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Generation of a tailored routing network for disabled people based on collaboratively collected geodata

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A B S T R A C T

The generation of a routing network for disabled people inherits a number of prerequisites that need special consideration. Widespread routing applications that rely on commercial or governmental geodata sources are not feasible for this specific task, due to the lack of detailed information about features such as sidewalks, surface conditions or road incline. In recent years the research community has experienced a strong increase in studies related to routing applications tailored to disabled people in which the lack of a sophisticated dataset played a major role. This study proposes an algorithm for the generation of a disabled people friendly routing network, based on collaboratively collected geodata provided by the *OpenStreetMap* (OSM) project. This new representation of a routing graph can be used in numerous applications and maps dedicated to people with disabilities. The algorithm is tested and evaluated for selected areas in Europe, resulting in newly generated extended networks that include sidewalk information. The results have shown that the success of the final implementation of the introduced algorithm depends highly on the attribute quality of the OSM dataset.

Introduction

Routing and navigation applications on the Internet, in cars or on personal smartphones are omnipresent. Most common devices and applications rely on geodata provided by one of the well-known proprietary data providers such as Navteq® or TomTom®. These providers offer routing network data which is suitable for motorized and (for selected cities) non-motorized path finding applications. People with special needs, however, who rely on a more specialized dataset, cannot utilize the provided commercial geo-information and require highly detailed ground-truth data. Commercial geodata providers do not offer this detailed information due to the high costs that arise during the collection and the maintenance of the data.

In the past few years the number of freely available and open source geo-information platforms on the Internet has increased tremendously. These new data sources are oftentimes referred to as *Volunteered Geographic Information* (VGI; Goodchild, 2007). As the name implies, most of these platforms rely on the contributions of non-professional volunteers that collaboratively collect geodata. A number of possible motivational factors that trigger VGI project contributions has been identified in a recent study, including the desire to make geospatial information freely available to everyone, learning new technologies, relaxation and recreation, self-expression or just pure fun (Budhathoki & Haythornthwaite, 2012). The contribution patterns found in VGI projects tend to be more casual in comparison to the contributions made to *Public Participation Geographic Information Systems* (PPGIS) in which volunteers collect geodata for a particular purpose, such as to improve landuse planning or discuss policy issues and decision making (Brown, 2012). One of the biggest and most established projects in the realm of VGI is *OpenStreetMap*[1] (OSM). In contrast to the aforementioned proprietary data providers, the OSM project data is distributed under an *Open Data Commons Open Database License* (ODbL[2]). This particular license allows interested Internet users to download, copy, distribute, transmit and adapt the collected geodata, free of charge, as long as OSM and its contributors are credited in the final project.

Despite early concerns about the credibility and reliability of VGI (Flanagin & Metzger, 2008) several studies demonstrated the potential of OSM in a variety of applications in recent years. OSM data has been utilized to develop a number of *Location Based Services*

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[1] http://www.openstreetmap.org (accessed on 5 October 2013).
[2] http://opendatacommons.org/licenses/odbl/ (accessed on 27 November 2013).

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(LBS; Neis & Zipf, 2008), to evaluate the urban accessibility in the aftermath of an earthquake (Bono & Gutiérrez, 2011) and to simulate future urban growth patterns in Mumbai (India) (Moghadam & Helbich, 2013). At the time of writing, the project had more than 1.4 million registered members who contributed with varying intensity to the project. In a number of major cities the volunteers collect information about sidewalks, road surfaces, road incline, pedestrian crossings, and tactile paving.[3] This level of detail is essential when considering the creation of a suitable routing graph for disabled people, such as wheelchair users or elderly people. The terminology used to describe the target user group for the developed algorithm can vary and will be discussed in more detail in the Section 2 of this paper. However, the main research question of this study is: How can freely available, collaboratively mapped geodata be utilized to generate a routing network for disabled people with special navigation information needs? The benefit and advantage of this newly generated routing network lies in its multipurpose character. This allows the network to be used in route-planning, real-time navigation or for both online and print maps, by providing detailed information about the "best" individual route based on the user's limitations. The open approach to data collection efforts in OSM lead to high object densities and details in selected urban areas, at times illustrating barriers for disabled people. For areas that do not provide this level of detail, the map can easily be edited to serve the individual purpose.

