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CITY COMPANION: AN ACCESSIBLE APP FOR VISUALLY IMPAIRED INDIVIDUALS TO ACCESS CITY INFORMATION AND NAVIGATION

Abhishek Madan, Department of Computer Science Engineering, Indian Institute of Industry Interaction Education and Research, Chennai, Tamil Nadu 600066
Kati Sandeep, Department of Computer Science Engineering, Indian Institute of Industry Interaction Education and Research, Chennai, Tamil Nadu 600066
Marisetti Aravind, Department of Computer Science Engineering, Indian Institute of Industry Interaction Education and Research, Chennai, Tamil Nadu 600066
Gangireddy Prasannakumarreddy, Department of Computer Science Engineering, Indian Institute of Industry Interaction Education and Research, Chennai, Tamil Nadu 600066

ABSTRACT

Artificial intelligence has the potential to improve the quality of life for people with impairments, especially when it comes to mobility support. This article presents an assistive technology solution designed to help people with visual impairments cross streets safely. The technology uses deep learning algorithms in conjunction with signal trilateration technique to scan images and reliably identify visually impaired pedestrians from the surrounding population. When a possible user is detected, the system is notified by WiFi signals that are sent via a mobile application that is installed on the user's phone. By utilizing this data, the software—which is based on an intelligent semaphore that was first used to improve urban mobility in the context of smart cities—is able to interact with users in an efficient manner, analyze traffic patterns, and make the required modifications to enable a safe street crossing. Over the course of a year, the suggested approach was tested and put into use in Germany. Trial studies with pedestrians who are blind or visually impaired have confirmed its viability and usefulness in actual settings. Through the utilization of artificial intelligence and smart city infrastructure, this creative solution presents a viable path toward enhancing the safety and mobility of those with visual impairments.

Keywords:
Artificial Intelligence, Visually Impaired Pedestrians, Wi-Fi Signals, Smart City Context

I. Introduction

A smartphone software called City Companion was created to give visually impaired people easy access to city information and navigational tools. By providing users with independence and confidence when navigating metropolitan surroundings, this cutting-edge program seeks to empower users. The app offers a wealth of information about the area, including local services, public transportation alternatives, attractions, and amenities. Voice commands and screen readers make it simple for users to obtain this information, making it accessible to those who are visually impaired [1]. Users may navigate city streets, public transportation networks, and indoor locations with the use of City Companion's comprehensive navigation assistance. The application employs GPS, beacon, and comprehensive map technologies to offer users personalized, step-by-step navigation instructions based on their mobility requirements and preferences. With the use of the app's voice-guided navigation instructions, users can get real-time direction without depending on visual indicators. Voice prompts make it simple for users to freely traverse complicated urban surroundings by giving clear and succinct directions. Users of City Companion can tailor their navigation choices according to criteria including favorite routes, walking speed, and method of transportation. With this customized method, the software is made to fit each user's specific requirements and preferences, even in places with spotty internet. Users can download maps and city information for offline usage with City Companion's offline functionality [2]. In order to accommodate places with low connectivity, this guarantees that users may get crucial municipal information and navigation help even in locations with poor network coverage. Users can download maps and city information for offline usage with City Companion's offline capabilities. This guarantees that even in places with inadequate network coverage, users may obtain crucial municipal information and navigation support. The software has safety features like emergency assistance buttons, real-time location sharing with trusted contacts, and alerts about potential impediments or hazards along the user's trip. When navigating the city, these features give consumers increased protection and peace of mind. Users are encouraged to interact with the community through City Companion by exchanging advice, suggestions, and criticism with other users. With the help of this interactive platform, users can collaborate and make a positive impact on the accessibility and inclusion of urban areas [3]. All things considered, City Companion is an invaluable resource for those who are blind or visually impaired, giving them the knowledge, help, and encouragement they require to move confidently and freely in urban settings. The app encourages inclusivity in urban settings and helps close the accessibility gap by utilizing creativity and technology. Smartphone-based assistive technologies are becoming more and more popular since they are user-friendly, increase productivity, and facilitate better interactions for blind people. Through a variety of techniques, including direct exploration, text entry, gesture-based interfaces, and multi-touch gestures on smartphones and smartwatches, these technologies allow blind persons to carry out basic tasks. Even with their potential advantages, touchscreen interfaces pose a number of accessibility problems for blind users, such as overwhelming amounts of information, trouble navigating, poor support for organizing, steeper learning curves, and challenging non-visual element discoverability [4]. Advances in mobility aids, object identification, pathfinding solutions, and recognition systems have been made in response to these issues in assistive technology for the blind. The range of tools available to help people with visual impairments is growing because to innovations like retinal implants, smart canes, tactile displays, interfaces, wearable electronic travel aids that are smaller than a fingernail, smartphone-based gadgets, and apps. These technologies are intended to help individuals with special needs become more independent, navigate more easily, and obtain information more readily. Through the utilization of contemporary cellphones and wearable technology, assistive technologies are enabling visually impaired people to lead more integrated, productive, and satisfying lives [5]. The following is the arrangement of the forthcoming sections: Section 2 lays out the relevant literature, Section 3 discusses potential strategies, Section 4 offers the findings and a discussion, and Section 5 concludes the framework proposal.

