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Barrier-Free Routes in a Geographic Information System for Mobility Impaired People

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***Abstract*—It is always difficult to travel alone in a wheelchair without prior knowledge of the accessibility of the planned route. The majority of people prefer the shorter route. On the other hand, those with ambulatory limitations may prefer a longer route with proper ramps and drop curbs. This study aims to design obstacle management so that a registered user can report the accessibility of a ramp. The research includes an algorithm for generating barrier-free routes on the derived graph paths. When a wheelchair user encounters an obstacle while navigating the suggested route, the algorithm redirects them to their destination. A simulation test was performed, and the entire approach was evaluated using the survey method. The results showed that the proposed routing algorithm could find the shortest paths and reroute users to an unobstructed path. Respondents were highly pleased with the proposed navigation system's performance and thought it was accessible, usable, and reliable. As a result, the study may provide a novel approach to designing a geographic information system for use in a wheelchair navigation system.**

Keywords—geographic information system, mobility-impaired person, obstacle management, optimization, routing algorithm, shortest-path

I. Introduction

Traveling alone in a wheelchair without prior knowledge of the accessibility of the intended route is often a problem [1] – [3]. Ordinary people typically take the shortest route, but people with motor disabilities may prefer a long way without an uphill. They cannot make quick decisions, particularly when they are out in the field. They usually try to remember routes and information about accessibility in each area they visit. This strategy can prove problematic in the future, especially if they encounter a dynamic or static obstacle that differs from their previous experience.

These people usually cannot attempt a new route quickly because they are unprepared for various risks, such as being stranded in front of a road with insufficient drop curbs. Hence, many wheelchair users are hesitant to travel to a few places because they are unfamiliar with the new world and its accessibility requirements [4] [5]. Some wheelchair users may be able to overcome these difficulties, while others may not. As a result, obstacle detection becomes essential when dealing with wheelchair users, as proven in map navigation services [6] [7]. The obstacle management system will ensure that the safest path is found to circumvent impediments.

II. Review of Related Literature

In our previous studies, we looked at how to derive the graph representation of the road network for people with limited mobility [8]. It then used mathematical risk modeling and the Analytic Hierarchy Process to optimize the routes of the extracted graph model [9]. The optimal routes based on the user's geolocation and destinations were then produced utilizing the node combination technique based on Dijkstra's algorithm using a database containing the locations of the wheelchair-accessible ramps [10]. This led to the creation of a wheelchair navigation system in the form of a mobile application.

The following literature and studies were reviewed to find ways to generate barrier-free routes using an obstacle management. Proponents [11] developed and implemented a method for estimating the shortest path based on crowd-sourced constraints and obstacles. The technique was built on top of Google Maps' routing service, which was used to calculate the shortest distance between two points. Users provided limits, obstacles, and impassable areas as polygons, and the A* path-finding algorithm was used to guide users around a block. The application's barriers and paths, on the other hand, were not followed.

Authors [12] also proposed an algorithm for creating optimal routes for Automated Guided Vehicles (AGVs) in warehouses. The algorithm was designed to deal with a wide range of real-world situations, including obstacles. Each AGV executes the task according to the routing algorithm by starting in an initial position and orientation, then moving to a pre-determined position and orientation, resulting in minimum direction. The path was made up of a collection of AVG's positions and orientations. Based on Dijkstra's algorithm, the shortest path algorithm was tested in MATLAB under various working conditions.

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Researchers [13] also created a mobile app that calculated barrier-free routes between two points based on a user's profile. The starting position of a route was determined using Bluetooth 4.0 transmitters, which send UUIDs to the server that include the transmitter's geolocation. They used geolocations, which are the global coordinate system, instead of specialized coordinate systems for each house. As a consequence, their approach is applicable to a wide variety of subjects.

Finally, reference [14] created an augmented reality (AR) decision support system for motor-impaired people's navigation aid on the campus of the University of Lille. Their system offered mobility information and allowed wheelchair users to move freely and faithfully from one location to another in real-time. The prototype made use of geological mapping to propose the quickest route to the target as well as potential roadblocks to avoid. However, because the blocks and itineraries were not recorded in a database, they were inaccessible to other study participants.

III. Methodology

This study aims to design an obstacle management so that a registered user can report the accessibility of a ramp. The obstacle management features an algorithm to create barrier-free routes on the derived graph paths. When an obstacle is encountered while navigating the suggested route, the algorithm redirects wheelchair users to their destination.

