ROUTE GUIDING WITH VERTICAL CONSIDERATION FOR VISITORS ON FOOT

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ABSTRACT:

Route guiding has become increasingly essential in pedestrian navigation within the urban space. Large buildings of multi-stories (such as hotel, hospital, and airport complexes) dominate the urban setting. When set against an uneven terrain like the case of Hong Kong, wayfinding in the urban space is not an easy task. The aim of this research is to identify elements in the urban space on which a traveler on foot needs route guidance. The proposed method adopts an aggregated approach in defining a behavioral space within a physical environment. By categorizing the types of urban travelers, the audience of the route guiding system can be targeted. An analysis of the diversity and demand of wayfinding can help sort out the connections among data, people and environment. Various approaches to find optimal paths are assessed against the consideration of vertical movements within built structures and over natural landscapes in the urban space. Vertical movements are considered in terms of walking distance, journey time and climbing effort. The research is an attempt to understand data needs for the establishment of a route guiding system (using the geographic information systems technology) that considers the vertical dimension in navigation on foot.

1. Introduction

1.1 Motivation

With the upgrade of hardware capabilities and the downward trend of buying costs, a personal route guiding system would seem attractive among people in similar ways as a mobile phone. Each route guiding service will target explicit types of travelers pending their modes of movement such as walking on foot, riding a bicycle, driving a vehicle, taking one or more than one types of public transportation, etc. Route guiding services must be chosen by users to suit their needs. Until recent years, researchers have shifted their focus from the passenger to the pedestrian perspectives given advancement in telecommunications technologies. This paper is an attempt to study what roles geographic information systems (GIS) have in navigation and to the wider audiences.

Pedestrian route guiding service is most relevant in the urban space where crowds are gathered and buildings are compact. Many wayfinding studies have been conducted in places like city town centers, airports, and campuses (Lam et al 2003). But very few of them addressed issues caused by the vertical dimension. Since pedestrians have the freedom to walk/climb or take lifts/escalators in man-made structures, the environmental setting and presentation format, as well as route guidance instructions will surely be different from other navigation systems.

This research targets individuals who not only travel on foot but are also unfamiliar with the environment enroute. How will the vertical dimension affect the data construct of a route guiding system is our research focus. The University of Hong Kong campus is used as a test environment. The campus information will be analyzed, modeled, and simulated to spell out the data construct necessary to support route guiding services with vertical consideration.

1.2 Definition of terms

- **Route guiding**

  A route is a directed path between a pair of specified locations. This route must be determined prior to issuing a series of travel instructions.

- **Wayfinding**

  Wayfinding is a part of route guiding. It involves means to find a way that traverses two locations within a large-scale space.

- **Network analysis**

  Network analysis concerns the framework and methodology for wayfinding based upon graph theory. The origin and destination locations are denoted as nodes and links are needed to connect a pair of nodes along the path. Impedance represents costs against which the flows along links are inhibited.

- **Landmark**

  A landmark is an object or structure that marks a locality and is used as a point of locational reference.

1.3 Research Questions

The primary research focus concerns the development of a non-planar route guiding system for new visitors. In addressing the research focus, several questions are designed to extract relevant information.

a) What are the characteristics of the environment that trigger the need for this guiding service?

b) What kinds of data are needed to enable the development of a route guiding system with a vertical/height concern?

c) How are these data integrated and maintained in a working system?

2. Basic information

2.1 Characteristics of the physical environment

The physical environment is an urban space with vertical dimensions to consider. Characteristics of the environment may be classified broadly on the following grounds:

- Accessibility – The space must be accessible by the general public.
- Administration – An enclosed region must be under a single authority to assure steady management.
- Flow – The built structures are multilevel and may not confine necessarily to one building.

Airports, hospitals, and school campuses are good examples within which visitors frequently need guidance. Many researchers (Abu-Ghazzeh, 1996, Raubal and Egenhofer 1998) have completed studies about wayfinding or route guiding in these environments.

However, an urban space might not be flat. Built structures must align with the natural landscape to yield staircase like constructions. There are also suspended walkways built to connect two buildings for improved accessibility. Hence, it is possible that the ground level of a building is not the only entrance to a building. This actuality will affect on foot navigation and must be considered in route guiding.

