Real-Time Walk Light Detection with a Mobile Phone

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Abstract. Crossing an urban traffic intersection is one of the most dangerous activities of a blind or visually impaired person's travel. Building on past work by the authors on the issue of proper alignment with the crosswalk, this paper addresses the complementary issue of knowing when it is time to cross. We describe a prototype portable system that alerts the user in real time once the Walk light is illuminated. The system runs as a software application on an off-the-shelf Nokia N95 mobile phone, using computer vision algorithms to analyze video acquired by the built-in camera to determine in real time if a Walk light is currently visible. Once a Walk light is detected, an audio tone is sounded to alert the user. Experiments with a blind volunteer subject at urban traffic intersections demonstrate proof of concept of the system, which successfully alerted the subject when the Walk light appeared.

Keywords: blindness, visual impairment, traffic intersection, pedestrian signals

1 Introduction

Crossing an urban traffic intersection is one of the most dangerous activities of a blind or visually impaired person's travel. For some pedestrians with poor or non-existent vision, the rhythm of traffic sounds may indicate when it is time to cross; at some intersections, Audible Pedestrian Signals (APS) provide a clearly audible signal at that time. Unfortunately, such signals are either unreliable or absent at many traffic intersections, and may be inaccessible to pedestrians with combined hearing and vision impairments.

Several types of technologies have been developed to assist blind and visually impaired individuals in crossing traffic intersections. Most prevalent among them are Audible Pedestrian Signals, which not only generate sounds that tell blind and visually impaired individuals when to cross intersections, but also furnish acoustic cues that some pedestrians can localize to help them properly orient themselves to the crosswalk [2]. Talking Signs® [5] allow blind travelers to locate and identify landmarks, signs, and facilities of interest, at intersections and other locations, using signals from installed infrared transmitters that are converted to speech by a receiver carried by the traveler.

However, the adoption of both Audible Pedestrian Signals and Talking Signs® is very sparse, and they are completely absent in most US cities. More recently, Bluetooth beacons have been proposed [3] to provide real-time information at intersections that is accessible to any user with a standard mobile phone, but like Talking Signs® this solution requires special infrastructure to be installed at each intersection.

The alternative approach that we propose in this paper is to use a portable computer vision-based system, named "Crosswatch" [6,7], to identify important features in an intersection, including the Walk light. With this system (Fig. 1), the user takes an image of the intersection with a mobile phone camera, which is analyzed by software run on the phone, and the output of the software is communicated to the user with audio tones. The great strength of the computer vision approach is that it offers virtually unlimited potential for acquiring information about one's surroundings, but does not require any infrastructure beyond what is already provided for normally sighted people – namely, pedestrian signal lights and painted street markings.

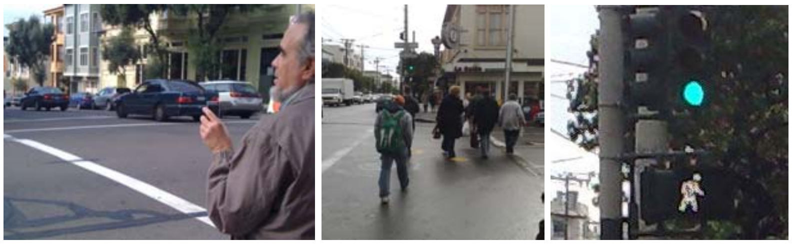

Fig. 1. Overview of proposed Crosswatch system. Left to right: (a) Blind pedestrian holding mobile phone. (b) Image of crosswalk taken from across the street. (c) Zoomed-up area of (b) shows Walk light visible at the end of the crosswalk. Proposed system is programmed to generate audio alert when Walk light is detected.

Experiments with a blind volunteer subject at urban traffic intersections demonstrate proof of concept of the system, which successfully alerted the subject when the Walk light appeared. This is the first example of a truly portable system we are aware of that provides timing information at traffic intersections based solely on existing traffic signals already used by sighted pedestrians, without the need for any added infrastructure (such as APS or other guidance systems requiring on-site installation).