To put the developed obstacle management feature to the test, the proponents created a map editor where users can mark the accessibility of a ramp. The path-finding algorithm was also modified to include the new obstacle-free shortest path. Finally, a software quality survey to assess the application's accessibility, usability, and reliability was used. The tool was based on the ISO/IEC 20510 quality characteristics, which were comprised of eight criteria. However, since certain criteria were difficult to measure, the survey tool focused solely on functionality, reliability, and usability [15], which could be easily assessed [16].

According to scientists [17], the remaining characteristics were hard to ascertain unless assessed by highly qualified IT specialists. Nevertheless, functionality requirements are directed towards accuracy and interoperability. The reliability requirements are centered on dependability and consistency. Lastly, the usability requirements describe the usefulness of the software. The software quality questionnaire was made up of 15 questions. The assessment was quantified on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Face validity was used to measure the survey tool's dependability. The survey tool was used on a subset of the intended survey participants. Cronbach's Alpha (CA) was used to assess the survey tool's internal consistency, with a result of 0.91 regarded as excellent.

TABLE I. Descriptive Interpretations of the Functionality, Usability, and Reliability of the System

Point	Descriptors	Scale	Descriptive Interpretation		
			Functionality	**Usability**	**Reliability**
5	Strongly Agree	4.51 – 5.00	Very High	Very High	Very High
4	Agree	3.51 – 4.50	High	High	High
3	Modestly Agree	2.51 – 3.50	Moderate	Moderate	Moderate
2	Disagree	1.51 – 2.50	Low	Low	Low
1	Strongly Disagree	1.00 – 1.50	Very Low	Very Low	Very Low

The mean values were interpreted in Table I. Follow up interviews were used to triangulate the results. The proponent employed purposive sampling to target mobility-impaired people, their family members and friends, and Information Technology (IT) professionals in the city Central Business District (CBD) of Baguio due to their substantial direct participation in the achievement of the research's objective. The study targeted a total of 35 people aged 18 and up, regardless of gender.

IV. Results and Findings

A. *Wheelchair Navigation System Architecture*

As illustrated in Fig. 1, the wheelchair navigation system comprises an API that permits the usage of a geographic map offered by Google Maps. The wheelchair navigation system comprises an API that permits the usage of a geographic map offered by Google Maps. It makes use of a MySQL database hosted in the cloud. The mobile device serves as a gateway between the application and the user. It also keeps track of the user's current location. The Internet is required to ensure that the mobile application and other components can be accessed. In the data layer, the cloud server saves the node coordinates, accessibility matrix, and weight matrix. These data are crucial for correctly deploying the optimized and secured route. The data are processed and localized by the client layer before being shown on a mobile device. In the service layer, Google Maps provides localization services. Finally, the administrator's panel facilitates content creation and system management.

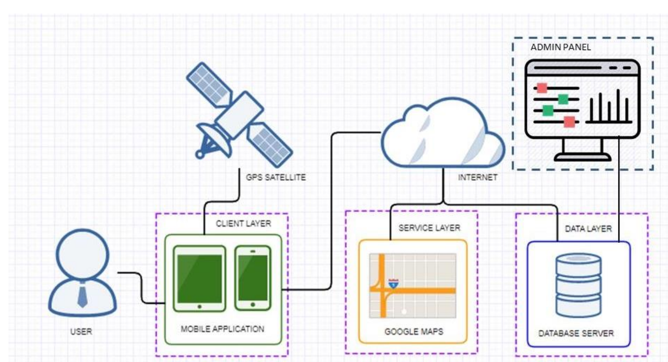

Fig. 1. Wheelchair navigation system architecture.

The mobile application was created in Kotlin, with a minimum SDK API 16 for Android 4.1 and an API Level 30 deployment unit. On the other hand, the administrator's panel was an online page built using PHP and Codeigniter frameworks. The software specifications of the mobile application are specified in Table II. It is made up of seven functional modules that all work together to create a reliable and robust wheelchair navigation system implementing the proposed GIS in the Baguio CBD.