2.2 Type of audience

Like other systems, our pedestrian route guiding service can only target a selected group of audience. Arthur (1992) categorized users into several groups according to variation in personal ability and conduct. Travelers may suffer perceptual, cognitive, literacy or mobility impairment. Individuals from the first three groups may have difficulties perceiving information presented on the route guiding system. The last group needs routing on special conditions (e.g. no staircase) and more restricted criteria. At this initial stage, our research will consider only travelers without impairment (i.e. those who do not belong to any one of four impairments mentioned earlier) as prospective users of the route guiding service.

The selected target group may still vary in terms of age, gender, educational background, or spatial capability. Many researchers (Cornell et al 2003, Davis and Pederson 2001, Malinowski and Gillespie 2001, Schimitz 1999, Vila et al 2003) have concluded by empirical methods that these factors do affect an individual's ability to perceive and react to the navigation service. The general public, however, are treated equal at the initial stage of this investigation.

Environmental factors (e.g. weather conditions, personal preference, or safety concern) that might affect the selection of paths in a real wayfinding process are also not considered in our study. Some individuals might prefer climbing up stairs instead of taking a lift for health or enjoyment reasons. These instances are enormous to exemplify and certainly out of reach by the proposed guiding system.

2.3 Type of information to present

The type of information to present is associated primarily with the intention of the users:

Original purpose of the visit

All man-made structures are meant to achieve certain goals, such as schools for studying, hospitals for treating patients, etc. Related spatial activities may include finding a room, locating a person or the whereabouts of an incident within the structure. These are some apparent reasons why a user needs to visit a place.

Exploration visit

In some cases, a visitor may have no specific intention but to wander around the environment. Personal preferences and other factors like the duration of stay and the time of visit may be prudent considerations for a guiding system that provides advices on preset excursions.

Other personal needs

In addition to demands planned ahead of time, it is possible to have on the spot requests along the way. More explicitly, a visitor may experience body need for a toilet or restaurant, emergency need for a fire exit, or financial need for a bank or shop.

Nagao and Katsuno (1998) tested a Hyper Campus System on an augmented reality in which GIS data view can be superimposed on the "real" view by means of direct entry into the human vision field. The types of information of interest are grouped as follows:

1) Campus area information – campus map, building locations, information on outdoor services.

2) Architecture information – outlook images of buildings, history of construction, information on events related to buildings.

3) Indoor information – floor plans, room information, laboratory information, information on indoor activities.

4) Class information – timetable of classes, lecture room information.

5) University information – other university related information.

6) User behavior history – chronological list of places visited and information accessed.

On the whole, there are many decision variables forming the contents of information in a route guiding system. Additional data collected should provide more information but may decrease the operational efficiency of the system. The balance among data, cost, and speed should be further investigated.

2.4 Modeling the physical environment

Researchers have been known to simulate the real world using virtual reality or augmented reality in a computerized setting (Huber and Sieber 2001, Nagao and Katsuno 1998). The backdrops for some applications have been elevated from two-dimensional (2D) to three-dimensional (3D) or even multi-dimensional (plus time, for instance) setting (Elvins et al 1999, van Dijk et al 2003).

Shiode (2001) did a thorough review on the current development of 3D digital urban models. Three categories of models were summarized in his article. The first approach utilized various methods for capturing heights and façade information at the data input stage. The second approach combined utility and analytical features from different platforms to yield the desired functionality. The third group was derived from the amount of geometric content for the degree of reality.

However, not all study favors the multimodal over the 2D approach. Draper (2000) showed in an empirical study that a 2D map is easier to understand than its 3D counterpart in a wayfinding cognitive test. A 2D approach augmented with multimedia addition might be a reasonable alternative in view of cost and time constraints.

2.5 Presenting route guidance

The presentation of route directions and instructions hinges on a few conditions:

- Time of usage
  - ☐ Advanced planning and search for route directions
  - ☐ Accompanying or enroute directions
- Medium of delivery
  - ☐ Speech or verbal instructions
  - ☐ Text or written instructions
- Format of instruction
  - ☐ Street-based instructions
  - ☐ Landmark-based instructions
  - ☐ Cardinal direction-based instructions
  - ☐ Time-based instructions

In considering time of usage, accompanying or enroute directions are possible only if the user's present location and orientation can be determined. With regard to the medium of delivery, text or written instructions are unambiguous and understandable by the general public while speech or verbal instructions can supplement at a later stage. We would prefer landmark-based instructions as the format of instructions because many footpaths in our large-scale setting are missing names and the remaining options not favored in Hong Kong.

