cities.html [accessed by 3 September 2009]

Tang, M.W.F., and L.S.C. Pun-Cheng, 2004. Algorithmic development of an optimal path computation model based on topographic map features, in *Proceeding from Geo-Imagery Bridging Continents,* XX th ISPRS Congress, July 12-23, 2004. http://www.isprs.org/congresses/istanbul2004/comm4/comm4.aspx.