Users Are Doing It For Themselves: Pedestrian Navigation With User Generated Content

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Abstract

Route planning has over the few past years become common in the context of driving cars and other vehicles. However, with the advent of powerful mobile devices, such as smart-phones, systems helping pedestrians finding their way in complex urban environments have emerged. We present a prototype system for mobile pedestrian navigation, called OurWay*, based on user generated maps and collaborative annotations of network segments. We are particularly concerned with users with various permanent or temporary disabilities, like wheelchair users, or parents pushing baby strollers. By letting users rate the accessibility of locations, the system will compute bespoke routes matching their abilities and preferences. We explore the potential of the concept through a combination of field work and lab trials, using real life data. We also demonstrate that collaboratively collected geodata has promising properties as a foundation for innovative geospatial applications. Initial results indicate that few user annotations are needed to produce good routes.*

1 Introduction

Pedestrian navigation is a challenge in complex urban structures, in particular in unfamiliar territory. For the physically impaired, like wheelchair users or parents with baby strollers, finding and following a reasonable route from one place to another may become difficult, not to say impossible, when encountering barriers like stairways, steep hills and missing sidewalks. Contrary to the related field of car navigation, with its abundance of tools, services and content providers, tools for pedestrian wayfinding are scarce. Notable exceptions can be found in Japan, where the availability and usage of pedestrian mobile route planners in larger cities, such as Tokyo [26, 17], is rapidly increasing. The reason for this, in addition to the widespread use of advanced mobile services, might be the relatively low market penetration of cars, and the comparatively high reliance on public transportation.

Pedestrian wayfinding diverges from car navigation in mainly two aspects:

- Pedestrians are not strictly bound to follow designated roads, paths and sidewalks, but may walk through parks, or take short-cuts through shopping malls. Hence, the underlying transport network becomes more complex, both to generate and to maintain.
- Pedestrians are a more heterogeneous group than car drivers, as car drivers usually are only limited by whether or not there exists a road between given waypoints. Pedestrians may be categorized according to a wide set of criteria, reflecting physical abilities and personal preferences. User profiles also depend on context: a father becomes temporarily disabled when pushing a baby stroller. Accordingly, route planning tools should be able to cope with a variety of user profiles.

Our main strategy for resolving these issues, is to turn to the users themselves. Inspired by the rapidly growing community efforts in phenomena such as wikis, media sharing services and open source software development, we have built a prototype system, called *OurWay*, that enables pedestrians to grade road segments with regards to accessibility, for subsequent use in route planning. Using this mechanism, knowledgeable users, for example people that live and spend time in a particular area, can create feedback and essentially map out their neighborhood. Using this mechanism, users, can draw upon each other's knowledge to quickly find the better paths through town.

We have also leveraged principles and tools for collaborative mapping, by using the OpenStreetMap [22] infrastructure to build the underlying geographic network. The

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users generate the content in the field by using off-the-shelf mobile devices, such as smartphones and Bluetooth GPSs.

The purpose of the paper is twofold. First, we want to explore, on a proof-of-concept basis, how members of a group could benefit from using a collaborative system, such as OurWay, to find good routes in urban environments. Second, we will use this case to demonstrate the potential of user generated mobile content, as the geographic network of streets, sidewalks and paths, along with the individual ratings of accessibility, is built by collaborative efforts in the field, and shared among all users.

In the next section we briefly review a selection of related work. The OurWay prototype is presented in Section 3, and results from the preliminary experiments are given in Section 4. We discuss our findings and propose modifications and extensions of our concept in Section 5, before giving some final remarks in Section 6.

2 Related Work

Route planning for pedestrians is emerging from where classic vehicle routing meets the increased power and versatility of mobile devices. Early commercial efforts include the pioneering DoCo-Navi [26] and the later KDDI's EZ Navi Walk [17]. Karimanzira et al. [15] have looked at using machine learning techniques to generate routes tailored for disabled pedestrians, although the majority of the work in the field has been aimed towards tourist guides and similar [14].