II. Correlated publications

The unique requirements of visually impaired people who can become disoriented and require help locating themselves were covered by Paiva et al. [6]. In contrast to conventional navigation techniques like GPS, which depend on street names or coordinates, people with visual impairments need reference points in order to travel safely in the event of becoming lost. Thus, using the Landmark Position model, this study presents a conceptual architecture for outdoor positioning adapted to the requirements of visually impaired people. Using Internet of Things technology, Ramirez et al. [7] concentrated on improving the Electronic Long Cane design to help visually impaired people communicate with their environment. The gadget was to be modified with Human-Smart Cities in mind. Through the integration of IoT principles, individuals with visual impairments are able to obtain vital information, hence enhancing the functionalities of the electronic cane that was previously designed. Furthermore, by reducing power usage and using recyclable materials to make the cane, the initiative contributes to project sustainability and highlights green IoT practices. A new app was created by Mayordomo-Martínez et al. [8] to address software sustainability principles and promote sustainable activities. It provides an accessible search and filtering tool for individuals with impairments, enabling them to choose the best solutions by displaying results in a graphical, visual, and user-friendly manner. The app also hopes to promote diversity in the community by making local businesses more aware of accessibility. Usability tests show that the application provides a satisfying user experience (UX). The use of mobile technology to help visually impaired people cross streets more comfortably and confidently was investigated by Huang et al. [9]. It is an action research-based case study that centers on the creation and deployment of Taiwan's Smart Accessible Pedestrian Signal System (SAPSS). The system, which combines hardware, software, and a user-side mobile application, is built on ability-based design principles to guarantee accessibility and provides visually impaired people with a more comfortable way to cross streets. Two field tests with 19 visually impaired end users were used to assess the usefulness and efficacy of the SAPSS. Twenty people with visual impairments participated in these interviews, as shown by Faria et al. [10]. Following a thematic analysis, the following topics were found to have insights: Daily activities include interacting with the present appliances, objects, and environments at home and in the nearby area. Participants' attitudes regarding technology. The smart home context in Brazil Anticipations concerning the features of smart homes and the anticipated ways in which users would engage with these systems.

III. Suggested approach

In order to help visually challenged people, we explicitly suggest a pedestrian detection and tracking method in this section. The method combines a deep learning model with a heuristic for determining pedestrian locations via signal trilateration. The system enables communication between an installed smartphone application on the user's device and smart traffic signals. Wi-Fi signals are used to establish this wireless communication. As seen in Figure 1, at least three Wi-Fi antennas are placed thoughtfully at junctions. Smart traffic lights at the crossing are outfitted with IP cameras that are constantly monitoring the surrounding region. The system initiates the localization process as soon as a visually impaired pedestrian carrying the mobile application walks into at least one antenna's Wi-Fi range. The system detects the user's location quadrant by using signal trilateration. A processing thread is started for each pedestrian, visually impaired or not, inside the monitored zones coverage area. The traffic light cameras are always watching these monitoring locations. After that, a pre-trained algorithm created especially to find pedestrian traces is applied to the collected photos. We'll cover more about this paradigm in the part that follows.

Figure 1: Installation of cameras and smart traffic lights at an intersection

3.1 DL approach for supporting pedestrian track

The OpenVINO 2 (Open Visual Inference and Neural Network Optimization) open-source toolbox from Intel is the source of the pre-trained DL technique used in this project. It is noteworthy that this model is based on an EfficientNet. The pre-trained algorithms in the suggested solution collect the following data at a pace of one per second: picture data, the positional coordinates within the image, the event's date and time, the segmented pedestrian's dimensions, and the colors that are most prevalent. Base64 encoding is used to save the image data in an efficient manner. This encoding technique is frequently used to incorporate binary data—like images—into other forms; in this example, Apache Avro was the format of choice.

