**ROAD CROSSING ASSISTANT FOR BLIND**

**Abstract**

The ability to detect the status of pedestrian signals at street intersections is a critical aspect of safe outdoor navigation for the blind and visually-impaired, especially in unfamiliar environments. Existing outdoor navigation devices for the blind prove insufficient in providing such guidance due to their reliance on limited mobile computational resources. In this work, we propose a mobile-cloud collaborative approach for context- aware outdoor navigation, where we use the computational power of resources made available by cloud computing providers for real-time image processing. The system architecture we propose also has the advantages of being extensible and having minimal infrastructural reliance, thus allowing for wide usability. We have developed an outdoor navigation application with integrated support for pedestrian crossing guidance and report experiment results, which suggest that the proposed approach is promising for real-time crossing guidance for blind pedestrians.

**INTRODUCTION**

There are over 21.2 million visually impaired or blind people in the United States today and many more in the world. The two biggest challenges for independent living of the blind and the visually impaired as stated in are access to printed material and safe and efficient navigation. In order to navigate safely, blind people must learn how to detect obstructions, find curbs when outside and stairs when inside buildings, interpret traffic patterns, find bus stops and know their own location. This implies being fully aware of the context of their living and working environment.

Crossing at urban intersections is a difficult and possibly dangerous task for the blind, hindering independent safe navigation. Assistive technology researchers have been working on this problem for years, not many of the proposed solutions being widely adopted. The currently widespread solution, also known as an accessible pedestrian signal (APS), uses a special sound/speech output to notify blind people about the status of a pedestrian signal at an intersection. However, this solution requires installation of expensive equipment at the intersections, limiting its applicability. In order to implement this solution, an extra terminal device for controlling the speaker should be added to the current traffic lights infrastructure, and this modification requires large amounts of money as well as time.

In this paper we propose an efficient and universally applicable solution for helping the blind safely cross at urban intersections. The proposed solution, based on mobile-cloud computing does not require any modification to existing pedestrian signal infrastructures, while providing guidance in real-time and being highly available.

The rest of this paper is organized as follows: Section 2 briefly mentions related work in pedestrian signal detection; Section 3 discusses the challenges involved in providing crossing guidance to blind pedestrians; Section 4 describes the mobile-cloud solution we propose for the stated problem; Section 5 gives the details of the run-time behaviour of the proposed system; Section 6 provides experiments results on the response times of the proposed system and Section 7 concludes with future work directions.

**PEDESTRIAN CROSSING GUIDANCE CHALLENGES**

The inherent difficulty of providing real-time crossing guidance to blind users at intersections is the fast image processing required for locating and detecting the status of pedestrian signals in the immediate environment. As real-time image processing is demanding in terms of computational resources, mobile devices with limited resources fall short in achieving accurate and timely detection.

The problem of providing real-time feedback about the status of pedestrian signals in the immediate environment faces challenges even when a mobile-cloud collaborative approach as explained below is taken. One of the main concerns about this approach is the time it takes to send the video frames to the remote server for processing and to receive a response. The real-time nature of the problem requires response times ideally less than 1 second to provide accurate and safe guidance to the blind or visually impaired user. While the server having sufficient computation, resources takes negligible time to process the received frames, network latency could create a bottleneck on the timeliness of the response to be received by the user. Continuous Internet connectivity is another problem faced by the proposed approach. Signals from wireless networks would be weak or mostly unavailable at outdoor locations, which is the main setting the application is supposed to work at. However, availability of data plans by major cell phone carrier companies today alleviates this problem. Many people are already subscribed for these data plans for a low monthly cost for continuous connectivity.

Another major challenge faced is the short battery life of the mobile device. A continuous video recording approach to the problem exhausts the battery of the mobile device too soon, causing service interruption.

The most accurate solution for detecting the status of pedestrian signals would be using a mobile device and cloud service to locate the blind user and then using the mobile device to capture the electronic signal emitted by the existing traffic lights system and send a request to the system for obtaining the time when the lights would turn green (or white based on the country). However, we found this solution had fateful difficulty on design as the electronic communication signal in existing pedestrian signal system is somehow confidential and not supported to be captured by outside applications.

**PROPOSED SYSTEM**

The context-aware navigation system architecture we propose is a two-tier architecture. The two main components are the mobile device with integrated GPS receiver and compass, which could be any smart phone device in the market and the cloud server, which is basically the Web Services Platform that can be employed to support a variety of context-awareness functionalities. The mobile device is responsible for local navigation, local obstacle detection and avoidance, as well as interacting with the user and the cloud side. It is responsible for providing location data to the cloud, which will perform the desired location specific

functionality and communicate the desired information as well as relevant context information and warnings of potential hazards in context back to the mobile device.