Personalized route planning means that the route planner adapts to the user's specific needs and desires, such as Balke et al.'s prototype [3]. Kawabata et al. propose a context dependent metadata layer over the physical space to generate optimal routes according to the users' preferences [16]. Wuersch and Caduff point out that pedestrians are not confined to the underlying network of streets and sidewalks, but may use open areas like parks and squares. As a consequence, they explore aspects of treating routes as a sequence of waypoints [28].

Collaborative route planning is a variation of personalized route planning that has received little attention from researchers, although research into collaboration in recommender systems has matured (such as [11]). Still, some headway has been made using multiple agents sharing experiences to create a distributed case based reasoning system [20]. Others have looked at collaboration through users offering each other clues, either through direct participation [6] or more indirectly through photographs in geoannotated wikis [5].

To personalize routes, one must somehow capture the user's preferences. Haigh et al. suggest letting users rate routes using an *efficiency* β value to decide whether to reuse old solutions or explore new territory [10], while Akasaka and Onisawa have looked at using fuzzy measures to capture users' preferences, and assign roads sets of attributes based on detailed user input [1, 2]. Rogers and Langley, however, point out that an explicit user model may be too costly to develop and give too few assurances of accuracy to be worthwhile [23]. Examples of explicit pedestrians models are found in [24] and references therein.

Level-of-service (LOS) is a common term in transportation planning and research, and describes systems and methods for modeling suitability, efficiency and other aspects of vehicle transportation. The LOS concept has also been applied to pedestrian domains. Unfortunately, due to regional variations and lack of standards, pedestrian LOS frameworks differ substantially, as evident when comparing for instance the work reported in [19] (US) and [9] (Australia).

In the *MAGUS* project, a comprehensive LOS model for wheelchair users is developed, based on questionnaires, interviews, observations and physical measurements of starting and rolling resistance [4]. The final system is a GIS application, aiming to assist new users and enable better navigation for existing users, and as a means for planners. However, Sobek and Miller point out that the detailed LOS model would be extremely costly to establish and maintain, and that the application requires too much time from the users [25]. MAGUS is implemented with an expensive and proprietary GIS system, and they are of the opinion that this may further limit the practicality of the application.

Based on these observations, Sobek and Miller present an alternative system for route planning for disabled pedestrians, called *U-Access*. They propose simplified models of both level-of-service and users, claiming that this still generate good results. The implementation of the concept is web based, and leverages open geodata standards, thus providing access for users without specialized and expensive software.

In our work we propose an even simpler approach. First, we allow the users to organize themselves based on self-identification, creating groups we can assume share abilities and preferences. Second, we let the users collaboratively generate a simple LOS model based on shared user annotations. Finally, we leverage open standards and open geodata, and implement the prototype as a modular system with open source components.

3 The OurWay Prototype

We have developed a prototype to explore our concept of collaborative pedestrian route planning [12]. The OurWay system is a loose coupling of server and client-side components communicating over the HTTP protocol and exchanging XML formatted data. Figure 1 shows the basic architecture of the system.

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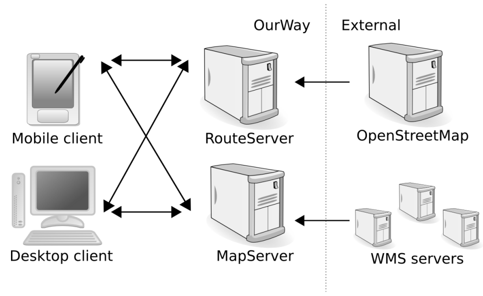

Figure 1: OurWay architecture

3.1 Implementation

OurWay is comprised of two clients and two servers.

Clients The two clients are nearly identical; One is implemented on a smartphone/PDA device, running the Windows Mobile 5 operating system, the other as a desktop C# based application. Their main functionality is to provide a map based user-interface for route planning and user rating of the quality of the streets, sidewalks and paths. In addition, both clients allow the user to create new segments for the underlying geographic network, either semi-automatically by GPS tracking, or manually by drawing on the map.

