Crowdsensing Wayfinding for Urban Mobility Accessibility

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Abstract

Urban spaces have traditionally been designed with a strong emphasis on motor vehicle traffic, often neglecting the accessibility needs of people with mobility impairments. This work investigates how collecting data from users' smartphones during daily movement can be used to support inclusive wayfinding solutions.

CCS Concepts

• **Human-centered computing → Accessibility systems and tools**; **Empirical studies in ubiquitous and mobile computing**.

Keywords

crowdsensing, road accessibility, smartphone, wayfinding

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1 Introduction

When navigating unfamiliar areas, most people rely on digital maps that provide directions between locations. These tools generally overlook the accessibility requirements of people with limited mobility. A key obstacle to building accessible navigation services lies in the absence of granular and inclusive urban data. For example, enabling the identification of routes that avoid stairs or prioritize ramps would require detailed infrastructure data that is rarely available in current map systems. Manually collecting and maintaining such a dataset would involve substantial time and cost [1, 5]. However, the ubiquity of smartphones presents an alternative approach. These devices, equipped by-design with multiple sensors and connectivity, enable the use of crowdsensing to gather geo-referenced environmental and accessibility-related data directly from citizens [2, 3, 4]. This concept underpins our system, which leverages on decentralized data collection using existing smartphone sensors. The collected data are subsequently processed by back-end services to generate mobility-friendly routes. The generated routes prioritize accessibility features such as smooth road condition, the presence of ramps and low-gradient paths,

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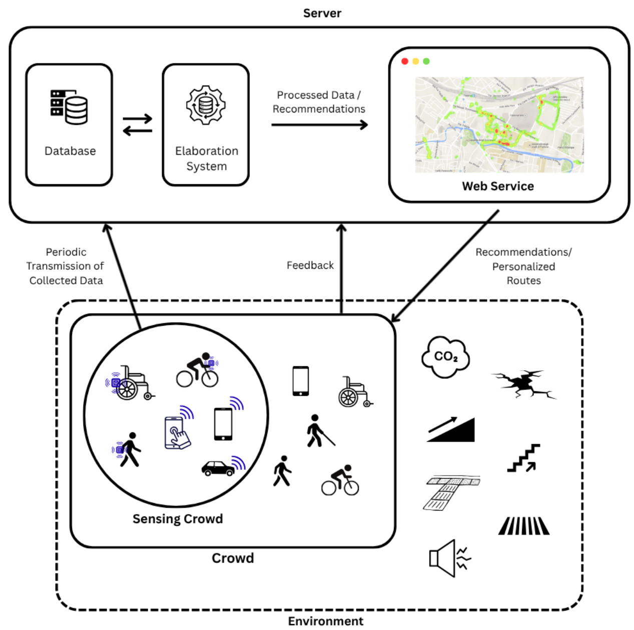

Figure 1: Crowdsensing for urban mobility accessibility.

2 Crowdsensing Architecture

To address the challenges previously outlined, we created a modular and layered system that supports efficient crowdsensing and accessible route generation. As illustrated in Figure 1, our architecture follows a layered approach. At its foundation lies the sensing crowd, which consists of heterogeneous users equipped with mobile devices and embedded sensors. These devices directly collect raw data from external environment including ambient noises, lighting and detecting structural obstacles or accessibility features. Unlike traditional single-device sensing applications, crowdsensing leverages the collective contribution of many individuals, thereby producing a richer and more representative dataset.

In the proposed model, raw data collected by the sensing crowd are first preprocessed directly on mobile devices to harmonize heterogeneous formats, filter noise, and reduce redundant information.

Data are not transmitted continuously but only periodically, for instance when connected to Wi-Fi or after user confirmation, thus saving energy and bandwidth. The preprocessed data are then uploaded to a server, stored, and further analyzed using methods ranging from simple rules to advanced AI techniques. The resulting insights are shared through a web service that allows users to view aggregated outputs, such as accessibility maps or recommended routes, and contribute additional feedback.

