Implementation of Crosswalk Lights Recognition System for the Blind's Safety

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Abstract

Recently, disabled people are exposed to various risk of traffic accidents, but, at the time of this writing, the installation rate of sound signals for the visually impaired is very low, at 57% in South Korea. In this paper, we focused on several recent services that help the visually impaired to walk safely and try to help the visually impaired through voice guidance. In this paper, we proposed crosswalk lights recognition system for the visually impaired providing real-time lights state by voice so that safe walking environment of the visually impaired can be guaranteed. We implemented crosswalk lights recognition system prototype using IoT parts like Raspberry Pi. Unlike the conventional sound guidance, we tried to provide voice guidance through crosswalk lights image recognition. The performance evaluation achieved a recognition success rate of 92.7% by day and 67.3% by night.

Key words: Visually Impaired, Crosswalk Light Detection, Object Detection, Raspberry Pi, Voice Guidance

Introduction

As always, people with disabilities, classified as the traffic weak, are exposed to various traffic accident risks, but there are very few disability protection areas designated around disabled facilities. According to data from Seoul in Korea, only 7 out of 631 disabled facilities were in disability protection areas as of last year [1]. In addition, the installation rate of the acoustic signal that allows the blind to cross the crosswalk safely without the help of others is only 57% [2]. Most currently installed acoustic signals for the visually impaired are manually operated at the touch of a button or by remote control. However, it is difficult to access the acoustic signal button because it cannot be easily found by the visually impaired. The signal occasionally does not work, so the visually impaired may not hear the announcement. Also, the acoustic signal does not provide guidance about real-time signal states such as flashing lights.

In this paper, we implemented a system that enables the blind to cross pedestrian crossings independently without operating and acoustic signals. First, the current signal state is accurately recognized so that the visually impaired can know the state of the crosswalk. The system recognizes crosswalk lights in real time and guides the current signal to the visually impaired by voice. This will provide a safe walking environment for the visually impaired.

Related Works

A. Crosswalk Guidance System for the Blind using RFID

This system provides the information necessary for the visually impaired using RFID tag authentication in the crosswalk [3]. When the visually impaired with an RFID tag approaches a crosswalk, and RFID reader installed at a pedestrian traffic light recognizes the tag and delivers the relevant information. This has an advantage of providing information selectively only to the visually impaired who have RFID, unlike the existing pedestrian guidance system. However, to use the system ,a RFID tag must be carried and used in a white stick. In addition, there is a problem that the RFID reader antenna must be additionally installed in the pedestrian traffic lights located in all crosswalks.

B. Application of BLE-Based Audible Pedestrian Signal (APS)

The system allows the blind to select a sound signal using a smartphone to make safe and convenient crossings [4]. Smartphones and acoustic signals are connected via bluetooth. This has an advantage that it can be used like an existing acoustic signal equipment other than a smartphone. However, since the smartphone and the audio signal communicate with bluetooth, communication may be lost due to environmental obstacles.

System Architecture and Implementation

The real-time crosswalk lights recognition system for the blind consists of a server and Raspberry Pi. Raspberry Pi equipped with camera streams the video to its own streaming server and the server receives the video from Raspberry Pi streaming address. The server perceive the crosswalk light in the received video through the Google object detection API [5]. Then, the color of the crosswalk light is detected and classified into red, green, and flashing lights by the Walkable judgement algorithm. The determined signal is delivered to the Raspberry Pi and voiced to the blind.

A. System Overview

The real-time signal recognition system for the blind consists of Raspberry Pi client and a server. Fig. 1 shows the structure of the system. First of all, the camera module of Raspberry Pi client shoots real-time video and uploads to a streaming server. The recognition server gets the video from the Raspberry Pi streaming server and divides it into 5 frames per second. The crosswalk lights recognition module receives the frames and detects crosswalk lights. The crosswalk lights extracted from the crosswalk lights object recognition model

