People Helping Computers Helping People: Navigation for People with Mobility Problems by Sharing Accessibility Annotations

Harald Holone and Gunnar Misund

Østfold University College, Halden, Norway

Abstract. Accessibility maps are valuable tools for people with mobility problems navigating in the urban landscape, in particular for first time visitors. However, the costs of establishing and maintaining such maps prohibit widespread use. Moreover, smartphones, GPS positioning and a growing number of open geospatial tools and technology are becoming commodities. Letting users create and augment geospatial data is opening up for a host of novel user generated geospatial services. Maps, or more precisely, the geospatial data they depict, might for instance be used for route planning. For pedestrians, not to say people with mobility problems, such tools are scarce. In this paper, we explore the combination of accessibility maps and route planning for people with mobility problems. To overcome the cost problems of accessibility surveys, we propose a novel concept, *OurWay*, which allows the users to annotate the accessibility of their surroundings. This user generated content provides a basis for computing satisfactory routes, from one location to another, matching the user's preferences and needs. We present findings from two experiments, which bear evidence of the validity of the concept, and discuss its potential as a tool for surveying and route planning.

1 Introduction

Accessibility maps are acknowledged as efficient tools for people with mobility difficulties when navigating in urban areas, in particular if they are first-time visitors. However, the process of acquiring and compiling sufficient and relevant data is time and cost-consuming. Once gathered, the problem of updating the data becomes evident. Hence, if at all available, chances are high that the content of the maps soon go stale.

Another complicating matter is the lack of standard accessibility models. The result is a plethora of differing practices, often reflecting, if existing, local legislation and regulations. Still worse, the addressed users of such maps constitute a highly heterogeneous group, with different needs and preferences; a raised curb may be experienced as uncomfortable with a baby stroller, however, for a wheelchair user it would represent a non-negotiable obstacle.

In this paper we demonstrate the potential of user generated geographical accessibility information for navigational purposes. We present a grassroots oriented method for establishing accessibility information, and review results from

K. Miesenberger et al. (Eds.): ICCHP 2008, LNCS 5105, pp. 1093–1100, 2008.

two sets of experiments with a prototype implementing this method. Further, we discuss additional uses of the prototype in an accessibility context.

We start by summarizing related work within the fields of pedestrian route planning and accessibility mapping, and then go on to describe the prototype in Section 3. The experiments are described in Section 4, and findings are presented and discussed in Sections 5 and 6. Finally, we conclude our paper and sketch out future work.

2 Related Work

Our research is mainly contributing to two fields of research; 1) Pedestrian route planning, and 2) Accessibility mapping.

2.1 Pedestrian Route Planning

Early commercial efforts in pedestrian navigation include the pioneering DoCo-Navi [1] and the later KDDI's EZ Navi Walk [2], both deployed in Japan. Karimanzira et al. [3] 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 [4].

Personalized route planning means that the route planner adapts to the user's specific needs and desires. Kawabata et al. propose a context dependent meta data layer over the physical space to generate optimal routes according to the users' preferences [5].

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. Still, some headway has been made using multiple agents sharing experiences to create a distributed case based reasoning system [6].

2.2 Accessibility Mapping

Literature on accessibility mapping is scarce. However, in the general setting of transportation planning, the notion of level-of-service (LOS) is frequently treated. The LOS concept comprises systems and methods for modeling suitability, efficiency and other aspects of transportation, including pedestrian navigation. Unfortunately, due to regional variations and lack of standards, pedestrian LOS frameworks differ substantially, as evident when comparing for instance the work reported in [7] (US) and [8] (Australia). Church et al. gives an overview of formalized measures of accessibility, and promotes the concept of *relative* accessibility[9].

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 [10]. 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 [11]. Further, MAGUS is implemented with an expensive and proprietary GIS system.

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. We let the users collaboratively generate a simple LOS model based on shared user annotations. In addition, we take advantage of open standards and open geodata, and implement the prototype as a modular system with open source components.

3 The OurWay Prototype

This section gives an overview of the implemented prototype, dubbed *OurWay*, including the client software running on a mobile phone, the route planning server and details on how user annotations are applied to the geographical network to yield better routes.