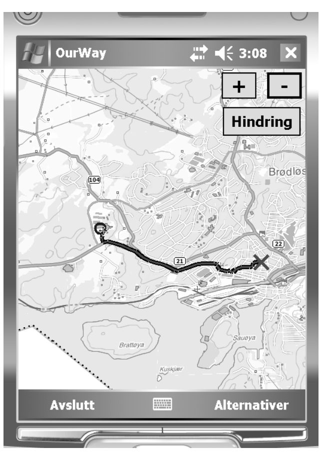

Figure 2: Screenshot of OurWay prototype, running in an emulator

A screenshoot from the mobile client is shown in Figure 2. The buttons labeled plus and minus zoom in and out of the map, while the third button lets the user report feedback. Most other functionality is available throught the two menues at the bottom of the screen. Note that the GUI has not been the focus of this project, and we have therefore not applied any HCI techniques to its design.

Servers The two servers are responsible for providing maps and calculating routes, respectively, in addition to administrative services. The map server is implemented in PHP, while the route server is a Java Servlet.

The Map Server's task is to deliver background maps to the clients, in the form of image tiles. The server transforms the map requests into appropriate calls to a specified geodata provider. We use the Web Map Service (WMS) protocol, initially developed by the Open Geospatial Consortium, and an international standard (ISO) since 2005 [8]. By leveraging this widely used specification, the server can access any WMS based map provider, without changing the implementation.

To reduce the number of WMS calls and speed up delivery, the server maintains a local tile cache based on the clients' positions. In our case, we used both aerial imagery and topographic maps.

The Route sERVER is responsible for calculating and delivering routes based on the supplied user group, start point, and end point. It delivers the routes as an ordered list of geographic points. It also handles ratings from users and assigns these to the relevant edges in the road network during the route calculation. The underlying geometric network is imported from the OpenStreetMap (OSM) server. We explain the route calculation process in some detail in the following section.

3.2 Route Calculation With User Ratings

The central collaborative feature of our prototype application is the rating of accessibility of geographic areas, and the sharing of these ratings inside user groups. Users are able to change groups at any point, and create new groups if they wish. In the current implementation, user groups do not share information, even if the user groups have similar needs.

Users can rate the network used for route planning by pointing out good, bad, or inaccessible points along a route. For instance, if a wheelchair-user comes across a stretch of road where he must get off the sidewalk to circumvent an obstacle, he could mark this point as bad. Even worse, if the wheelchair-user is lead up a road that is simply too steep for him, he could mark the spot inaccessible, and the route planner would never again attempt to route a wheelchair user up that road.

User feedback causes roads to appear shorter or longer than they really are, by applying weights to the corresponding edges in the underlying road graph. This way, the search algorithm will attempt to avoid stretches of road that have received negative feedback. Roads marked as inaccessible will appear prohibitively long and thus never be used by the route planner.

The user feedback is represented as floating point weights. When a route is calculated, an edge in the network is assigned a value equal to its geographic length multiplied

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with any prevailing user feedback assigned to it. Currently, the most negative feedback an edge has been given is the one that is used, although other modes can be imagined, like having the last feedback count, or calculating some average between all user feedbacks.

We have chosen the three weights 0.5, 4.0, and 42000.0. We arrived at the first two weights through informal experimentation, where we found that these worked well for us. The final weight is an arbitrarily large number that effectively renders a road untraversable.

For the purpose of route planning, we consider an edge to be a stretch of road or path or otherwise between two intersections, such that the stretch itself does not contain any intersections. This means that the geometry of the road is not considered when creating the graph of the map, only the topology. Furthermore, it means that negative user feedback offered at the bottom of a very long, winding path up a hill, will make the hill nigh insurmountable, while similar negative feedback for a short road in an urban setting will have a much smaller effect.