3.2 Signal locations

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The technology helps visually impaired people cross the roadway safely by using the Kendall rank correlation coefficient computation. However, it's likely that a correlation won't be detected or won't reach the 80% criterion in some circumstances, such as high data noise levels or poor vision. Under such circumstances, the system's use of data from the cameras and signals to precisely identify and track the blind pedestrian is compromised. The system initiates a contingency assistive procedure in response to this possible occurrence. Through this process, a pedestrian who is visually challenged can make educated decisions about safely crossing the street by knowing the color of the traffic signal.

3.3 System architecture

The essential elements of the system's architecture and design are outlined in this section. The suggested system uses IP cameras in smart traffic lights to monitor intersections and carry out signal trilateration and image processing algorithms. It consists of three main hardware components, such as smartphones, WiFi antennae, and smart traffic lights. WiFi antennas at crossroads make it easier for cellphones to exchange signals. A system overview is given in Figure 2. There are two primary software components at play here: the mobile application and the smart traffic light computations (signal trilateration, neural network-based image processing, and data correlation). WiFi signals are only used for geolocation; high-speed cellular network technology, such as 3G or 4G, is required for information transmission between the mobile application and smart traffic lights. The Smart Traffic Light, which has a huge resolution LED display and an Intel I3 processor, is used in the suggested system. A Canon camera that can capture images at a frame rate higher than 40 frames per second is integrated into this smart traffic signal. With its motorized camera angle adjustment system and support for many connection protocols, it can tilt vertically up to 80 degrees on the Y-axis. The device is positioned at a minimum height of 5.5 meters, and its distance from the approved crossing area is adjustable in accordance with the particulars of the site.

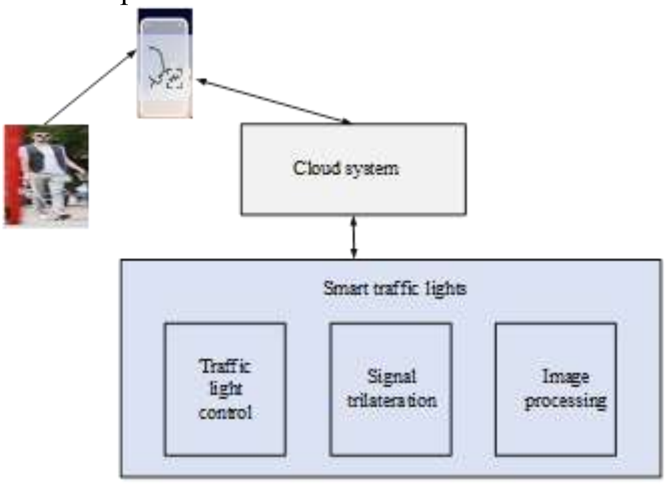

Figure 1: Overview of the system

3.4 Mobile application

A smartphone software for Android that helps visually impaired people move around cities can be a useful tool to improve their accessibility and navigation. An outline of its features and functionalities is provided below:

speech instruction and Navigation: To assist visually impaired users in navigating city streets, walkways, and public transportation systems, the software offers step-by-step speech instruction. It determines the user's present location using GPS technology and provides directions to their intended place.

Real-Time Alerts and Notifications: As the user travels, the app notifies and alerts them in real-time to potential dangers or impediments such as construction zones, uneven terrain, or impending traffic crossings. When traversing metropolitan surroundings, these warnings assist users in staying informed and making safer choices.

Information on Public Transportation: The app provides details on local transit stops, bus routes, and train schedules, among other public transportation options. By having access to real-time information on arrival timings, delays, and service interruptions, users may make better travel plans.
Features for Accessibility: To help users who are visually impaired, the app has been created with accessibility in mind. This covers voice commands, high contrast user interfaces, and screen readers. To fit their tastes and requirements, users can alter variables including text size, color schemes, and auditory feedback.
Integration with Wearable Devices: To offer hands-free navigation and alerts, the software may integrate with wearables like smartwatches or Bluetooth-enabled navigation aids. This frees up users' hands for other jobs or mobility assistance by enabling them to get instructions and notifications straight on their wearable device.
Community-Driven Features: Users may be able to provide advice, comments, and suggestions regarding accessible routes, transit options, and local attractions via the app's community-driven features. Users may confidently explore unknown locations and find new routes with the help of this crowdsourced knowledge.

3.5 Setting up the app

Several obstacles had to be overcome in order to physically deploy the solution, particularly because the smart traffic lights were already installed. Our main operational challenge was to install the necessary components with the least amount of disruption to vehicle flow. A logistical operation was planned to reroute traffic in the city in order to address this. In order to record both car traffic and people waiting to cross the street, not only at the crossing but also in the crosswalk area, we placed Wi-Fi antennas and cameras in the proper positions. We also established an uninterruptible power supply system with a four-hour capacity to ensure continuous operation during power outages, which are frequent during stormy weather. Our attention turned to connecting the system with the pre-existing semaphore software once it was operational. For this integration, it was essential that the Wi-Fi signal be calibrated at each location. In order to do this, the signal strength of each Wi-Fi antenna in the crosswalk waiting areas was measured using a drone. Following these installations and modifications, the assistive system was tested for thirty-one days. The system was then made accessible for visually impaired users to perform validation tests, guaranteeing the practicality and efficacy of the system.