The OurWay prototype server stores the necessary geospatial data and user annotations, and provides route-planning functionality. The client application runs on a mobile phone, and provides a map and functionality for route planning and accessibility rating.

The server employs a standard algorithm to find the shortest path between two points in the geographical network. The ratings from the users are translated into weights proportional to inaccessibility. The algorithm treats inaccessible segments in the network as longer than they are in real life. Since the method finds the overall shortest route with respect to weighted distance, it avoids inaccessible locations when there is a viable alternative route. We have deliberately made the granularity of feedback quite coarse. Users can choose among *good*, *uncomfortable* and *inaccessible* when they decide to provide feedback to the system.

The system enables automatic GPS positioning and tracking when operating in outdoor mode. Indoors, we have used manual panning and zooming to let the users indicate their positions. However, the OurWay architecture allows for leveraging other positioning systems as well when available.

Access to the core geospatial data is crucial in a navigation system. Whereas access to rendered map images on the web has become plentiful, the underlying data is usually costly to obtain and often comes with restrictive licensing. Alternatives to the traditional geodata providers, like the national mapping agencies and the commercial counterparts, are emerging. In particular, through the OpenStreetMap project[1], users are able to produce and consume high-grade geospatial data for free. We implemented OurWay to use OpenStreetMap as the primary

[1] OpenStreetMap (`http://www.openstreetmap.org`) is a grassroots effort to build a free and detailed street map of the world.

provider of geospatial data. When we later decided to perform an indoors experiment, we produced compatible indoors map data by feeding the OpenStreetMap production chain with ground plan drawings of our campus area.

The client, Figure 1(b), can request a route from one node to another, which will be rendered on top of the building map, and provide feedback on accessibility along the route.

4 Experiments

In this section we present findings from two studies performed with the OurWay prototype. First, we focused on the validity of the concept of user annotated routes in an outdoor setting [12], and measured the rate of route convergence, that is how fast the routes improved to a point where no further user annotation was encouraged.

Second, we've tested the concept in an indoors setting, focusing more on how and why people annotate, and the usability of the system from a service perspective [13].

4.1 Proof of Concept: Baby Stroller Navigation

The main objective of our initial study was to gather first-hand experience as users of the prototype. We chose to use parents with baby strollers as the user group in this phase.

Using OurWay to generate routes, the research team pushed the stroller through the city-scape of a small city (Halden, Norway), including streets in the center of the city as well as a fairly hard-to-navigate park with poor trails and steep climbs, see Figure 1(a).

We selected two places on opposite sides of the city centre, and let OurWay suggest a route to take us between the two places. We followed the suggested route whilst providing feedback through the system as we encountered obstacles, inconveniences and good stretches of road. This was repeated until the route suggested by OurWay was considered to have no further room for improvement.

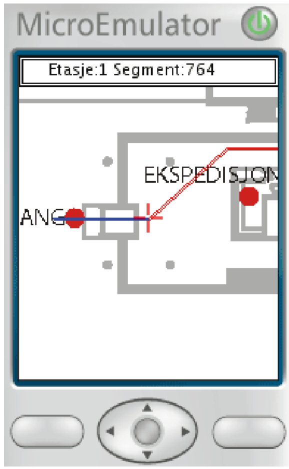
The field work was followed up by a lab study where we used a desktop version of the route planner to carry out the same type of route planning exercises between several locations in the city.

4.2 Concept Usability: Indoor Wheelchair Navigation

Our second study was set up to study the annotation practice exhibited by users, and to evaluate the usability of the OurWay concept as such. In this phase, we chose to perform the navigational tasks indoors in a campus building, with wheelchair users as participants, see Figure 1(c).

The campus building is a five floor building with diverse floor layouts, covering 30.000 square meters. A set of navigational tasks were selected, and each participant used the OurWay client running on a mobile phone to navigate through the tasks in a predefined sequence. After each task, a short interview was conducted to assess the user's experience.

(a) Outdoor navigation



(b) Mobile navigator

(c) Indoor navigation

The first participant started with a geographical network with no existing user annotations. Annotations made by the users were kept throughout the experiment, thus participants would benefit from the work done by others.