The actual search algorithm is the classic A* algorithm for finding an optimal route through a network.

4 Prototype Evaluation

The OurWay prototype was evaluated in an incremental study where we simulated users interacting with the system while we observed the behavior of the prototype. We limited the study to one single user group: normally fit parents with baby strollers. This study was an initial proof-of-concept exercise, focusing mainly on technical aspects.

The study was split into three parts. We first created the geographic network we would use for route planning by gathering map data using the OpenStreetMap infrastructure, as explained in the next section. Then we engaged in a field test, before carrying out systematic lab trials.

4.1 Street Map

The OurWay framework relies on a detailed map of available roads, sidewalks and paths. The clients provide functionality for adding new nodes and edges, however, this is primarily intended for minor updates. Hence, in a practical situation, the system has to be bootstrapped with an initial map with a reasonable level of detail.

However, developing and experimenting with applications depending on real life geospatial data is not trivial. Access to geodata is often expensive[1], and sometimes complicated and cumbersome, due to for instance inefficient distribution systems and problems with interpreting formats and converting data. In particular, the challenge may become overwhelming when trying to integrate data from multiple sources in one single application.

These problems are widely recognized, and several initiatives have emerged to deal with them. On an interoperability level, the perhaps most prominent effort is the Open Geospatial Consortium, which has developed and promoted a family of specifications, some of which have become ISO standards (see e.g., [18] and references therein for details on semantics and interoperability of geodata).

On a content level, the Digital Chart Of The World (DCW), published by United States Defense Mapping Agency (DMA) in 1992 [7], has been, and still is, the most comprehensive dataset with global coverage. The Global Mapping Project is working on product similar to DCW, free for non-commercial use. It is a joint effort, with contributions from national mapping agencies [21].

However, the mentioned open sources provide data on coarse scales, typically 1:1 million, and is unusable for applications dealing with street level problems. During the past years, many initiatives in collaborative content generation, often in the form of wikis, have emerged. The most outstanding example is Wikipedia, which from its start in 2001 has grown from a modest experiment to a highly respected and frequently cited information source on a global scale, outrivalling many traditional encyclopedias.

The Wikipedia concept has as a parallel in the geospatial domain, the OpenStreetMap (OSM) project [22], founded in 2004. OSM provides a complete infrastructure supporting collaborative map making on a global scale, including tools for mobile data acquisition, editing applications, administrative and storage services and browsing and downloading facilities. The OSM data is distributed under a Creative Commons license, which in practice allows any kind of use, as long as OSM is attributed, and that new products are shared under the same conditions.

At the time of writing, OSM has approximately 7500 contributing users, and close to 70 million uploaded GPS points. Several areas and cities, in particular in Great Britain, have reached a coverage making the data usable in various kinds of applications. As an example, the Britain based property search engine Nestoria is providing OSM content as an alternative to Google maps.

For the reasons stated above, OSM became the data provider of choice in the OurWay project. Our main test area was Halden, a small town in Southern Norway, with a population of around 28000. When starting the project, the OSM coverage of Halden was not complete. The authors and a couple of students undertook the task of supplementing the network. We used both GPS tracking, with cars, bikes, and on foot, and tracing on top of high resolution aerial imagery, provided by the local municipality. Figure 3 illustrates the mapping process. The resulting geographic network is a relatively complete map of downtown Halden

[1] A notable exception is US geodata, which, due to legislation on public sector information, is freely available for usage in most applications.

(a) GPS tracks (b) Final geographic network

Figure 3: Mapping Halden the OSM way

(approx. 2 km^2).

The OSM infrastructure provides functionality for categorization of the road networks, in order to enable applications to distinguish between for instance foot paths and highways. However, the OurWay server discard this information, thus treating all parts of the network equally. In this way, all additional information on the usability of the components of the network is provided by the users themselves as feedback in the field.

4.2 Field Work

For the field tests, the main objective was to gather experience as users of the prototype. The authors brought a PDA type smartphone with the prototype installed and a baby stroller. Using OurWay to generate routes, we pushed the stroller through the city-scape, including a fairly hard-to-navigate park with poor trails and steep climbs.