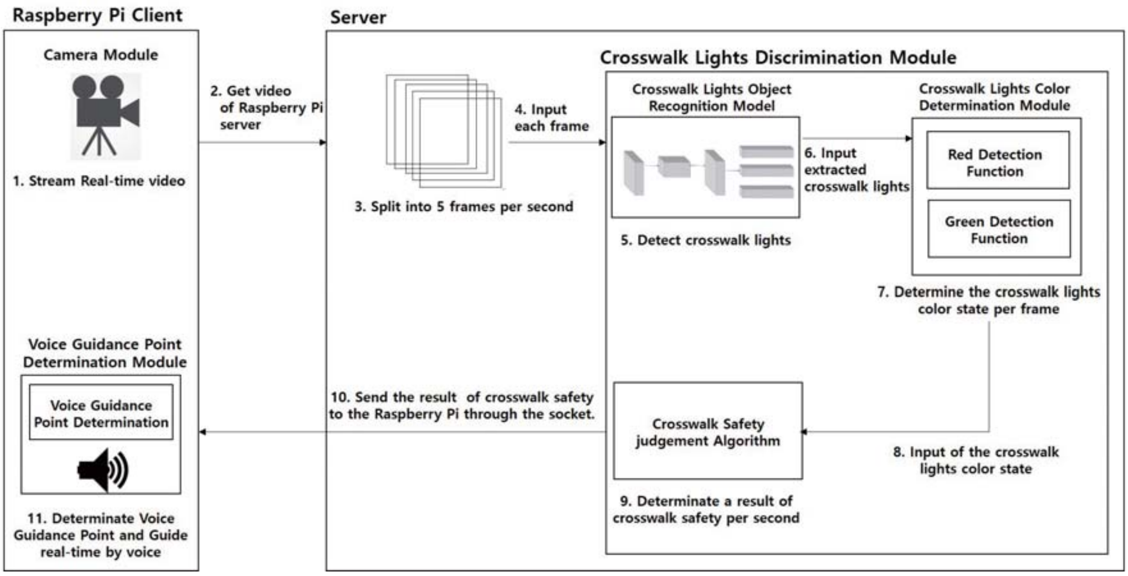

Fig. 1 Structure of the system

are given as inputs to the crosswalk lights color determination module. The color state is given as input to the crosswalk safety judgement algorithm. Finally, a result of crosswalk safety is obtained. The color state obtained from the server is delivered to the Raspberry Pi through the socket and guided to the visually impaired by the voice in real time according to the voice guidance point algorithm.

In this paper, TensorFlow, cuda and cudnn are installed on the server to run the Google object detection model for system traffic light recognition. Raspberry Pi outputs real-time video to the server and recognition results to users respectively. For real-time video shooting, an 8mp camera module was connected and the resolution was set to 320 x 240.

B. Crosswalk Lights Object Recognition Model

In order to generate a high recognition rate of crosswalk lights recognition model, day and night images from various locations were collected and used as training data. Collected images are labeled with LabelImg[6] to specify the location of the crosswalk lights. Of the 5,366 images collected, 5,266 were used for training and 100 were used for performance evaluation.

The collected data was trained using the Google object detection API in the faster_rcnn_resnet101_coco[7] model. Google object detection API provides 25 models trained on COCO data sets. Faster R-CNN is a model that introduces Region Proposal Networks(RPN) and calculates the GPU through the internal RPN, not the external slow GPU [8]. In addition, the model is capable of processing about 5fps, which enables processing in near real time. When training, batch size was 1, the number of training was 200,000 times, and the size of the input image was 500 x 500.

C. Algorithm of Crosswalk Lights Discrimination

The crosswalk lights object image is detected and cut through the crosswalk lights object recognition model and is given as inputs to the crosswalk lights color determination module. Fig. 2 shows the algorithm of crosswalk lights color determination. The algorithm detects red or green and returns the crosswalk lights color state as True or False. To call the function to detect red and green, Fig 3 is the function to detect red. It detects red and returns True if the hsv color value is between 0 and 10 or between 170 and 180, and False otherwise. Fig. 4 shows the function to detect green. It detects green and returns True if the hsv color value is between 25 and 102, and False otherwise. Fig. 5 is the algorithm of crosswalk safety judgement. It uses the color state to calculate if the blind can cross the crosswalk. It returns red, green or flashing lights. Finally, if it is a green or flashing lights, it is judged to cross the crosswalk. Then, the result of crosswalk safety is sent to the Raspberry Pi client via socket. Fig. 6 shows an algorithm of voice guidance point determination of Raspberry Pi. The result of guidance point is 1 when there is no crosswalk light detected, 2 for flashing lights, 3 for red light and 4 for green light. The voice guidance for each light is played. When a change in the crosswalk lights is detected, the voice corresponding to the light is provided. The visually impaired can be provided with voice guidance in real time.

```
ReadTrafficLights

read crop_img
if crop_img has traffic light then
   call DetectRed function
   if crop_img has red color then
      set red_flag to False
   else then
      set red_flag to True
   call DetectGreen function
   if crop_img has green color then
      set green_flag to True
   else then
      set green_flag to False
   define result_flag using AND operation
   between red_flag and green_flag to allow
   walking only for the green light
else then
   define result_flag as unable to walk

return result from the crop_img
```