We were mostly interested in how, when and why the users annotated (or didn't annotate) during navigation, and the usability of the OurWay concept. However, we also wanted to compare the use of OurWay in an indoor setting with our previous experience from the outdoor experiment.

5 Findings

During the initial outdoor 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.

Further, the field tests provided us with usable values for the weights associated with these three categories. The weights influence the geographical distance of route segments as seen by the route planner. We also decided to use a Wiki-style approach for handling multiple annotations for the same place, letting the last annotation count in the route calculations.

The main finding from the outdoor exercises was that the annotation process converged surprisingly fast. After relatively few annotations, the system would produce satisfactory routes, where the users felt no urge to make additional annotations.

Another encouraging finding was that satisfactory routes where not significantly longer, typically in the range from 5 to 15 percent, with respect to geographical distance.

The promising results with regards to convergence rate in our proof-of-concept experiment were also found in the indoors experiment with wheelchair users. The routes converged quickly, with the majority of the annotation "work" completed after only two participants had completed their tasks.

The users also expressed confidence in OurWay as a navigational tool, with obvious room for improvement such as automatic positioning and wayfinding help. However, the annotation practice varied a lot from participant to participant. Some were eager to document the physical surrounding to benefit others, whereas others were purely focused on solving their own navigational tasks. In fact, the only predictable behavior was that the participants all annotated when it was *necessary* for them to request an alternative route to their destination. Interestingly, the system works despite this selfish behavior, and the routes converged quickly and successfully avoids obstacles such as flights of stairs.

Our findings in the two sets of experiments lead us to regard the OurWay concept as promising, both algorithmically and from a usability standpoint.

6 Discussion

We first discuss the potential of the OurWay concept as a tool from different, albeit overlapping, user perspectives. Further, we emphasize the role of openness in the OurWay concept.

Route finding is the primary application of the OurWay concept, and it has been the focus of our two studies. We have demonstrated that with a reasonably annotated geographical network, OurWay successfully serves end-users with optimized routes. In contrast to traditional route planning systems, user feedback is an integral part of the OurWay concept. The user will always have the possibility of annotating his physical surroundings, correct mistakes or add to the OurWay knowledge base. By making sure the threshold for user annotation is low, this can lead to a user based maintenance of collaboratively collected accessibility information. Further, by harvesting the side-effect of requesting an alternative route, users can create valuable data simply by "consuming" route suggestions.

With the inspiring results from the route finding experiments, we suggest two other, supplementing usages of the concept. First, as a tool applicable for campaign like situations, and further as a documentation and verification aid.

Surveying is one way to bootstrap the system with accessibility annotations. In our experiments, we have started out with a "neutral" geographical network, and let the users create annotations through use. Our findings suggests that route suggestions converge rapidly, with few participants and iterations involved. As our indoors experiment shows, the concept holds even when users are acting only in their own self interest.

We suggest that using the concept in a campaign-like setting, for instance an interest group mapping the accessibility in a public building or place, would yield even better results in a shorter amount of time. Such a setting could be viewed as a community of practice with a shared goal of mapping out accessibility issues, and thus coordinate their work and annotate on behalf of the group.

This is a light-weight, grassroots alternative to resource demanding, formalized assessment of accessibility in rural and built environments. As such, it can be viewed as an instance of *universal participation.*

Accessibility verification is the third possible application of the OurWay concept. That is, comparing accessibility annotations from OurWay with guidelines and regulatory laws for public spaces and buildings. This entails using the data collected either from route planning or surveying, or a combination of both, and using this as a documentation of the physical environment.

We anticipate local differences in accessibility requirements for public spaces and buildings. OurWay, by being a light-weight system with little emphasis on the finer details of why something might be regarded as inaccessible, has a benefit in this case with regards to flexibility. Adjustments can also be made to fit particular local needs.

The role of openness in OurWay is important. OurWay has been developed on a core of Open Source frameworks and technologies, and will be released under the GPL license. Additionally, the entire geospatial infrastructure used in OurWay is open. The tools are primarily from the OpenStreetMap project, as is the geographical network we use for outdoors route planning.