Although the researchers have substantial local knowledge of the test area, the field excursions taught us more about the precise obstacles facing people with baby strollers. We improved our understanding of the local geography and gained some insight into what sort of obstacles would matter to the baby strolling user group.

During the tests, we learned that as a user, it was reasonable to distinguish between only three kinds of accessibility: what was uncomfortable, what was completely inaccessible, and what was experienced as good. The first category would include anything where we felt it was uncomfortable to maneuver. This could include steep climbs as well as roads with poor or confusing sidewalks. By inaccessible, we meant places we were forced to carry the baby stroller, or roads that lacked sidewalks altogether. Positive feedback was given when we came across places we experienced as a relief from the roads around, or where it was especially easy to maneuver.

Further, the field tests provided insight into how to estimate the values of the weights associated with the three categories. Conceptually, these weights are supposed to reduce or increase the actual distances in order to reflect the users' positive and negative experiences. After some trial and error, we decided on the weights 0.5 for a good review, 4.0 for uncomfortable areas, and 42000.0 for an inaccessible point. Estimating parameters like this is notoriously difficult, however, these values yielded satisfactory results in our tests.

An obvious question to ask is under what circumstances users will find themselves motivated to annotate their environment. In a parallel study, we have started to look into different aspects of motivation for use and contribution to this kind of system [13]. Preliminary findings indicate that people are more likely to react to and annotate negative experiences, thus possibly leading to less use of the "good" category of feedback. Further, within some groups, such as those organized in associations for physically disabled, the shared goal of universal access can be a strong motivational factor. Ensuring system trust and information trust is another topic which is key to motivate use of such a navigational tool.

4.3 Lab Trials

The final part of the study was performed in the lab where we used the desktop version of the route planner. Apart from being a technical system test, the main objective was to study how user feedback affected the quality of the proposed routes.

We performed a set of tasks, where we simulated finding and following routes between two waypoints, and giving feedback during the "walks". The simulated user was supposed to belong to a user group with normally fit persons pushing baby strollers.

During each task, we performed a number of iterations, where a route between the given waypoints was generated, based on existing user feedback. We then "walked" the route, and used our local knowledge of the geography and the experience garnered earlier to identify and report comfortable, uncomfortable and inaccessible areas.

The first iteration of each task was carried out with a neutral network, i.e., one that had not received any prior user feedback. We stopped the iterations when there were no need for more feedback, in other words, when the process converged on a stable solution.

4.3.1 Results

The following results are drawn from experimenting with four navigation tasks. The trips were estimated to be in the range of ten to thirty minutes pushing a stroller at normal speed. The area covered included pedestrian streets, paths

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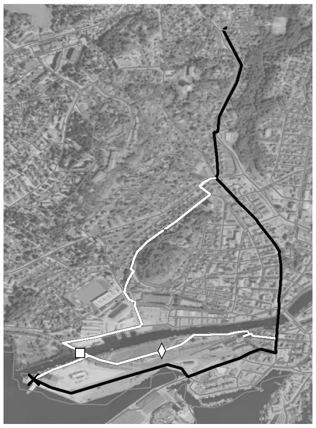
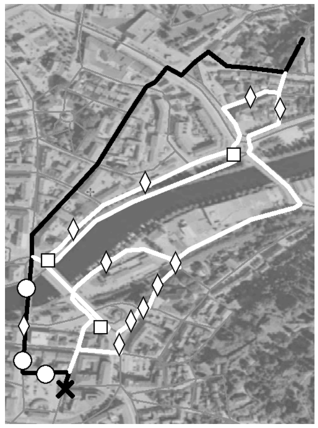
in parks and sidewalks on local and regional highways. In the following we describe each case in some detail.



