NavCog: turn-by-turn smartphone navigation assistant for people with visual impairments or blindness

Dragan Ahmetovic*
dragan1@cmu.edu

Cole Gleason*
cgleason@cs.cmu.edu

Kris M. Kitani*
kkitani@cs.cmu.edu

Hironobu Takagi†
TAKAGIH@jp.ibm.com

Chieko Asakawa*†
CHIE@jp.ibm.com

*Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213, USA

†IBM Research
19-21 Nihonbashi Hakozaki-cho
Chuo-ku, Tokyo 103-8510 Japan

ABSTRACT

NavCog is a novel smartphone navigation system for people with visual impairments or blindness, capable of assisting the users during autonomous mobility in complex and unfamiliar indoor/outdoor environments.

The accurate localization achieved by NavCog is used for precise turn-by-turn way-finding assistance as the first step, but the ultimate goal is to present a variety of location based information to the user, such as points of interest gathered from social media and online geografic information services.

CCS Concepts

•Information systems → Global positioning systems; Location based services; **•Human-centered computing → Accessibility technologies;** Auditory feedback; Smartphones; **•Social and professional topics → Assistive technologies; People with disabilities; •Networks →** *Sensor networks;*

Keywords

Assistive technologies, Bluetooth low-energy beacons, Turn-by-turn navigation, Navigation assistance for people with visual impairments or blindness, Indoor and outdoor localization

1. INTRODUCTION

Many blind people are capable of independently traversing familiar routes. This task relies on the capability to craft a detailed cognitive map of the environment through prolonged exploration, and often, through training with Orientation and Mobility (O&M) professionals [1]. For new or rarely visited places, when there is not enough time to explore the area in advance, autonomous travel can be much harder.

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The cues for orienting in unknown environments, such as signs, text or landmarks, are generally easy to access visually, but are much harder to access without sight. Furthermore, the presence of obstacles and hard to distinguish path branches can confuse even an user familiar with the surroundings.

A number of assistive technologies tackle the issue of localization and navigation assistance for people with visual impairments. In outdoor areas GPS [6] is generally used, but the GPS signal tends to be limited or absent in indoor environments. Other non-digital approaches have been attempted, such as tactile tiles, which is a popular assistive technology. Cane users are able to sense the pattern embossed on the floor tiles to follow the predefined paths through buildings.

Mobile device technologies are also frequently used for mobility assistance. For example, RFID tags can be installed in the pavement to be detected with a white cane augmented with an rfid sensor [2]. Wi-Fi access points already available in the surroundings can also be used to localize the device based on the strength of signals as detected by the mobile device [3]. Other solutions propose to use Visible Light Communication (VLC) technology to localize the relative position of the mobile device with respect to VLC-augmented led lights in the environment captured by the mobile device videocamera [4].

For localizing the user's mobile device in the environment with a high position accuracy, NavCog relies on bluetooth low energy (BLE) beacons installed in the environment (similarly to [7]), and on sensors available on the smartphone, such as accelerometer and gyroscope. In our test environment, NavCog has been able to achieve an accuracy of 1.5m on average, which is higher than the precision of GPS of Wi-Fi localization. which is necessary for precise navigation assistance. In addition, differently from many common approaches, the installation of BLE beacons does not require any structural modifications to the environment.

NavCog has been released with an open source license and it is already available for download on Apple app store

2. THE NAVCOG SYSTEM

The architecture of the NavCog system revolves around three key components: the iOS NavCog app, the map server and BLE beacons in the environment.

2.1 The Bluetooth beacons

The BLE beacons used by NavCog adhere to the iBeacon protocol [5]. They are installed every 6m - 12m, based on the accuracy required or the possible obstacles, alternating the side of the path on which they are positioned. Once deployed in the environment, the beacons periodically broadcast their identifier to nearby NavCog devices. The aggregated information from multiple beacon signals is used to localize the NavCog Device inside the environment. The reasons to use BLE beacons are multiple: Adding beacons does not require any structural changes to the environment, it allows us to localize the user more precisely than with other techniques such as GPS or wifi-based positioning, and the position of the device is computed on the mobile device, without the need to share the user's position with others.

We localize a device by creating a map of received signal strengths (RSS) of beacons for each point of the environment. Afterwards, it is possible to localize the device by comparing its reading of surrounding beacon signals strengths with previously gathered RSS map. To create the RSS map, we gather a number of BLE beacons RSS samples for every 1m along each path in the environment. The set of samples for a point defines the signal fingerprint of that point. Once we have the fingerprints for all the points in the environment, we save them to a K-d tree data structure.

We use the K-nearest neighbors (KNN) algorithm to localize a device, given its current RSS reading s_0, and the previously gathered k-d tree RSS map. We first find a K number of samples $S = \{s_1 \cdots s_K\}$ that are most similar to s_0. We then retrieve the set of the points $P = \{p_1 \cdots p_K\}$ that have those samples in their fingerprints. We then compute the position P_0 of the queried signal s_0 as the average of the coordinates of the points P.

2.2 The map server

The map server allows to store the information about each mapped environment and update the NavCog apps on users' mobile phones as needed. It is possible to create and edit the venue maps through a web based interface. The users can upload the maps to an "open map server" or save them directly to NavCog-enabled mobile devices as private maps.

The map is created through a web based interface as a JSON file containing the floor plan of the environment, the paths and the K-d tree fingerprinting data gathered previously. The map is either uploaded to the map server to be dispatched to NavCog-enabled devices, or it can be loaded directly to a user device as a private map. The position computation is then performed exclusively on the mobile device, without any need to share the location information with the map server or any third party.

The map editing tool interface is divided in 4 action tabs, positioned on the left, and the map area occupying the rest of the screen. The File tab is used to import and export map data and edit the languages and localization properties of the map. The Map tab allows the creation of new map layers and regions, the Topology tab is used to manage nodes and edges of the paths used during the navigation, and the Beacons tab is used for the management of the beacons.

2.3 The NavCog app

NavCog iOS app uses information from BLE beacons and the map server, along with gyroscope data from the mobile device, to assist the user during navigation. For the interaction with the app and for instructing the user on how to navigate in the environment, we rely on Voiceover screen reader, which is already preinstalled on iOS smartphones.

The initial interface of Navcog is called the planning interface, and it allows the user to select the map of a venue, choose the starting and the ending points of the navigation from a list, and start the navigation. Pressing the "Start navigation" button initiates the navigation procedure and activates the navigation interface. This view shows the map of the surroundings of the user in the center and the navigation buttons in the four corners. The map shows the current navigation state, the current position of the user as a blue dot, and the traversed path as a blue line. The buttons allow the user to terminate the navigation ("Stop navigation"), replay the last instruction ("Previous instruction") or ask for more information about the surrounding area ("Additional information"). If the user reaches an area that is associated to additional accessibility instructions in the map, the "Accesibility notification" vocal message is played, and the user can request the accessibility iinstructions with the "Accesibility information" button.

Vocal output and sonification are used to guide the user. While navigating, the user is conveyed the distance from the ending node of the edge through synthesized vocal messages (e.g., 20 meters.. 10 meters..), or with a repeated clicking sound that increases in frequency the closer the user is to the destination. Once the user reaches a node, the system notifies to the user the action to perform (e.g., rotate right). Once the user has aligned correctly with respect to the new edge, according to the gyroscope data, NavCog plays a sound to confirm that the user is facing the correct direction. Afterwards, the next instruction is forwarded to the user (for example, "in 15m, rotate left"). Once the destination has been reached, the app notifies the user and returns to the navigation planning interface.

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