The use of open tools, standards and data makes it possible to deploy the system practically anywhere, and opens up possibilities for accessibility mapping where resources are scarce, e.g. in developing countries or in rural areas with low population densities.

7 Concluding Remarks and Future Work

We have described prototype implementations of the OurWay concept, and reported from two sets of experiments. One proof-of-concept experiment with baby strollers in an outdoor, urban environment, and a second experiment indoors with wheelchair users, focusing more on the usability aspects of such a collaborative system.

The encouraging results with regards to route convergence and the observations of annotation behavior has led us to discuss other potential usages of the OurWay concept. The collaborative route planner can also find usage as a tool for surveying and verification with regards to accessibility.

From this discussion, several imminent research themes arise. Perhaps the most important is the issue of trust, and in particular end-users trust in the information provided by a collaborative system like OurWay. Ensuring trust and reliability of accessibility information is a theme that deserves special attention. In this context, the role of privacy becomes important, especially when we know that trust in information to a certain degree is related to knowing the information source.

Finally, testing the OurWay concept with heterogeneous user groups, and looking at ways of sharing accessibility information between these heterogeneous groups is an area we want to explore further.

Acknowledgments. We would like to thank Håkon Tolsby, Steinar Kristoffersen and Håkon A. Holmstedt for their contributions to the project, and Øyvind Håkestad for contributing to development of the OurWay tools. The project is partly funded by the Norwegian Research Council and the Norwegian Mapping Authorities.

References

1. Telecom Tribune: NTT DoCoMo To Launch Navigation Service for Pedestrians Using Enhanced GPS Technology. Telecom Tribune 14(10), 2–2 (January 2000)
2. de la Fuente, C., Raper, J., Stanley, M., Norris, P., O'Donnell, M.: Location-based services: understanding the Japanese experience (2005)
3. Karimanzira, D., Otto, P., Wernstedt, J.: Application of machine learning methods to route planning and navigation for disabled people. In: MIC 2006: Proceedings of the 25th IASTED international conference on Modeling, indentication, and control, Anaheim, CA, USA, January 2006, pp. 366–371. ACTA Press (2006)
4. Huijnen, C.: Mobile tourism and mobile government - an inventory of European projects. Technical report, European Centre for Digital Communication (EC/DC) (April 2006)
5. Kawabata, M., Nishide, R., Ueda, M., Ueshima, S.: Graph-based Approach to Context-adaptable PNS and its Application Scenarios. In: Proceedings of the 21st International Conference on Data Engineering Workshops (ICDEW 2005). IEEE Computer Society, Los Alamitos (2005)
6. McGinty, L., Smyth, B.: Shared Experiences in Personalized Route Planning. In: Haller, S.M., Simmons, G. (eds.) FLAIRS Conference, pp. 111–115. AAAI Press, Menlo Park (2002)
7. Landis, B., Vattikuti, V., Ottenberg, R., McLeod, D., Guttenplan, M.: Modeling the Roadside Walking Environment: A Pedestrian Level of Service. Transportation Research Record 1773, 82–88 (2001)
8. Gallin, N.: Quantifying Pedestrian Friendliness-Guidelines for Assessing Pedestrian Level of Service. In: Conference Proceedings: Walking the 21st Century, Perth, Australia (February 2001)
9. Church, R., Marston, J.: Measuring Accessibility for People with a Disability. Geographical Analysis 35(1), 83–97 (2003)
10. Beale, L., Field, K., Briggs, D., Picton, P., Matthews, H.: Mapping for Wheelchair Users: Route Navigation in Urban Spaces. The Cartographic journal 43(1), 66–81 (2006)
11. Sobek, A., Miller, H.: U-Access: A web-based system for routing pedestrians of differing abilities. Journal of Geographical Systems 8(3), 269–287 (2006)
12. Holone, H., Misund, G., Holmstedt, H.: Users Are Doing It For Themselves: Pedestrian Navigation With User Generated Content. In: Proceedings of The First International Conference on Next Generation Mobile Applications, Services and Technologies, pp. 91–99. IEEE, Los Alamitos (2007)
13. Holone, H., Misund, G., Tolsby, H., Kristoffersen, S.: Aspects of Personal Navigation with Collaborative User Feedback (2008) (in preparation)