Leveraging Street Cameras to Support Outdoor Navigation for Blind Pedestrians

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Introduction: Blind and low-vision (BLV) people use GPS-based systems for outdoor navigation assistance, which provide turn-by-turn instructions to get from one place to another. However, such systems do not provide users with real-time, precise information about their location and surroundings which is crucial for safe navigation. In this work, we investigate whether street cameras can be used to address aspects of navigation that BLV people still find challenging with existing GPS-based assistive technologies. We conducted formative interviews with six BLV participants to identify specific challenges they face in outdoor navigation. We discovered three main challenges: anticipating environment layouts, avoiding obstacles while following directions, and crossing noisy street intersections. To address these challenges, we are currently developing a street camera-based navigation system that provides real-time auditory feedback to help BLV users avoid obstacles, know exactly when to cross the street, and understand the overall layout of the environment.

Research Questions: In this work, we investigate street cameras' potential for supporting aspects of outdoor navigation that require precise and real-time knowledge of BLV pedestrians' location and surroundings. To this end, we take preliminary steps to answer the following research questions:

RQ1. What aspects of outdoor navigation do BLV people find challenging when using GPS-based assistive technology?
RQ2. How should street camera-based systems be designed to address these challenging aspects of outdoor navigation?
RQ3. To what extent do street camera-based navigation systems address these outdoor navigation challenges?

Formative Study: We recruited six BLV participants (three males and three females; aged 29–66) by posting on social media platforms and snowball sampling. We found that anticipating the environment layout, avoiding obstacles while following instructions, and crossing street intersections safely were the three major themes representing aspects of outdoor navigation that participants reported as being challenging.

Street Camera-Based Navigation System: We introduce a navigation system that we are currently developing to answer RQ2: How should street camera-based systems be designed to address the challenging aspects of outdoor navigation? The prototype consists of three components: street cameras, computational server, and smartphone app.

***System Components*:** *Street cameras:* The system uses two cameras mounted at the corner of the second floor and twelfth floor of our institution's building. Both cameras face the same four-way street intersection. The video feeds from these cameras are directly streamed onto the computational server for further processing. *Computational server:* The computational server processes the video feeds using state-of-the-art computer vision models to track pedestrians, vehicles, and identify pedestrian signals. Using the two camera views at different heights, along with an image from Apple Maps' street view of the same intersection, the system finds visual correspondences to generate a bird's-eye view representation of the environment (Figure 1e). Additionally, it stores the map information that includes labeled regions (e.g., streets, crosswalks, sidewalks, pedestrian lights) and the location of relevant POIs (e.g., pharmacy, café) within the bird's-eye view representation. *Smartphone app:* Figure 1a–c shows the iOS app that acts an interface between the user and the computational server, enabling them to access the map information and to receive real-time audio feedback via a Bluetooth earpiece.

(A) Localization (B) Exploration Mode (C) Guidance Mode (d) Second Floor Street Camera View (e) Bird's Eye View Map Representation

User Interaction and Experience: BLV pedestrians use the smartphone app to establish a connection with the server via the localization mechanism. Once localized, users can choose from either of two navigation modes: guidance or exploration mode. *Localization mechanism:* To determine the user's position on the bird's-eye view map, the system must differentiate them from other pedestrians in the environment. We achieved this by introducing an action recognition module that can identify users from the second-floor camera feed.

Navigation modes: To address the challenging aspects of outdoor navigation that we identified from our formative study; we designed the street camera-based navigation system to support the following two modes of navigation: *Guidance Mode:* Figure 1c shows this mode, where BLV users can choose a destination from the list of nearby POIs and receive real-time audio feedback in the form of turn-by-turn instructions. *Exploration Mode:* Figure 1b shows this mode, where BLV users can choose to navigate the environment without any specific destination in mind. Like guidance mode, this mode also provides users real-time feedback to prevent veering (Section 3.2.1), avoid obstacles (Section 3.2.2), and cross street intersections safely (Section 3.2.3). Additionally, this mode is designed to address BLV users' challenge to anticipate environment layouts (Section 3.2.1). The user can scrub their finger on their smartphone to learn the bird's-eye view map spatial layout.

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