In the following we present two proof of concept solutions we devised, based on our architecture, which are able to collect information related to the accessibility of urban mobility. The first one collects routes that are frequently preferred by users with impairments and the second one detects road conditions that could affect the mobility of an impaired person.

3 Crowdsensing-Based Accessible Routes

Our first solution uses GPS to identify the routes most frequently taken by users with mobility impairments, which are therefore likely to be accessible and can be recommended to others with similar needs [7]. The application workflow comprises iterative stages. Data collection starts after a fixed time interval or once the user has moved at least y meters. A path begins when the user moves more than M meters from the starting point at a speed consistent with their mobility and ends when they remain stationary in the same area for at least x seconds. Afterward, the application decides whether to transmit the route to the server. A path is considered *frequently traveled* only if: (i) it matches at least n previously recorded daily routes within a time window of m days, and (ii) it has not already been sent that day. Users may also provide explicit feedback on their routes (e.g., comfort, accessibility, or issues). On the server side, the backend eliminates duplicates and stores only new routes.

Our second solution leverages on the sensors available in regular smartphones, such as accelerometer, gyroscope, and GPS to detect road anomalies such as potholes, cracks, bumps, and uneven pavements, as well as infer slope and overall surface nature [6]. A wheelchair was equipped with a smartphone to collect acceleration and gyroscope magnitude data that are subsequently analyzed for road anomalies detection that would jeopardize accessibility. Normalization and filtering are performed to make the measurements reliable and avoid outliers, anomalies, and false positives. The road slope is detected as well; to this aim, the phone's orientation and gravity sensor data are correlated with GPS elevation.

As mentioned, crowdsensed data from multiple users is then aggregated into a comprehensive road condition map. The system can integrate data about sidewalk conditions, curb cuts availability, tactile paving for visually impaired users, and the presence of obstacles or construction zones, as summarized in Table 1. Even more interesting, the application uses gathered data and accessibility-related crowdsensed information to offer customizable route planning features where users can filter paths based on their specific accessibility needs, selecting preferences such as maximum acceptable surface roughness or quality, preferred slope gradients, or avoidance of certain types of road defects (see Figure 2).

Table 1: Crowdsensed data types and their relevance.

Crowdsensed Data	Route Condition Aspect	Relevant Users
Road Surface Quality	Roughness, bumps, potholes	Wheelchair users, people with reduced mobility
Slope Gradient	Inclines and declines	Wheelchair users, people with cardiac or motor impairments
Sidewalk Conditions	Width, smoothness, obstacles	Wheelchair users, people using walking aids
Curb Cuts	Ramps at intersections	Wheelchair users
Tactile Paving	Tactile indicators on sidewalks	Visually impaired users
Obstacles / Construction	Temporary or permanent barriers	All pedestrians

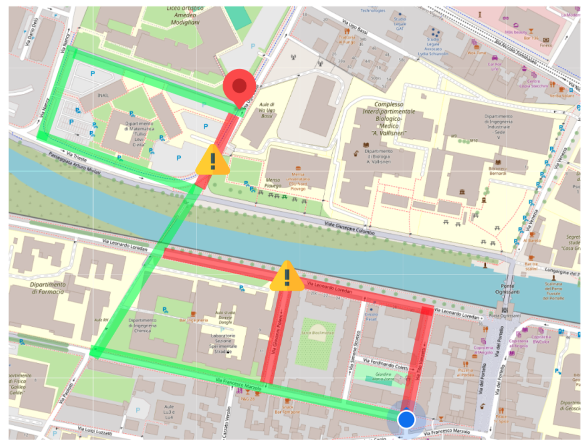

Figure 2: Map showing possible routes between two locations. The route quality is color–coded (e.g., red for mobility-related problems, green for no issues), alert markers highlight specific obstacles such as steep slopes or barriers.

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