3. Case Study

3.1 Background

Situated at the mid level of a mountainside, the University of Hong Kong (HKU) has a main campus congested with high-rise buildings. Campus directories in two-dimensional representation (Figure 1) are posted close to the gate entrances where the majority of visitors start their journeys. They are also erected in open spaces where people tend to gather or stop for a rest. This directory system is confusing for a complex campus packed with buildings not only distributed on hilly terrains but also connected with corridors or steps at different elevations.

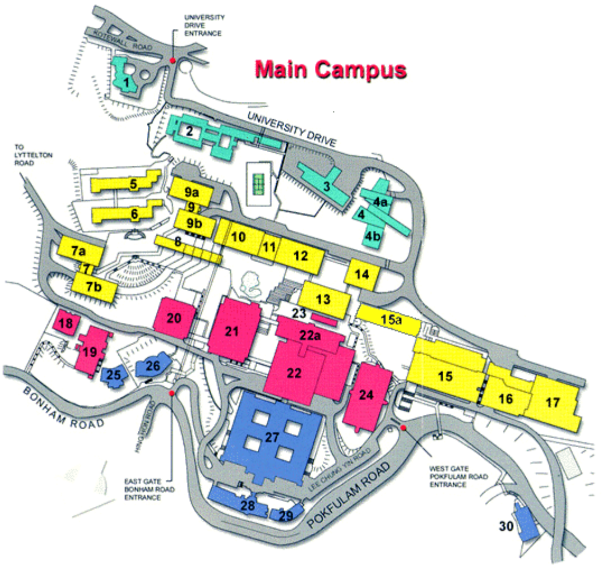

Figure 1: Main Campus of the University of Hong Kong

3.2 Data construct for network analysis

The spatial environment of the HKU campus is characterized as follows:

- Does not necessarily possess unique reference points in space

  A visitor may start from any place on campus, walk along a path, through a building, and continue to other destinations situated on campus. Hence the routing exercise may not be limited to only one modeled setting.

- Naming system is missing for certain routes

  All public roads and streets hold official names. Private owned roads are sometimes unnamed. This naming gap will cause difficulties in street-based route instructions.

- Walking paths for pedestrians are not necessarily represented

  The campus road network can be derived by extracting centerlines from existing roads in a digital map. However, footpaths for pedestrians are often overlooked. These unofficial paths are often preferred over regular roads in campus navigation and a comprehensive field survey may be needed to verify and record such footpaths.

3.3 The modeling procedure

Five components have been identified as essential to the data construct.

Node

- Building Entrance/Exit points:

  These include entrances located on the ground level of each building and alternative entrances into a building which may be located on other floors of the building.

- Mover Entrance/Exit points

  Lifts are bi-directional but escalators are uni-directional (up or down) in the moving direction.
- Split points

  An open space that leads to many directions of travel is represented as a split point.
- Turning points

  A winding path with an abrupt bend in the route direction needs a turning point at the juncture.

Link

A link is an edge connecting two nodes and along which pedestrians walk. Four kinds of paths are possible in view of the slope angle: horizontal, vertical, diagonal, and staircase. Most people would prefer walking on horizontal surfaces. When they get into a lift, the movement becomes vertical. Walking on steps or taking an escalator would entail a diagonal movement. Staircases are differentiated from escalator services because of differences in efforts.

Landmark

Landmarks are selected based upon criteria identified by Lynch (1960): singularity, prominence of spatial location, distant, accessibility, content, meaning, use or cultural significance, and prototypicality.

The following examples from the HKU campus are listed by geometrical categories:

- Point landmarks – Sun Yat-Sun statue
- Line landmark – the June Fourth Memorial Words on the Swire Bridge, Zhong Shan staircase
- Polygon landmarks – Lily pond, Main Library

Optimal path

The computation for an optimal path must consider user preferences. Some possible solutions are:

- Shortest route by distance measured
- Quickest route by time spent
- Simplest route by minimal turns
- Easiest route by least effort devoted
- Scenic route by significant landmarks

Psychological factors also play an important role in the choice of a route. For instance, visitors might be willing to walk up one or two flights of stairs, but would prefer to take a lift when available for longer distances. The decision variables for computing the optimal path are critical factors to consider.