(a) Task 1



(b) Task 2

Figure 4: Final routes (black) and intermediate routes (white). Inaccessible, inconvenient and good spots are marked with squares, diamonds and circles, respectively. OpenStreetMap network (thin gray lines). Background aerial imagery courtesy of Halden Municipality.

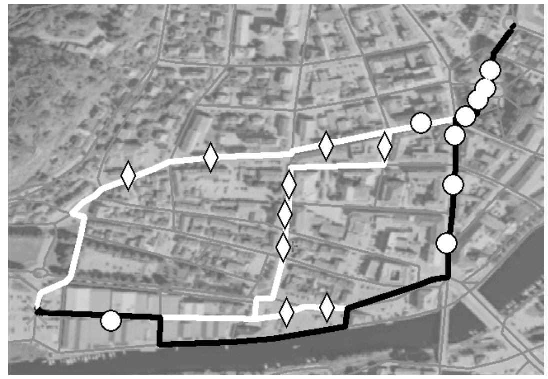
Task 1 The trip starts in a residential area, crosses the town center and ends up in the harbor area. Tista river has to be crossed, see Figure 4(a). The first proposed route mainly follows sidewalks and footways down to the shopping area at the river bank, and then uses a path leading to a bridge that is too narrow for a stroller. Hence, this part of the route is rated inaccessible.

The next route uses another bridge, designated for bikes and pedestrians, resulting in a slightly longer route. It follows a rather cumbersome footway along the river out to the harbor, and this segment is rated uncomfortable.

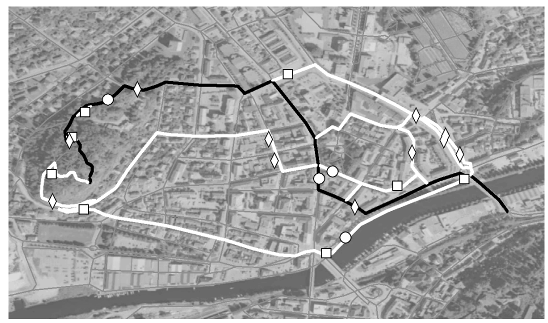
In the final iteration, the last leg of the route follows sidewalks and crosses open harbor areas. Interestingly, this route is identical to one frequently used by one of the authors. The solution converged after three iterations, including feedback consisting of only two ratings, one on an inaccessible segment, and one on an uncomfortable path.

Task 2 This is a typical 10 minutes walk, from the town square on the south side of the river, to the Porsnes highschool on the other side of the river. The ground between the two waypoints is quite heterogeneous, from dedicated footways to industrial areas and busy streets with sidewalks, as seen in Figure 4(b). To reach a satisfactory route, we made five iterations, with 16 feedbacks, three inaccessible stretches, eleven bad segments and two good parts.

Task 3 This trip is also fairly short, from one shopping mall to another, in a relatively homogeneous mixed shopping/residential city area, with no major obstacles. A good solution was achieved after three iterations. No inaccessible areas were identified, however five segments were rated comfortable, and nine stretches were considered uncomfortable. See Figure 5(a) for details.



(a) Task 3



(b) Task 4

Figure 5

Task 4 This is the most challenging case, estimated 20 minutes through a highly diversified area. It starts in a park with a labyrinth of dirt paths, continues through residential and shopping areas and crosses a regional highway and the river. There are many potentially inaccessible constructs, such as stairways and narrow footpaths in uneven terrain. Not surprisingly, this case needed more iterations to converge than the other tasks. After eight passes, eight reported major obstacles, ten uncomfortable parts and two good ratings, an acceptable route emerged. However, the final solution included one bad segment, marked in the first iteration. The intermediate solutions varied substantially, probing rather a large area all together, as seen in Figure 5(b).

To further analyze the test results, we introduce the *penalty factor*, which is the ratio between a given route between two waypoints and the shortest path computed without user feedback. The penalty factor reflects the additional cost of choosing an alternative route to avoid obstacles and unpleasant stretches. Table 1 shows how the penalty factor increases over the iterations in each of the four tasks.

