A Personalised Pedestrian Navigation System

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Abstract

Many existing navigation systems facilitate pedestrian routing but lack the provision of personalised route alternatives tailored to individual needs. Previous research suggests that pedestrians often prioritise factors such as safety or accessibility over the shortest possible route. This paper investigates ways to enhance existing pedestrian navigation systems and improve walking experiences by providing personalised routes based on walking preferences. This is achieved by defining a set of routing preferences and implementing a modified version of Dijkstra's algorithm. The goal of this work is to promote walking by enhancing mobility, accessibility, comfort, and safety.

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1 Introduction

Currently, leading navigation applications do not (or rarely) provide pedestrians with personalised routes based on their needs. Among the widely used navigation apps utilised by pedestrians, notable examples include Google Maps, and Citymapper[2] which is particularly popular among commuters due to its emphasis on public transit. Both applications offer turn-by-turn directions from the starting point to the destination, with Citymapper performing better with live public transport information. It is important to note that both Citymapper and Google Maps predominantly suggest the shortest or fastest walking routes, and wheelchair-accessible routes are only available if public transport is incorporated into the journey (this is the case in London). The Mayor of London has launched the first ever Walking Action Plan[3] for UK's capital city, and the mayor's vision is to make London the world's most walkable city by 2041. We aim to support this vision by implementing a pedestrian navigation application that provides personalised routes tailored to individual walking preferences, as opposed to solely recommending the fastest or shortest paths. A comparison with Google Maps shows that our generated routes excel in meeting users' walking needs by incorporating route features that align with user preferences.

2 Related Work

Many researchers have investigated the impact factors such as safety, travel purposes, weather conditions and traffic flow on pedestrian route choice [2, 7]. Bovy [2] reviewed theories and models of wayfinding behaviour and applied them in transport networks. He summarised

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[2] `https://citymapper.com/london?lang=en`
[3] `https://content.tfl.gov.uk/mts-walking-action-plan.pdf`

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the influential attributes into three categories, i.e., traveller, trip route, and circumstances. In Asha's study to learn routing choices [1], pedestrians cited safety and time-saving as the two most important factors when choosing their routes. One study determined seven criteria for pedestrian route choice: complexity, landmarks, accessible assistance, roadways, obstacles, intersections, and personal preferences [3]. In another study, the authors suggested SWEEP (Safety, Wealth, Effort, Exploration, and Pleasure) as significant route quality attributes utilised in a route recommendation system survey [10]. In recent years, there has been a growing interest in improving pedestrian navigation by integrating pavement facilities, the walking environment and pedestrian profiles for customised path finding [4, 11, 6, 8]. Fang *et al.*,[5] proposed a people-centric framework for pedestrian navigation based on three layers, namely physical sense, physiological safety, and mental satisfaction. The interdisciplinary review on mobile spatial navigation system [9] offered valuable design recommendations aimed at enhancing the accessibility and inclusivity of navigation systems. These recommendations encompassed the inclusion of physical accessibility information and the provision of personalised route options.

3 Pedestrian Routing Preferences

Routing preferences are quantified using a set of weights or costs, which are assigned based on characteristics related to the pavement and its surrounding environment. These preferences determine the type of route that will be chosen. Various studies have shed light on the primary determinant influencing pedestrians' route selection. For instance, one study [3] delves into the challenges confronted by visually impaired pedestrians when navigating between origin and destination, while another study [10] identifies a range of quality attributes, including safety and exploration, through a survey on route recommendations. Through an analysis of the existing literature, we have identified seven walking preferences: safety, presence of tactile paving, proximity to leisure areas, residential neighborhoods, low traffic volume, straightforwardness, and availability of step-free access.