2 Finding Walk Lights in Images

The Walk light is a pedestrian signal that is lit when it is time for pedestrians to cross. Walk lights have different shapes and colors in different places; we focus on a variety of Walk light that is common in the US, a white icon in the shape of a person walking (Fig. 1c). (It should be straightforward to extend our approach to encompass other Walk light shapes and colors.) After the Walk period ends, the Walk light is replaced by a Don't Walk symbol, indicating when pedestrians should not cross. (At some traffic intersections there is also an intermediate "countdown" timer signal indicating the amount of time remaining before the Don’t Walk symbol appears, but we defer analysis of this type of signal for future work.) Our goal is to design a computer vision algorithm to rapidly detect the Walk light whenever it is present, so that the user is alerted for as long as it is lit.

There is a variety of past work on traffic signal light detection in computer vision, including some research aimed at vehicle traffic light detection [4] and other work [1] specifically addressing Walk light detection for visually impaired pedestrians. All the work that we are familiar with in this vein exploits the fact that the lights being detected are colored (i.e. not white) in order to narrow the search for targets of the appropriate shape; for our application, however, the Walk light is white, so color is not as powerful a cue. Moreover, the algorithms described in this work were all implemented on portable PCs, whereas we seek a solution that runs on the much more convenient (but less computationally powerful) mobile phone platform.

To add to the challenge of a reliable, real-time solution, we note that the Walk light appears very small at typical viewing distances (across the street – see Fig. 1b for a representative example). Moreover, in order to process images at least one or two frames per second, we are forced to acquire the images in video mode, which has much lower resolution (VGA, i.e. 640 x 480 pixels) than the highest-resolution still images available on the Nokia N95 (5 Megapixels, i.e. 2592 x 1944 pixels). As a result, the Walk light appears to be small and blurry (and is sometimes subject to color distortions) in typical images (Fig. 2), which makes recognizing it on the basis of its shape more difficult.

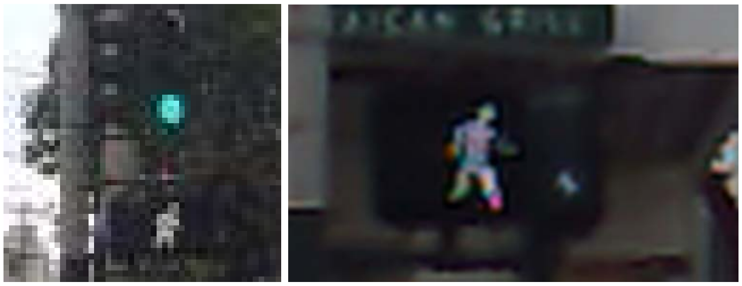

Fig. 2. Zoomed-up images of Walk lights, photographed from typical viewing distances, rendered at the lower resolution available to the camera running in video mode. Note that the Walk icon is blurry, hard to resolve clearly, and may be subject to color distortions.

Our solution to these challenges is to narrow our search using a powerful additional cue: at typical viewing distances, the Walk light is far enough away that it appears close to the horizon. If we can estimate the location of the horizon in the image, then we need only search a narrow strip of the image near the horizon rather than the entire image (Fig. 3a). Fortunately, most modern mobile phones (including the N95) have built-in accelerometers (i.e. tilt sensors) that continuously estimate the direction of gravity [7], which in turn determines the horizon line with only a few simple calculations.

Our search for the Walk icon in the image strip near the horizon proceeds in several stages. First, the image strip is analyzed to determine which pixels are bright and close to white in color, and which pixels are dark (brightness and darkness are assessed relative to other pixels in the strip). Second, candidate Walk icons are identified by finding small regions of bright whitish pixels surrounded by dark pixels (Fig. 3a). Third, the shape of these candidates is compared with the correct Walk icon shape using template convolution to score the candidates and rule out the ones that have an obviously incorrect shape. Finally, for the top-scoring 15 candidates, the shape is explicitly analyzed for the presence of a two legs and a head, which must be visible (even if the resolution is poor).