Fig. 2 Algorithm of Crosswalk Lights Color Determination

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```
DetectRed
initialize the Threshold to 0.01
read img
read img_hsv
read mask0, mask1 according to the range of red light

set mask to the sum of mask0 and mask1
set rate1 to the counts of non_zero values

if rate1 is higher than Threshold then
    return True to show traffic light has red light on
else then
    return False to show traffic light has red light off
```

Fig. 3 Red Light Detection

```
DetectGreen
initialize Threshold to 0.01
read img
read img_hsv
read mask according to the range of green light

set rate2 to the counts of non_zero values

if rate2 is higher than Threshold then
    return True to show traffic light has green light on
else then
    return False to show traffic light has green light off
```

Fig. 4 Green Light Detection

```
SignalDetermination - Server
if division of frame count is 1 then
    increment frame count per sec
    read crop_img
    call ReadTrafficLights function
    read result_flag

    if green is detected in crop_img then
        set result per frame to 1 to calculate number
        of green light per sec
    else then
        set result per frame to 0 to calculate number
        of red light and blink per sec

    increment result per sec
    if division of frame count per sec is 0 then
        if crop_img has no traffic light then
            send 1 through socket connection
        else if crop_img is blink then
            send 2 through socket connection
        else if crop_img is red then
            send 3 through socket connection
        else if crop_img is green then
            send 4 through socket connection
        initialize result per sec to 0
  increment frame count
```

Fig. 5 Algorithm of Crosswalk Safety Judgement

Implementation Results and Performance Evaluation

A. Implementation Results

In this section, we describe the prototype implementation of the crosswalk lights recognition system. Fig. 7 shows the server screen that recognizes crosswalk lights in the image. Red, green, flashing and no crosswalk lights are shown clockwise from the top left. When the crosswalk light is recognized, the walking signal is determined every second and

```
VoiceGuidance - Raspberry Pi
while connection is on do
    read data received through socket connection
    if data is primally received data then
        if data means 'red light' then
            play the 'red.wav' file for 5 seconds
        else if data means 'green light' then
            play the 'green.wav' file for 3 seconds
        else if data means 'blink' then
            play the 'blink.wav' file for 3 seconds
        else if data means 'no traffic light' then
            play the 'none.wav' file for 3 seconds
    else if data is not primally received data then
        if data is different from just before data then
            if data means 'red light' then
                play the 'red.wav' file for 5 seconds
            else if data means 'green light' then
                play the 'green.wav' file for 3 seconds
            else if data means 'blink' then
                play the 'blink.wav' file for 3 seconds
            else if data means 'no traffic light' then
                play the 'none.wav' file for 3 seconds