**SYSTEM FLOW**

The different steps taken by the system to achieve crossing guidance are as follows:

* 1. Application captures GPS signal and communicates with the Google Maps Server to determine the current location of the blind user.
  2. Once the application detects that the blind user is at an urban intersection and will possibly cross it, it triggers the phone camera to take a picture and send the picture to the Server running on the Amazon EC2 Cloud.
  3. The server does the image processing applying the Pedestrian Signal Detection algorithm and returns the result about whether it is safe for the blind user to cross the intersection.
  4. If the result is positive, the Android Application notifies the blind user to cross the intersection with speech feedback. Otherwise, it repeats step 2 until the result is positive.

The most critical components of this system are the location detection application running on the Android Phone and the Image Processing Application running on the Amazon EC2 Cloud.

Following are detailed information about these two components.

1. *Positioning*

For positioning, we extended the WalkyTalky navigation application, which is an open source project that can speak out the address of a nearby location passed by the user and navigates the user to the destination using GPS and Google Maps. We removed the graphical user interface of this application as it is useless for the blind people. The automatic image capturing function was added to the application as well. In order to make the detection more accurate, we enabled the Compass function in the application. The reason for using the Compass function is obtaining the heading direction of the blind.A user arrives at an intersection but is not heading the correct direction. With the heading direction information, the application can detect this case and warn the user to change his/her position to point exactly in the direction of the pedestrian signal so that a better picture can be taken.

1. *Multi-cue Signal Detection Algorithm*

The pedestrian signal detector of the developed system uses a cascade of boosted classifiers based on the AdaBoost algorithm, which is popular for real-time object recognition tasks and haar-like features to detect the presence and status of pedestrian signals in a picture captured by the camera of the Android mobile phone. We are currently investigating the effectiveness of a multi-cue algorithm in providing accurate guidance to the user at intersections. As seen in figure 4, the presence of contextual clues including other pedestrians crossing in the same direction, a zebra crossing and the status of traffic lights in the same direction provide additional information to make an accurate decision about whether the user should cross. With the help of Cloud Computing, we will be able to run all detection algorithms (those detecting the state of other contextual cues) in parallel to make a more informed and conservative decision at the crossing. Another important aspect we will take into consideration in development of the detection algorithm is the universal aspects of pedestrian signals. As signals in different countries and even different cities can be dramatically different from each other, it will be important to focus on the common features at the image processing stage, instead of training the detector with a dataset of signal images, which may not be comprehensive.

**EXPERIMENTAL EVALUATION**

The two most important aspects of the pedestrian signal status detection problem are timeliness of response and accuracy. The real-time nature of the problem necessitates response times of less than 1 second as stated before, while high accuracy of detection should be achieved to ensure safety of the user. Experiments were performed to test the response time of the pedestrian signal detector application developed. Test data used in the experiments consists of pictures at

outdoor locations of the Purdue University campus, which include scenes of different pedestrian signals. The application developed was installed on an Android mobile phone, connected to the Internet through a wireless network on campus. The sample task in the experiments involved processing five different resolution level versions of pictures. The average response times, which were determined by the time period between capturing a frame and receiving the response from the server running at Amazon Elastic Compute Cloud about the pedestrian signal status, were measured for each frame resolution level as determined by a Java platform- specific measure. A resolution level of 0.75 stands for the original frame as captured by the camera, whereas the lower resolution levels represent compressed versions of the same set of frames, where image quality falls with decreasing resolution level. The response times for different resolution levels are seen in figure 5 below. Response times for the original frames are around 660 milliseconds on average, which are acceptable levels for the real-time requirements of the problem. We also see that response time decreases further when lower-quality, compressed versions of the frames are sent to the remote server instead of the originals.

**CONCLUSION AND FUTURE WORK**

In this paper we proposed a mobile-cloud based pedestrian signal detector integrated into an outdoor navigation application for the blind and visually impaired using the Android platform for the mobile component and the Amazon EC2 platform as the cloud component. We also conducted experiments to test the appropriateness of the developed system for real-time guidance and the results are promising for wide adoption of a navigation aid based on the proposed system.

Our future work will involve development and experimentation of a system using camera modules placed on eye glasses instead of using the native camera of the mobile device for a more accurate and comfortable system. We will also investigate privacy issues arising from the sending of possibly confidential data (location and image data) to the cloud for processing and work on solutions for protecting privacy under the real-time response constraint.