- **Safety** preference indicates a secure and protected setting for pedestrians, which is particularly beneficial for individuals, especially women, who walk alone during nighttime. It is widely regarded as one of the most critical factors influencing pedestrians' route selection [9].
- **Tactile paving** enables individuals who are completely or partially blind to navigate along designated routes specifically equipped with tactile indicators.
- **Leisure spots** signifies routes with attractions such as green space, wetlands, shopping centres, and tourism spots which are particularly favoured by tourists and leisure walkers.
- The preference for a **residential neighborhood** highlights routes that primarily pass through residential areas, as opposed to industrial or commercial zones. This choice results in a quieter and less crowded path for pedestrians.
- The preference for **low traffic volume** prioritises pedestrians who prefer to avoid walking alongside high-volume motorways. This preference suggests routes with minimal traffic and reduced ground emissions and noises, providing a healthier and more pleasant walking experience.
- **Straightforwardness** promotes walking routes with minimal crossings and turns and is particularly targeted for joggers and elderly, or anyone who would typically prefer a straight path in order to avoid crossings and turns.

- The inclusion of **step-free access** suggests routes that are suitable for wheelchair users and accommodate the needs of individuals who require barrier-free access, e.g., those pushing pramchairs or carrying bulky luggage.

The street network is depicted as a graph, where street segments are represented by edges and street junctions are represented by nodes. Each edge in the graph has an initial weight value equivalent to its length. The suggested preferences are assigned to the edges as numerical values, which are then added to the base weight. Each edge is associated with a single weight value. The weight values are derived by pulling relevant data from OpenStreetMap (OSM)[4] and CrimeRate[5]. OpenStreetMap uses a variety of tags to identify elements of street segments and junctions. Likewise, for each pedestrian preference, a corresponding OSM tag is defined, and its value is utilised to determine the weight assigned to a particular edge. The resulting route consists of a sequence of interconnected edges that link the source and the destination. The total cost of the route is determined by summing the weights of these edges. A modified version of Dijkstra's algorithm is employed to compute the costs of all the potential routes in such a way that the cost of each route is different based on the users' selection of preferences. While the conventional Dijkstra's algorithm examines all nodes in the graph to determine the shortest path between the starting and ending nodes, our approach employs Dijkstra's algorithm to analyse only specific nodes that are selected based on the users' preferences to identify the path with the lowest cost. The route with the lowest cost is deemed optimal, while the other routes are considered less favorable.

4 Prototype and Evaluation

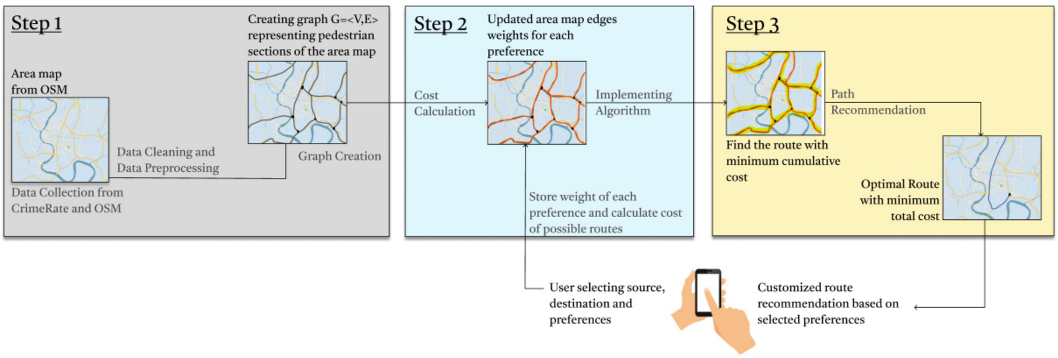


Figure 1 Workflow of the development of a prototype pedestrian navigation system.

Figure 1 depicts a workflow flowchart of the prototype navigation system, with critical steps in each block represented. Two main data sources, OpenStreetMap and CrimeRate, are utilised in developing the prototype of a pedestrian navigation system. The case study focuses on an area measuring 0.7km^2 situated in the borough of Harrow in northwest London. The selection of this area is deliberate as it offers sufficient pavement and surrounding environment features that cover the proposed walking preferences. The OpenStreetMap data is used to construct the underlying geographical map for producing graphs that depict street networks. Crime incidents at the street level within the study area are collected from

[4] https://www.openstreetmap.org/
[5] https://crimerate.co.uk/

CrimeRate between December 2019 and November 2022. This data source was collected to determine the weight value of “safety”. These crime incidents are classified into 12 distinct types of crime: burglary, damage & arson, drugs, other crime, other theft, possession of weapons, public order crimes, robbery, shoplifting, theft from person, vehicle based crimes, and violence and sexual crimes. This data will undergo data cleaning and preparation to convert it from its raw form (such as .osm/.xslx) and to remove any incomplete data for further operations.