	Iterations							
Task	1	2	3	4	5	6	7	8
1	2554m	1.14	1.16					
2	927m	1.04	1.06	1.09	1.09			
3	770m	1.08	1.10	1.17				
4	1307m	1.07	1.10	1.10	1.10	1.10	1.11	1.12

Table 1: Penalty factor: For each task (row), we give the length in meters of the initial shortest path (first column), and then the computed factor for the following iterations.

It's worth noting that the penalty factor is a conservative measure of the overhead of choosing more comfortable alternatives, considering that avoiding obstacles and inconvenient segments may indeed yield an all together faster route. With this in mind, the penalty factors in our cases seem surprisingly low, in the worst case the best alternative is only 1.16 times longer than the shortest path without user feedback.

One reason for the low penalty factors, is that the urban test area is relatively dense with respect to the underlying network, i.e., there are many and short edges, resulting in a generous solution space, where the algorithm is able to find many alternatives that are relatively similar.

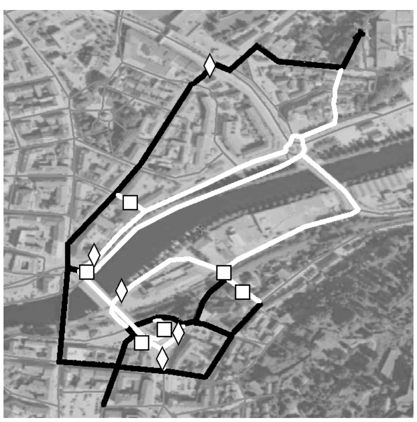


Figure 6: Navigating by trial and error. The ground covered is marked as black, and the proposed, but not used, segments are in white. Annotations are indicated as in Figure 4.

This could lead to the hypothesis that it would be easy for a newcomer to find a good route just by trial and error. To pursue this aspect, we performed an additional experiment, based on Task 2, to simulate this kind of user behavior. We started out with a neutral network, calculated an initial shortest path route, and followed the route until we found an inaccessible or uncomfortable segment. We then reported the point, and asked for a new route, from the current location to the final destination. The procedure was repeated until we reached the target. Not surprisingly, this resulted in a route with numerous backtracking elements, see Figure 6. The penalty factor reached 1.83, significantly higher than the converged route in the corresponding previous experiment (1.09).

The results will be further discussed in the following section.

5 Discussion and Future Work

We chose to carry out the initial round of field testing of the prototype ourself for a handful of reasons. It allowed us to gain first-hand experience as users, giving us valuable insight for the design of a larger study with independent users. Also, it gave us the opportunity to discuss the number of feedback levels and weighting of user feedback, both prerequisites for a larger scale study. Furthermore, as the group consisted of representatives of the case user group, we were able to realistically judge accessibility, giving our findings real value. Finally, continuing the experiments in the lab was made easier and more realistic, since we had our own experiences in mind whilst in the lab.

Our field and lab experiments have led us to several discoveries we consider worthwhile for further research, and some of these will be highlighted the following section.

5.1 Algorithmic Issues

Route distance and the number of iterations to reach route convergence are not correlated, rather the homogeneity and lack of obstacles in an area are determining factors.

It is worth mentioning that a fast convergence of a route planning iteration does not necessarily indicate a high quality route. If there are few alternative routes, a negatively rated segment might be unavoidable, as seen in Figure 5(b), where the final route takes the user through three segments rated as inconvenient. This is of course related to the choice of feedback weights, and a subject for further research.

Proper handling of multiple user feedback on road segments will be crucial to the adaptiveness of the system. In the current prototype, only the most negative feedback on a segment is considered. This leaves the system vulnerable to malicious annotations, since a more positive feedback on the same segment has no effect. Fortunately, experimenting with different ways of handling multiple user feedback is easily achieved by changing the cost function in the route planner. Inspired by wikis, one obvious alternative is to use the last feedback on a segment when calculating the adjusted length. This allows for a more dynamic network, where corrections from users have an immediate effect. This also leads to interesting issues such as edit-wars and malicious edits found in wikis .