end
```

Fig. 6 Algorithm of Voice Guidance Point Determination of Raspberry Pi

delivered to the Raspberry Pi through the socket, like '1' for no crosswalk light, '2' for flashing, '3' for red, and '4' for green.

Fig. 8 shows the Raspberry Pi screen that guides the user whether they can after receiving using the result from the server. The above screen is a state in which red light is recognized, so '3' is printed and then, it cannot recognize anything of light. In this case, the Raspberry Pi says "I'm looking for a crosswalk light" for "4", and after finding a red light, it plays "Red light. Please wait." The screen below shows that the crosswalk light is green and then changed to flashing. At first, "Green light went on. You can cross the crosswalk." When it is changed to the flashing light, it sounds "Changed to the flashing light."

Fig. 7 Screen of a server for detecting crosswalk light from

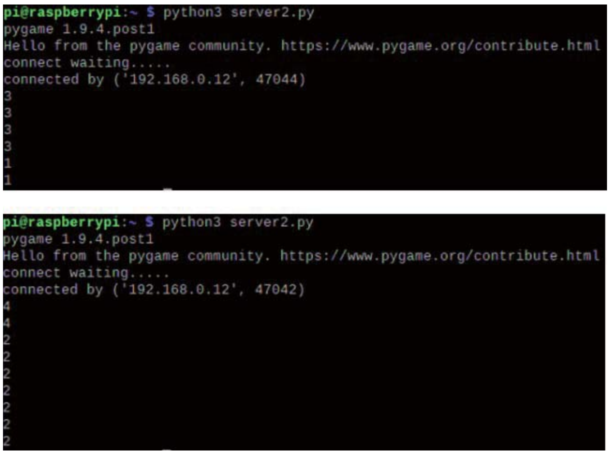

Fig. 8 Screen of a Raspberry Pi for voice Guidance

B. Performance Evaluation of the Crosswalk Lights Discrimination

Table 1 compares the performance of ssd_mobilenet_v1 coco and faster rcnn resnet101 coco used for the crosswalk light recognition model. Faster rcnn resnet 101 coco is about 3.5 times faster than ssd mobilenet v1 coco. As a result of comparing the accuracy of the test data with the two models, ssd mobilenet v1 coco is 75% and faster rcnn resnet 101 coco is 98%. In this paper, we applied faster rcnn resnet 101 coco model for higher accuracy.

TABLE I
Comparison of Recognition Models for Crosswalk Lights Object

	Speed(ms)	Coco mAP	Accuracy
SSD mobilenet	30	21	75%
Faster rcnn	106	32	98%

Table. 2 shows the test results of the crosswalk safety decision. The test was conducted with each 50 crosswalk light images for day and night. Each crosswalk light was red, green, and flashing for 5 seconds. Of the 50 images taken during the day, 45 red lights, 47 green lights, and 47 flashing lights were correctly recognized. Of the 50 images taken at night, 36 red lights, 37 green lights, and 28 flashing lights were correctly recognized. The accuracy was 92.7% during the day and 67.3% at night. Crosswalk safety decision accuracy was higher at daytime than at night because the light spreads less than at night.

TABLE II
Accuracy Measurement of Crosswalk Safety Judgement

	Red	Green	Splashing
Day	90%	94%	94%
Night	72%	74%	56%

Conclusion and Future Works

In this paper, we proposed a crosswalk lights recognition system for the blind's safety. In the past, the acoustic signal for the visually impaired existed, but many acoustic signal was broken or did not work. The crosswalk lights recognition system to solve this problem recognizes the crosswalk lights and informs the real-time guidance by voice.

In order to recognize crosswalk lights, crosswalk light images of various positions were used as training data during the daytime and at night. Then, Faster R-CNN resnet 101 model was selected for the recognition of crosswalk lights for it is high speed and accuracy. The model was trained using Google object detection API. Finally, the accuracy of the model was 92.7% during the day and 67.3% at night, which makes it possible to accurately recognize crosswalk lights.

Raspberry Pi streams real-time video into the server and the server splits the video into frames. The server recognizes the crosswalk light using trained crosswalk lights object recognition model. After determining the crosswalk lights through various algorithms we implemented in this paper, the result is delivered to Raspberry Pi client. The user can determine whether to cross the crosswalk through the voice provided by the Raspberry Pi.

Future research will use the crosswalk location information database to supplement the system so that it can be activated when the blind approach the crosswalk. In addition to crossing the crosswalk, we will recognize obstacles to be avoid while walking to support the visually impaired.

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References

[1] J. Tak, "Neglected Disability Safety", *The Kyunghyang Shinmun*, July 2019, [online] http://news.khan.co.kr/kh_news/khan_art_view.html?artid=201907220600005&code=940601

[2] D. Jung, "The installation rate of the audio signal for the visually impaired is only 57%", *welfarenews*, June 2019, [online] http://www.welfarenews.net/news/articleView.html?idxno=69527

[3] I. Park and D. Park, "A Study on Crosswalk Guidance System for the Blind using RFID," *The Institute of Electronics Engineers of Korea - Computer and Information*, Vol. 47, No. 6, pp. 124-130, Nov 2010.

[4] H. Kim, J. Kim and I. Jang, "Development and Application of BLE-Based Audible Pedestrian Signal (APS) for Intersection Safety Crossing of Blind People," *Journal of Information Technology Services*, Vol. 16, No. 4, pp. 223-234, Dec 2017.

[5] Google Object Detection, [online] https://github.com/tensorflow/models/tree/master/research/object_detection

[6] LabelImg, [online] https://github.com/tzutalin/labelImg

[7] faster_rcnn_resnet101_coco,[online] https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md

[8] Shaoqing, R., Kaiming, H., Ross, G and Jian,S, "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks," *IEEE Transactions on Pattern Analysis and Machine Inteligence*, Vol. 39, No. 6, pp. 1137-1149, June 2017.

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