IV. Analysis of the results

Our goal in this study is to present first results from the installation that was carried out in Germany. The need to comprehend how visually impaired people interact with mobile devices led to the decision to include this functionality. We used the User-Centered Design (UCD) approach in conjunction with a group of visually impaired users to guarantee the app's efficacy. By working together, we were able to determine the essential elements that a mobile application interface ought to include in order to facilitate navigation in urban environments. Then, we carefully designed the audio cues of the system to inform users of important information. These include asking users which crossing street they prefer and informing them of their position with respect to the crossroads as well as the names of the streets there. We used a sliding mechanism on the screen to make it easier for users to respond; for one option, horizontal gestures were used, and for another, vertical motions. In addition, we came up with a useful way to notify people via smartphone vibrations as they get closer to the crossing. When the user responds in the positive, the system plays audio data, including the traffic light's current state, the presence of cars, and instructions for navigating the crossing process. For users who are blind or visually challenged, this material is provided through literal transcription to ensure clarity and comprehension.

Table 1: Connection of App over three months

Year	App	Cross assistance	Segmentation
01/2024	8	5	5
03/2024	13	13	13

05/2024	114	92	110

Table 1 presents the system's operating dynamics during a three-month period, including metrics like the quantity of connections to the app, the number of triggered crossing assistance cases, and the quantity of successful segmentations. One person was introduced to the app in the first month of 2024, which led to seven connections to the application. Six times out of these seven connections, safe crossing assistance was triggered, suggesting a high degree of use. The app became popular in March 2024 as a result of its marketing on a social networking group, which increased the quantity of contacts and users. Notably, for every connection instance, safe crossing assistance was activated successfully. As we moved near May 2024, the app saw an increase in usage due to increased user interest. Improved system performance was seen in the large percentage of cross-requests (97.5%) that achieved satisfactory segmentation. Additionally, 81.8% of all app connections resulted in the successful completion of safe crossing assistance. The remaining 19.3% either chose not to cross or obtained assistance from somebody without alerting the platform.

Table 2: Memory consumption and Accuracy analysis

Year	Memory consumption (MB)	Accuracy (%)
01/2024	800	92%
03/2024	850	96.1%
05/2024	900	97.3%

Table 2 outlines the accuracy and memory usage over a three-month period. To make sure the app works well, especially for customers with slower internet connections or restricted data plans, track how much data it uses. This include keeping an eye on how data is used and, if needed, optimizing data transport protocols. Examine how accurate the location-based services and GPS positioning are in the app's geolocation features. This guarantees that consumers get precise navigational directions and information about surrounding businesses. This section looks at how cars behaved when there was a pedestrian present, including how far they stopped from the crosswalk and how long they stopped. For a number of reasons, including parking, waiting for a traffic light, or ceding to pedestrians, cars may come to a halt. We set a baseline distance of 11 meters to identify if a vehicle stopped because a person was present. We presumed a car was responding to a pedestrian if it stopped this far from the crosswalk when the pedestrian was crossing or in the crosswalk approach area (CIA). The percentages of cars that stopped within ten meters of passing the crosswalks at both signalized and unsignalized locations are shown in Figure 3. Spot A had the lowest percentage of stopping drivers among signalized locations. This may be because the lanes are smaller than at other signalized locations, which may discourage cars from waiting for the signal and maybe breaking it. Spot F, on the other hand, showed a greater percentage, indicating that the presence of a speed camera might serve as a deterrent and encourage vehicles to obey the signal. It is noteworthy that the analysis we conducted was limited to the behaviors of vehicles and pedestrians; signal phases were not taken into account at the same time. Furthermore, the presence of a pedestrian crossing the street at the same time as a passing car suggests that one or both parties have violated the traffic signal, endangering everyone's safety when driving. In contrast, most automobiles did not stop before passing the crosswalk at unsignalized sites, especially positions G and H. Spot H demonstrated a comparatively elevated percentage of stops, potentially attributable to its safety features, including red urethane pavement markings, "school zone" signage, and safety barriers lining both sides of the road. In a similar vein, Spot G displayed a noteworthy stopping %. But in the absence of signal lights, drivers were less likely to follow safe driving procedures, like halting ahead of the crosswalk until pedestrians had moved out of the way. Surprisingly, when there were pedestrians on the road in places D, E, and I—designated school zones—at least half of the automobiles did not stop. These results emphasize the necessity of taking proactive steps to promote pedestrian pausing and avert possible collisions in these regions.