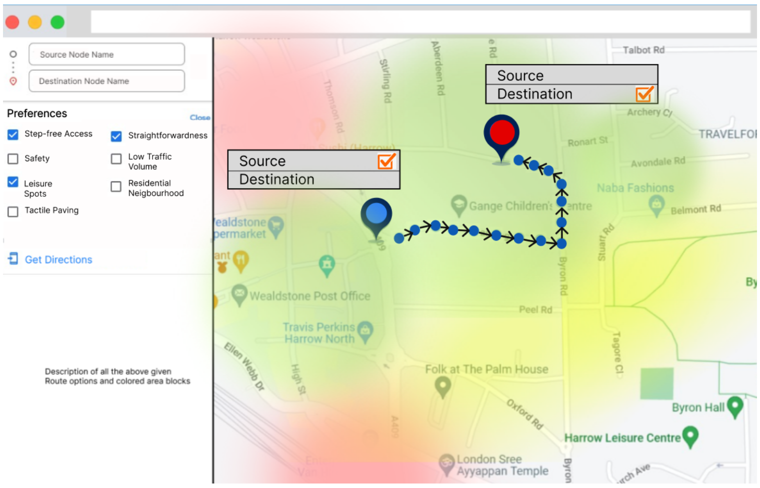
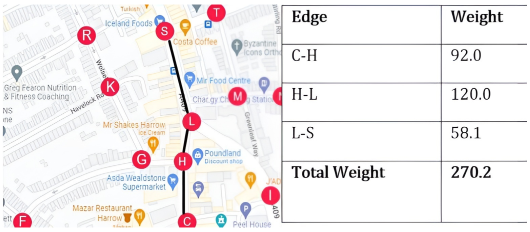


Figure 2 A visualisation of the suggested route based on user preferences by the prototype.

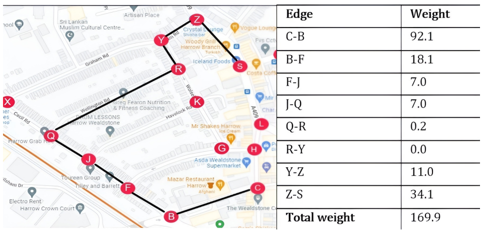
Figure 2 shows the web-based prototype interface, with three required inputs as the source (blue pin), the destination (red pin), and three chosen preferences from the list of seven preferences displayed in the left panel. The user can either click on map or type in the source and destination input fields in the left panel to indicate where they want to go. According to Figure 2, A user has made a specific request for a route that fulfills the following criteria: step-free access, includes leisure spots, and has a minimal number of turns. The displayed route connecting the blue pin and the red pin is suggested by the algorithm in such a way that it meets the walking preferences. The coloured bubbles on the map indicate whether or not an area contains routes that meet the user’s preferences. Routes within the green bubbles are those that meet user preferences to the highest degree (lowest cost), while red represents routes that meet user preferences to the lowest degree (highest cost). A yellow highlighted area indicates that the routes in that area are moderately meeting user preferences (medium cost). The purpose of the bubble visualization is to enhance pedestrians’ awareness of their surroundings, enabling them to explore other route alternatives and at the same time avoid unpleasant walking experiences.

The evaluation of the prototype is carried out between the routes computed by the proposed routing algorithm (R_1) and those generated by Google Maps (R_2). In Figure 3, it can be seen that R_2 suggests a straight route from C to S, whereas R_1 in Figure 4 suggests a completely different route, which circles around the major nodes H and L and takes a longer journey to reach the destination. The reason for this is that according to CrimeRate, a higher number of reported crimes is reported in the vicinity of nodes H and L. Since safety is always the top priority, the prototype generates route R_1, which bypasses these crime-prone areas thus is safer with a total cost of 169.9. In contrast, the route suggested by Google Maps does not avoid the crime points and has a higher total cost of 270.2.