The remainder of this article is structured as follows: Section 2 presents some background information and related research in the field of routing networks and wayfinding for disabled people. Section 2 also contains detailed information about the requirements and parameters that the generated network should inherit and the routing algorithm should take into account when computing a route. Additionally, the OSM project and research related to the project will be briefly introduced. In Section 3, the methodology including data preparation and the generation of the tailored routing network is described. Section 4 includes the evaluation of the presented algorithm by testing the generated sidewalk networks for selected areas in Europe. The article concludes with a discussion of potential algorithm limitations, a summary of the findings and an outlook on future research.

Background and related work

Routing applications on mobile devices and desktop computers are oftentimes used when planning a trip or during a visit of an unfamiliar place such as a new city. While the local knowledge of an individual helps to find the shortest or fastest path in familiar places on a day to day basis, routing applications can help to experience a similar situation in unfamiliar areas. Disabled people rely on very detailed information about potential obstacles in their neighborhood or in areas in which their daily life takes place. However, when visiting unknown places regular routing applications tailored to motorized traffic or pedestrians do not provide the detailed information needed. Depending on the requirements of the user, information about sidewalks, steps, surface conditions, crossings or tactile paving could be essential and heavily improve the routing experience of a disabled person.

Research that focuses on routing specifications and applications for disabled people, such as wheelchair users, blind, deaf or elderly people, has experienced a strong increase in recent years (Kammoun, Dramas, Oriola, & Jouffrais, 2010; Kasemsuppakorna & Karimia, 2009; Sobek & Miller, 2006). The most important finding that needs to be considered in any related analysis is that geodata requirements vary significantly depending on the project's purpose. Routing applications for non-motorized traffic, such as pedestrians, have different geodata requirements than applications tailored to motorized traffic and vice versa (Corona & Winter, 2001; Walter, Kada, & Chen, 2006). Similarly, patterns between geodata implemented in these widely used applications and the geodata requirements for applications tailored to disabled people need to be evaluated.

Routing network requirements for disabled people

Several studies in the past have highlighted the prerequisites that the geodata source of choice has to fulfill to be considered for a potential navigation system for pedestrians (Gaisbauer & Frank, 2008), wheelchair users (Charles, Kincho, Jean-Claude, & John, 2002; Kasemsuppakorna & Karimia, 2009) or blind people (Kammoun et al. 2010). Oftentimes the customized system and its corresponding data are created through extensive surveys. A specification by the German Institute for Standardization (*Deutsches Institut für Normung* (DIN)) provides a foundation for this particular type of information. DIN 18024-1 describes the accessibility requirements for disabled people in public transit infrastructure and buildings. The standards include a number of recommendations for different handicap types, which also help to define the target user group for which our study was conducted: (Source: DIN 18024-1):

- Wheelchair users
- Blind and visually impaired people
- Deaf and hearing impaired people
- Walking impaired people
- People with other handicaps
- Elderly people
- Children and people of short or tall statue

Based on the specification, some of recommended parameters that need to be implemented in the final dataset can be surface information, incline and width of a street segment. However, based on a number of different studies, other parameters for a disabled friendly routing network have been determined (Beale, Field, Briggs, Picton, & Matthews, 2006; Ding et al. 2007; Kasemsuppakorna & Karimia, 2009; Matthews, Beale, Picton, & Briggs, 2003; Menkens et al. 2011; Sobek & Miller, 2006). Table 1 summarizes all parameters based on the findings of the studies, the DIN 18024-1 and some newly defined parameters based on our research.

In some of the studies the desired geodata was traced from satellite imagery (Kasemsuppakorn & Karimi, 2008; Kasemsuppakorna & Karimia, 2009), while others developed tools that generated a network by utilizing a buffer method (Karimi & Kasemsuppakorn, 2012), implementing pedestrian GPS traces (Kasemsuppakorn & Karimi, 2013), developing a binary image processing method to retrieve a pedestrian network (Gaisbauer & Frank, 2008; Kim, Park, Bang, & Yu, 2009) or presented an automated method to generate a sidewalk network from building blocks (Ballester, Pérez, & Stuiver, 2011).

Collaboratively collected geodata: the OpenStreetMap project

User-Generated Content (UGC) (Anderson, 2007) and particularly *Volunteered Geographic Information* (VGI) (Goodchild, 2007) have become a widely known Internet phenomenon in recent years. The OSM project, initiated in 2004, is the most successful VGI project based on collaboratively collected and freely available geodata (Goetz, 2012a; Mooney, Corcoran, & Winstanley, 2010; Neis, Goetz, & Zipf, 2012). Most contributors collect the geodata by utilizing GPS

[3] http://www.blind.accessiblemaps.org/index2.html (accessed on 5 October 2013).