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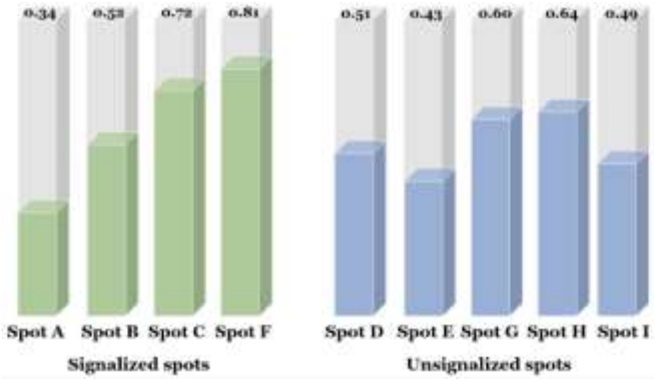

Figure 3: Signalized and unsignalized spots

V. Discussion

This study presents a mobile application that aims to provide visually impaired people with improved access to navigation and city information. By giving visually impaired users easy-to-use tools to traverse city streets, get information about nearby places, and receive real-time updates about their surroundings, the app seeks to enhance their urban mobility experience. City Companion provides an intuitive user interface that is customized to meet the distinct requirements and preferences of its users by utilizing user-centered design concepts and ongoing input from visually impaired people. Through the use of accessibility features and smartphone technology, the app makes interaction and navigation smooth, allowing people with visual impairments to confidently and independently explore and navigate urban surroundings. A key component of the suggested system is its ability to read and modify the surroundings to suit the needs of the user, which is essential when developing solutions for people with impairments. We actively engaged users at every level of the development process, according to the principals of the user-centered paradigm throughout. In order to create a solution that is both efficient and easy to use, it was crucial to comprehend how these consumers interact with mobile application interfaces and the urban environment. This system can identify and locate visually challenged people and provide individualized directions along with real-time descriptions of traffic and crossing conditions. Additionally, by lengthening the time between pedestrian crossings, it can modify the environment to meet user needs and guarantee safer crossings. Although the results of our real-world pilot study were encouraging, we realize that there are a number of limitations to our study. It is still important to improve the system's accuracy under difficult situations like poor sight or at night. Furthermore, collecting performance and usage data over a longer time frame may improve the creation of statistical insights. Potential usability problems brought on by noise pollution in crowded cities provide another difficulty, which is why research into alternate forms of communication is still being done. Furthermore, a comparison of different forms of our approach could be beneficial to our study. Many solutions have been developed to help visually impaired people live in cities, but there are still major barriers to overcome, especially when it comes to inclusive smart cities. We support the development and application of technical solutions that put accessibility, usability, safety, and economic viability first. Notably, our technology uses the infrastructure already in place to improve pedestrian safety by integrating smoothly into the computational platforms of digital traffic lights. But only a certain number of concurrent operations for visually impaired person segmentation can be supported at each intersection because of processing limitations. When capacity is reached, the system initiates an emergency protocol, alerting impacted users and putting backup plans in place.

VI. Conclusion

This study introduces a novel assistive technology development in the field of AI-driven technology that aims to improve visually impaired pedestrians' mobility, with a particular focus on street crossings. To the best of our knowledge, this study is the first to use mobile devices, image processing, artificial intelligence (AI), sensors, and smart traffic lights to enable visually impaired pedestrian crossings.

This approach, which is based on the Internet of Things and Smart Cities concepts, represents the convergence of data and intelligent infrastructure. This technology, which adds Wi-Fi antennas and segmentation software to traditional smart traffic lights, increases their functionality by detecting traffic and pedestrian conditions, sending real-time photos to traffic control centers, and enabling Wi-Fi signal contact with pedestrians. Its capabilities go beyond aiding pedestrians to include a range of traffic control duties, which improves both urban movement and safety. Additionally, this system's data collection helps create an extensive training database, which increases its efficacy and versatility even more. This solution offers an innovative way to deploy assistive technology for visually impaired pedestrians by making the most of shared infrastructure within a smart city framework while reducing the need for portable devices. Moreover, visually challenged users benefit greatly from the smooth interaction between traffic regulating systems and assistive software. This integrated method guarantees safer and more effective street crossings for visually impaired people by adjusting traffic light signals based on actual traffic circumstances.

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