Edge	Weight
C-H	92.0
H-L	120.0
L-S	58.1
Total Weight	**270.2**

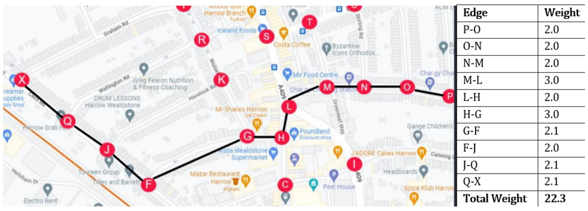
Figure 3 Suggested route from C to S by Google Maps (R2).



Edge	Weight
C-B	92.1
B-F	18.1
F-J	7.0
J-Q	7.0
Q-R	0.2
R-Y	0.0
Y-Z	11.0
Z-S	34.1
Total weight	169.9

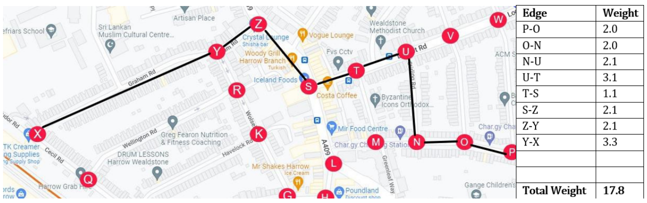
Figure 4 Suggested route from C to S by our method prioritising safety (R1).

Figure 6 shows a route suggested by R_1 from processing multiple preferences (tactile paving and straightforwardness) selected by a user. Graham Road (X-Y-Z) and Grantt Road (N-O-P) are more accessible for visually impaired pedestrians as compared to the route suggested by R_2 suggested by Google Maps (Figure 5). Regarding the straightforwardness of the route, there are no crossings on the route suggested by R_1 and there is one crossing on the route R_2 suggested by Google Maps. Therefore, the most optimal route is R_1 with a total cost value of 17.8 compared to R_2 with a total cost value of 22.3.



Edge	Weight
P-O	2.0
O-N	2.0
N-M	2.0
M-L	3.0
L-H	2.0
H-G	3.0
G-F	2.1
F-J	2.0
J-Q	2.1
Q-X	2.1
Total Weight	22.3

Figure 5 Suggested route from P to X by R2.



Edge	Weight
P-O	2.0
O-N	2.0
N-U	2.1
U-T	3.1
T-S	1.1
S-Z	2.1
Z-Y	2.1
Y-X	3.3
Total Weight	17.8

Figure 6 Suggested route from P to X by R1 with multiple preferences.

5 Conclusions and Future Work

This paper introduces an improved pedestrian navigation system that offers personalised routes considering seven walking preferences. The study primarily focuses on addressing the needs of commuters, particularly female pedestrians who have to traverse longer distances during night time. Additionally, the system aims to cater to pedestrians with physical challenges, the elderly, individuals accompanied by children or infants, leisure walkers and tourists. The implemented prototype is capable of computing a range of personalised routes, allowing users to select up to three preferences. This functionality goes beyond what major existing navigation applications currently offer. We believe the proposed system can encourage more walking by increasing confidence, safety and comfort in travel.

To enhance the proposed algorithm, it is suggested to incorporate open spaces, such as squares and parks, into the graph representation. The algorithm can be further optimised by addressing scenarios where conflicting preferences arise, such as situations where a route cannot simultaneously be the safest and the shortest. Enhancements can be made to ensure that the algorithm can provide more balanced routes that strike a suitable compromise between different preferences. Future work also includes taking into account temporal attributes when it comes to pedestrian routing, as time has a significant impact on walking needs. The initial application can be improved by incorporating adjustments that allow the display of information (such as walk time, reported crimes, etc.) within the colored bubbles. This enhancement will enable visual representation of route comparisons in a way that is easily understandable. Additionally, conducting a human study to evaluate the real user experiences of the prototype would be beneficial in assessing its effectiveness and gathering valuable feedback.

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