The above detection procedure is fast and effective in many intersection scenes, but to further reduce the likelihood of false positive Walk light detections we conduct an additional test: the candidate Walk light must appear near to and below a green traffic light (Fig. 3b), which is detected as a bright green light that is surrounded by dark pixels. While there are some rare traffic intersections where a Walk light is *not* accompanied by a nearby green light, we accepted this as a temporary restriction for our prototype system.

Fig. 3. Left to right: (a) In image strip near horizon, candidate regions are selected for processing by detection algorithm. (b) Final Walk light detection, with confirmation by presence of green traffic light above.

3 User Interface

The preceding Walk light detection algorithm was developed and tested on a desktop computer and then ported to the Nokia N95 camera phone running Symbian C++ in video capture mode. The algorithm was implemented to run as quickly as possible on the cell phone, so that at least one image could be processed per second.

In order for the detection algorithm to work reliably, we decided in our prototype Walk light detection system to require the user to hold the mobile phone camera close to the horizontal. Since many blind and visually impaired users have little or no visual feedback about the angle they are holding the camera at, we added a simple user interface to help them correct for unintentional deviations from the horizontal: any time the camera tilt or slant exceeds a small amount (as determined by the direction of gravity estimated by the accelerometer), the system alerts the user with beeping sounds. With a small amount of practice, users learn how to quickly align the camera to the horizontal in order to stop this beeping and allow the system to work properly. (In the future, we will investigate the possibility of using the tilt/slant estimates to automatically unrotate the images captured by the camera so that they appear horizontal to the detection algorithm.)

4 Experimental Results and User Testing

We explained the purpose and operation of the system to a completely blind volunteer subject, and advised him on how best to hold the camera phone. Particular emphasis was placed on the importance of moving the camera slowly to avoid motion blur, ensuring the camera lens was not covered (e.g. by the user's fingers), and holding the camera close to horizontal. After a brief indoor training session with an image of a Walk light scene displayed on a computer monitor, we took the subject to a nearby traffic intersection to test the system. The subject stood across from three separate Walk lights in the intersection, and during two Walk cycles in front of each Walk light (a total of six trials), the system issued approximately ten "Walk" tones per Walk cycle (each Walk signal lasted either 14 or 23 sec.). No "Walk" tones were issued when the Walk light was not lit, although the experimenters encountered occasional, isolated false positives when testing the system themselves.

The main challenge in using the system was to point the camera approximately in the direction of the Walk light, the risk being that the camera may be pointed too far to the left or right to view the Walk light (even if it is held perfectly horizontal). We experimented with using other Crosswatch functionality previously developed [7] to detect two-stripe crosswalk stripes (the two stripes are on either side of the Walk light, as in Fig. 1b) as a way of pointing the user in the correct direction before searching for Walk light. For our test subject this functionality did not seem to be necessary, but it seems natural to integrate crosswalk and Walk light detection in future versions of the system to make it easier to use.

5 Conclusion

We have demonstrated a novel mobile phone-based computer vision system for helping blind and visually impaired pedestrians detect Walk lights to help them cross traffic intersections. A prototype system has been implemented on the Nokia N95 camera phone, which searches for the Walk light at least once per second and provides audio feedback whenever a crosswalk is detected. We have conducted preliminary experiments with blind volunteers to test the system, demonstrating its feasibility.

Future improvements and extensions to the system will emphasize improving its accuracy (especially eliminating false positives), removing the requirement that a green traffic light be present to confirm the Walk light, and adding the ability to detect Don't Walk lights and countdown timers. We will experiment with using the phone's built-in vibrator to provide tactile feedback for users with hearing impairments (or for users with normal hearing in noisy environments). Porting the software to newer and more powerful mobile phones such as the iPhone and Android will allow us to acquire higher-quality video images and improve the speed of the computer vision algorithms. Extensive user testing will be conducted to guide the development of the system and to optimize its usefulness and usability.

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