Data acquisition of terrain/landscape

The Survey and Mapping Office of the Land Information Center of Hong Kong offers for sale digital topographic map data and digital land boundary data. The 1:1,000 maps with building outlines, roads, spot heights and contours are used to construct a base map for the HKU campus (Figure 2).

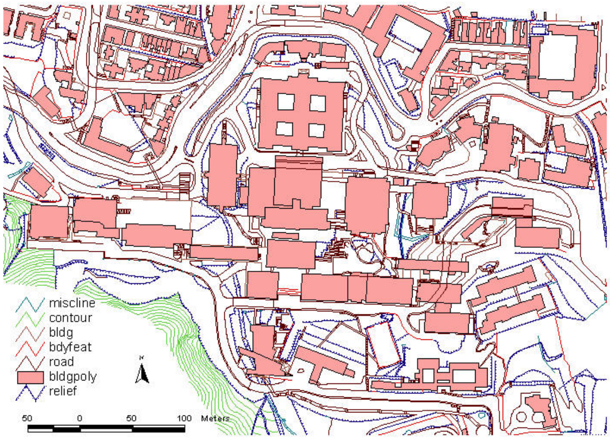

Figure 2: A digital map of the University of Hong Kong

Data on the man-made features must be weed out in the preparation of a digital elevation model (DEM) for the landscape. For instance, there exist spot height values for overpasses, bridges, and podiums or rooftops. Distinction among spot height, relief, and contour data must be made clear to enable integration and the creation of a 3D perspective view of the campus. The data modeling procedure was accomplished with the 3D Analyst extension of ArcView GIS software and as outlined in Figure 3.

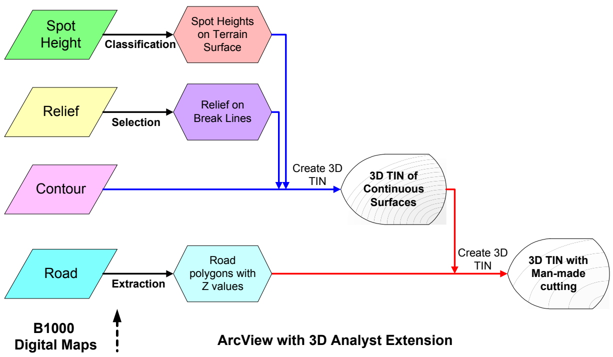

Figure 3: Data modeling for DEM

3.4 Route directions

We indicated earlier that the landmark-based format of instruction is chosen to provide route guidance in our research. Following is one example of route directions within the HKU campus.

☐ Route directions from the *West Entrance* to the *Hui Oi Chow Science Building*:

- ⇦ Start from the *West Entrance*
- ⇦ Walk by steps to the front of lifts at the *Haking Wong Building*
- ⇦ Take lift up to the fifth floor
- ⇦ Go by the left corridor until the end
- ⇦ Turn right and should see *James Hsioung Lee Building* straight ahead
- ⇦ Turn left and the *Hui Oi Chow Science Building* is on your left.

The series of guiding instructions is close to the human's natural language. With the exception of the beginning and ending statements, instructions are formed with action verb, direction of action, and moving media. Some combinations are listed in Table 1.

Action Verb	Direction for action	Moving Media
Move	Forward	Oneself
Turn	Right Left	Oneself
Go Walk	Straight, Directly forward	Oneself
Take	Up Down	Lift Escalator Stairs
Pass		Corridor
Cross		Road

Table 1: Possible combination for route directions

4. Conclusion

This research tries to consider the vertical dimension in designing a route guiding service for visitors on foot. The context of vertical dimension is examined in terms of characteristics of physical features, type of audience, and type of information of interests. There remain questions on how to integrate more effectively spatial and attribute data with vertical/height information, how to model the data construct in a network analysis system, and how to maintain various components of an operational system. The function of a navigation service is not only to show the spatial layout of a physical environment but also to provide a migration from directional aids to knowledge entrance about a space of unfamiliar setting.

Route guiding may evolve further through advancements in data acquisition, processing, and presentation methods. However, the spatial settings, human issues in the environment, activities correlated with space, the association with time, and even the interrelationships among them will likely remain consistent. It is important to analyze these basic factors for a better theoretical construct whose performance would ultimately benefit from better technologies.

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