TABLE II. MOBILE APPLICATION FUNCTIONAL REQUIREMENTS

Requirement Number	Feature	Description
FR01	Find Route	It allows users to generate routes utilizing the PWD ramps from one location to another.
FR02	Map and Nearby Places	It visualizes the user's current location and the surrounding PWD ramps, as well as their corresponding accessibility information.
FR03	Socials	It allows registered users to build a social network of family members and friends around them.
FR04	Monitor User	It provides real-time movement tracking for the user's social network. Unless the user enables it, this is turned off by default.
FR05	Travelogue	It collects data on places the user has visited, such as travel information.
FR06	Registration	The app enables users to register.
FR07	Map Editor	It enables registered users to define the accessibility of the ramps and report new ramps on the map.

B. Ramp Accessibility Module User and Admin Side

The mobile application has been updated to include a map editor that allows users to mark inaccessible ramps as well as a module that allows the administrator to monitor and approve reported accessibility issues.

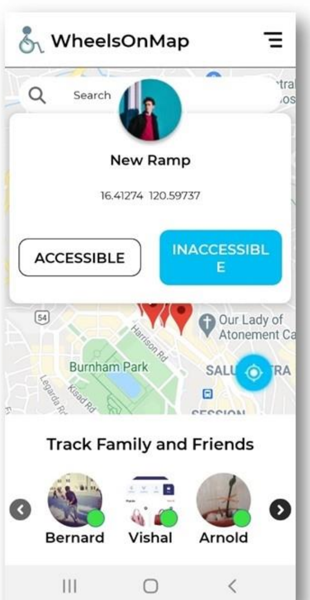

Fig. 2. Ramp accesibility module.

Using the mobile application, the user must select one of the ramps to define its accessibility, as shown in Fig 2. A window will show from which the user can choose whether the ramp is accessible or inaccessible. The user must include a brief description of the accessibility report.

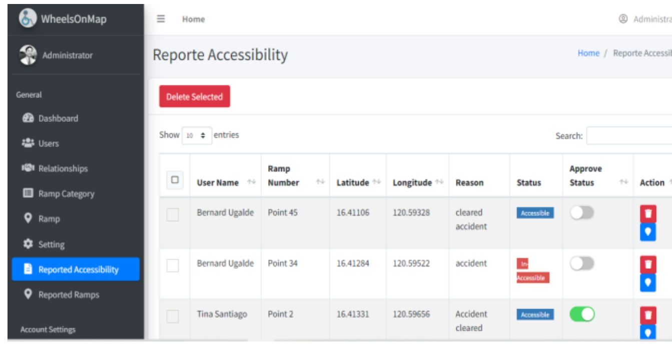

Fig. 3. Reported accessibility.

All accessibility reports are saved and will appear in the administrator dashboard, as shown in Fig 3. The administrator has the option of approving or rejecting the reported accessibility. If the report is about inaccessibility, then the ramp changes color to red in the mobile application. Otherwise, the color of the ramp will be green.

C. The Obstacle-Free Shortest Path

If an obstacle occurs along the suggested route, the algorithm in the mobile application's find route applies the following pseudo code to divert wheelchair users to their destination utilizing a novel obstacle management strategy, as demonstrated in Algorithm 1.

Algorithm 1. ShortestPathObstacleFree

```
ShortestPathObstacleFree (G,NW,UP,src,dst,O)
    currnode=src; j=1;
    SOP[j]=currnode
    While (currnode!=r)
        S = OPTIMALPATH (G, NW, UP, src, dst);
        i=1;
        While  (0[S[i],P[i+1]] == 0 and currnode! =dst)
            i=i+1; currnode=p[i];
            j=j+1; SOP[j]=currnode;
        endWhile
        if(currnode!=dst)
            src=p[i]:
            NW[p[i],p[i+1]] = ;
        endIf
    endWhile
EndShortestPathObstacleFree
```

D. Simulation Test Results

Test runs were done to verify and validate the module's functionality, as shown in Fig 4. The routes were evaluated with one or more nodes were designated as unreachable.

Fig. 4. Obstacle management test run.