In order to enable changes in the underlying road network, it is vital to separate user feedback from the network itself, and rather keep the feedback as point annotations, associated with network segments at the time of use. Further, this separation allows for points of interest (POIs) from different sources to be integrated in the system. Objectively measured accessibility for street crossings, sidewalks, and roads could be mapped to our pragmatic user feedback model. Further, interest points such as parking spaces, toilets and shopping centers with accessibility information could be included, and allow for route planning with POIs as intermediate goals in a route.

The current prototype handles each user group separately, i.e., there is no sharing of user feedback across the groups. Also, the concept of discrete user groups is open for questioning, since there obviously are differences in perceived quality of the routes between individuals in the group. Alternative ways of handling this include dynamic user groups based on trust networks, and hierarchical groups where some feedback is considered to apply to all groups, with additional feedback within the groups. Using universal access information as a backdrop, each user group could augment and tailor the information to their specific needs.

The experiment results are achieved on a neutral network with no extra information for distinguishing car roads from sidewalks, bridges or stairs. In fact, the prototype will ignore additional metadata information even if provided. Utilizing such information could clearly impact the route planner positively, however the complexity involved in maintaining an unambiguous set of attributes, combined with the positive results of our tests makes our pragmatic approach very attractive.

5.2 Usage Patterns

It is highly likely that the users' perception of the quality of a route segment is linked with the *change* in quality, rather than the objectively measured quality at any given point. Coming from a foot path, it is easier to appreciate a paved sidewalk as good, than if the route generally consisted of paved sidewalks. For this reason, we anticipate that user feedback will tend to appear at points of change in road quality, and to a lesser degree in homogeneous stretches of road.

This is well illustrated by the special case of an inaccessible route segment, where the user will give feedback on the point where it becomes inaccessible, and not have the opportunity to explore the route beyond that point.

In a related study, we are taking on the issue of users' motivation for contributing to a system such as OurWay. Inspired by research on wikis (especially Wikipedia), we are curious to see if users will take responsibility for geographical regions, in the same way that Wikipedia contributors take responsibility for Wikipedia pages on their *watchlist* [27]. This also brings up the need for a visualization method to display changes in an area over time. The non-linearity of geotagged information makes this an interesting issue for further research.

6 Conclusion

In this paper, we presented a collaborative navigation system for pedestrians with varying physical abilities and personal preferences. The OurWay infrastructure enables users to find bespoke routes matching the specific profile of their group.

User participation plays a vital role on two levels in the system. The street network on which the route planning takes place is collaboratively created by OSM contributors. Further, user feedback on route segments makes the route planner adapt to perceived accessibility by users in distinct user groups. The feedback is immediately available for the community using the OneWay services.

Technically, we found the prototype to behave as expected, from each individual component, to the system as a whole. However, our main research objective was to explore the effect of collaboration in route planning, utilizing map making and route feedback tools.

The OpenStreetMap infrastructure enabled us to generate a complete geographic network of the test area with surprisingly small efforts. We used various techniques for creating the OSM data, from field based GPS tracking to tracing features from freely available aerial imagery.

We were able to demonstrate that a relatively small number of annotations was sufficient to generate good bespoke routes, even when starting out with a completely neutral network. This was confirmed both in the field and in our lab trials.

The preliminary findings are promising, and inspires our future work in the direction of user experience trials, studies on user motivation for contribution and use, and issues such as sharing of ratings across user group boundaries, estimation of feedback weights and integration of different data sources.

Part of our initial motivation for creating OurWay was the different requirements for navigation posed by pedestrian users as opposed to car drivers. Nevertheless, it seems obvious that the type of user involvement utilized by OurWay has numerous potential applications, including route planning for different groups of vehicle users. Letting users plan routes along attractive stretches of roads, where attractiveness is defined by a peer group seems to follow naturally from the OurWay concept.

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