TABLE III. THE SHORTEST ROUTE WITH OBSTACLE SIMULATION RESULT

Path	Destination		Route	New Route	Remarks
	End Node	Land Mark			
Route 1	47	Rose Garden	52 ⇒ 10 ⇒ 11 ⇒ 12 ⇒ **13** ⇒ 14 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 40 ⇒ 41 ⇒ 48 ⇒ 47	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5 ⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 40 ⇒ 41 ⇒ 48 ⇒ 47	Remove 13
Route 2	73	Baguio Museum	52 ⇒ 10 ⇒ 11 ⇒ 12 ⇒ **13** ⇒ 14 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 78 ⇒ 71 ⇒ 72 ⇒ 73	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5 ⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 78 ⇒ 71 ⇒ 72 ⇒ 73	Remove 13
Route 3	82	Igorot Park	52 ⇒ 10 ⇒ 11 ⇒ 12 ⇒ **13** ⇒ 14 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 32 ⇒ 33 ⇒ 34 ⇒ 82	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 32 ⇒ 33 ⇒ 34 ⇒ 82	Remove 13
Route 4	70	Sunshine Park	52 ⇒ 10 ⇒ 11 ⇒ 12 ⇒ **13** ⇒ 14 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 78 ⇒ 71 ⇒ 70	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5 ⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 78 ⇒ 71 ⇒ 70	Remove 13
Route 5	61	NBI Baguio	52 ⇒ 10 ⇒ 11 ⇒ 51 ⇒ 55 ⇒ 56 ⇒ 57 ⇒ **59** ⇒ 58 ⇒ 60 ⇒ 61	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5 ⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 78 ⇒ 71 ⇒ 68 ⇒ 67 ⇒ 119 ⇒ 61	Remove 59
Route 6	99	Baguio City Hall	52 ⇒ 10 ⇒ 11 ⇒ 12 ⇒ **13** ⇒ 14 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 42 ⇒ 43 ⇒ 123 ⇒ 124 ⇒ 125 ⇒ 127 ⇒ 126 ⇒ 128 ⇒ 129 ⇒ 131 ⇒ 103 ⇒ 104 ⇒ 106 ⇒ 107 ⇒ 94 ⇒ 95 ⇒ 105 ⇒ 100 ⇒ 99	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5 ⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 30 ⇒ 37 ⇒ 38 ⇒ 39 ⇒ 42 ⇒ 43 ⇒ 123 ⇒ 124 ⇒ 125 ⇒ 127 ⇒ 126 ⇒ 128 ⇒ 129 ⇒ 131 ⇒ 103 ⇒ 104 ⇒ 106 ⇒ 107 ⇒ 94 ⇒ 95 ⇒ 105 ⇒ 100 ⇒ 99	Remove 13
Route 7	97	Baguio Police Station	52 ⇒ 10 ⇒ 11 ⇒ 12 ⇒ **13** ⇒ 14 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 32 ⇒ 33 ⇒ 34 ⇒ 82 ⇒ 83 ⇒ 84 ⇒ 85 ⇒ 86 ⇒ 87 ⇒ 88 ⇒ 89 ⇒ 90 ⇒ 91 ⇒ 92 ⇒ 97	52 ⇒ 10 ⇒ 9 ⇒ 8 ⇒ 7 ⇒ 6 ⇒ 5 ⇒ 4 ⇒ 3 ⇒ 16 ⇒ 15 ⇒ 80 ⇒ 26 ⇒ 31 ⇒ 32 ⇒ 33 ⇒ 34 ⇒ 82 ⇒ 83 ⇒ 84 ⇒ 85 ⇒ 86 ⇒ 87 ⇒ 88 ⇒ 89 ⇒ 90 ⇒ 91 ⇒ 92 ⇒ 97	Remove 13

The findings of the tests are summarized in Table III. Based on the testing conducted, the application was able to construct a new path that avoided an inaccessible ramp. The newly generated route utilized other available adjacent ramps while maintaining the shortest route towards the destination ramp. Although the routes were longer, they included a path that was deemed safe for users due to its usage of PWD ramps. These findings corroborated those of [14]. The participants expressed great satisfaction with the experiment's outcome, based on the follow-up interview.

E. Software Quality Survey Results

Mobility-impaired people, their family members, and IT experts assessed the application's functionality, usability, and reliability using the software quality survey. Table IV displays the overall outcome of the survey. With weighted mean scores of 4.95, 4.92, and 4.82, the application was evaluated to have very high functionality, usability, and reliability. Hence, the proposed system indicated a very high quality, with an overall weighted mean calculated as 4.90.

According to the follow-up interview, the mobility-impaired people were pleased with the various aspects of the mobile application because it provided them with a complete solution for getting around the city. They stated that they would be willing to use the application in their everyday routine.

The family members were relieved to learn that the application would put them at ease when a family member needed to travel alone in their wheelchair. They were generally pleased with the overall features of the mobile application. They also believe that the application would be extremely beneficial to a family member with limited mobility.

TABLE IV. OVERALL WEIGHTED MEAN FOR THE SOFTWARE QUALITY SURVEY

Criteria	Weighted Mean	Interpretation
Functionality	4.95	Very High Functionality
Usability	4.92	Very High Usability
Reliability	4.82	Very High Reliability
Overall Weighted Mean	**4.90**	**Very High Software Quality**

Finally, the IT professionals were astounded that the proposed solution could create a map of PWD ramps, generate routes, and visualize it on top of the Google Maps API. They stated that accomplishing this would need much effort and analysis. They suggested, however, that a turn-by-turn capability and dynamic recalculation of the weight while navigating based on the factual information in the area could be considered in the future. Lastly, they stated that the application was highly recommended for people with limited mobility.

V. CONCLUSIONS AND RECOMMENDATIONS

This study aimed to design an obstacle management so that a registered user can report the accessibility of a ramp. Indeed, the research was able to design an algorithm for generating barrier-free routes on the derived graph paths. The simulation test revealed that the solution was able to redirect users to obscured path. The corresponding application was of high software qualify. Our study recommends identifying the proposed solution's performance against existing GIS for a mobility-impaired person in terms of travel time, route, and travel distance. A provision for artificial intelligence-based [18 – 20] will also be explored in the next version of the system.

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Certification of Author Contribution

We hereby certify that the following statement outlines the contributions made by each author to the creation of this work. This certification serves to acknowledge and authenticate the individual contributions, ensuring transparency and proper recognition of each author's involvement in the research/project.

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Barrier-Free Routes in a Geographic Information System for Mobility Impaired People

Publisher: IEEE

Bernard H. Ugalde ; Renato R. Maaliw ; Suresh Palarimath ; Mohammed Bakhit Al Mahri ; Albert A. Vinlua... All Authors

Abstract:
It is always difficult to travel alone in a wheelchair without prior knowledge of the accessibility of the planned route. The majority of people prefer the shorter route. On the other hand, those with ambulatory limitations may prefer a longer route with proper ramps and drop curbs. This study aims to design obstacle management so that a registered user can report the accessibility of a ramp. The research includes an algorithm for generating barrier-free routes on the derived graph paths. When a wheelchair user encounters an obstacle while navigating the suggested route, the algorithm redirects them to their destination. A simulation test was performed, and the entire approach was evaluated using the survey method. The results showed that the proposed routing algorithm could find the shortest paths and reroute users to an unobstructed path. Respondents were highly pleased with the proposed navigation system's performance and thought it was accessible, usable, and reliable. As a result, the study may provide a novel approach to designing a geographic information system for use in a wheelchair navigation system.

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I. Introduction

Traveling alone in a wheelchair without prior knowledge of the accessibility of the intended route is often a problem [1]–[3]. Ordinary people typically take the shortest route, but people with motor disabilities may prefer a long way without an uphill. They cannot make quick decisions, particularly when they are out in t... ber routes and information about accessibility in each area they visit. This strategy can prove problematic in the future, especially if they encounter a dynamic or static obstacle that differs from their previous

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Comments

This paper presents design of an obstacle management so that a registered user can report the accessibility of a ramp in path of a wheelchair. The obstacle management features an algorithm to create barrier-free routes on the derived graph paths for mobility impaired people.

Idea is new and useful but technical details are missing. Authors failed to provide information how and for which OS the WheelsOnMap app was developed. They also did not provide any details of WheelOnmap server (shown in figure 2). What is that server, where is that installed and running? Technical details are missing. The paper is too short.

completed — Weak Accept 3

Comments

The authors presented the algorithm to manage the obstacle and provide a barrier-free pathway for mobility-impaired people. A good literature review has been done. The paper lacks an adequate explanation of the methodology.

completed — Accept 4

Comments

The research talks about how a GIS system can be designed for people who have limitations and how it can provide them an obstacle free shortest path thus allowing them to get from point A to point B quicker, faster and with limited obstacles. There is also an option for the user to report on the accessibility of the ramp or the route. This would help to train the algorithm and also provide guidance as well. The author has also provided examples on how the algorithm would work in a real world scenario, while also not routing via an inaccessible ramp. The research created a method for constructing barrier-free graph paths.Simulations showed the method might reroute people to an unobscured path. High-quality software was used. This study proposes comparing the suggested solution's trip time, route, and distance to existing GIS for a mobility-impaired person.